City and County of San Francisco
2018-2019 Civil Grand Jury

MEMORANDUM

TO: Mayor and Members of the Board of Supervisors

CC: Angela Calvillo, Clerk of the Board of Supervisors

FROM: Anatolia Lubos, Grand Jury Administrative Analyst

DATE: July 18, 2019

SUBJECT: Civil Grand Jury Report, "Act Now Before It Is Too Late: Aggressively Expand and Enhance Our High-Pressure Emergency Firefighting Water System"

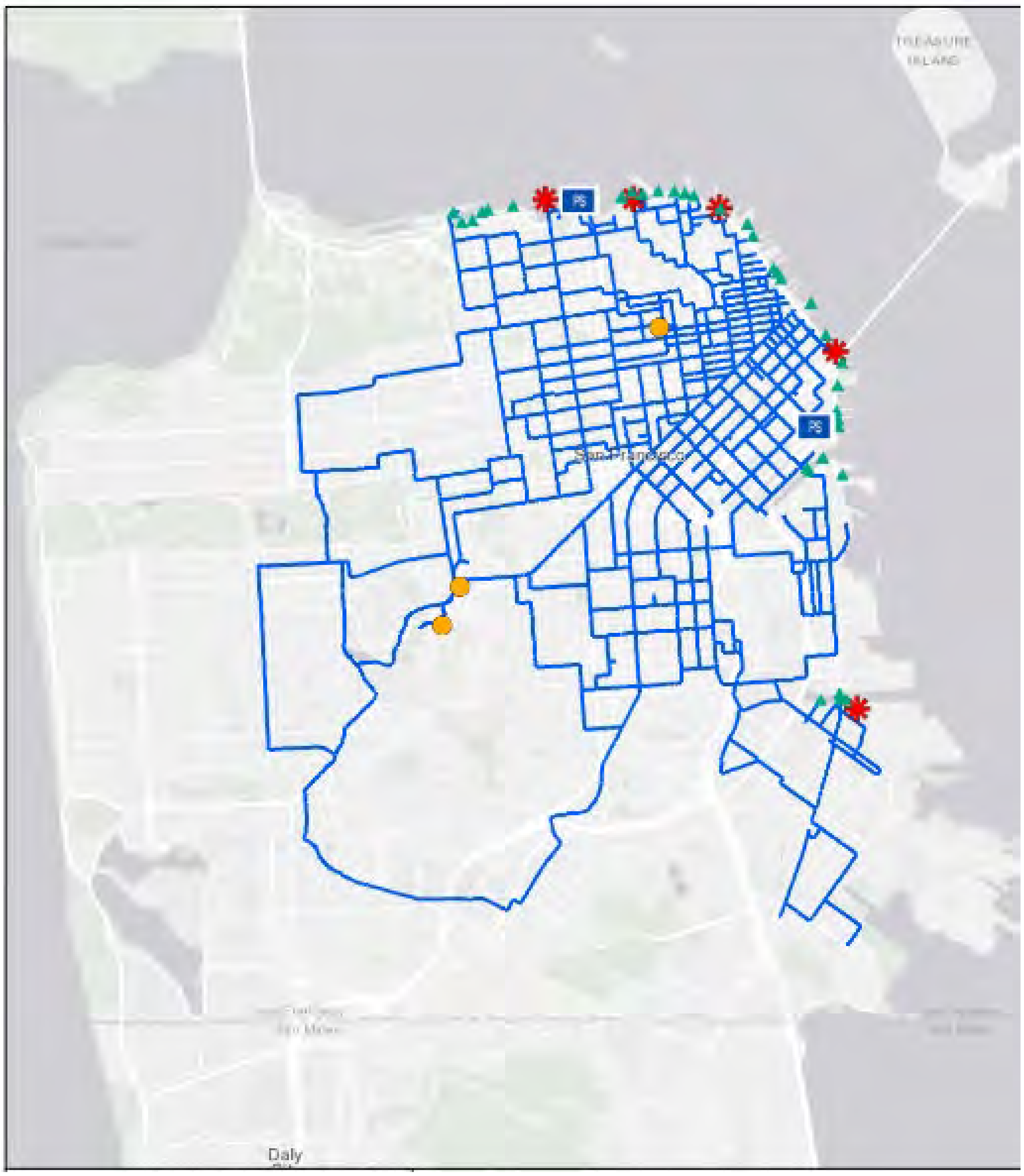
The previous version of the aforementioned Civil Grand Jury report as received and distributed on Monday, July 15, 2019 was incomplete and omitted Appendices F to R (inclusive).

Enclosed is the complete report.

400 McAllister Street, Room 008, San Francisco, CA 94102
Phone: 415-551-3635

CITY AND COUNTY OF SAN FRANCISCO
2018-2019 CIVIL GRAND JURY

ACT NOW BEFORE IT IS TOO LATE: AGGRESSIVELY EXPAND AND ENHANCE OUR HIGH-PRESSURE EMERGENCY FIREFIGHTING WATER SYSTEM



CITY AND COUNTY OF SAN FRANCISCO
2018-2019 CIVIL GRAND JURY

THE CIVIL GRAND JURY AND ITS OPERATIONS

California state law requires that all 58 counties impanel a Grand Jury to serve during each fiscal year. *California Penal Code Section 905; California Constitution, Article I, Section 23*

The Civil Grand Jury investigates and reports on one or more aspects of the County's departments, operations, or functions. *California Penal Code Sections 925, 933(a)*

Reports of the Civil Grand Jury do not identify individuals interviewed by name. *California Penal Code Section 929*

The Civil Grand Jury issues reports with findings and recommendations resulting from its investigations to the Presiding Judge of the Superior Court. *California Penal Code Section 933(a)*

Each published report includes a list of those elected officials or departments that are required to respond to the Presiding Judge of the Superior Court within 60 or 90 days as specified. *California Penal Code Section 933*

California Penal Code Section 933.05 is very specific with respect to the content of the required responses. Under Section 933.05(a), for each finding, the response must:

1) Agree with the finding, or
2) Disagree with it, wholly or partially, and explain why.

Similarly, under Penal Code Section 933.05(b), for each recommendation, the responding party must report that:

1) The recommendation has been implemented, with a summary of the implemented action; or
2) The recommendation has not been implemented but will be within a set timeframe; or
3) The recommendation requires further analysis, with an explanation of what additional study is needed, and the timeframe for conducting that additional study and the preparation of suitable material for discussion. This timeframe may not exceed six months from the date of publication of the Civil Grand Jury's report; or
4) The recommendation will not be implemented because it is not warranted or reasonable, with an explanation.

Any San Francisco resident who is a US citizen and is interested in volunteering to serve on the Civil Grand Jury for the City and County of San Francisco is urged to apply. Additional information about the San Francisco Civil Grand Jury, including past reports, can be found online at http://civilgrandjury.sfgov.org/index.html .

CITY AND COUNTY OF SAN FRANCISCO
2018-2019 CIVIL GRAND JURY

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EXECUTIVE SUMMARY

San Francisco is one of the most vulnerable cities in the world, and certainly in the United States, to the risk of fire following an earthquake. In 1906, the City suffered tremendous destruction and devastation from the fires that followed a major earthquake. Over 3,000 people died and approximately 28,000 buildings were destroyed. In 1995, the 6.9-magnitude Kobe, Japan earthquake ignited over 100 fires, with several large conflagrations and major fire damage. We know the question is when, not if, another major earthquake will strike San Francisco and ignite numerous fires.

The Civil Grand Jury believes it is essential that we take prompt and aggressive action to expand and enhance our defenses against the inevitable fires following an earthquake before it is too late. All parts of the City – north and south, east and west, rich and poor, downtown and residential neighborhoods – deserve to be well protected against this catastrophic risk.

Today, the City has a seismically safe high-pressure Auxiliary Water Supply System (AWSS) -- separate and distinct from the low-pressure municipal water supply system (MWSS) -- that provides excellent firefighting protection to parts of the City. However, large parts of the City, such as the outer Richmond, outer Sunset, and Bayview/Hunters Point, among others, do not have a high-pressure AWSS and are not nearly as well protected.

Plans to develop a seismically safe high-pressure AWSS for the western portions of our City are now moving forward. But even though City leaders have known about this issue for decades, the City still does not have concrete plans or a timeline to provide a more robust emergency firefighting water supply for all parts of the City that need one.

In 2014, the U.S. Geological Survey (USGS) estimated there is a 72 percent chance of one or more magnitude 6.7 or greater earthquakes striking the Bay Area between 2014 and 2043. Earlier this year Mayor London Breed announced that planning for such a disaster is a priority. But at our current pace and funding levels, expansion of a high-pressure AWSS to currently unserved parts of the City will not be completed for another thirty-five (35) years or more–well after the USGS predicts we will be struck by one or more major earthquakes.

The Civil Grand Jury makes the following recommendations, among others which are more fully discussed herein:

- The City should be prepared to fight fires in all parts of the City in the event of a repeat of a 1906 size earthquake;
- The City should aggressively develop a high-pressure, multi-sourced, seismically safe emergency water supply for those parts of the City that don't currently have one, with a target completion date of no later than 2034;
- As an interim measure, the City should immediately replace and expand its inventory of Portable Water Supply System (PWSS) hose tenders, which are comparatively cheap, can be acquired much more quickly than the high-pressure AWSS, and were essential in fighting the 1989 Loma Prieta fire, but are now past their useful life;
- The new PWSS hose tenders should be strategically placed in those areas of the City that do not have a high-pressure, multi-sourced, seismically safe emergency water supply.

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BACKGROUND AND PROBLEM STATEMENT

No one knows when the next large earthquake is coming. But it is coming.

A. Fire Following Earthquake Is a Major Risk to The City

"San Francisco will sustain major damage from fires following future earthquakes, in addition to the damage caused by shaking."[1] As explained in a 2010 report prepared for the City,

> In San Francisco, over 90 percent of buildings are constructed from wood, many of them directly touching their neighbor buildings. Earthquakes in places with this type of construction have caused the two largest peacetime urban fires in history: in 1906 in San Francisco and in 1923 in Tokyo.[2]

A main reason the 1906 fire was so devastating is that the earthquake destroyed much of the water system.[3]

Fires following earthquakes remain a major threat today. In 1994, approximately 110 fires were ignited after the Northridge earthquake in Los Angeles County, even though it was "only" a 6.7-magnitude earthquake.[4] In 1995, the 6.9-magnitude Kobe, Japan earthquake ignited over 100 fires, with several large conflagrations and major fire damage.[5] In Kobe "broken water

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[1] Applied Technology Council (ATC) ATC 52-1, Here Today–Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Potential Earthquake Impacts, prepared for the Department of Building Inspection, CCSF, under the Community Action Plan for Seismic Safety (CAPSS) Project (2010) ("ATC 52-1, Potential Earthquake Impacts"), https://sfgov.org/esip/sites/default/files/FileCenter/Documents/9753-atc521.pdf at p. 25.

[2] *Id.*; footnote omitted.

[3] See Scawthorn, C., O'Rourke, T. D. & Blackburn, F., *The 1906 San Francisco Earthquake and Fire---Enduring Lessons for Fire Protection and Water Supply*, Earthquake Spectra, Volume 22, S135-S158 (2006) ("Scawthorn, O'Rourke & Blackburn, 1906 Lessons"), http://www.sparisk.com/documents/06Spectra1906SFEQandFire-EnduringLessonsCRSTDOFTB.pdf ; see also Scawthorn, C., Water Supply In Regard to Fire Following Earthquake, Pacific Earthquake Engineering Research Center, College of Engineering, University of California, sponsored by the California Seismic Safety Commission, Berkeley (2011) ("PEER 2011, Water Supply Following Earthquake"), https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf at p. 5.

[4] See discussion in Scawthorn, C., SPA Risk LLC, *Analysis of Fire Following Earthquake Potential for San Francisco, California*, prepared for the Applied Technology Council on behalf of the Department of Building Inspection City and County of San Francisco (October 2010 Rev. 1) ("Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco"), http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at p. 7; PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf at pp. 12-17.

[5] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf at pp. 17-19; ATC, 52-1, Potential Earthquake Impacts, https://sfgov.org/esip/sites/default/files/FileCenter/Documents/9753-atc521.pdf at p. 25.

mains left the fire department helpless, and fires destroyed more than 7,000 buildings."[6] A magnitude 7.9 earthquake would be an estimated 10 times larger than a magnitude 6.9 earthquake, and would release approximately 31 times more energy.[7]

San Francisco is by far the most densely populated large city in California and is the second most densely populated large city in the country.[8] With mostly wood construction in many areas, this dense City remains at significant risk.[9]

B. AWSS Background and Current Status

After the 1906 earthquake and its devastating fires, the City built an independent emergency water supply for firefighting, known as the AWSS.[10]

The AWSS is a separate, non-potable emergency firefighting water supply system that at present consists of approximately 135 miles of high-pressure (HP) pipelines, 230 cisterns, two above-ground storage tanks, a reservoir, and two salt-water pumping stations.[11] Applying a "belt

[6] ATC 52-1, Potential Earthquake Impacts, https://sfgov.org/esip/sites/default/files/FileCenter/Documents/9753-atc521.pdf at p. 25.

[7] See the United States Geological Survey's "How Much Bigger ….?" Calculator, located at https://earthquake.usgs.gov/learn/topics/calculator.php , where one can compare the relative size and strength of different magnitude earthquakes.

[8] Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at p. 6.

[9] Ibid.

[10] See generally SFPUC, Frequently Asked Questions–Fire Suppression Water Systems, dated November 2017 "SFPUC 2017 FAQ", https://sfwater.org/modules/showdocument.aspx?documentid=11507 attached as Appendix N; see also Scawthorn, O'Rourke & Blackburn, 1906 Lessons, http://www.sparisk.com/documents/06Spectra1906SFEQandFire-EnduringLessonsCRSTDOFTB.pdf

[11] AECOM / AGS, a Joint Venture, CS-199 Planning Support Services for Auxiliary Water Supply System (AWSS) Project Report (Final Report), February2014 ("CS-199"), at p. 7, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055; SFPUC Fact Sheet, dated Summer 2012, located at https://www.sfwater.org/modules/showdocument.aspx?documentid=2501 and printed March 6, 2019. The online Fact Sheet is outdated, as the City has added approximately 30 more cisterns through the 2010 and 2014 ESER bonds. The SFFD also has three large capacity fireboats berthed at Pier 22 ½ and an additional, smaller fireboat berthed at the San Francisco Marina Yacht Harbor.

People sometimes confuse Emergency Firefighting Water System (EFWS) and AWSS, or use them interchangeably. EFWS is the broader concept, including all emergency sources of water and the means for delivering them. AWSS is sometimes described as including cisterns, and other times not. Compare CS-199, at p. 7, ("AWSS is a water supply system consisting of pipelines, cisterns, reservoir, storage tanks, and salt-water pump stations.") https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 with AECOM, Westside Emergency Firefighting Water Systems Options Analysis Report, January 5, 2018 ("2018 Westside Options Analysis"), at pp. 10-13, 20 (differentiating between EFWS and AWSS, and discussing cisterns as a supplement to but not part of AWSS), https://www.sfwater.org/modules/showdocument.aspx?documentid=11740.

and suspenders" approach, if the City's MWSS mains break leaving low-pressure hydrants useless, firefighters will have access to other sources of water, including the Twin Peaks Reservoir and the Bay. Unlike the MWSS, AWSS pipelines were designed to withstand movement from an earthquake.[12]

The AWSS is "remarkably well designed to furnish large amounts of water for firefighting purposes under normal conditions and contains many special features to increase reliability in the event of an earthquake."[13] The AWSS is "designed to provide water at higher pressures than the potable water system, allowing firefighters to use water from the AWSS hydrants without requiring a fire engine."[14]

Another of the key features of the AWSS is its redundancy. The HP AWSS was designed with both a redundant water supply and a gridded main system.[15] This feature provides a more reliable emergency water supply system, allowing potential pipe breaks to be bypassed.[16] As succinctly stated by an outside expert, "the AWSS achieves high reliability by having multiple sources, a highly redundant network and special piping and valves."[17]

The AWSS was originally built over 100 years ago, at a time when the northeast portion of the City contained both the central business district and the majority of the City's population.[18] As a result, the multi-sourced, HP AWSS pipeline network primarily covers just the northeastern part of the City.[19]

The City has been considering expanding the HP AWSS for decades. For example the Analysis by the Ballot Simplification Committee of 1986's Proposition A, Fire Protection Bonds, specifically noted that parts of the City were not served by the HP AWSS:

This report will use EFWS as the broader concept, and will generally use AWSS to refer to the HP AWSS (the 135 miles of pipelines and associated facilities but not including cisterns), although we will not change quotes. This distinction is important, as there are cisterns in the southern and western portions of the City, but not the HP AWSS.

[12] CS-199, at p. 8, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055.

[13] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf,, at p. 80; see also Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at pp.12-15.

[14] 2018 Westside Options Analysis, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740 at p. 10.

[15] *Id.*, at p. 37.

[16] Ibid.

[17] C. Scawthorn, January 5, 2018 memorandum to D.Myerson & S.Huang of SFPUC re Review of "Westside Emergency Firefighting Water System Options Analysis" "Scawthorn 2018 memo"), https://www.sfwater.org/modules/showdocument.aspx?documentid=11740 .

[18] See SFPUC 2017 FAQ, Question 2, at https://sfwater.org/modules/showdocument.aspx?documentid=11507 , a copy of which is attached as Appendix N.

[19] *Id.*

THE WAY IT IS NOW: Since the 1906 earthquake and fire, the San Francisco Fire Department has had programs to improve its fire protection system. A bond issue in 1977 paid for the most recent improvements, including an extension of the high pressure firefighting water system which operates independently from the City's domestic water supply. However, there are still parts of the City which are not served by that high pressure system.[20]

In June 2003, the 2002-2003 Civil Grand Jury recommended that the HP AWSS be extended "to serve all parts of the City."[21] Yet three decades after the 1986 bond and 16 years after the prior Civil Grand Jury report, many neighborhoods still do not have HP AWSS pipelines.[22] Plans are moving forward to fund a new HP AWSS using potable water on the west side through an upcoming Earthquake Safety and Emergency Response Bond (ESER) issuance, but at the City's current pace it will take approximately 35 years or more to build out a HP AWSS pipeline system that serves all neighborhoods, including the southern portions of the City.[23] The City does not have a plan with a firm timeline for completion of this work or firm plans to fund all the work that needs to be done.

C. Problem Statement

Certain parts of the City, such as the northeast quadrant, are well protected against the risk of fires following an earthquake. These well-protected areas have a multi-sourced, redundant, Emergency Firefighting Water System (EFWS), including the HP AWSS. Unfortunately, other parts of the City are protected only by the low-pressure MWSS and by cisterns, which are not

[20] The 1986 Ballot Simplification Committee Analysis explained the proposal for Proposition A as paying for improvements including extending the high-pressure system and installing a high-pressure pump station at Lake Merced. Proposition A passed, but large areas of the City still do not have the protection of the independent high-pressure water system, and Lake Merced still does not have a high-pressure pump station. A copy of the Analysis by the Ballot Simplification Committee of the 1986 Proposition A is attached as Appendix L.

[21] 2002-2003 Civil Grand Jury for the City and County of San Francisco, Keeping the Faucets Flowing: Water Emergency Preparedness In San Francisco (June 2003), http://civilgrandjury.sfgov.org/2002_2003/Keeping_the_Faucets_Flowing_Water_Emergency.pdf , at p. 2.

[22] Neighborhoods currently without HP AWSS hydrants include Bayview Heights, Crocker Amazon, Excelsior, Ingleside, Merced Manor/Parkside, Mission Terrace, Oceanview, Outer Mission, Outer Richmond, Outer Sunset, Portola, Sea Cliff, Stonestown, and Sunnyside. A map showing the current layout of HP AWSS pipelines is on the cover and is attached as Appendix I.

[23] March 4, 2019 and March 11, 2019 SFPUC presentations and accompanying materials provided to the Emergency Firefighting Water System Management Oversight Committee. The amount of funding potentially available through the 2020 ESER bond and through water rates has been increased since the March 2019 Emergency Firefighting Water System Management Oversight Committee meetings. Thus, it *may* now be somewhat less than the 35 years presented in March. It has been difficult to tie down the City's "pace of funding" given there are no firm long term plans and the amount of funding available through an ESER bond can and does change. Although 35 years may be off somewhat, it remains the best (indeed only) current articulation of pace of funding and a timeline provided to the Civil Grand Jury.

nearly as reliable for fighting fires following a major earthquake and, unlike the HP AWSS, need fire engine support to effectively deliver water to a fire.[24]

The problem addressed in this report is how to ensure that all parts of the City – north and south, east and west, rich and poor, downtown and residential neighborhoods – are well protected from fires following earthquakes before it is too late.

METHODOLOGY

Members of the Civil Grand Jury conducted interviews with representatives of:

- The San Francisco Public Utilities Commission
- The San Francisco Fire Department
- The San Francisco Department of Public Works
- The San Francisco Office of Resilience and Capital Planning
- The San Francisco Department of the Environment
- The San Francisco Fire Commission
- The Board of Supervisors

Members of the Civil Grand Jury also conducted interviews with:

- Retired members of the San Francisco Fire Department
- A retired fire chief from a local jurisdiction
- Technical experts in the fields of engineering, wildfires, and water supply for fighting fires after earthquakes
- Concerned community members

Members of the Civil Grand Jury reviewed numerous planning and engineering reports specifically focusing on the AWSS or the PWSS, listed in Appendix D.

Members of the Civil Grand Jury also reviewed the relevant parts of articles, publications and reports regarding fires following earthquakes and related issues. These more general sources, some of which discuss the AWSS or PWSS but are not solely focused on them, are listed in Appendix E. [25]

[24] See discussion of expected problems of relying on a municipal water supply system in Section D of the Discussion, at pp. 18-20.

[25] Several of these publications are technical papers, and the Civil Grand Jury is comprised of lay citizens. When we cite or refer to technical papers it is generally for the conclusions or other non-technical information; we do not purport to be knowledgeable regarding the intricacies of fire spread models or the like.

DISCUSSION

Succinctly stated, "water supply is critical to firefighting."[26] Without a reliable water supply, the San Francisco Fire Department (SFFD) cannot be realistically expected to fight fires following a major disaster such as an earthquake.

A. San Francisco is Highly Vulnerable to Fires Following a Major Earthquake

San Francisco is highly vulnerable to fire after an earthquake, more than any other city in the country.

As explained in a 2008 article for the International Association for Fire Safety Science,

> Densely built environments are highly vulnerable to disasters. Common problems include: (a) narrow streets enabling fire to spread easily from one building to another; (b) streets cluttered with collapsed buildings in an earthquake restricting fire engine access; (c) shortage of open spaces which function as fire breaks or evacuation sites; (d) older and less robust wooden houses that easily collapse and burn in an earthquake ….[27]

San Francisco has significantly higher population density than any other county in California, as shown in Figure 1 on the next page: [28]

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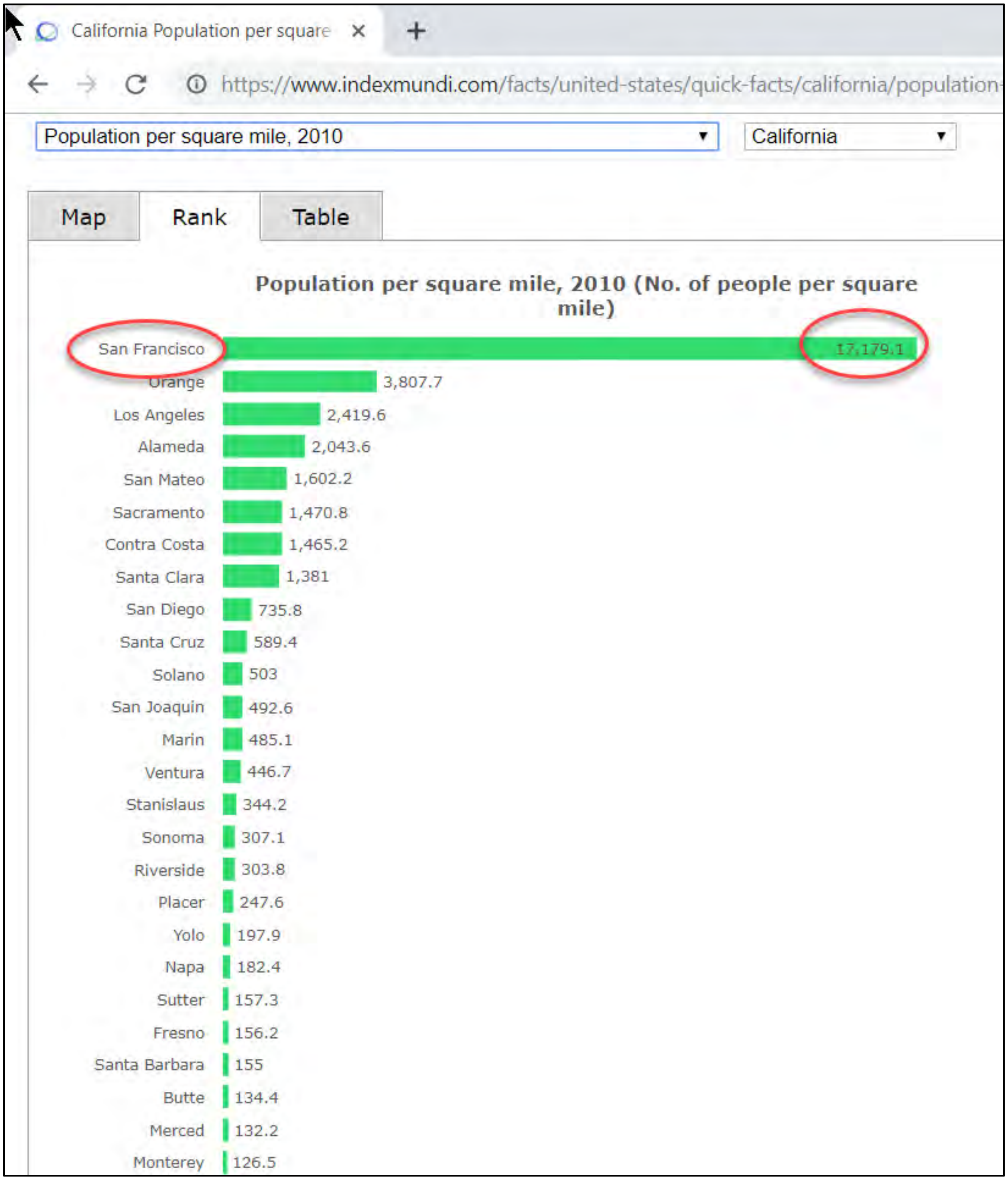
[26] Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at p. 12.

[27] Himoto, K., Akimoto, Y., Hokugo, A., and Tanaka, T., Risk and Behavior of Fire Spread in a Densely-built Urban Area, International Association for Fire Safety Science (2008), http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1000.9412&rep=rep1&type=pdf. at pp. 267-268 (parenthetical reference omitted). San Francisco does have streets that operate as fire breaks: Market St., Van Ness Ave., Geary St. (west of Gough), Dolores St., Mission St, 19th Avenue, Park Presidio Blvd., Alemany Blvd., and Third Street.

[28] See https://www.indexmundi.com/facts/united-states/quick-facts/california/population-density#chart .

Figure 1

Population Density By County



Similarly, based on 2016 data, San Francisco is the eighth densest city in the country with a population above 50,000, and other than New York City is the densest city with a population above 100,000:[29] See Figure 2, below.

Figure 2

Population Density by City

https://www.governing.com/gov-data/population-density-land-area-cities-map.html

laps & Data - Geography - U.S. Census Bureau

- Passaic, N.J.: 22,424 persons/sq. mile

The following table lists population densities for U.S. cities with populations of at least 50,000 as of 2016:

Search:

City	Population Density (Persons/Square Mile)	2016 Population	Land Area (Square Miles)
Union City, New Jersey	54,138	69,296	1
West New York, New Jersey	52,815	53,343	1
Hoboken, New Jersey	42,484	54,379	1
New York, New York	28,211	8,537,673	303
Passaic, New Jersey	22,424	70,635	3
Somerville, Massachusetts	19,738	81,322	4
Huntington Park, California	19,561	58,879	3
San Francisco, California	18,581	870,887	47
Jersey City, New Jersey	17,860	264,152	15
Paterson, New Jersey	17,438	147,000	8
Cambridge, Massachusetts	17,316	110,651	6
East Orange, New Jersey	16,528	64,789	4

San Francisco also has many narrow streets, and buildings that will almost certainly collapse in an earthquake and obstruct many streets, blocking traffic including fire engines. We also have a heavy concentration of older, wooden homes that are densely concentrated and highly flammable.[30]

[29] https://www.governing.com/gov-data/population-density-land-area-cities-map.html.

[30] ATC 52-1, Potential Earthquake Impacts, https://sfgov.org/esip/sites/default/files/FileCenter/Documents/9753-atc521.pdf at p. 25.

This is not just the Civil Grand Jury's perspective. Many experts, and numerous witnesses interviewed by the Civil Grand Jury, have opined that San Francisco faces "the most serious conflagration risk" and "will sustain major damage from fires following future earthquakes…."[31]

In July 2010, SPA Risk LLC (Dr. Charles Scawthorn, principal) prepared a report entitled, *Analysis of Fire Following Earthquake Potential for San Francisco, California*, for the Applied Technology Council (ATC) on behalf of the City's Department of Building Inspection.[32] The report concluded that San Francisco is at "significant risk" due to fire following earthquake, and that the SFFD's fire engines[33] "will almost certainly not be able to respond to all post-earthquake fires, which are estimated to be about 100 on average (with a 10% chance of as many as 140) for a magnitude 7.9 San Andreas event."[34]

A key table in that 2010 report is copied below:

Table 1

Bounds for Losses to Buildings Due to Fire Following Earthquake[35]

	25% - 75% Confidence Range		
	Ignitions	Loss $ billions	Total Burnt Building Floor Area Mill. Sq. ft.
San Andreas Mw 7.9	68 ~ 120	$ 4.1 ~ $ 10.3	11.2 ~28.2
San Andreas Mw 7.2	52 ~ 89	$ 2.8 ~ $ 6.8	7.7 ~ 18.6
San Andreas Mw 6.5	48 ~ 70	$ 1.7 ~ $ 5.1	4.7 ~ 14.0
Hayward Mw 6.9	27 ~ 46	$ 1.3 ~ $ 4.0	3.6 ~ 11.0

[31] See, e.g., Scawthorn, C., *Fire following earthquake: Estimates of the conflagration risk to insured property in greater Los Angeles and San Francisco*, All-Industry Research Advisory Council, Oak Brook, Ill. (1987), http://www.sparisk.com/documents/AIRACFFEs.pdf , at p. iii ("Scawthorn 1987"); ATC 52-1, Potential Earthquake Impacts, https://sfgov.org/esip/sites/default/files/FileCenter/Documents/9753-atc521.pdf at pp. vi, 25-29.

[32] Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf .

[33] SFFD now has 44 frontline fire engines, and 19 relief engines, according to information provided by the SFFD. At the time of the 2010 report, the City apparently had 42 frontline engines.

[34] Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at p. 2. A copy of the Abstract (or summary) of that report is attached as Appendix K.

[35] Ibid. These estimates already take into account the AWSS system as it existed in 2010 (i.e., prior to the addition of more cisterns and other work performed under the 2010 and 2014 ESER bonds). The damage estimates do not include business interruption losses, loss of tourism or loss of property tax revenues.

As explained in that report, there is significant uncertainty regarding how many fires might be ignited following an earthquake, and the extent of damage they are likely to cause. One of the key variables is completely outside the City's control: wind. In 1989, the City was extremely lucky that there was no wind.[36] Indeed, "stronger wind conditions would have resulted in much greater fire spread in the Marina…."[37]

According to the 2010 report, there is a 25% chance that fires and damages could fall below the ranges in Table 1 on the preceding page, and an equal likelihood that they could exceed the ranges in that table.[38] Earlier this year (2019) the San Francisco Public Utilities Commission (SFPUC) engaged Dr. Scawthorn to update his analysis, but that update will not be completed until after this report has been issued. However, the key is not the precise numbers but "their overall magnitude."[39] Indeed, given the escalation in Bay Area home values over the last decade, one can only assume that the dollar loss estimates will increase substantially.

B. The USGS Warns the San Francisco Bay Area Has a High Likelihood of a Major Earthquake

In 2014, the USGS estimated there is a 72 percent chance of a 6.7 or greater magnitude earthquake striking the Bay Area by 2043.[40] This was based on a new model, commonly referred to as the third Uniform California Earthquake Rupture Forecast, or UCERF3.[41]

Small earthquakes occur more frequently than large earthquakes.[42] According to the updated model, the probability that an earthquake magnitude 6.0 or larger will occur in the San Francisco region before 2043 is 98 percent. By comparison, the probability of at least one earthquake of magnitude 6.7 or larger is 72 percent for the same area, and the probability of at least one earthquake of magnitude 7.0 or larger is 51 percent. [43]

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[36] Scawthorn and Blackburn, Performance of the San Francisco Auxiliary and Portable Water Supply Systems in the 17 October 1989 Loma Prieta Earthquake, presented at Fourth U.S. National Conference on Earthquake Engineering May 20-24, 1990.

[37] *Id.*, at p. 6.

[38] Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at p. 2, attached as Appendix K.

[39] *Ibid*.

[40] See USGS, Earthquake Outlook for the San Francisco Bay Region 2014–2043, Fact Sheet 2016-3020 (2016) (version 1.1), https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf , attached as Appendix G.

[41] UCERF3: A New Earthquake Forecast for California's Complex Fault System, Fact Sheet 2015-3009 (2015) https://pubs.usgs.gov/fs/2015/3009/pdf/fs2015-3009.pdf , attached as Appendix F.

[42] USGS, Earthquake Outlook for the San Francisco Bay Region 2014–2043, Fact Sheet 2016-3020 (2016) (version 1.1), https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf , attached as Appendix G.

[43] UCERF3: A New Earthquake Forecast for California's Complex Fault System, Fact Sheet 2015-3009 (2015) https://pubs.usgs.gov/fs/2015/3009/pdf/fs2015-3009.pdf , attached as Appendix F.

Table 2 below is a simplified version of a table from a USGS fact sheet showing the likelihood of one or more events of varying size for the San Francisco region within the next 30 years based on this new model:[44]

Table 2

San Francisco Region Section of Table from March 2015 USGS Fact Sheet 2015-3009

San Francisco Region		
Magnitude (greater than or equal to)	Average repeat time (years)	30-year likelihood of one or more events
5	1.3	100%
6	8.9	98%
6.7	29	72%
7	48	51%
7.5	124	20%
8	825	4%

Although these figures are for the region, and not just the City and County of San Francisco, the predictions are sobering. To put these predictions in perspective, the 1989 Loma Prieta earthquake had a magnitude of 6.9, and, even though the epicenter was approximately 60 miles from San Francisco, it was the largest earthquake to strike the City since 1906.[45] Using the USGS online calculator,[46] a 7.5 magnitude earthquake, which has a 20% chance of happening by 2043, would be almost four times bigger than Loma Prieta, and would release almost eight times the energy. An 8.0 magnitude earthquake would be over 12.5 times bigger than Loma Prieta, and would release almost 45 times the energy. And this is without addressing the risk that the next major earthquake's epicenter could be much closer than 60 miles away.

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[44] *Id.*, at p.4; Table 2 above is a simplified version of Table 1 of Fact Sheet 2015-3009, attached as Appendix F.

[45] See USGS, M 6.9 October 17, 1989 Loma Prieta Earthquake, https://earthquake.usgs.gov/earthquakes/events/1989lomaprieta/; USGS, M 6.9 - Loma Prieta, California Earthquake, https://earthquake.usgs.gov/earthquakes/eventpage/nc216859/executive.

[46] See USGS, "How Much Bigger ….?" Calculator, located at https://earthquake.usgs.gov/learn/topics/calculator.php , where one can calculate how much bigger one earthquake is than another.

The USGS has also warned that the pace of large earthquakes is likely to increase:

> In the 50 years prior to 1906, there were 13 earthquakes with a magnitude between 6 and 7, but only 6 earthquakes of similar magnitude in the 110 years since 1906. The rate of large earthquakes is expected to increase from this low level as tectonic plate movements continue to increase the stress on the faults in the region.[47]

The warnings and predictions from the USGS should be a wake-up call to all of us.

C. The Existing High-pressure AWSS System Only Covers Part of the City

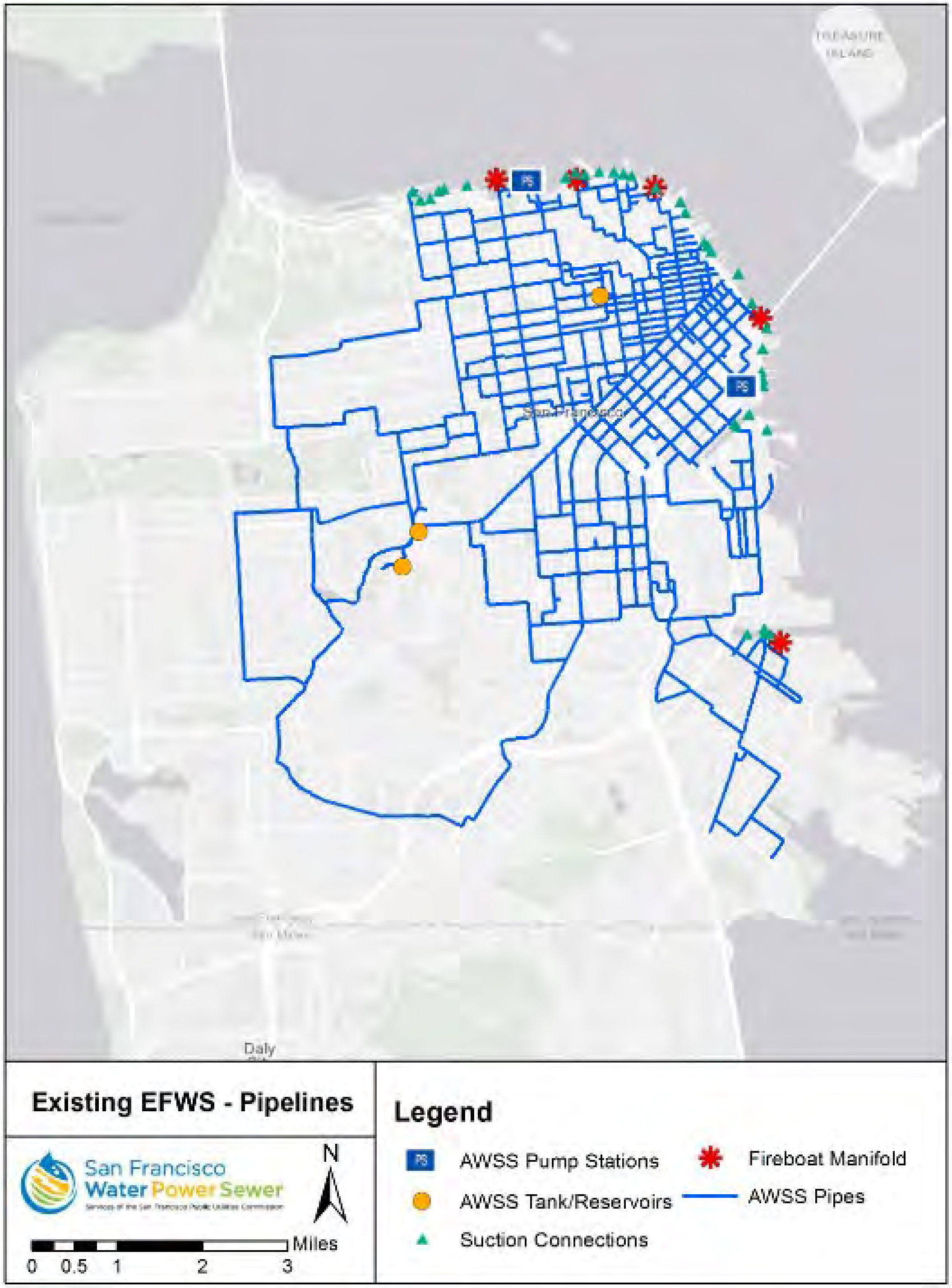
The history and condition of the existing HP AWSS have been described in detail in multiple other reports.[48] Figure 2, on the following page, shows the location of the HP AWSS:[49]

[47] USGS, Earthquake Outlook for the San Francisco Bay Region 2014–2043, Fact Sheet 2016-3020 (2016) (version 1.1), https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf . See also Aster, R., California's other drought: A major earthquake is overdue, *The Conversation* (January 30, 2018), https://theconversation.com/californias-other-drought-a-major-earthquake-is-overdue-90517; *California's Current Earthquake Hiatus is an Unlikely Pause*, Seismological Society of America, published April 3, 2019, https://www.seismosoc.org/news/californias-current-earthquake-hiatus-is-an-unlikely-pause/, printed on April 5, 2019.

[48] See, e.g., CS-199, at pp. 7-11, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055; Scawthorn, O'Rourke & Blackburn, 1906 Lessons, http://www.sparisk.com/documents/06Spectra1906SFEQandFire-EnduringLessonsCRSTDOFTB.pdf ; Madsen, M., Reports on an Auxiliary Water Supply System for Fire Protection for San Francisco, California (1908), https://sfpuc.sharefile.com/share/view/4743f327acfd4ba7 .

[49] Map supplied by the SFPUC on May 7, 2019.

Figure 3
Map of Existing High-Pressure AWSS



On a district by district basis, Supervisorial Districts 1, 4, 7 and 11 are not nearly as well protected by the HP AWSS as, for example, Districts 3 or 6:[50] See Table 3 below.

Table 3
HP AWSS Hydrants and Miles of Main by District

Supervisorial District	# of AWSS Fire Hydrants	Miles of AWSS Mains
1	42	5
2	170	14
3	327	23
4	3	0
5	188	16
6	366	27
7	79	7
8	110	9
9	110	9
10	222	18
11	24	1
TOTAL	1641	130

In fact, six of the eleven Supervisorial Districts, Districts 1, 4, 7, 8, 9 and 11, each have less than ten miles of AWSS mains. Districts 1, 4, and 11 each have less than 50 AWSS fire hydrants.

The areas not protected by the HP AWSS would need to rely primarily on getting emergency firefighting water supplies from the City's MWSS through its low-pressure hydrants or from cisterns. For a number of reasons detailed below, these resources are unlikely to provide adequate water to protect residents from fires after a major earthquake.

[50] Data provided by SFPUC on March 13, 2019.

D. The Municipal (Domestic) Water Supply System Is "Highly Vulnerable to Catastrophic Failure"[51]

No one knows with certainty what will happen in a major earthquake. But common sense says we should look at past experience and listen to experts when they warn us not to rely on the MWSS for firefighting following an earthquake.

As explained in a 2009 report prepared for the SFPUC,

> By their nature, domestic water mains are more vulnerable to earthquake damage. Numerous service connections and the jointed construction that is the industry norm contribute to their vulnerability.[52]

San Francisco has made a tremendous effort to improve and seismically reinforce its regional and local water system by means of the $4.8 billion Water System Improvement Project (WSIP).[53] The WSIP is one of the largest water infrastructure programs in the nation and the largest infrastructure program ever undertaken by the City. Among its objectives has been reducing the water system's vulnerability to earthquakes, with a particular emphasis on seismically reinforcing the regional delivery system, transmission mains, and reservoirs.[54]

Although the WSIP greatly enhances the reliability of the MWSS, and in particular the transmission mains and reservoirs, the 2009 report emphasizes that, unlike the HP AWSS, the local MWSS system is vulnerable to a major earthquake due to the numerous branches and service connections that can break and drain the system.[55]

This has been borne out by experience in San Francisco and elsewhere. In the 1906 earthquake, an estimated 23,000 breaks in the MWSS resulted in the loss of water and pressure.[56] In the much smaller 1989 Loma Prieta earthquake, there were 69 main breaks and 54 service

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[51] See SF Fire Commission Resolution 2010-01, https://sf-fire.org/sites/default/files/FileCenter/Documents/2446-Resolution%202010-01%20PWSS%20Grant%20Funding.pdf at p.1. A copy of SFFC Resolution 2010-01 is attached as Appendix M.

[52] Metcalf & Eddy, at p. 18, http://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/b2754026-dded-4ee6-b24c-2cf837f3bc00. The SFPUC has initiated a planning study to better understand the current level of reliability of the entire potable distribution system, focusing on backbone pipes, but that study will take several years to complete.

[53] See SFPUC's WSIP webpage, https://sfwater.org/index.aspx?page=114 .

[54] See, e.g., list of WSIP projects at https://sfwater.org/index.aspx?page=968 .

[55] Metcalf & Eddy, at pp. 18-19, http://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/b2754026-dded-4ee6-b24c-2cf837f3bc00. The Civil Grand Jury is not questioning the importance or the efficacy of the WSIP, which is essential to rapidly restoring potable water service to residents following an earthquake. But fire suppression needs an immediately available supply of water, which the MWSS is unlikely to be able to provide following a major earthquake.

[56] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf, p. 6. Other reports have provided somewhat different, but still extremely high estimates. Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at p. 13 [over 28,000 breaks, including service breaks]. But whatever the precise number of water main breaks in 1906, the earthquake devastated the water supply system which contributed to the horrific fires that nearly destroyed the City.

connection breaks in the Marina district alone.[57] Because of these breaks, low-pressure hydrants located in the Marina could not provide adequate water or pressure for firefighting.[58]

Other recent major earthquakes have also caused substantial damage to municipal water supply systems. In the 6.7-magnitude 1994 Northridge earthquake, there were over 1,000 water main breaks and over 100 fires.[59] In the 6.9-magnitude 1995 Kobe, Japan earthquake, "water loss seriously impaired firefighting."[60] There were over 2,000 breaks in the underground piping, and large fires burned freely due to lack of water.[61] Similarly, in the 2011 Eastern Japan earthquake there was extensive damage to water supply lines.[62] Even the relatively small 6.0-magnitude 2014 South Napa earthquake "highlighted the vulnerability of water and wastewater systems to earthquake-related ground failure, the additional fire hazards that earthquake-related water system failures can pose, and the fiscal challenges that public agencies face in improving the seismic resiliency of these systems, both pre- and post-earthquake."[63]

Experts have predicted that in a future major San Francisco earthquake, the MWSS could sustain over 1,000 breaks.[64] Various reports have said it in different ways, but the clear takeaway is that the MWSS should not be relied upon to save the City from fires following a major earthquake:

- "MWSS pipes will sustain damage in certain areas of the City, which will impair the ability to deliver water for firefighting."[65]
- "In such an emergency it is likely that the potable water distribution system would be compromised by pipe breaks and leaks."[66]

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[57] CS-199, at p. 11, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055; see also O'Rourke, T.D., Lessons Learned For Lifeline Engineering From Major Urban Earthquakes, presented at Eleventh World Conference on Earthquake Engineering (1996) ("O'Rourke, Lessons Learned").

[58] Scawthorn, C., Porter, K., and Blackburn, F., Performance of Emergency-Response Services After the Earthquake, chapter in The Loma Prieta, California, Earthquake of October 17, 1989, Marina District, T.D. O'Rourke editor, USGS Professional Paper 1551-F (1992)

[59] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf, at p. 16; O'Rourke, Lessons Learned, at p. 3.

[60] O'Rourke, Lessons Learned, at p. 3.

[61] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf, at pp. 18-19.

[62] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf, at p. 24.

[63] Johnson, L. and Mahin, S., The 6.0 M_w South Napa Earthquake of August 24, 2014: A Wake-up Call for Renewed Investment in Seismic Resilience across California, Pacific Earthquake Engineering Research Center prepared for the California Seismic Safety Commission, CSSC Publication 16-03, PEER Report No. 2016/04 (2016), https://ssc.ca.gov/forms_pubs/cssc_603peer201604_final_7_20_16.pdf, Finding 2.3, at p. iii.

[64] Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at p. 2.

[65] CS-199, p. 11, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055.

- "…the usual firefighting water supplies will almost certainly fail…."[67]
- "World renowned scientists, whose area of expertise is the modeling of the destructive effects of earthquakes on underground infrastructure, have identified the domestic water system of San Francisco as highly vulnerable to catastrophic failure in the event of a major Bay Area earthquake."[68]

Moreover, unlike AWSS hydrants, low-pressure hydrants connected to the MWSS require a fire engine to extract and pump the water to sufficient pressure for firefighting.[69] Given that fire engines are likely to be in high demand and potentially overwhelmed in a major earthquake, this is yet another reason why an alternative source of water is necessary.[70]

E. Cisterns Provide Limited Protection

Cisterns are underground tanks, unconnected to any water source.[71] Typically, cisterns in San Francisco hold approximately 75,000 gallons of water.[72]

The City has 229 cisterns located throughout the City, as shown by Figure 4 on the next page[73]:

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[66] 2018 Westside Options Analysis, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740 at p. 10.

[67] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf, at p. 39.

[68] SFFC Resolution 2010-01, p. 1, https://sf-fire.org/sites/default/files/FileCenter/Documents/2446-Resolution%202010-01%20PWSS%20Grant%20Funding.pdf and attached as Appendix M.

[69] CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 , at pp. 55-56.

[70] Scawthorn, O'Rourke & Blackburn, 1906 Lessons, at pp. S153-1S54, http://www.sparisk.com/documents/06Spectra1906SFEQandFire-EnduringLessonsCRSTDOFTB.pdf .

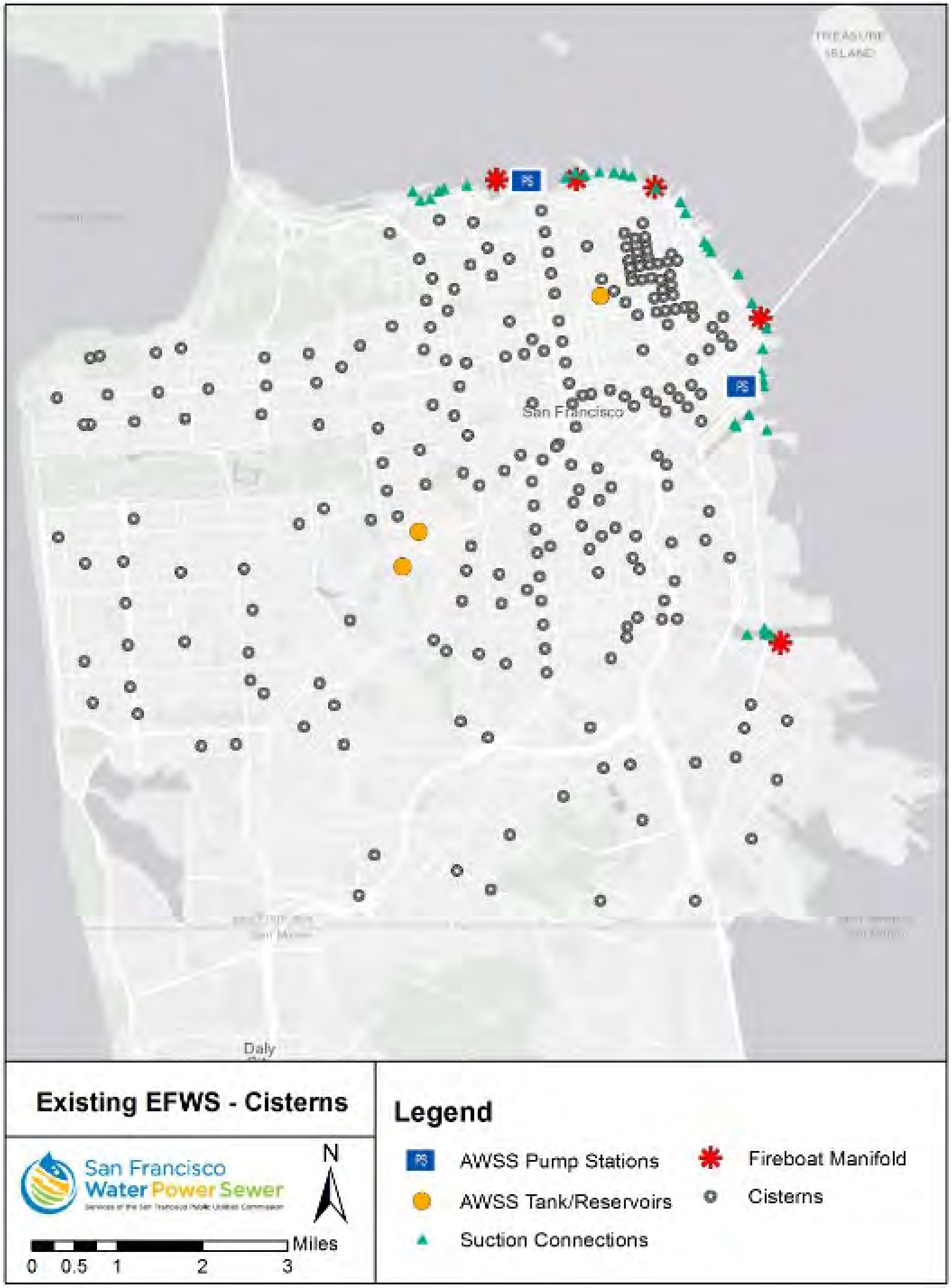
[71] CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 , at p. 13.

[72] See SFFD Water Supplies Manual, http://ufsw.org/pdfs/water_supplies_manual.pdf , at pp. 4.1, 6.13-6.17; PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf , at p. 77.

[73] Map provided by SFPUC on May 7, 2019.

Figure 4

Map of Existing Cisterns



By Supervisorial District, the breakdown of cistern locations is listed in Table 4 below.

Table 4

Cisterns by Supervisorial District

Supervisorial District	Cisterns
1	17
2	23
3	46
4	12
5	20
6	26
7	12
8	27
9	21
10	20
11	5
TOTAL	229

Notably, Districts 1, 4, 7 and 11, which currently have the fewest miles of HP AWSS pipelines, also have the fewest cisterns. This is especially true of District 11, with only one mile of AWSS main pipeline and only five cisterns. [74]

Cisterns provide a valuable backup or "last resort" in the event of damage to the MWSS and AWSS. In the 1994 6.7-magnitude Northridge earthquake, the MWSS suffered over 1,000 water main breaks.[75] Firefighters used backyard swimming pools as water supply sources. In the 1906 earthquake, San Francisco's 23 cisterns were credited with saving a major building in the Financial District when the water mains broke.[76]

Cisterns, however, have limited capacity[77] and are therefore unlikely to be effective against serious fires following a major earthquake. In the 1995 6.9-magnitude Kobe earthquake,

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[74] In recent years, the SFPUC has built 30 additional cisterns, funded by the 2010 and 2014 ESER bonds. These 30 new cisterns are included in the totals in the above table. Half of these new cisterns were strategically located in the Richmond and Sunset districts, which now have 17 and 12 cisterns, respectively, to begin to address concerns that those areas of the City were inadequately protected. SFPUC 2017 FAQ, Question 4, https://sfwater.org/modules/showdocument.aspx?documentid=11507 .

[75] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf , at pp. 12-17.

[76] Scawthorn 1987, http://www.sparisk.com/documents/AIRACFFEs.pdf , at p. S140.

[77] SFFD Water Supplies Manual, http://ufsw.org/pdfs/water_supplies_manual.pdf , at pp. 4.1, 5.6-5.7.

however, the city's 968 cisterns provided little help to firefighters because they drained in 10 minutes.[78]

San Francisco's typical cistern would drain within an hour of continuous firefighting.[79] Given that on average it takes several hours to put out a four-alarm fire,[80] cisterns cannot be expected to successfully fight post-earthquake conflagrations in parts of the City not protected by AWSS. In addition to providing limited firefighting water, cistern water must be extracted and pressurized by an engine, requiring more staff and time to deploy than, for example, AWSS hydrants.[81]

F. The PWSS Inventory Needs to Be Modernized and Expanded

In addition to the MWSS and cisterns, the SFFD intends to rely on the City's Portable Water Supply System, or PWSS, to fight fires in non-AWSS areas.

In the 1980s, the SFFD developed and implemented the PWSS, an above-ground, large-diameter hose system used to move water great distances from a water source to a fire. PWSS units consist of a hose tender, or truck, equipped with approximately one mile of large-diameter five-inch hose (larger than the normal three-inch hose), along with a portable pump, portable hydrants that allow water to be distributed from a large-diameter hose, and other essential firefighting equipment.[82] With its portable pump, a hose tender can be used to draft and pressurize water from alternative water sources, such as lakes, lagoons, a fireboat (as in the 1989 Loma Prieta earthquake), cisterns, or even broken water mains. It can also be used to extend the reach of the HP AWSS system to blocks or neighborhoods without a HP hydrant.[83]

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[78] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf , at pp. 17-19. San Francisco's cisterns are larger than Kobe's, but the point remains they are only good for a limited duration. *Id.*, at p. 77.

[79] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf , at p. 77.

[80] Information provided by SFFD.

[81] CS-199, at pp. 13, 56, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055.

[82] Scawthorn, O'Rourke, Blackburn, S150-151. A detailed description of the PWSS can be found in Scawthorn, C. and Blackburn, F. (1990), Performance of the San Francisco Auxiliary and Portable Water Supply Systems in the 17 October 1989 Loma Prieta Earthquake, presented at Fourth U.S. National Conference on Earthquake Engineering May 20-24, 1990, and provided by SFPUC. The PWSS and its five-inch hoses are different from a prior, abandoned concept of a Flexible Water Supply System, using massive, 12-inch hoses in lieu of expanding the HP AWSS. That concept was proposed in AECOM / WRE, a Joint Venture, CS-229 Task 16 and 19, Emergency Firefighting Water System (EFWS) Spending Plan for the Earthquake Safety Emergency Response (ESER) 2014 Bond (November 2015), https://sfwater.org/Modules/ShowDocument.aspx?documentid=8246. It was abandoned as impractical after concerns over, among other things, how 12-inch diameter hoses would block traffic.

[83] Figure 6-1 on page 83 of CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055, is a map of the City showing how the PWSS can be used to expand the areas protected by the AWSS. Figure 6-1 assumes certain extensions of the AWSS

Currently, there are only five PWSS hose tenders, three of which are located in the "unprotected areas"[84] of the Sunset district and Hunter's Point. In the SFFD's opinion, the PWSS hose tenders are "past their useful life."[85] The newest hose tender, housed in the Sunset, is 27 years old. The second newest, in Hunter's Point, is over 30 years old. The remaining three are over 45 years old.[86]

Firefighters and emergency response experts have been calling for a large-scale expansion of the PWSS for years.[87] In January 2010, the San Francisco Fire Commission (SFFC) issued Resolution 2010-01, encouraging the SFFD to pursue approximately $10 million in grant funding to expand the PWSS. The SFFC recognized that the City's MWSS is highly vulnerable to a catastrophic failure in the event of a major earthquake, and that the AWSS does not cover the entire City. The SFFC declared that the PWSS has been proven effective in the above-ground transmission of water for firefighting, that the PWSS can work in conjunction with and supplement the AWSS, and that the City did not have a sufficient number of units to supply all areas of the City where the AWSS does not extend.[88] Unfortunately, that grant was not funded, and the City has not yet purchased any additional PWSS hose tenders.[89]

Also in 2010, the Applied Technology Council issued several reports as part of the City's Community Action Plan for Seismic Safety, or the "CAPSS Project."[90] Among its recommendations was one similar to ours: Improve emergency water supply systems to cover those neighborhoods not served by the HP AWSS. As explained in that report,

> The Auxiliary Water Supply System provides a redundant water system for fighting fires after earthquakes and at other times, and incorporates many earthquake resistant features in its design. However, this system covers only northern and eastern City neighborhoods, those that were developed in the early

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that do not presently exist, and does not take into consideration the limited size of the existing PWSS inventory. As a result, Figure 6-1 in CS-199 overstates the current level of protection, but does show what could be accomplished with a larger inventory of PWSS hose tenders.

[84] These areas are of course not completely unprotected, but as discussed above they do not have a HP AWSS. The City's outside expert AECOM/AGS, A Joint Venture, has referred to the portion of the City protected by the HP AWSS as the "Protected Area." See CS-199, at p. 8, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055

[85] Information provided by SFFD.

[86] Information provided by SFFD.

[87] See Fire Dept.'s Ace in the Hole, San Francisco Independent, January 31, 1990, attached as Appendix Q.

[88] SFFC Resolution 2010-01, https://sf-fire.org/sites/default/files/FileCenter/Documents/2446-Resolution%202010-01%20PWSS%20Grant%20Funding.pdf

[89] Information provided by SFFD.

[90] According to the CAPSS website, CAPSS was started in the Department of Building Inspection beginning in 1998, and was a nine-year, $1 million study to understand, describe, and mitigate the risk San Francisco faces from earthquakes. CAPSS produced an extensive analysis of potential earthquake impacts as well as community-supported recommendations to mitigate those impacts. See https://sfgov.org/esip/capss .

> part of the last century when the system was constructed. *The City needs adequate, reliable water sources to fight post-earthquake fires in all neighborhoods. There are a number of options to improve the water supply in neighborhoods not served by the Auxiliary System, including expanding the City's Portable Water Supply System, which can be deployed wherever needed. This important issue needs to be addressed as soon as possible*. (Emphasis added)[91]

In 2014, outside consultant AECOM/AGS, a Joint Venture, advised the City that "[a]dditional PWSS units would be a prudent investment for SFFD/SFPUC."[92]

The SFFD submitted a request for funding to purchase 20 newly designed PWSS hose tenders in the fiscal year 2019/2020 budget, but the Civil Grand Jury understands that only four new PWSS hose tenders are included in the Mayor's May 31, 2019 two-year budget proposal.[93] The proposed new SFFD hose tenders are designed to be more efficient and maneuverable than older models, with four-wheel drive to overcome obstacles on roads, the ability to carry up to 6,000 feet of five-inch fire hose, and only one firefighter required to operate each vehicle. Each vehicle will have a high-volume onboard water pump, and a portable submersible water pump. Both pumps will be able to draft water from the Bay, reservoirs, or other water sources. These new hose tenders could be connected together to carry water over many miles of the City. The SFFD estimates these new PWSS vehicles, fully equipped with hoses and appliances would cost approximately $1 million per vehicle.[94]

Given the time required to build or extend a HP pipeline system, acquiring additional PWSS hose tenders is a practical intermediate step to enhance fire protection throughout the City. The SFFD advised the Civil Grand Jury that additional PWSS hose tenders could be acquired and in service within a year or so, or at the outside two years. The failure to obtain grant monies should not stop the City from making this important investment in public safety.

Although the Civil Grand Jury recommends immediately replacing and expanding PWSS units, this is not a long-term solution. A successful PWSS deployment requires a nearby water source, and personnel to unwind a mile of heavy, five-inch-diameter hose through potentially

[91] Applied Technology Council (ATC) ATC-52-2, Here Today–Here Tomorrow: The Road to Earthquake Resilience in San Francisco, A Community Action Plan for Seismic Safety (2010), prepared for the Department of Building Inspection, CCSF, under the (CAPSS) Project, at pp. 53-54, https://sfgov.org/esip/sites/default/files/FileCenter/Documents/9757-atc522.pdf

[92] CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 at p. 85. Although this report referred to the PWSS as an investment in the colloquial sense, the PWSS is not a fixed asset and thus does not involve a capital expenditure. As such, purchasing new hose tenders will need to come from city funds, not bonds. The Civil Grand Jury nevertheless believes that acquiring more PWSS hose tenders is long overdue.

[93] Information provided by SFFD. The City's budget process is of course ongoing. It is therefore uncertain whether the Board of Supervisors will approve sufficient funding for the four new units or conversely whether the Board of Supervisors will increase the funding for purchasing new PWSS units. We also understand that a request for funding for PWSS hose tenders has been made to state officials, but at this time the SFFD does not know if that request has been approved.

[94] Information provided by SFFD.

congested and damaged city streets.[95] Moreover, although hose tenders can draft water from the Bay, they are not designed for use in the ocean – the only unlimited water source on the west side of the City.[96] Given these challenges, PWSS is essentially an important but temporary "Plan B."

G. Efforts to Expand the High-Pressure AWSS Need to Be Accelerated

As discussed in Section B above, the USGS estimates there is a 72 percent chance of a 6.7 or greater magnitude earthquake striking the Bay Area before 2043.[97] In early April of 2019, USGS researchers issued a new study warning that "the next 100 years of California earthquakes along [the San Andreas, San Jacinto and Hayward] faults could be a busy one."[98] Each year we delay construction of an expanded HP AWSS we are gambling, pushing our luck that a major earthquake won't hit before we're ready.

City departments, including the SFPUC, which assumed jurisdiction over the operation and maintenance of the AWSS from the SFFD in 2010, have been analyzing the reliability of the EFWS and the possible expansion of the HP AWSS for over a decade.[99] An analysis in 2009 indicated that the 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."[100] In actuality, and as discussed in Section I below,[101] the SFPUC's consultant's metric is overly optimistic: a 50% score really means that we will have about half of the water needed to meet *median* firefighting demands following a 7.8-magnitude earthquake. Put differently, if the firefighting demands are above the median estimate, this analysis indicates that even with a score of 99% there will be insufficient water to meet the demand.

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[95] Metcalf & Eddy (2009), http://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/b2754026-dded-4ee6-b24c-2cf837f3bc00, at pp. 4-5; information provided by SFFD.

[96] According to the SFFD, there is no known SFFD access to the ocean on the western side of the City, but SFFD is continuing to investigate potential access areas where it might be able to use a PWSS unit.

[97] See USGS, Earthquake Outlook for the San Francisco Bay Region 2014–2043, Fact Sheet 2016-3020, https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf.

[98] See *California's Current Earthquake Hiatus is an Unlikely Pause*, Seismological Society of America, published April 3, 2019, https://www.seismosoc.org/news/californias-current-earthquake-hiatus-is-an-unlikely-pause/, printed on April 5, 2019.

[99] See e.g., Metcalf & Eddy (2009), http://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/b2754026-dded-4ee6-b24c-2cf837f3bc00, CS-199 (2014), https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055, CS-229 (2015), https://sfwater.org/Modules/ShowDocument.aspx?documentid=8246, 2018 Westside Options Analysis (2018), https://www.sfwater.org/modules/showdocument.aspx?documentid=11740, among other reports.

[100] SFPUC FAQ, Question No. 3, https://sfwater.org/modules/showdocument.aspx?documentid=11507 and attached as Appendix N.

[101] See pages 35-36 below.

Figure 5, below, shows EFWS reliability by so-called Fire Response Areas (FRAs)[102] as of 2010, i.e., prior to recent improvements.

Figure 5
Map of EFWS Reliability Scores by FRA as of 2010[103]

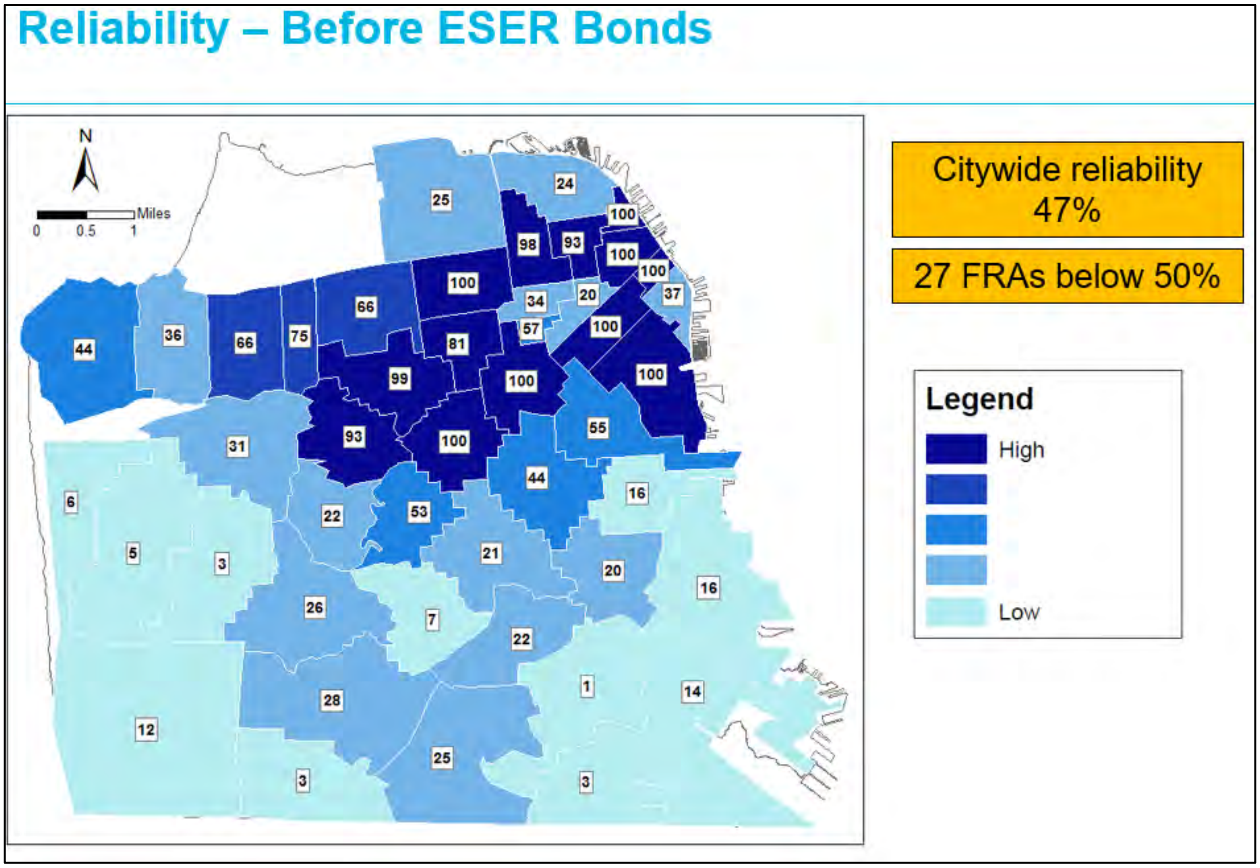

Figure 5 shows that as of 2010 the majority of the City scored below 50%, and in some cases far below. In 2010 and again in 2014, voters approved Earthquake Safety and Emergency Response (ESER) Bonds. The 2010 ESER bonds provided approximately $102 million for the EFWS, and the 2014 ESER bonds provided $54 million. The money was spent on assessing the existing HP AWSS, rehabilitating and upgrading core facilities (existing water storage tanks, pipelines, salt-water pumping stations) that needed seismic strengthening or other repairs or improvements, adding 30 cisterns, and other tasks.[104]

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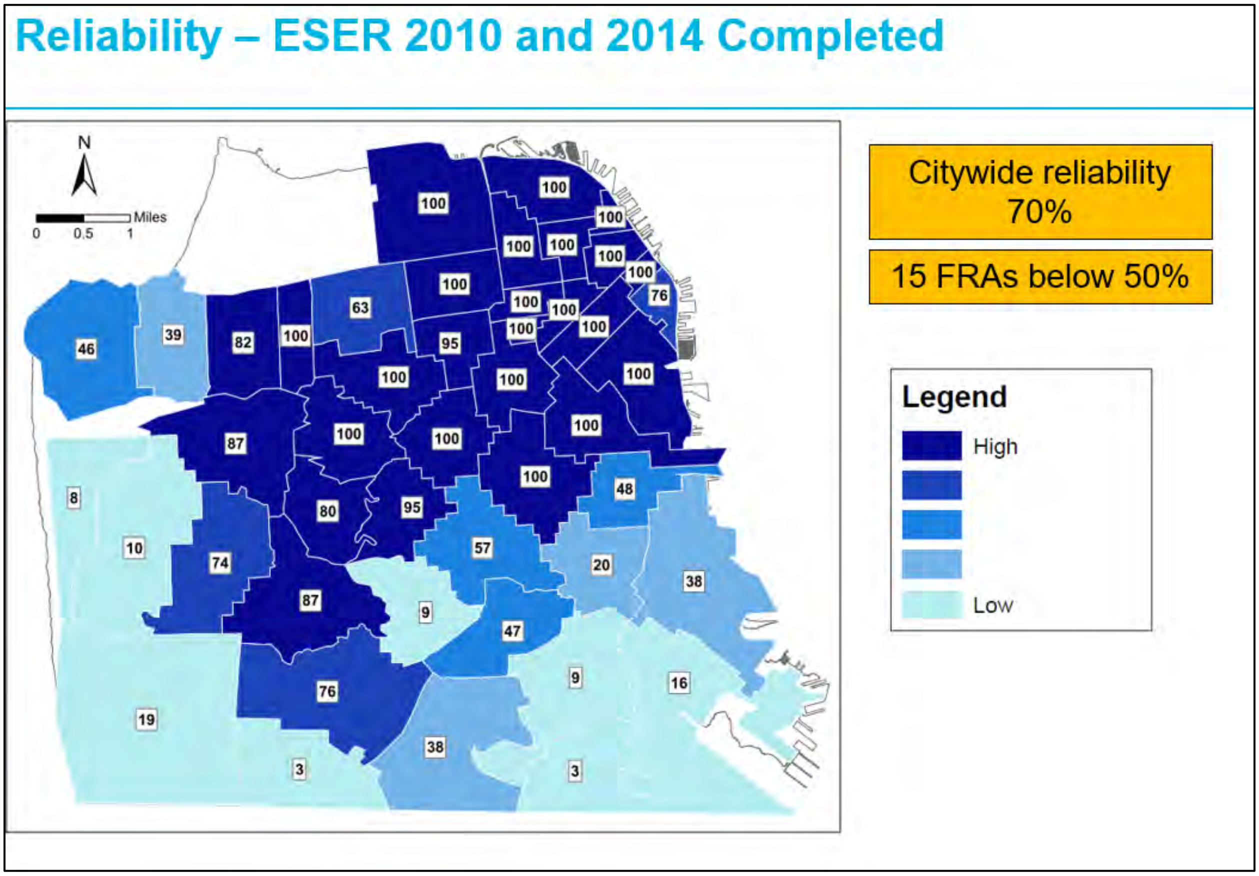
[102] The SFFD divides the City into 46 areas for initial alarm response, also referred to as Fire Response Areas or FRAs. A map showing the different FRAs is attached as Appendix J.

[103] Map supplied by SFPUC. Identical map, except for legend, in AECOM / AGS, JV, Auxiliary Water Supply System Planning Study Summary, https://sfwater.org/Modules/ShowDocument.aspx?documentid=4907 at p.3.

[104] A February 26, 2019 status list provided by the SFPUC for the various projects undertaken pursuant to the 2014 and 2014 ESER bonds, showing which are in planning, in design, in construction, complete, canceled or

The result has been significantly improved EFWS reliability scores, as shown by Figure 6:

Figure 6
Map of EFWS Reliability Scores by FRA After 2010 and 2014 ESER Bond Work Completed [105]



The SFPUC has performed important work in analyzing what needs to be done and by repairing existing facilities. *But today, nine years after the 2010 CAPSS report called for action as soon as possible, 16 years after the 2002-2003 Civil Grand Jury called for expanding the HP AWSS to the entire City, almost 33 years after the 1986 Fire Protection Bonds Analysis stating*

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postponed is attached as Appendix O. See also Earthquake Safety and Emergency Response (ESER) Bond, Citizens' General Obligation Bond Oversight Committee Reports & Quarterly Reports, found at http://www.sfearthquakesafety.org/eser-reports.html

[105] This map assumes completion of work in progress, which is expected by late 2020 according to the SFPUC. The SFPUC has retained outside experts to update the anticipated water demands by FRA but that work has not been completed.

the improvements would include extending the HP AWSS and installation of a HP pump station at Lake Merced, and over a hundred years after the AWSS system was first built, we are still decades away from reliably protecting all neighborhoods.

Over the past year, the SFPUC has made substantial progress in developing plans to improve EFWS on the west side. Specifically, the SFPUC and the SFFD propose to develop a new, separate AWSS system using potable water ("Potable AWSS") for the western part of the City. The Potable AWSS approach contemplates a dual-purpose pipeline, independent from the existing HP AWSS network.[106] The Potable AWSS would function as a potable water transmission main during normal operations and would provide HP emergency firefighting water supply for major fires. The new pipeline would provide "daily reliability and water quality benefits as well as a post-earthquake potable water supply to the Richmond and Sunset districts",[107] but in the event of an earthquake or other emergency, the transmission main would automatically be isolated from the remainder of the potable distribution system and converted to a dedicated HP system, similar to the existing or conventional AWSS.[108] To increase reliability, the new pipeline would be made of modern, seismically reliable material.[109]

The SFPUC currently anticipates having approximately $195 million,[110] from water rates and from an expected 2020 ESER bond (assuming voter approval), to spend on extending the HP AWSS and improving EFWS reliability over the next five to seven years.[111] The current Potable AWSS proposal is divided into two phases, as the projected $195 million is insufficient to

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[106] 2018 Westside Options Analysis, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740 at pp. 7, 10, 13.

[107] *Id.*, at p. 8. The Potable AWSS would eliminate the need for a project that the SFPUC had been planning to supply potable water to the Richmond District, saving up to $30 million. *Id.* Today the potable water supply to the Richmond District depends on two transmission mains that run north from the Sunset District. One of those mains was built in 1915. The other was recently replaced with a ductile iron main. The Potable AWSS would provide a third transmission main, built with modern earthquake resistant pipe. *Id.*, at p. 13.

[108] A detailed description of the Potable AWSS concept can be found in CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055, CS-229, https://sfwater.org/Modules/ShowDocument.aspx?documentid=8246, and 2018 Westside Options Analysis, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740. The actual proposal has evolved over time, so the alignment discussed in those 2014, 2015 and 2018 reports has changed, as have the water sources. This plan is still under review and the alignment may well change again before the plan is finalized and ready for any required public hearings or environmental or other review. But the underlying concept of a Potable AWSS and how it would operate remains the same.

[109] New pipe would be so-called Earthquake Resistant Ductile Iron Pipe (ERDIP), the most seismically reliable pipe available. ERDIP pipe performed admirably in several recent Japanese earthquakes See Scawthorn 2018 memo, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740 at p. 6, re ERDIP pipe.

[110] Information supplied by the SFPUC. The $195 million is adjusted for inflation as the build out will occur over several years. This is roughly equivalent to $160 million in 2018 dollars according to the SFPUC.

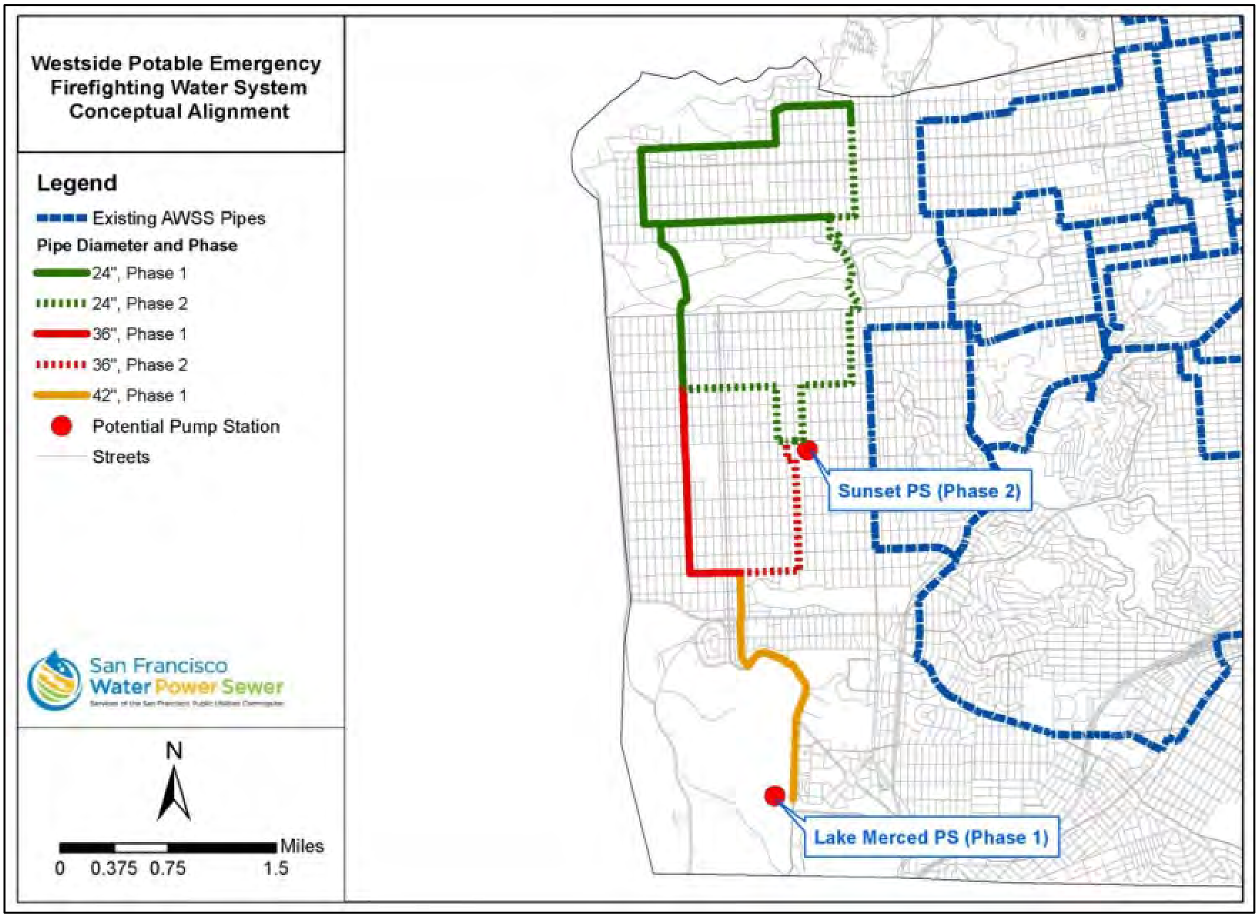
[111] Meetings with SFPUC representatives. The Board of Supervisors approved the 2020-2029 ten-year Capital Plan at its April 30, 2019 meeting. See https://sfbos.org/sites/default/files/bag043019_minutes.pdf . The new ten-year Capital Plan can be found at http://onesanfrancisco.org/the-new-plan/overview .

complete the entire project. Phase 1 involves adding approximately 8.6 miles of new pipe.[112] A conceptual potential pipe alignment would extend north from Lake Merced along the west side, through the western portion of the Sunset and Richmond districts, and then have two pipelines head east, one immediately south of the Presidio and one in the southern Richmond district.[113]

A conceptual potential alignment of both Phase 1 and Phase 2 is shown in Figure 7 below:[114]

Figure 7

Conceptual Potential Alignment for Potable West Side AWSS



[112] Information provided by SFPUC. The phasing and the potential, proposed or conceptual alignment discussed above and on the following pages are still in the planning stages and are subject to change. Detailed designs have not yet been completed, much technical analysis remains to be done, and the project has not yet undergone environmental reviews.

[113] The current furthest west AWSS pipeline is located east of Park Presidio Boulevard.

[114] Provided by the SFPUC on April 10, 2019. See footnote 121 on page 32.

The Potable AWSS pipeline network would tie into an existing, recently seismically reinforced, potable 60-inch transmission main, providing a source for normal, potable-water operations.[115] The proposed Phase 1 also includes adding a new HP pumping station at Lake Merced.[116] Although the water in Lake Merced is deemed non-potable, Lake Merced contains approximately a billion gallons or more, making it an excellent source of water for emergency firefighting purposes.[117]

The SFPUC and SFFD's future west side plans (Phase 2) include an additional 5.6 miles of pipeline for better coverage and potentially an additional pumping station at Sunset Reservoir, for another source in case of a broken pipe or other emergency.[118] However, the SFPUC and the SFFD do not anticipate having the additional approximately $120 million[119] needed to complete that portion of their plan until the next round of ESER bonds, which may not be for another five to seven years or even longer.[120]

Unfortunately, the Potable AWSS on the west side only addresses the EFWS deficits on the west side of the City. Many other City neighborhoods along its southern part, from Park Merced in the west to Visitacion Valley in the east, will be no closer to having a multi-sourced, seismically reliable HP AWSS or substantially enhancing their neighborhood's EFWS even if this westside Potable AWSS plan moves forward.

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[115] According to the SFPUC, this transmission main connects to both (a) the Crystal Springs Reservoir in San Mateo County and to the 9'6" Crystal Springs Bypass tunnel, which is supplied by Calaveras Reservoir, San Antonio Reservoir, and the SFPUC's upcountry water sources (Hetch Hetchy, Don Pedro, etc.). These potable water sources were seismically reinforced by the SFPUC's Water System Improvement Program (WSIP), a $4.8 billion program to improve water system reliability, including seismic reliability. See SFPUC webpage on WSIP, https://www.sfwater.org/index.aspx?page=114 .

[116] Like the conceptual potential pipeline alignment, the size, location and design of any new pumping station is at present unknown and uncertain. The Civil Grand Jury understands that the Potable AWSS project is currently moving forward with design, technical studies, environmental and management reviews, but is of course also dependent upon approval of necessary funding.

[117] Information provided by SFPUC; see also V. Matuk and N. Salcedo, Lake Merced Hydrology and Water Quality, http://online.sfsu.edu/bholzman/LakeMerced/water.htm ("Estimates of the capacity of the lake also vary greatly from a low of 768 million gallons to high of 1.93 billion gallons."). The Sunset pumping station shown in the figure on the preceding page is being considered as a potential part of Phase 2.

[118] Per the SPFUC, the Sunset Reservoir Pumping Station will also be connected to a seismically reinforced, potable 54-inch transmission main. Unlike the northeast quadrant, where the AWSS pipeline system is a grid and thus provides an excellent measure of redundant support in case of a broken pipe, the proposed Potable AWSS would not be a grid. The lack of redundant pipelines creates a somewhat higher level of risk. However the use of modern ERDIP significantly reduces the risk of pipeline failure, and having redundant water sources provides additional comfort as it would enable back-feeding and reduces the risk of a potential single point of failure. 2018 Westside Options Analysis, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740 at p. 37.

[119] This cost estimate is in 2018 dollars. Unless otherwise stated, all cost estimates provided by the SFPUC, SFFD and SFDPW to the Civil Grand Jury for work on the EFWS system and discussed in this report are in 2018 dollars.

[120] Even if new bonds are issued in five to seven years, design and construction of the new pipelines and new pumping station would take several more years.

The limited scope of the SFPUC's current plans is the result of budgetary constraints. The Mayor and the Board of Supervisors determine what bond proposals are placed before the voters, how frequently, and what is included. The SFPUC and the SFFD must operate within the financial constraints they are given.

The SFPUC has rough estimates showing that extending the high-pressure AWSS throughout the City–or building separate but functionally equivalent Potable AWSS systems in areas without a HP AWSS–will cost approximately $500 million in addition to the funds already targeted for Phase 1 of the Potable West Side system, as discussed above.[121] The SFPUC is not presently planning a programmatic City-wide expansion; it merely has developed a rough list of possible projects for various parts of the City that are not presently served by the HP AWSS (as well as other projects to reinforce or otherwise improve the HP AWSS system in those areas that are currently served by the HP AWSS).[122]

This roughly $500 million estimate is a huge amount of money, but as discussed in Section A above, the risk of incurring the costs from a major, inadequately-fought fire is far greater.

First and foremost is the risk to human life. In 1906, an estimated 3,000 people lost their lives, and 225,000 were left homeless. The City is obviously much better prepared today, with

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[121] See "Candidate EFWS Projects" list dated May 8, 2019, attached as Appendix P. The actual total of projects related to system expansion is approximately $485 million, plus the $160 million for Phase 1 of the Westside project, for a total of $645 million. We have rounded the $485 million up to $500 million for the sake of simplicity and in recognition of the fact that these are all very preliminary high level estimates.

This Candidate EFWS Projects list is an internal SFPUC document: it is a list of potential project alternatives provided by the SFPUC staff to the EFWS Management Oversight Committee. The list contains potential projects that could be implemented in the future if approved by the EFWS Management Oversight Committee, if funding is made available, and if and when they go through the required environmental review. Due to the preliminary nature of the list, some of the estimated costs on this candidate project list are merely planning level estimates and would likely change if the SFPUC decided to move forward with a detailed design for a given project. Some of these projects, such as the Potable AWSS on the west side, are moving forward towards completion of design and technical studies and required environmental review based on management direction and the anticipated availability of funds. However, others are still simply candidate project alternatives that management may never proceed with.

This May 8 Candidate EFWS list also includes various proposals and potential projects to improve the seismic safety of the approximately 20 miles of HP AWSS pipes in the so-called infirm zones, as well other supply or proposed projects under consideration unrelated to any potential HP AWSS expansion. May 8, 2019 Candidate EFWS Project list attached as Appendix P; see CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 at p. 31 for a map of infirm zones.

Although the original AWSS system was designed to be seismically strong, and to survive an earthquake, it was designed shortly after the 1906 earthquake and installed by 1913. Most of the AWSS pipelines fared well during the Loma Prieta earthquake, although that was 60 miles away and not as big an earthquake as we will someday face. See, e.g., PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf at pp. 9-12. Accordingly, no one knows for certain how the existing AWSS will fare in a major earthquake, especially in liquefaction areas or so-called infirm zones. The infirm zone projects, which are estimated to cost $135 million, involve installing new, backbone ERDIP pipe in each infirm zone, so that even if the existing AWSS pipe fails there will be at least one reliable major high-pressure pipeline in each area. Information provided by SFPUC; see also Appendix P.

[122] The recently approved 2020-2029 ten-year Capital Plan does not designate nearly enough money for EFWS to complete a City-wide expansion of the HP AWSS system. See http://onesanfrancisco.org/the-new-plan/overview

fire suppression systems, the existing HP AWSS, and modern building standards. Yet the 2017 North Bay fires and the 2018 Camp fire that destroyed the town of Paradise demonstrate how destructive and fast-moving fires can be under windy conditions. [123] In 1906, residents fled to the south and the west, to relatively uninhabited portions of the City that did not burn. Today, the entire City is densely populated and there would literally be no place for residents, especially our many senior citizens, to run to escape a fast-moving conflagration.

Second, in terms of property value, San Francisco has billions of dollars at risk. As discussed in Section A of this report, and in particular Table 1, a 2010 report prepared for the City estimated the range of losses due to fire following an earthquake could exceed $10 billion for a 7.9-magnitude event – in 2010 dollars. The damage estimates in Table 1 do not include business interruption losses, loss of tourism or loss of property tax revenues, all of which would undoubtedly be substantial.[124]

The substantial increase in San Francisco property values over the last decade undoubtedly increases the potential losses. In light of the dire consequences we face, the approximately $650 million price tag to expand the HP AWSS throughout the City (which includes Phase 1 of the proposed Potable AWSS on the west side), seems well worth the expenditure.

The Civil Grand Jury is not in a position to know whether each of the SFPUC's potential projects is essential, how the costs will change after detailed design work, further studies and environmental reviews, or whether more cost-efficient approaches exist. We are also not in a position to weigh the relative merits of the approximately $320 million in non-expansion-related projects on the SFPUC's Candidate EFWS Projects list.[125] But we do know that the current approach is taking too long. The SFPUC itself estimates that build-out of the AWSS "would take ~ 35 years using current funding rate assuming 5 year bond cycle."[126]

The most recent public timeline provided by the SFPUC is in CS-199, and is moot as the various projects have evolved over time. However, that timeline relies upon the issuance of

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[123] As discussed above, wind is a major factor in fire spread. See, e.g., Kearns, F. and Moritz, M., *The Conversation* (November 16, 2018), https://theconversation.com/how-fierce-fall-and-winter-winds-help-fuel-california-fires-106985; Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf at pp. 8-9, 15, 18-19. The 1923 Tokyo earthquake and subsequent fires are probably the most devastating in peacetime, with substantially greater loss of life (an estimated 140,000 killed) than the 1906 earthquake. See Eidinger, J. Editor, Fire Following Earthquake, Revision 11 (2004), http://home.earthlink.net/~eidinger , downloaded from the internet on March 6, 2019 at pp. 1-2, 19-23; see also Great Tokyo Earthquake of 1923, at http://factsanddetails.com/japan/cat26/sub160/item2226.html. Among the reasons for the devastation in Tokyo were winds of approximately 28 miles per hour at the time of the earthquake, with increasing wind throughout the day. *Id.*

[124] See CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 at pp. 95-97.

[125] See May 8, 2019 Candidate EFWS Projects list, attached as Appendix P.

[126] SFPUC Emergency Firefighting Water System, Management Oversight Committee presentation dated March 4, 2019, at p. 32. The City is not committed to a five year bond cycle, so it could be even longer, although the increased level of funding in the proposed 2020 ESER bond indicates that things may be moving more rapidly.

ESER bonds every five to seven years, through and including a 2045 bond issuance, such that work would not be completed until 2049.[127]

Either way, this means that areas of our City, such as District 11, would not be as well protected as other areas, and would not have a HP AWSS in place if, as predicted by the USGS, a major earthquake hits the Bay Area before 2043.

Accordingly, the Civil Grand Jury recommends a major acceleration of these efforts, such that all areas of the City are protected by a seismically sound, multi-sourced, HP emergency water firefighting system within 15 years, i.e., by no later than 2034.

H. The Bottom Line: Act Fast, but Ensure Redundancy

Among the most important factors in designing an EFWS is redundancy. This is true whether the City chooses to extend the existing AWSS or to adopt a different approach. Regardless of the specific plan, there must be multiple, redundant sources of water such that if one source fails or a pipe breaks, firefighters have other means to obtain necessary water supplies.

In the Loma Prieta earthquake the Marina district was saved by the combination of the PWSS and a fireboat, or "the backup to the backup."[128] Unpredictable stuff happens, especially in a major earthquake, and redundancy is necessary.[129] This means not just looped pipe systems but also multiple sources of water. One of the great ironies of the 1906 earthquake is that San Francisco is surrounded by water yet it burned due to a lack of water.

The original HP AWSS was designed with both a redundant water supply and a gridded main system.[130] The system in the northeast quadrant of the City "seeks high post-earthquake

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[127] Figure 5-1, *Preferred Alternative Planning Level Schedule*, from CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 at p. 71, and attached as Appendix R.

[128] See Scawthorn, C., Porter, K., and Blackburn, F., Performance of Emergency-Response Services After the Earthquake, chapter in The Loma Prieta, California, Earthquake of October 17, 1989, Marina District, T.D. O'Rourke editor, USGS Professional Paper 1551-F (1992); Scawthorn, C. and Blackburn, F., Performance of the San Francisco Auxiliary and Portable Water Supply Systems in the 17 October 1989 Loma Prieta Earthquake, presented at Fourth U.S. National Conference on Earthquake Engineering May 20-24, 1990, and provided by SFPUC; Blackburn, F., Report on Firefighting Requirements Following Earthquake and Current Proposals by the SFPUC (2018).

[129] See, e.g., Metcalf & Eddy, http://s3-us-west-2.amazonaws.com/ucldc-nuxeo-ref-media/b2754026-dded-4ee6-b24c-2cf837f3bc00 at p. 20; CS-199, at p. 11 ("Multiple redundancies in fire water supply systems are necessary."), https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055

[130] 2018 Westside Options Analysis, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740 at p. 37.

reliability via multiple sources of supply."[131] Those sources include two above-ground storage tanks, a reservoir, two salt-water pumping stations, plus several fire boat manifolds if needed.[132]

Many citizens have called for installing a salt-water pump station or stations on the west side, arguing that the ocean provides an unlimited source of water.[133] A salt-water pump station north of Golden Gate Park would also provide geographic diversity of water sources, as the other proposed pumping stations and HP water sources are all south of Golden Gate Park. Dr. Scawthorn, the City's consultant, has asserted that a salt-water pump station on the west side "would be very beneficial."[134]

The Civil Grand Jury recognizes that this may raise environmental and other issues, and may or may not be necessary in light of the potential use of Lake Merced.[135] Nevertheless, the Civil Grand Jury strongly believes in having redundant and geographically diversified water sources, and developing a robust water source in the northwest quadrant of the City seems to us to be beneficial. Other areas of the City have added protection from the SFFD's four fireboats, which can be connected to the PWSS to provide an alternate water supply, as in Loma Prieta. Unfortunately, fireboats are not designed to work in the open water of the Pacific Ocean, and PWSS hose tenders cannot practically drive onto beaches to draft water from the ocean.[136] For these reasons, a salt-water pumping station on the west side seems particularly appropriate.

The need for further EFWS projects is underscored by two additional considerations, discussed more fully below. First, the reliability scores cited in the SFPUC's consultant's reports over-state how effective our current plans are likely to be upon completion. Second, these scores – and our safety – are predicated on being able to properly maintain and operate the existing AWSS assets, especially critical assets, so they are ready when needed.

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[131] Scawthorn 2018 memo, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740 at p. 2.

[132] CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 , at pp. 7-8.

[133] Pendergast, T, *Plan to Protect Neighborhood Abandoned*, Richmond Review (November 2017), https://sfrichmondreview.com/2017/11/02/plan-to-protect-neighborhoods-abandoned/ ; Fracassa, D, *SF Moves to Build Water System to Fight Fires for When the Worst Hits*, San Francisco Chronicle (February 11, 2018), https://www.sfchronicle.com/politics/article/SF-moves-to-build-water-system-to-fight-fires-12605847.php ; Doudiet, T., *Commentary–Sound the Fire Alarm!*, Richmond Review / Sunset Beacon (November 3, 2017), https://sfrichmondreview.com/2017/11/03/commentary-thomas-w-doudiet/ ; Wuerfel, N., *Commentary–SFPUC Misleads Public*, Richmond Review / Sunset Beacon (November 13, 2018), https://sfrichmondreview.com/2018/11/13/commentary-nancy-wuerfel-2/ .

[134] Scawthorn 2018 memo, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740, at p. 7.

[135] Any plan to add a salt-water pump station would need to be responsive to concerns about reducing or even eliminating if possible any impacts on marine life.

[136] Information provided by the SFFD.

I. Current FRA Reliability Scores Promote Overconfidence

The SFPUC's and the SFFD's goal is to provide a certain Level of Service (LOS) for emergency firefighting water supply throughout the City. In particular, the SFPUC has articulated the following LOS objective:

> AWSS will reliably provide water to supply the "probable fire demands" after a magnitude 7.8 San Andreas earthquake. Each FRA will have a minimum of 50% reliable water supply to meet probable fire demands. The Citywide average will be a minimum of 90% reliable water supply to meet probable fire demands.[137]

The Civil Grand Jury agrees with the goal that the City should be prepared to fight fires following a magnitude 7.8 San Andreas earthquake. However, we are concerned with the current measures of "reliability." As discussed below, the "reliability scores" being used by the City create a misleadingly optimistic impression and imply a false precision.

As explained in CS-199, "[i]n the context of this study, reliability is defined as the percentage of the water demand met by AWSS high-pressure system and other sources."[138] Put differently, the reliability score methodology "does not actually represent an estimate of reliability but is a ratio of the EFWS capacity and demand."[139]

The ratio of capacity and demand is a useful measure, but the scores being used are overly optimistic in that the estimated "demand" used is the *median* estimated demand.[140] By definition, half the time one would expect worse conditions and therefore greater demand for water to fight fires. Using a demand estimate that is by definition insufficient half the time is not truly preparing for a repeat of the 1906 earthquake.

The problem of using the median demand is exacerbated by the wide variation in the potential number of fires, fire size, and water demands.[141] As just one example, San Francisco was lucky that there was little to no wind during the Loma Prieta earthquake. Yet as any resident of our City knows, the City often experiences significant wind conditions.

Another problem with the reliability scores is that they ignore where in the FRA a fire is, as well as the size of each FRA. For example, the southeastern portion of the City has several geographically large FRAs.[142] Although water may be able get to the northern part of a particular FRA, the southern part of that FRA may not be as well protected. In addition, the

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[137] 2018 Westside Options Analysis, at p. 7, https://www.sfwater.org/modules/showdocument.aspx?documentid=117400 ; CS-199, at p. 102, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 .

[138] CS-199, at p. ix, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055.

[139] Scawthorn 2018 memo, at p. 6, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740.

[140] *Id.*, at p. 5.

[141] *Id.*, at p. 5.

[142] See map of FRAs, attached as Appendix J.

demand represents the water supply need for an entire FRA, and the scores assume that the SFFD "would utilize the Portable Water Supply System (PWSS) or engine relays to distribute the water supply within the FRA to the actual ignition locations."[143] This is an unrealistic assumption, given the City's current inventory of only five old PWSS hose tenders, and the likely demand on fire engines in a major earthquake with a multitude of fires.

The SFPUC is in the process of analyzing potential EFWS demands on a more detailed level, and has shared some of the preliminary results with the Civil Grand Jury. The Civil Grand Jury supports this approach and recommends that the SFPUC continue its efforts to make a more detailed analysis of emergency firefighting water needs (including above-the-median needs) by neighborhood, and not just by FRA.

J. Maintenance and Training Issues

1. Maintenance Issues

AWSS assets must be well maintained in order to be operational during an emergency. A 2014 study prepared for the SFPUC by its outside consultants AECOM/AGS, a Joint Venture found "maintenance deficiencies" because routine maintenance plans had not been established for all AWSS assets. Instead, maintenance was being performed on an "as needed" basis.[144]

During our investigation, the Civil Grand Jury learned that the SFPUC has not developed a number of the routine maintenance plans recommended in the 2014 report.[145] The SFPUC assured us that it has done a good job at maintaining AWSS, and disagrees with some of the recommendations in that 2014 report. Nevertheless, the SFPUC has yet to develop routine maintenance plans for some important AWSS assets.

As an example, the report recommended the SFPUC adopt plans to regularly exercise all AWSS system valves.[146] In response, the SFPUC expressed a "goal" to exercise critical valves every two years.[147] It has defined "critical valves" to include only 66 out of the approximately 1,685 valves in the HP AWSS system.[148] SFPUC personnel acknowledge that its current approach is not a "best practice," and that valves should likely be exercised on a regular basis. SFPUC personnel also acknowledge that its definition of what constitutes a "critical" valve requiring more frequent testing is probably too narrow.[149]

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[143] 2018 Westside Options Analysis, at p. 37, https://www.sfwater.org/modules/showdocument.aspx?documentid=11740.

[144] CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 at pp. 15-16, 24-26.

[145] Information provided by SFPUC.

[146] CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 at p. 25.

[147] Information provided by SFPUC.

[148] Ibid.

[149] Interviews with SFPUC personnel.

In another instance, the 2014 report recommended that all suction connections be cleaned on a regular basis.[150] The SFPUC noted that suction connections were cleaned in 2014, but that the agency had not adopted a routine maintenance plan.[151]

Now that the SFPUC has had time to focus on the condition of the AWSS, the Civil Grand Jury recommends that it utilize "best practices" for the maintenance of AWSS assets, including valves and suction connections, and that the SFPUC, with the help of the SFFD, redefine which valves in the system are "critical," and, therefore, require more attention and priority in its maintenance plans.

2. Coordinated Training and Drills

Another recommendation in CS-199, the 2014 report prepared for the SFPUC by its outside consultant AECOM/AGS, a Joint Venture, was that the SFPUC "prepare an emergency response program and conduct training exercise [sic]."[152] The report also recommended that SFPUC staff be trained on the AWSS system, including "communications, operational strategies," and "emergency response requirements."[153] Both of these recommendations were given "high" priority, and assessed to entail "low" ongoing cost.[154]

In 2015, the SFFD and the SFPUC entered into a Memorandum of Understanding ("MOU") regarding the operation and maintenance of water-supply systems related to fire suppression.[155] In Section C, entitled "Coordinated Emergency Operations Between the SFWD and SFFD", the MOU requires that "All members of the SFWD … must be trained in the AWSS and the AWSS SCADA system along with the SFFD Water Supply manual."[156] The MOU also specifies that "[t]he SFFD and the SFWD will collaborate for annual training on system operations and appropriate shut-down procedures during and after firefighting operations."[157] The MOU, therefore, requires the SFPUC and the SFFD to coordinate to train all SFWD personnel on the

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[150] CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 , at pp. 15-16, 24-26, 88, 135. There are approximately35 suction connections along the bay that allow engine pumpers to draw by suction from the bay, and a suction line with low-pressure hydrants along Fulton St. that draws from lakes in Golden Gate Park. Some of these suction connections are located on the bottom of the Bay and can be filled with silt or marine organisms that would interfere with water pumping.

[151] Interviews with SFPUC personnel.

[152] CS-199, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055 , at pp. x, 88.

[153] Ibid.

[154] Ibid.

[155] Memorandum of Understanding Regarding Operation and Maintenance of San Francisco Water Supply Systems Related to Fire Suppression, dated June 1, 2015 and signed in September 2015.

[156] *Id.*, at Section C.1.

[157] *Id.*, at Section C.3.

AWSS system and on other available water supply sources to fight fires in emergencies. It also requires coordinated, *annual* training on emergency operation of the system.

In 2017, the SFPUC updated its Emergency Response Plan.[158] A review of the Plan, however, offers little detail on the type of exercise conducted or how often exercises might be conducted in the future.[159] Similarly, although CS-199 identified the need for emergency training and a training exercise, CS-199 did not provide details as to the scope or frequency of any training exercises.

In the past several years the SFFD and SFPUC have taken advantage of many opportunities for joint training concomitant with their joint operation and maintenance of AWSS assets. For example, the two agencies test Pump Stations 1 and 2, on a monthly basis. The agencies also meet after greater-alarm fires to discuss coordination, and how to improve operations in the field. In addition, the SFFD and SFPUC have, on occasion, conducted joint emergency trainings involving earthquake disaster scenarios. In 2018, for example, they engaged in a "tabletop exercise" where high-level staff members were asked to respond to a hypothetical earthquake scenario to test their understanding of the emergency command structure.

The SFPUC anticipates that it will repeat this joint tabletop exercise at least every other year, and that it will conduct larger-scale simulations of post-earthquake emergency response procedures with the SFFD within the next two years. There is no formal document, however, outlining specific joint exercises or drills to be conducted by the two agencies.

In the 1989 Loma Prieta earthquake, human error was cited by some as a reason why AWSS was not available to fight fires in the Marina.[160] A 2011 survey of California fire and water agencies concluded, generally speaking, that "[f]ire and water department liaison is not very good" and that "[e]mergency firefighting water supply is not a focus."[161] Moreover, the report found that fire departments are not "regularly drilled for the very difficult task of moving water from the alternative water sources to the fire scene."[162]

The Civil Grand Jury believes that the City would be well served if the SFPUC and SFFD worked together to design and implement annual "hands-on" drills to make certain that their staff is prepared to use all available resources to fight fires after an earthquake. Accordingly, the Civil Grand Jury recommends that the MOU between the SFPUC and the SFFD be amended to include a more detailed roadmap for emergency response exercises to be held, City-wide,

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[158] Information provided by SFPUC.

[159] City Distribution Department (CDD) Earthquake Response Plan (updated December 2017), https://sfpuc.sharefile.com/share/view/s77bd1c3318e4355b

[160] See, e.g., Scawthorn, C., Porter, K., and Blackburn, F., Performance of Emergency-Response Services After the Earthquake, chapter in The Loma Prieta, California, Earthquake of October 17, 1989, Marina District, T.D. O'Rourke editor, USGS Professional Paper 1551-F (1992).

[161] PEER 2011, Water Supply Following Earthquake, https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf at p. 75. By contrast, both the SFPUC and the SFFD have indicated that they currently enjoy excellent communication.

[162] *Id.*

annually. In addition to tabletop scenarios, these exercises should include hands-on field testing in the operation of AWSS assets and PWSS units.

CONCLUSION

Over one hundred years ago, our City was destroyed by fire following an earthquake. Luckily, our predecessors learned from this catastrophe. They aggressively undertook to design, fund, and quickly build a supplemental emergency water supply system that provided firefighters with multiple options if one or more water sources were compromised – "belt and suspenders." They gave us an excellent emergency water system to protect our wonderful, seismically vulnerable City.

We have, however, long outgrown the protective reach of the system we inherited. Now it is our turn to aggressively implement measures to extend protections to reach all San Francisco neighborhoods. The time to act is now, before it is too late.

FINDINGS

F1. Fires resulting from an earthquake represent a significant risk of widespread damage and potential loss of life in San Francisco.

F2. The municipal water supply system (MWSS) is highly vulnerable to damage from a major earthquake and is not a reliable source for water supply for firefighting after a major earthquake.

F3. Approximately 30 cisterns have recently been added with funds from ESER bonds, but cisterns only have up to about an hour of water supply and thus do not provide sufficient water for fighting fires following a major earthquake.

F4. The City's high-pressure emergency water supply system, known as the Auxiliary Water Supply System (AWSS), does not cover large parts of Supervisorial Districts 1, 4, 7 and 11, roughly one-third of the City's developed area. As a result, these districts are not adequately protected from fires after a major earthquake.

F5. A high-pressure, multi-sourced, seismically safe emergency firefighting water supply will be costly but is essential to protect the City.

F6. Unless the City increases funding levels, it will be several decades (i.e., after the USGS predicts one or more major earthquakes will occur) before the southern parts of the City have a high-pressure, multi-sourced, seismically safe emergency firefighting water supply.

F7. The existing Portable Water Supply System (PWSS) inventory is inadequate. Investing in more PWSS hose tenders would provide a relatively quick, cost-effective interim means to improve protection of the southern and western parts of the City until a high-pressure, multi-sourced, seismically safe emergency water supply can be developed in those areas.

F8. Redundancy is an important feature of an emergency firefighting water system.

F9. Current plans to extend protections to the western part of the City do not include any high-pressure water sources north of Golden Gate Park.

F10. The "reliability scores" being used by the SFPUC impart an overly optimistic impression of the protection provided.

F11. The City does not have a timeline to fund and complete development of a high-pressure, multi-sourced, seismically safe emergency water supply for all parts of the City, including poor neighborhoods that historically have not been as well protected as the downtown business district and many richer neighborhoods.

F12. The SFPUC has not developed a number of the routine maintenance plans recommended in a 2014 report (CS-199), and has not adequately defined which AWSS valves are "critical" and therefore require increased attention.

F13. In the 2015 MOU between the SFFD and the SFPUC, the two agencies agreed to conduct joint AWSS trainings annually, but there is no formal protocol outlining specific joint AWSS exercises or drills using hypothetical disaster scenarios, such as a major earthquake.

RECOMMENDATIONS

R1. By no later than December 31, 2020, the Mayor, the SFPUC, the SFFD, and the Office of Resilience and Capital Planning should jointly present to the Board of Supervisors a detailed plan to ensure the City is well prepared to fight fires in all parts of San Francisco in the event of a 1906-magnitude (7.8) earthquake.

R2. The plan discussed in Recommendation R1 should include a detailed proposal, including financing sources, for the installation within 15 years of a high-pressure, multi-sourced, seismically safe emergency water system for those parts of the City that don't currently have one, i.e., by no later than June 30, 2034.

R3. The Board of Supervisors should direct the Budget and Legislative Analyst to study through an equity lens and issue a report to the Board regarding (a) which areas of the City do not have sufficient water supplies for the anticipated demand for water to fight fires following a major earthquake similar in magnitude to the 1906 earthquake, and (b) options to address the issue in both the short term and the long term. The Board should issue its request by no later than December 31, 2019, and the Budget and Legislative Analyst should complete its report by no later than December 31, 2020.

R4. As interim measure, by no later than June 30, 2021, the City should purchase the 20 new PWSS hose tenders being requested by the SFFD, to replace and expand its currently inadequate inventory.

R5. The SFFD should strategically locate the majority of the PWSS hose tenders in areas that at present only have low-pressure hydrants and/or cisterns.

R6. The SFPUC, the SFFD and the SF Department of the Environment should study adding salt-water pump stations to improve the redundancy of water sources, especially on the west side. Findings and recommendations from this study should be presented to the Board of Supervisors by no later than June 30, 2021.

R7. The SFPUC should (a) continue its efforts to complete a more detailed analysis of emergency firefighting water needs (including above-the-median needs) by neighborhood, and not just by FRA, and (b) present a completed analysis to the Board of Supervisors by no later than June 30, 2021.

R8. By no later than June 30, 2022, the Mayor and the Board of Supervisors should analyze whether to propose a separate bond for the development of a high-pressure, multi-sourced, seismically safe emergency water system for those parts of the City that don't currently have one, with a target date of completing construction by no later than June 30, 2034.

R9. By no later than December 31, 2020 the SFPUC, with the advice and subject to the approval of the SFFD, should (a) implement "best practices" for the maintenance of AWSS assets, and (b) redefine which AWSS valves in the system are "critical," and, therefore, require more attention and priority in the SFPUC's maintenance plans.

R10. By no later than June 30, 2020, the 2015 MOU between the SFPUC and the SFFD should be amended to include a detailed roadmap for annual emergency response exercises, including simulated disaster and earthquake drills involving the AWSS and the PWSS.

REQUIRED RESPONSES

Pursuant to Penal Code sections 933 and 933.05, the Civil Grand Jury requests responses as follows:

From the following City and County agencies and departments within 60 days:

- Office of the Mayor
  - Findings 4, 5, 6, and 11
  - Recommendations 1, 2, 4, and 8
- General Manager, San Francisco Public Utilities Commission
  - Findings 2, 4, 5, 6, 8, 9, 10, 11, 12, and 13
  - Recommendations 1, 2, 6, 7, 9, and 10
- Chief, San Francisco Fire Department
  - Findings 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 13
  - Recommendations 1, 2, 4, 5, 6, 7, and 10
- Office of the City Administrator
  - Findings 6 and 11
  - Recommendations 1, 2 and 8
- Chief Resilience Officer, Office of the City Administrator
  - Findings 6 and 11
  - Recommendations 1, 2 and 8
- Director, San Francisco Department of the Environment
  - Recommendation 6
- Budget and Legislative Analyst Office, Board of Supervisors
  - Findings 6 and 11
  - Recommendation 3

From the Board of Supervisors and other governing bodies within 90 days:

- Board of Supervisors
  - Findings 4, 5, 6 and 11
  - Recommendations 1, 2, 3, 4, 6, 7, and 8
- San Francisco Public Utilities Commission
  - Findings 2, 4, 5, 6, 8, 9, 10, 11, and 12
  - Recommendations 1, 2, 6, 7, 9, and 10
- San Francisco Fire Commission
  - Findings 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11
  - Recommendations 1, 2, 4, 5, 6, 9 and 10

GLOSSARY AND TABLE OF ACRONYMS AND ABBREVIATIONS

ATC — Applied Technology Council. A non-profit corporation whose mission is to develop and promote state-of-the-art, user-friendly engineering resources and applications for use in mitigating the effects of natural and other hazards on the built environment, and which prepared reports in 2010 for the City under the CAPSS Project.

AWSS — Auxiliary Water Supply System. An independent emergency firefighting system built after the 1906 earthquake. The AWSS at present consists of approximately 135 miles of high-pressure (HP) pipelines, 230 cisterns, two above-ground storage tanks, a reservoir, and two salt-water pumping stations. The AWSS HP pipelines can supply water at pressures up to 300 psi via hydrants with black, red or blue tops, depending upon location.

CAPSS — Community Action Plan for Seismic Safety. According to the CAPSS website, CAPSS was started in the Department of Building Inspection beginning in 1998, and was a nine-year, $1 million study to understand, describe, and mitigate the risk San Francisco faces from earthquakes. CAPSS produced an extensive analysis of potential earthquake impacts as well as community-supported recommendations to mitigate those impacts.

CCSF — City and County of San Francisco

CDD — City Distribution Division. The division of the SFPUC responsible for maintenance of both the MWSS and the AWSS.

DWSS — Domestic Water Supply System, also referred to as the Municipal Water Supply System, MWSS, or the potable water system. The SFPUC supplies potable (drinking) water throughout the City. The MWSS (DWSS) is a low-pressure system, typically ranging between 50 and 70 psi. The MWSS is also the primary supply for firefighting via fire hydrants with white tops.

ERDIP — Earthquake Resistant Ductile Iron Pipe. A modern type of pipe that is believed to be earthquake resistant and that has been subjected to several major earthquakes in Japan without any observed failures.

EFWS — Emergency Firefighting Water System. All emergency sources of water and the means for delivering them. Includes HP AWSS pipelines, cisterns, PWSS and fireboats.

ESER — Earthquake Safety and Emergency Response. ESER bonds are generally issued every five to seven years to address to fund repairs and improvements to infrastructure that allow the City to respond more quickly and effectively to a major earthquake or other disaster.

FRA	Fire Response Area. The SFFD divides the City into 46 areas for initial alarm response, referred to as Fire Response Areas or FRAs.
HP	High-pressure
LOS	Level of Service
MOU	A Memorandum of Understanding between the SFPUC and the SFFD Regarding Operation and Maintenance of San Francisco Water Supply Systems Related to Fire Suppression, dated June 1, 2015 and signed in September 2015.
MWSS	Municipal Water Supply System, also referred to as the Domestic Water Supply System, DWSS, or the potable water system. The SFPUC supplies potable (drinking) water throughout the City. The MWSS is a low-pressure system, typically ranging between 50 and 70 psi. The MWSS is also the primary supply for firefighting via fire hydrants with white tops.
PEER	Pacific Earthquake Engineering Research Center
PSI	Pounds per square inch
PWSS	Portable Water Supply System. A mobile above-ground large (five-inch) diameter hose system transported on trucks (hose tenders). A hose tender truck can carry approximately 5000 feet of five-inch hose. A more thorough description is provided at pages 23-26. The PWSS is not to be confused with the flexible water supply system, an idea for 12-inch diameter hoses that was abandoned as impractical.
SCADA	Supervisory Control and Data Acquisition. A computer system for gathering and analyzing real time data. SCADA systems are used to monitor and control a plant or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining and transportation.
SFDPW	San Francisco Department of Public Works
SFFC	San Francisco Fire Commission
SFFD	San Francisco Fire Department
SFPUC	San Francisco Public Utilities Commission
SFWD	San Francisco Water Department
USGS	United States Geological Survey
WSIP	Water System Improvement Program. The WSIP is a $4.8 billion dollar, multi-year program to upgrade the SFPUC's regional and local water systems. The WSIP, which is over 96% complete, is one of the largest water infrastructure

programs in the nation and the largest infrastructure program ever undertaken by the City.

APPENDICES

A. Table of Findings and Recommendations
B. Table of Findings with Required Responses
C. Table of Recommendations with Required Responses
D. List of Reports Specifically Focusing on the City's AWSS or PWSS
E. List of Additional Reports Reviewed
F. USGS, UCERF3: A New Earthquake Forecast for California's Complex Fault System, Fact Sheet 2015-3009 (2015) https://pubs.usgs.gov/fs/2015/3009/pdf/fs2015-3009.pdf
G. USGS, Earthquake Outlook for the San Francisco Bay Region 2014–2043, Fact Sheet 2016-3020 (2016) (version 1.1), https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf
H. Map of Existing EFWS, with HP AWSS, Cisterns and other Assets
I. Map of Existing HP AWSS system
J. Map of SFFD Fire Response Areas
K. Abstract (page 2) from Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco, http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf
L. Analysis by the Ballot Simplification Committee of 1986 Proposition A.
M. San Francisco Fire Commission Resolution 2010-01, dated January 14, 2010, https://sf-fire.org/sites/default/files/FileCenter/Documents/2446-Resolution%202010-01%20PWSS%20Grant%20Funding.pdf
N. SFPUC 2017 FAQ, https://sfwater.org/modules/showdocument.aspx?documentid=11507 printed March 6, 2019
O. SFPUC EFWS 2010 and 2014 ESER bond project status as of February 26, 2019
P. SFPUC Candidate EFWS Project list dated May 8, 2019
Q. Fire Dept.'s Ace in the Hole, San Francisco Independent, January 31, 1990
R. Figure 5-1, *Preferred Alternative Planning Schedule*, from CS-199, at p. 71, https://www.sfwater.org/Modules/ShowDocument.aspx?documentid=5055.

APPENDIX A
TABLE OF FINDINGS AND RECOMMENDATIONS

Findings	Recommendations
F1. Fires resulting from an earthquake represent a significant risk of widespread damage and potential loss of life in San Francisco. F2. The municipal water supply system (MWSS) is highly vulnerable to damage from a major earthquake and is not a reliable source for water supply for firefighting after a major earthquake. F3. Approximately 30 cisterns have recently been added with funds from ESER bonds, but cisterns only have up to about an hour of water supply and thus do not provide sufficient water for fighting fires following a major earthquake. F4. The City's high-pressure emergency water supply system, known as the Auxiliary Water Supply System (AWSS), does not cover large parts of Supervisorial Districts 1, 4, 7 and 11, roughly one-third of the City's developed area. As a result, these districts are not adequately protected from fires after a major earthquake. F5. A high-pressure, multi-sourced, seismically safe emergency firefighting water supply will be costly but is essential to protect the City. F6. Unless the City increases funding levels, it will be several decades (i.e., after the USGS predicts one or more major earthquakes will occur) before the southern parts of the City have a high-pressure, multi-sourced, seismically safe emergency firefighting water supply.	R1. By no later than December 31, 2020, the Mayor, the SFPUC, the SFFD and the Office of Resilience and Capital Planning should jointly present to the Board of Supervisors a detailed plan to ensure the City is well prepared to fight fires in all parts of San Francisco in the event of a 1906-magnitude (7.8) earthquake. R2. The plan discussed in Recommendation R1 should include a detailed proposal, including financing sources, for the installation within 15 years of a high-pressure, multi-sourced, seismically safe emergency water system for those parts of the City that don't currently have one, i.e., by no later than June 30, 2034. R3. The Board of Supervisors should direct the Budget and Legislative Analyst to study through an equity lens and issue a report to the Board regarding (a) which areas of the City do not have sufficient water supplies for the anticipated demand for water to fight fires following a major earthquake similar in magnitude to the 1906 earthquake, and (b) options to address the issue in both the short term and the long term. The Board should issue its request by no later than December 31, 2019, and the Budget and Legislative Analyst should complete its report by no later than December 31, 2020.

Findings	Recommendations
F6. Unless the City increases funding levels, it will be several decades (i.e., after the USGS predicts one or more major earthquakes will occur) before the southern parts of the City have a high-pressure, multi-sourced, seismically safe emergency firefighting water supply. F7. The existing Portable Water Supply System (PWSS) inventory is inadequate. Investing in more PWSS hose tenders would provide a relatively quick, cost-effective interim means to improve protection of the southern and western parts of the City until a high-pressure, multi-sourced seismically safe emergency water supply can be developed in those areas.	R4. As interim measure, by no later than June 30, 2021, the City should purchase the 20 new PWSS hose tenders being requested by the SFFD, to replace and expand its currently inadequate inventory.
F4. The City's high-pressure emergency water supply system, known as the Auxiliary Water Supply System (AWSS), does not cover large parts of Supervisorial Districts 1, 4, 7 and 11, roughly one-third of the City's developed area. As a result, these districts are not adequately protected from fires after a major earthquake.	R5. The SFFD should strategically locate the majority of the PWSS hose tenders in areas that at present only have low-pressure hydrants and/or cisterns.
F8. Redundancy is an important feature of an emergency firefighting water system. F9. Current plans to extend protections to the western part of the City do not include any high-pressure water sources north of Golden Gate Park.	R6. The SFPUC, the SFFD, and the SF Department of the Environment should study adding salt-water pump stations to improve the redundancy of water sources, especially on the west side. Findings and recommendations from this study should be presented to the Board of Supervisors by no later than June 30, 2021.
F10. The "reliability scores" being used by the SFPUC impart an overly optimistic impression of the protection provided.	R7. The SFPUC should (a) continue its efforts to complete a more detailed analysis of emergency firefighting water needs (including above-the-median needs) by neighborhood, and not just by FRA, and (b) present a completed analysis to the Board of Supervisors by no later than June 30, 2021.

Findings	Recommendations
F5. A high-pressure, multi-sourced, seismically safe emergency firefighting water supply will be costly but is essential to protect the City. F6. Unless the City increases funding levels, it will be several decades (i.e., after the USGS predicts one or more major earthquakes will occur) before the southern parts of the City have a high-pressure, multi-sourced, seismically safe emergency firefighting water supply. F11. The City does not have a timeline to fund and complete the development of a high-pressure, multi-sourced, seismically safe emergency water supply for all parts of the City, including poor neighborhoods that historically have not been as well protected as the downtown business district and many richer neighborhoods.	R8. By no later than June 30, 2022, the Mayor and the Board of Supervisors should analyze whether to propose a separate bond for the development of a high-pressure, multi-sourced, seismically safe emergency water system for those parts of the City that don't currently have one, with a target date of completing construction by no later than June 30, 2034.
F12. The SFPUC has not developed a number of the routine maintenance plans recommended in a 2014 report (CS-199), and has not adequately defined which AWSS valves are "critical" and therefore require increased attention.	R9. By no later than December 31, 2020, the SFPUC, with the advice and subject to the approval of the SFFD, should (a) implement "best practices" for the maintenance of AWSS assets, and (b) redefine which AWSS valves in the system are "critical," and, therefore, require more attention and priority in the SFPUC's maintenance plans.
F13. In the 2015 MOU between the SFFD and the SFPUC, the two agencies agreed to conduct joint AWSS trainings annually, but there is no formal protocol outlining specific joint AWSS exercises or drills using hypothetical disaster scenarios, such as a major earthquake.	R10. By no later than June 30, 2020, the 2015 MOU between the SFPUC and the SFFD should be amended to include a detailed roadmap for annual emergency response exercises, including simulated disaster and earthquake drills involving the AWSS and the PWSS.

APPENDIX B
TABLE OF FINDINGS WITH REQUIRED RESPONSES

Findings	Required Responses
F1. Fires resulting from an earthquake represent a significant risk of widespread damage and potential loss of life in San Francisco.	• Chief, San Francisco Fire Department • San Francisco Fire Commission • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission
F2. The municipal water supply system (MWSS) is highly vulnerable to damage from a major earthquake and is not a reliable source for water supply for firefighting after a major earthquake.	• General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Chief, San Francisco Fire Department • San Francisco Fire Commission
F3. Approximately 30 cisterns have recently been added with funds from ESER bonds, but cisterns only have up to about an hour of water supply and thus do not provide sufficient water for fighting fires following a major earthquake.	• Chief, San Francisco Fire Department • San Francisco Fire Commission
F4. The City's high-pressure emergency water supply system, known as the Auxiliary Water Supply System (AWSS), does not cover large parts of Supervisorial Districts 1, 4, 7 and 11, roughly one-third of the City's developed area. As a result, these districts are not adequately protected from fires after a major earthquake.	• Office of the Mayor • Board of Supervisors • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission
F5. A high-pressure, multi-sourced, seismically safe emergency firefighting water supply will be costly but is essential to protect the City.	• Office of the Mayor • Board of Supervisors • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission

Findings	Required Responses
F6. Unless the City increases funding levels, it will be several decades (i.e., after the USGS predicts one or more major earthquakes will occur) before the southern parts of the City have a high-pressure, multi-sourced, seismically safe emergency firefighting water supply.	• Office of the Mayor • Board of Supervisors • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission • Office of the City Administrator • Chief Resilience Officer, Office of the City Administrator • Budget and Legislative Analyst Office, Board of Supervisors
F7. The existing Portable Water Supply System (PWSS) inventory is inadequate. Investing in more PWSS hose tenders would provide a relatively quick, cost-effective interim means to improve protection of the southern and western parts of the City until a high-pressure, multi-sourced, seismically safe emergency water supply can be developed in those areas.	• Fire Chief, San Francisco Fire Department • San Francisco Fire Commission
F8. Redundancy is an important feature of an emergency firefighting water system.	• General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission
F9. Current plans to extend protections to the western part of the City do not include any high-pressure water sources north of Golden Gate Park.	• General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission

Findings	Required Responses
F10. The “reliability scores” being used by the SFPUC impart an overly optimistic impression of the protection provided.	• General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission
F11. The City does not have a timeline to fund and complete the development of a high-pressure, multi-sourced, seismically safe emergency water supply for all parts of the City, including poor neighborhoods that historically have not been as well protected as the downtown business district and many richer neighborhoods.	• Office of the Mayor • Board of Supervisors • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission • Office of the City Administrator • Chief Resilience Officer, Office of the City Administrator • Budget and Legislative Analyst Office, Board of Supervisors
F12. The SFPUC has not developed a number of the routine maintenance plans recommended in a 2014 report (CS-199), and has not adequately defined which AWSS valves are “critical” and therefore require increased attention.	• General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission
F13. In the 2015 MOU between the SFFD and the SFPUC, the two agencies agreed to conduct joint AWSS trainings annually, but there is no formal protocol outlining specific joint AWSS exercises or drills using hypothetical disaster scenarios, such as a major earthquake.	• General Manager, San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department

APPENDIX C
TABLE OF RECOMMENDATIONS WITH REQUIRED RESPONSES

Recommendations	Required Responses
R1. By no later than December 31, 2020, the Mayor, the SFPUC, the SFFD and the Office of Resilience and Capital Planning should jointly present to the Board of Supervisors a detailed plan to ensure the City is well prepared to fight fires in all parts of San Francisco in the event of a 1906-magnitude (7.8) earthquake.	• Office of the Mayor • Board of Supervisors • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission • Office of the City Administrator • Chief Resilience Officer, Office of the City Administrator
R2. The plan discussed in Recommendation R1 should include a detailed proposal, including financing sources, for the installation within 15 years of a high-pressure, multi-sourced, seismically safe emergency water system for those parts of the City that don't currently have one, i.e., by no later than June 30, 2034.	• Office of the Mayor • Board of Supervisors • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission • Office of the City Administrator • Chief Resilience Officer, Office of the City Administrator
R3. The Board of Supervisors should direct the Budget and Legislative Analyst to study through an equity lens and issue a report to the Board regarding (a) which areas of the City do not have sufficient water supplies for the anticipated demand for water to fight fires following a major earthquake similar in magnitude to the 1906 earthquake, and (b) options to address the issue in both the short-term and the long-term. The Board should issue its request by no later than December 31, 2019, and the Budget and Legislative Analyst should complete its report by no later than December 31, 2020.	• Board of Supervisors • Budget and Legislative Analyst Office, Board of Supervisors

Recommendations	Required Responses
R4. As interim measure, by no later than June 30, 2021, the City should purchase the 20 new PWSS hose tenders being requested by the SFFD, to replace and expand its currently inadequate inventory.	• Office of the Mayor • Board of Supervisors • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission
R5. The SFFD should strategically locate the majority of the PWSS hose tenders in areas that at present only have low-pressure hydrants and/or cisterns.	• Fire Chief, San Francisco Fire Department • San Francisco Fire Commission
R6. The SFPUC, the SFFD, and the SF Department of the Environment should study adding salt-water pump stations to improve the redundancy of water sources, especially on the west side. Findings and recommendations from this study should be presented to the Board of Supervisors by no later than June 30, 2021.	• Board of Supervisors • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission • Director, San Francisco Department of the Environment
R7. The SFPUC should (a) continue its efforts to complete a more detailed analysis of emergency firefighting water needs (including above the median needs) by neighborhood, and not just by FRA, and (b) present a completed analysis to the Board of Supervisors by no later than June 30, 2021.	• Board of Supervisors • General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department
R8. By no later than June 30, 2022, the Mayor and the Board of Supervisors should analyze whether to propose a separate bond for the development of a high-pressure, multi-sourced, seismically safe emergency water system for those parts of the City that don't currently have one, with a target date of completing construction by no later than June 30, 2034	• Office of the Mayor • Board of Supervisors • Office of the City Administrator • Chief Resilience Officer, Office of the City Administrator

Recommendations	Required Responses
R9. By no later than December 31, 2020, the SFPUC, with the advice and subject to the approval of the SFFD, should (a) implement "best practices" for the maintenance of AWSS assets, and (b) redefine which AWSS valves in the system are "critical," and, therefore, require more attention and priority in the SFPUC's maintenance plans.	• General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission
R10. By no later than June 30, 2020, the 2015 MOU between the SFPUC and the SFFD should be amended to include a detailed roadmap for annual emergency response exercises, including simulated disaster and earthquake drills involving the AWSS and the PWSS.	• General Manager, San Francisco Public Utilities Commission • San Francisco Public Utilities Commission • Fire Chief, San Francisco Fire Department • San Francisco Fire Commission

APPENDIX D
List of Reports Specifically Focusing On the City's AWSS or PWSS

2002-2003 Civil Grand Jury for the City and County of San Francisco, Keeping the Faucets Flowing: Water Emergency Preparedness In San Francisco (June 2003), http://civilgrandjury.sfgov.org/2002_2003/Keeping_the_Faucets_Flowing_Water_Emergency.pdf

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AECOM / AGS, JV, Auxiliary Water Supply System Planning Study Summary, prepared for SFPUC (February 2014), https://sfwater.org/Modules/ShowDocument.aspx?documentid=4907

AECOM / WRE, a Joint Venture, CS-229 Task 16 and 19, Emergency Firefighting Water System (EFWS) Spending Plan for the Earthquake Safety Emergency Response (ESER) 2014 Bond (November 2015) ("CS-229"), https://sfwater.org/Modules/ShowDocument.aspx?documentid=8246

AECOM, Westside Emergency Firefighting Water Systems Options Analysis Report (January 5, 2018) ("2018 Westside Options Analysis"), https://www.sfwater.org/modules/showdocument.aspx?documentid=11740

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Scawthorn, C., January 5, 2018 memorandum to D.Myerson & S.Huang of SFPUC re Review of "Westside Emergency Firefighting Water System Options Analysis", (Scawthorn 2018 memo"), https://www.sfwater.org/modules/showdocument.aspx?documentid=11740

Scawthorn, C. and Blackburn, F., Performance of the San Francisco Auxiliary and Portable Water Supply Systems in the 17 October 1989 Loma Prieta Earthquake, presented at Fourth U.S. National Conference on Earthquake Engineering May 20-24, 1990, and provided by SFPUC

APPENDIX E
List of Additional Reports Reviewed

Applied Technology Council (ATC) ATC 52-1, Here Today–Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Potential Earthquake Impacts, prepared for the Department of Building Inspection, CCSF, under the Community Action Plan for Seismic Safety (CAPSS) Project (2010)("ATC 52-1, Potential Earthquake Impacts"), https://sfgov.org/esip/sites/default/files/FileCenter/Documents/9753-atc521.pdf

Applied Technology Council (ATC) ATC-52-2, Here Today–Here Tomorrow: The Road to Earthquake Resilience in San Francisco, A Community Action Plan for Seismic Safety, prepared for the Department of Building Inspection, CCSF, under the (CAPSS) Project (2010), https://sfgov.org/esip/sites/default/files/FileCenter/Documents/9757-atc522.pdf

Aster, R., California's other drought: A major earthquake is overdue, *The Conversation* (January 30, 2018), https://theconversation.com/californias-other-drought-a-major-earthquake-is-overdue-90517

Blackburn, F., Report on Firefighting Requirements Following Earthquake and Current Proposals by the SFPUC (2018**)**

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Johnson, L. and Mahin, S., The 6.0 M_w South Napa Earthquake of August 24, 2014: A Wake-up Call for Renewed Investment in Seismic Resilience across California, Pacific Earthquake Engineering Research Center prepared for the California Seismic Safety Commission, CSSC Publication 16-03, PEER Report No. 2016/04 (2016), https://ssc.ca.gov/forms_pubs/cssc_603peer201604_final_7_20_16.pdf

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O'Rourke, T.D., Lessons Learned For Lifeline Engineering From Major Urban Earthquakes, presented at Eleventh World Conference on Earthquake Engineering (1996)

San Francisco Fire Department Emergency Operations Plan

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Scawthorn, C., Water Supply In Regards to Fire Following Earthquakes, Pacific Earthquake Engineering Research Center, College of Engineering, University of California, sponsored by the California Seismic Safety Commission, Berkeley (2011) ("PEER 2011, Water Supply Following Earthquake"), https://peer.berkeley.edu/sites/default/files/webpeer-2011-08-charles_scawthorn.pdf

Scawthorn, C., SPA Risk LLC, *Analysis of Fire Following Earthquake Potential for San Francisco, California*, prepared for the Applied Technology Council on behalf of the Department of Building Inspection City and County of San Francisco (October 2010 Rev. 1) ("Scawthorn 2010, Analysis of Fire Following Earthquake for San Francisco"), http://www.sparisk.com/documents/SPASanFranciscoCAPSSFireFollowingEarthquakeOct2010.pdf

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U.S. Geological Survey, Earthquake Outlook for the San Francisco Bay Region 2014–2043, Fact Sheet 2016-3020 (2016) (version 1.1), https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf

Appendix F

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UCERF3: A New Earthquake Forecast for California's Complex Fault System

With innovations, fresh data, and lessons learned from recent earthquakes, scientists have developed a new earthquake forecast model for California, a region under constant threat from potentially damaging events. The new model, referred to as the third Uniform California Earthquake Rupture Forecast, or "UCERF3" (http://www.WGCEP.org/UCERF3), provides authoritative estimates of the magnitude, location, and likelihood of earthquake fault rupture throughout the state. Overall the results confirm previous findings, but with some significant changes because of model improvements. For example, compared to the previous forecast (UCERF2), the likelihood of moderate-sized earthquakes (magnitude 6.5 to 7.5) is lower, whereas that of larger events is higher. This is because of the inclusion of multifault ruptures, where earthquakes are no longer confined to separate, individual faults, but can occasionally rupture multiple faults simultaneously. The public-safety implications of this and other model improvements depend on several factors, including site location and type of structure (for example, family dwelling compared to a long-span bridge). Building codes, earthquake insurance products, emergency plans, and other risk-mitigation efforts will be updated accordingly. This model also serves as a reminder that damaging earthquakes are inevitable for California. Fortunately, there are many simple steps residents can take to protect lives and property.

What is UCERF3?

California is sandwiched between the Pacific and North American tectonic plates, with the former migrating northwest about two inches per year compared to the latter. The plate boundary is far from smooth, reflecting more of a fragmented zone locked in a tectonic battle over which areas will give way, producing some of the steepest mountain ranges in the world. The sliding between plates is also not steady, but rather plays out in fits and starts with periods of rest interrupted by sudden slip along cracks in the Earth. These "fault ruptures" in turn cause the ground to shake, much like the ripples that radiate from a pebble tossed in a pond, and it is this shaking that causes the most damage in earthquakes.

Two kinds of scientific models are used to help safeguard against earthquake losses: an Earthquake Rupture Forecast, which tells us where and when the Earth might slip along the state's many faults, and a Ground Motion Prediction model, which estimates the subsequent shaking given one of the fault ruptures. UCERF3 is the first type of model, representing the latest earthquake-rupture forecast for California. It was developed and reviewed by dozens of leading scientific experts from the fields of seismology, geology, geodesy, paleoseismology, earthquake physics, and earthquake engineering. As such, it represents the best available science with respect to authoritative estimates of the magnitude, location, and likelihood of potentially damaging earthquakes throughout the state (further background on these models, especially with respect to ingredients, can be found in U.S. Geological Survey Fact Sheet 2008–3027, http://pubs.usgs.gov/fs/2008/3027/).

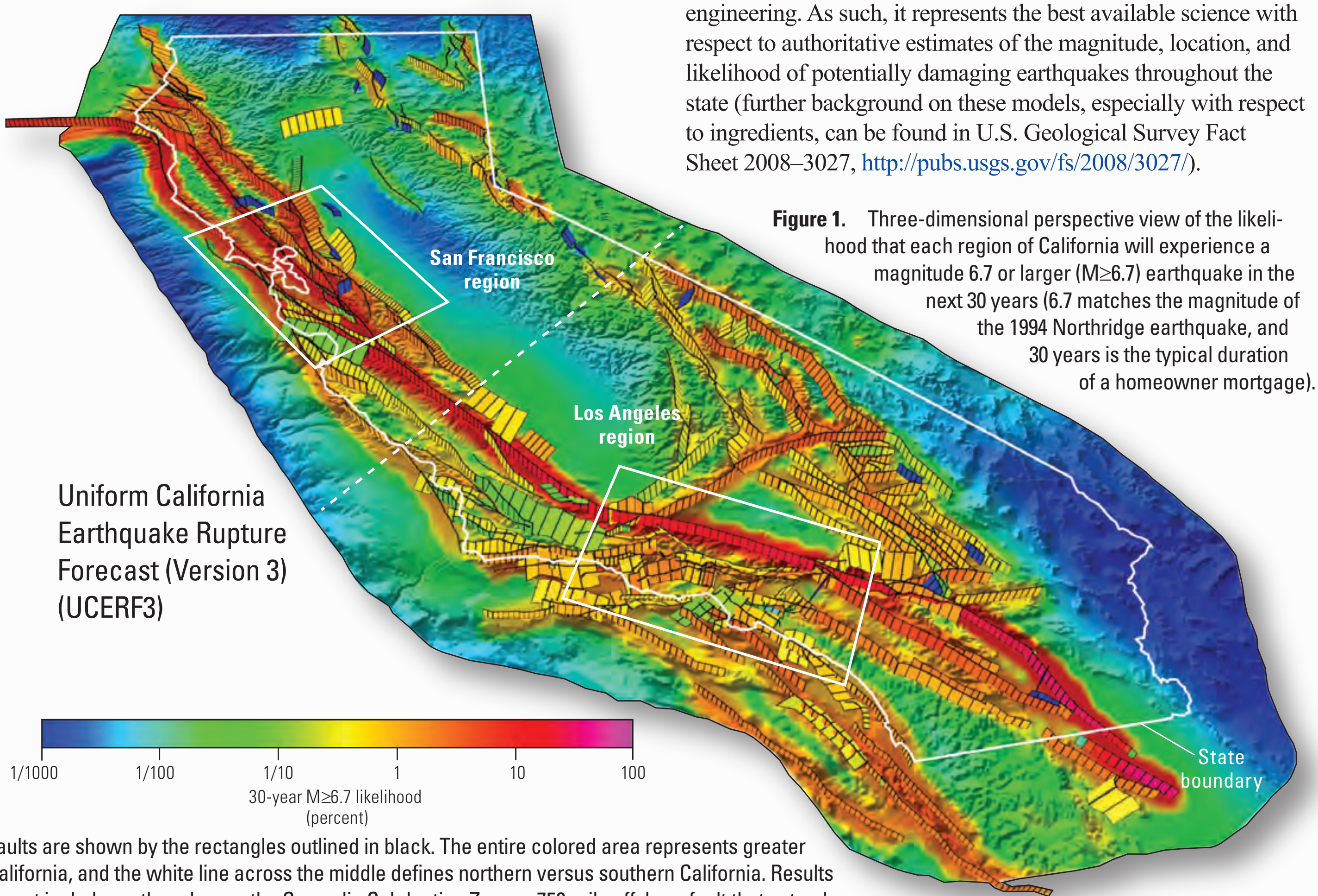

Figure 1. Three-dimensional perspective view of the likelihood that each region of California will experience a magnitude 6.7 or larger (M≥6.7) earthquake in the next 30 years (6.7 matches the magnitude of the 1994 Northridge earthquake, and 30 years is the typical duration of a homeowner mortgage).

Faults are shown by the rectangles outlined in black. The entire colored area represents greater California, and the white line across the middle defines northern versus southern California. Results do not include earthquakes on the Cascadia Subduction Zone, a 750-mile offshore fault that extends about 150 miles into California from Oregon and Washington to the north.

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http://dx.doi.org/10.3133/fs20153009
Fact Sheet 2015–3009
March 2015

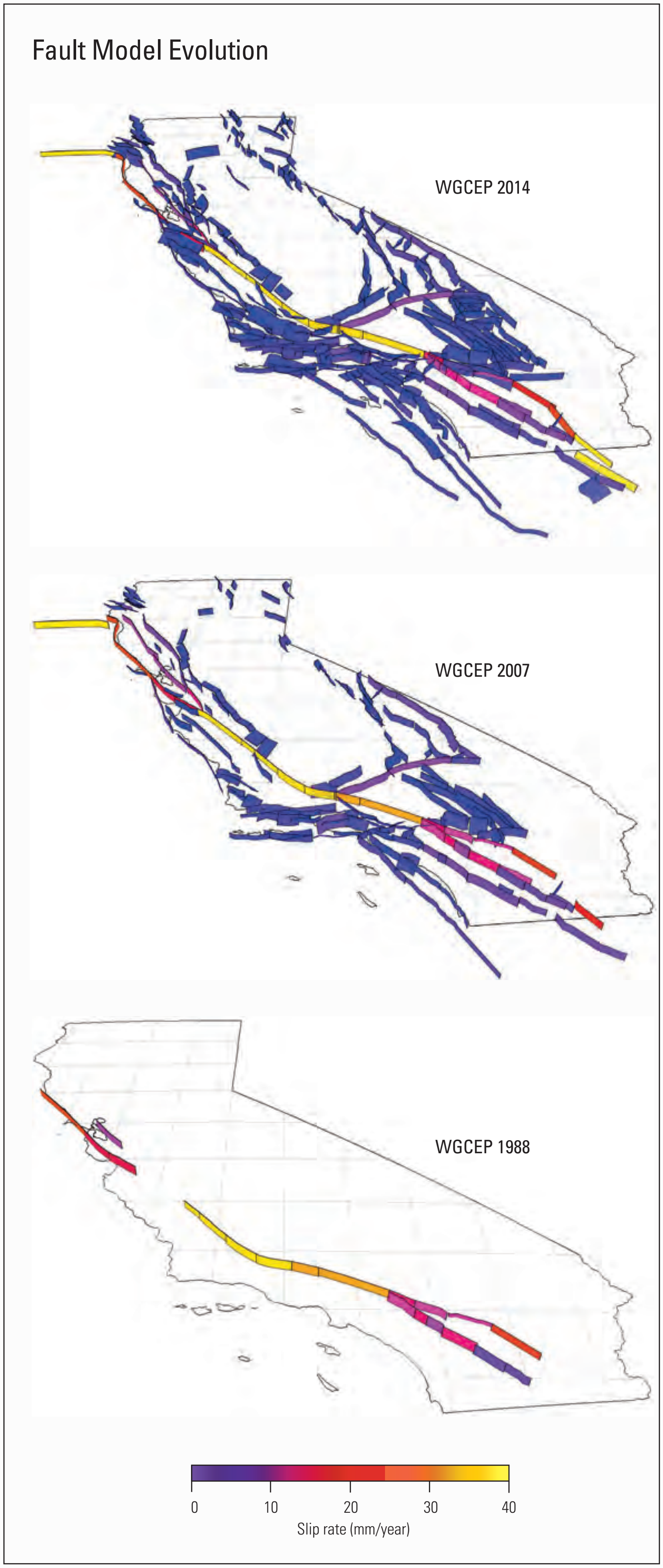


Figure 2. Changes with time of the inventory of faults used in California earthquake forecast models (WGCEP, Working Group on California Earthquake Probabilities).

Why a New Earthquake Forecast Model?

All scientific models, including earthquake rupture forecasts, are an approximation of the physical system they represent, in the same way that "the map is not the actual territory" (Korzbski, 1931). UCERF3 represents the latest model from the Working Group on California Earthquake Probabilities (WGCEP) (WGCEP, 2014), which also released forecasts in 1988, 1990, 1995, 2003, and 2007. This historical progression of models reflects increasingly accurate, detailed, and sophisticated representations of a particularly complex natural system.

A puzzling feature of previous models has been a forecasted rate of moderate-sized earthquakes (between magnitude 6.5 and 7.0) that is up to a factor of two higher than that observed historically. The first discovery of this discrepancy, by the 1995 WGCEP, was particularly disturbing in that one such event, the magnitude 6.7 1994 Northridge earthquake, had just surprised many as the costliest earthquake in U.S. history. In fact, the prospect of such events becoming more frequent contributed to an ensuing homeowner-insurance-availability crisis, as most insurance providers opted to pull out of the market altogether, rather than comply with a state law requiring they offer an earthquake option with each policy. This insurance availability crisis was ultimately solved in 1996 with the legislative creation of the California Earthquake Authority (http://www.earthquakeauthority.com), which has since become the largest earthquake insurance provider in the state. However, the discrepancy between the forecast rate and the observed rate at moderate magnitudes has remained through the most recent previous study (WGCEP, 2007), and scientists have hotly debated whether this is real or a result of some model limitation.

Recent earthquakes have fortunately provided clues. For example, the Northridge earthquake occurred on a previously unrecognized fault, which motivated scientists to search for other faults and quantify those that might be capable of producing damaging earthquakes. The effort has paid off. Whereas the 1988 WGCEP considered only 16 different faults, albeit the main ones, by the time of the WGCEP 2007 effort there were about 200. With UCERF3, there are now more than 350 fault sections in the model, thanks in part to using space-based geodesy where geologic data are limited. This historical progression is shown in the fault model evolution figure at left.

Another clue with respect to the moderate-magnitude rate discrepancy is that many recent earthquakes have plowed past previously inferred fault-rupture boundaries. That is, past models have generally assumed that earthquakes are either confined to separate faults, or that long faults like the San Andreas can be divided into different segments that only rupture separately. However, all three of the most-recent, largest earthquakes in California ruptured right past such boundaries, jumping from one fault to another as multifault ruptures. These were the 1992 magnitude 7.3 Landers, the 1999 magnitude 7.2 Hector Mine, and the 2010 magnitude 7.2 El Mayor–Cucapah earthquakes. The 2011 magnitude 9.0 Tohoku, Japan earthquake also violated previously defined fault-segment boundaries, resulting in a much larger fault-rupture area and magnitude than expected, and contributing to the deadly tsunami and Fukushima nuclear disaster.

Given these observations, the possibility of multifault ruptures clearly needed to be considered in our new model. In fact, as the inventory of California faults has grown over the years, it

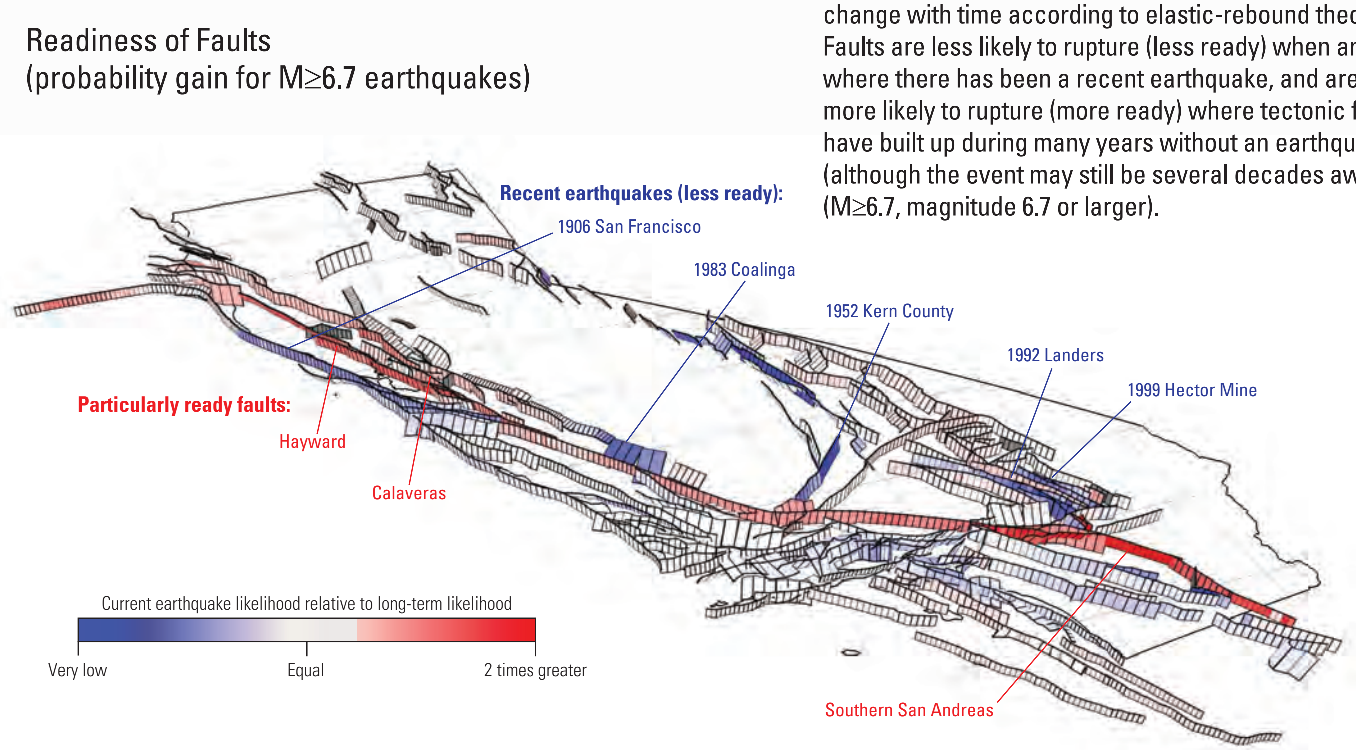


Figure 3. California earthquake likelihood in UCERF3 incorporates the concept that earthquake probabilities change with time according to elastic-rebound theory. Faults are less likely to rupture (less ready) when and where there has been a recent earthquake, and are more likely to rupture (more ready) where tectonic forces have built up during many years without an earthquake (although the event may still be several decades away) (M≥6.7, magnitude 6.7 or larger).

has become increasingly apparent that we are not dealing with a few well-separate faults, but with a vast interconnected fault system. In fact, it has become difficult to identify where some faults end and others begin, implying many more opportunities for multifault ruptures. As a consequence, UCERF3 now considers more than 250,000 different fault-based earthquakes, including multifault ruptures, whereas UCERF2 had about 10,000, and previous models had far fewer. Because we still lack a complete inventory of faults, UCERF3 (and UCERF2 before it) also includes the possibility of earthquakes on unrecognized faults elsewhere in the region.

Solving for the rate of all possible ruptures in the interconnected fault system represented a significant challenge. The UCERF3 methodological breakthrough, referred to as the “grand inversion,” allowed us to not only solve for the rate of each earthquake rupture, but to also draw upon a broader range of observations in doing so. For example, the previous rate discrepancy at moderate-magnitudes was turned into part of the solution. That is, because the total plate-tectonic deformation is generally well known, any increase in the rate of larger, multifault ruptures must come with a consequent reduction in rates at lower magnitudes. The grand inversion manages the overall plate-tectonic, fault-system budget mathematically, adding whatever multifault ruptures are needed to eliminate the rate discrepancy at moderate magnitudes. So, not only does UCERF3 include the types of multifault ruptures seen in nature, but doing so has also eliminated the overprediction of moderate-sized events, implying the latter was simply a manifestation of the isolation and segmentation of faults in the previous models.

UCERF3 also includes the notion of fault “readiness,” where earthquake likelihoods go down on faults that have recently ruptured, and build back up with time as tectonic stresses reaccumulate. Although this concept, known formally as Reid’s elastic rebound theory (Reid, 1911), has been around for more than a century, applying it in a model that includes multifault ruptures also proved challenging. A new methodology was therefore developed, which also relaxes the requirement that the date-of-last event be known where applied. That is, we may not know when the most recent event occurred on many California faults, but we do know that it had to have been prior to 1875 (the year when reliable recordkeeping began). Being able to account for this “historic open interval” for events that precede 1875 allowed us to quantify fault readiness throughout the entire fault system (fig. 3), rather than being limited to only a subset of faults as in previous studies.

There are many uncertainties in both the data and scientific theories that go into UCERF3, and alternative values for each element can lead to a different forecast. Consequently, UCERF3 is not a single model, but rather a collection of 5,760 different viable models. The results presented in the next section represent an average of these forecasts. Calculating grand-inversion results for all the models required the use of super computers, as they would have taken more than 8 years on a single desktop computer.

What Are the Results, and How Do They Differ from Previous Estimates?

UCERF3 results for various regions and faults of interest are shown in the figures and tables here. How have expected earthquake rates changed from the previous model? Overall, the results confirm earlier findings (California is earthquake country), but with some important refinements in certain areas. Considering the entire region, the average time between magnitude 6.7 and larger earthquakes has gone from 1 every 4.8 years in UCERF2, to 1 about every 6.3 years in UCERF3, representing a 30 percent decrease in the new forecasted

Table 1. Average time between earthquakes in the various regions together with the likelihood of having one or more such earthquakes in the next 30 years (starting from 2014). Values listed in parentheses indicate the factor by which the rates and likelihoods have increased, or decreased, since the previous model (UCERF2). “Readiness” indicates the factor by which likelihoods are currently elevated, or lower, because of the length of time since the most recent large earthquakes (see text). These values include aftershocks. It is important to note that actual repeat times will exhibit a high degree of variability, and will almost never exactly equal the average listed here.

Greater California region					
Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	0.12	(0.7)	100%	(1.0)	1.0
6	1.2	(0.9)	100%	(1.0)	1.0
6.7	6.3	(1.3)	>99%	(1.0)	1.0
7	13	(1.3)	93%	(1.0)	1.0
7.5	52	(1.0)	48%	(1.0)	1.1
8	494	(0.8)	7%	(1.5)	1.2

Southern California region					
Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	0.24	(0.7)	100%	(1.0)	1.0
6	2.3	(0.9)	100%	(1.0)	1.0
6.7	12	(1.5)	93%	(1.0)	1.0
7	25	(1.4)	75%	(0.9)	1.1
7.5	87	(1.2)	36%	(0.9)	1.2
8	522	(0.4)	7%	(2.5)	1.3

Northern California region					
Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	0.24	(0.7)	100%	(1.0)	1.0
6	2.4	(0.9)	100%	(1.0)	1.0
6.7	12	(1.2)	95%	(1.0)	1.0
7	25	(1.2)	76%	(1.0)	1.1
7.5	92	(0.9)	28%	(1.1)	1.0
8	645	(0.8)	5%	(1.4)	1.1

San Francisco region					
Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	1.3	(0.7)	100%	(1.0)	1.0
6	8.9	(1.0)	98%	(1.0)	1.0
6.7	29	(1.1)	72%	(1.1)	1.1
7	48	(0.9)	51%	(1.3)	1.1
7.5	124	(0.7)	20%	(1.6)	0.9
8	825	(0.7)	4%	(1.9)	1.0

Los Angeles region					
Magnitude (greater than or equal to)	Average repeat time (years)		30-year likelihood of one or more events		Readiness
5	1.4	(0.6)	100%	(1.0)	1.0
6	10	(1.1)	96%	(1.0)	1.0
6.7	40	(2.1)	60%	(0.8)	1.1
7	61	(2.0)	46%	(0.7)	1.2
7.5	109	(1.3)	31%	(0.9)	1.3
8	532	(0.4)	7%	(2.5)	1.3

rate (and note that most of these events occur in remote areas of the state). For magnitude 8 and larger, on the other hand, the rate has increased by 20 percent in UCERF3, with an expected repeat time of 494 years for UCERF3, down from 1 every 617 years in UCERF2. These changes are a direct and expected manifestation of including multifault ruptures in UCERF3. A more careful analysis of historical seismicity has also produced an increased rate for magnitude 5 and greater earthquakes, going from about 5.8 per year in UCERF2 to 8.3 per year in UCERF3. All of these trends are similar to those seen in various subregions of the state, with differences being slightly more dramatic for the Los Angeles area because that region has a large number of faults that can now host multifault ruptures.

Results are also expressed in terms of the likelihood of experiencing one or more earthquakes in the next 30 years, the duration of a typical home mortgage, and these values also take fault readiness into consideration (how long it has been since the most recent event). As in UCERF2, the likelihood for magnitude 6.7 and larger earthquakes somewhere in the entire region remains near certainty (greater than 99 percent). The likelihood is 7 percent for magnitude 8 and greater, a 50 percent increase over UCERF2, resulting from both the inclusion of multifault ruptures and the particular readiness of some large faults.

One particularly ready fault is the Southern San Andreas, which contributes to its continued status of being the most likely to host a large earthquake. Specifically, it has a 19 percent chance of having one or more events larger than magnitude 6.7 in the next 30 years near Mojave, Calif. The comparably low values for the Northern San Andreas, such as 6.4 percent near San Francisco, are partly because of the relatively recent 1906 earthquake on that fault. In fact, probabilities on two other Bay Area faults, the Hayward–Rodgers Creek and the Calaveras, currently rival or exceed those on the Northern San Andreas, in part because they are both relatively ready.

Compared to the previous model, UCERF2, the San Jacinto fault has a three-fold decrease in the likelihood of magnitude 6.7 or larger earthquakes. Much of this decrease is because of the inclusion of more multifault ruptures, as indicated by the factor of 57 increase in the likelihood of magnitude 8 and larger earthquakes. In other words, the fault has traded some moderate-sized events for rare larger ones.

The Calveras fault, on the other hand, has a three-fold increase in the likelihood of magnitude 6.7 or larger earthquakes. In UCERF2 most Calaveras events were well below magnitude 6.7, so the inclusion of multifault ruptures in UCERF3 has increased the frequency of earthquakes above magnitude 6.7.

We have only touched on a few of the more important changes between UCERF2 and UCERF3, and have highlighted only some of the influential factors. Many more are currently understood, and scientists will be further analyzing results and testing assumptions for years to come.

So what do these changes imply with respect to seismic hazard, the likelihood of ground shaking, as well as for seismic risk, the threat to the built environment with respect to fatalities and economic losses? The answer turns out to be entirely dependent on what you are concerned about. For example, increasing the likelihood of large multifault earthquakes, which consequently reduces the likelihood of moderate-sized events, may increase the risk to tall buildings or large bridges, but actually lower the risk to residential homes.

As a consequence, it is difficult to make generalizations about the hazard or risk implications of UCERF3 without first specifying both asset types and their locations. Conclusions will vary depending on whether you are designing a single family dwelling in Sacramento, retrofitting the San Francisco–Oakland Bay Bridge, considering the location of a nuclear power plant, laying pipeline across the San Andreas Fault, or considering aggregate losses over a large insurance portfolio. The practical implications will need to be considered on a case-by-case basis.

What Next?

UCERF3 can now be used to evaluate seismic hazard and risk in California. In fact, it has already been used for the 2014 update of the U.S. Geological Survey National Seismic Hazard Maps (http://earthquake.usgs.gov/hazards/), which in turn are used in building codes. The California Earthquake Authority, which is required by law to use the best available science, will use UCERF3 to evaluate insurance premiums charged to customers, as well as their own level of reinsurance. UCERF3 will be used in many other risk mitigation

Tabulated values represent the likelihood of having one or more earthquakes in the next 30 years (starting from 2014).

[At the points on the fault indicated by white circles. M≥6.7 means magnitude greater than or equal to 6.7, and likewise for the other two magnitude thresholds. %, percent. Values listed in parentheses indicate the factor by which the likelihoods have increased, or decreased, relative to the previous model (UCERF2), where "--" means the previous value was zero. "Readiness" indicates the factor by which probabilities are currently elevated, or lower, because of the length of time since the previous large earthquake]

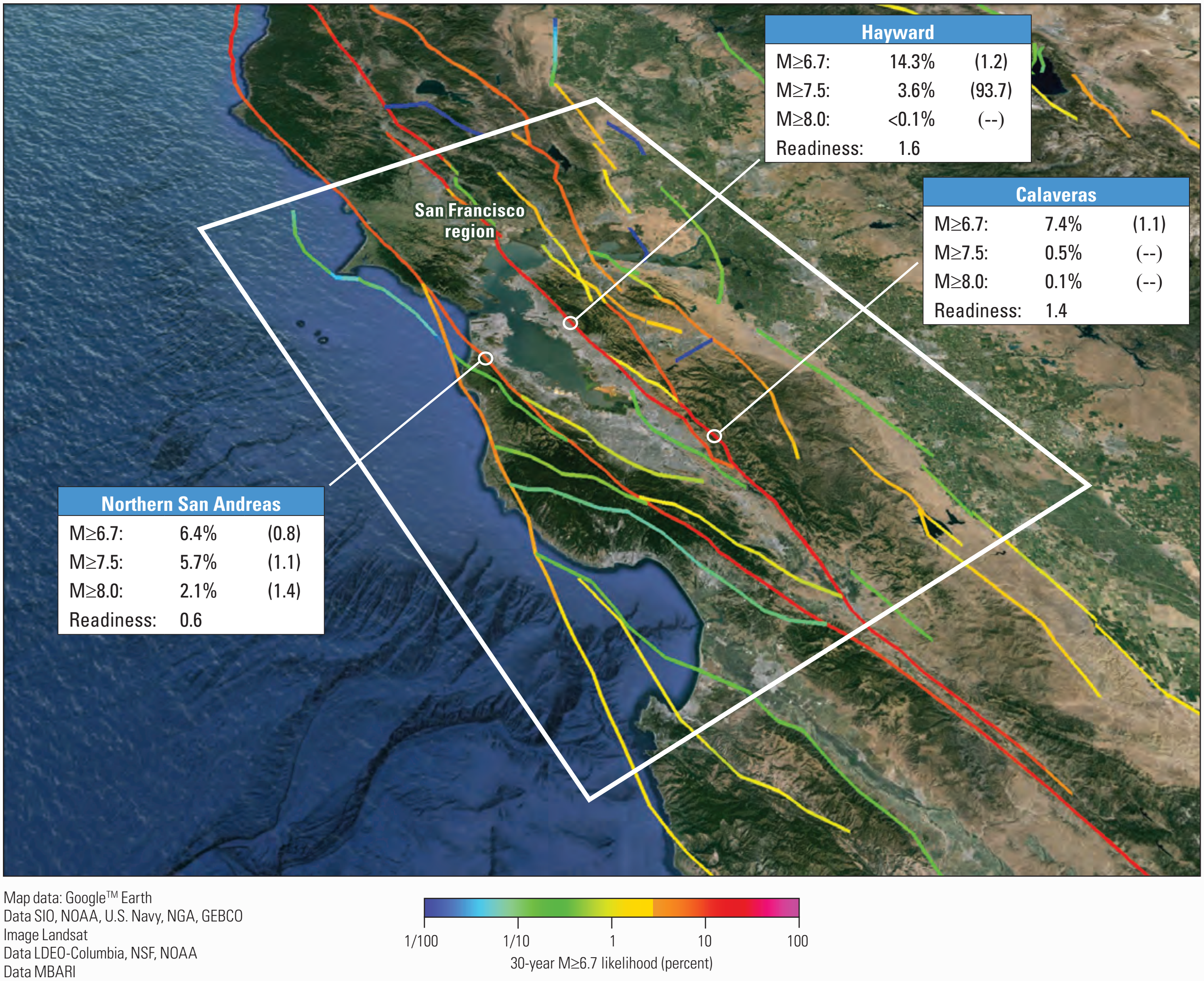


Figure 4. Likelihood of magnitude 6.7 or greater earthquakes in the next 30 years, from 2014, on the faults near San Francisco, Calif.

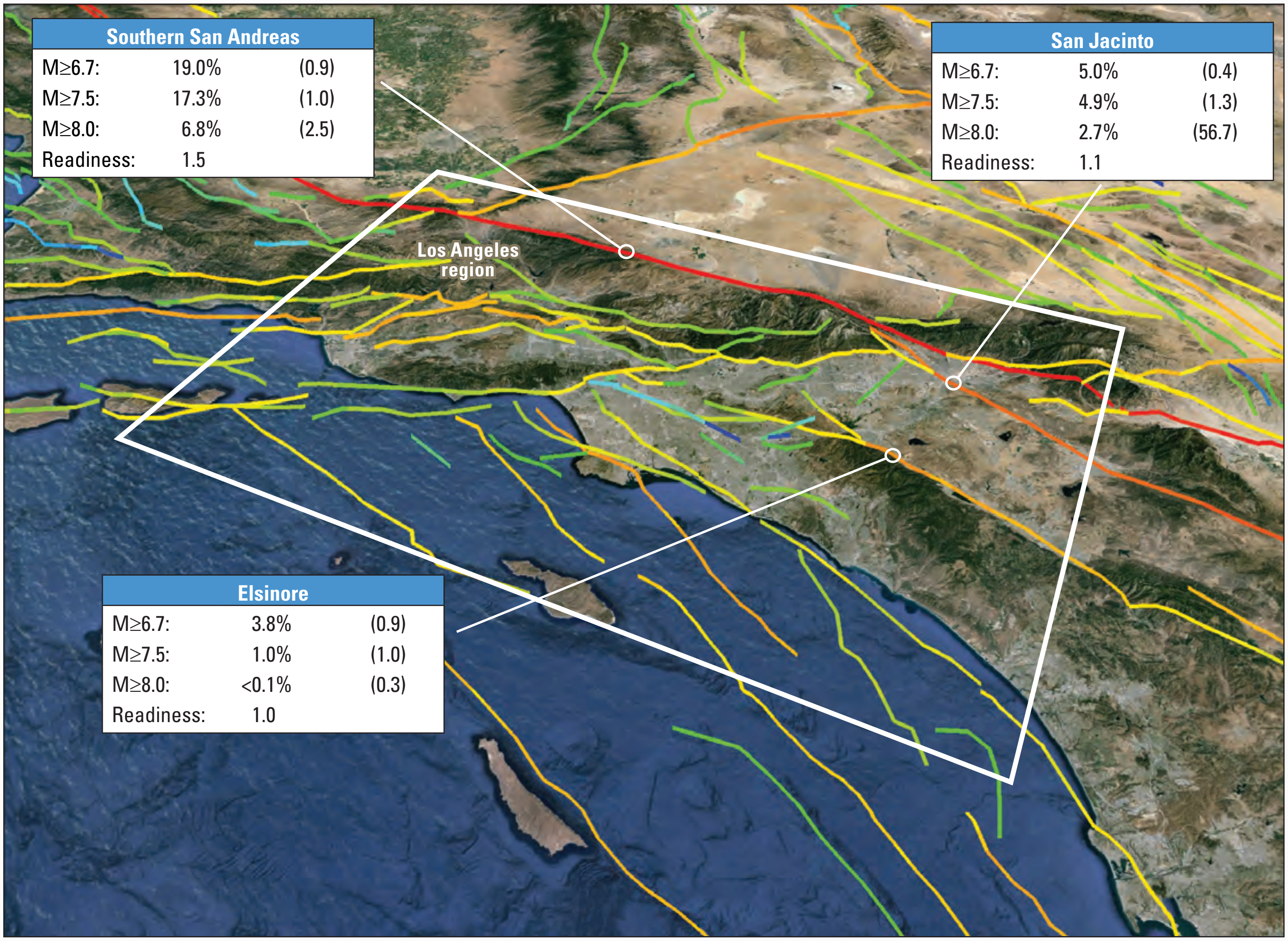
efforts in the years to come, including engineering design of buildings and lifelines, loss estimation for catastrophic bonds and other risk-linked securities, and emergency preparedness, all of which have the ultimate goal of increasing public safety and community resilience.

UCERF3 should also serve as a reminder that California is earthquake country, and residents should always be prepared. Simple safeguards include practicing "drop, cover, and hold on," securing items in your home and workplace that could fall during an earthquake, and storing seven-days worth of food and water. Homeowners can also consider structural retrofits, such as bolting the house to its foundation, as well as earthquake insurance options. For further guidance on how to prepare for, survive, and recover after big earthquakes, follow the Seven Steps to Earthquake Safety (http://www.earthquakecountry.org/sevensteps).

Although UCERF3 is a clear improvement over the previous model (UCERF2), it is still an approximation of the natural system. For example, it does not model the earthquake-triggering process that produces aftershocks, even though we know such events can be large and damaging. Through the National Earthquake Hazard Reduction Program (http://www.nehrp.gov), the U.S. Geological Survey and its partners will continue to conduct research aimed at improving our understanding of fault behavior and estimates of earthquake hazard in the future.

Tabulated values represent the likelihood of having one or more earthquakes in the next 30 years (starting from 2014).

[At the points on the fault indicated by white circles. M≥6.7 means magnitude greater than or equal to 6.7, and likewise for the other two magnitude thresholds. %, percent. Values listed in parentheses indicate the factor by which the likelihoods have increased, or decreased, relative to the previous model (UCERF2), where "--" means the previous value was zero. "Readiness" indicates the factor by which probabilities are currently elevated, or lower, because of the length of time since the previous large earthquake]



Map data: Google™ Earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
Data LDEO-Columbia, NSF, NOAA
Data MBARI

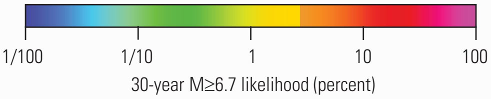


Figure 5. Likelihood of magnitude 6.7 or greater earthquakes in the next 30 years, from 2014, on the faults near Los Angeles, Calif.

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—Authors: Edward H. Field and members of the 2014 WGCEP

Cooperating organizations:
Southern California Earthquake Center (SCEC)
California Geological Survey (CGS)
California Earthquake Authority
U.S. Geological Survey

Additional Resources:

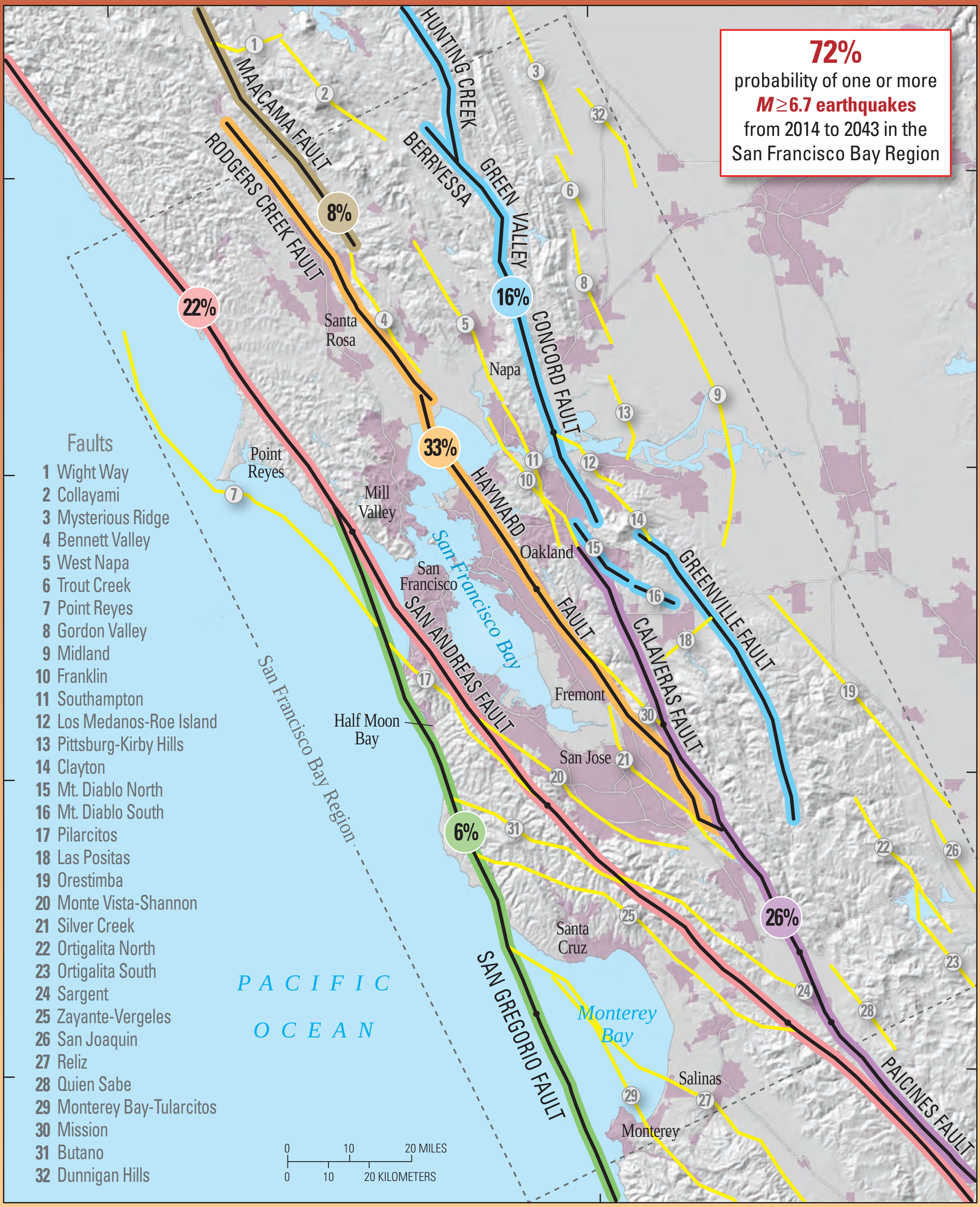
For general earthquake information contact:
1-888-ASK-USGS (1-888-275-8747)
http://earthquake.usgs.gov/
http://ask.usgs.gov
or
SCEC Education and Outreach: 213-740-3262

For UCERF3 information see:
http://www.WGCEP.org/UCERF3

For technical questions contact:
Edward (Ned) Field: field@usgs.gov

Appendix G

Earthquake Outlook for the San Francisco Bay Region 2014–2043



Using information from recent earthquakes, improved mapping of active faults, and a new model for estimating earthquake probabilities, the 2014 Working Group on California Earthquake Probabilities updated the 30-year earthquake forecast for California. They concluded that there is a 72 percent probability (or likelihood) of at least one earthquake of magnitude 6.7 or greater striking somewhere in the San Francisco Bay region before 2043. Earthquakes this large are capable of causing widespread damage; therefore, communities in the region should take simple steps to help reduce injuries, damage, and disruption, as well as accelerate recovery from these earthquakes.

EXPLANATION

- Major plate boundary faults
- Lesser-known smaller faults
- Urban areas

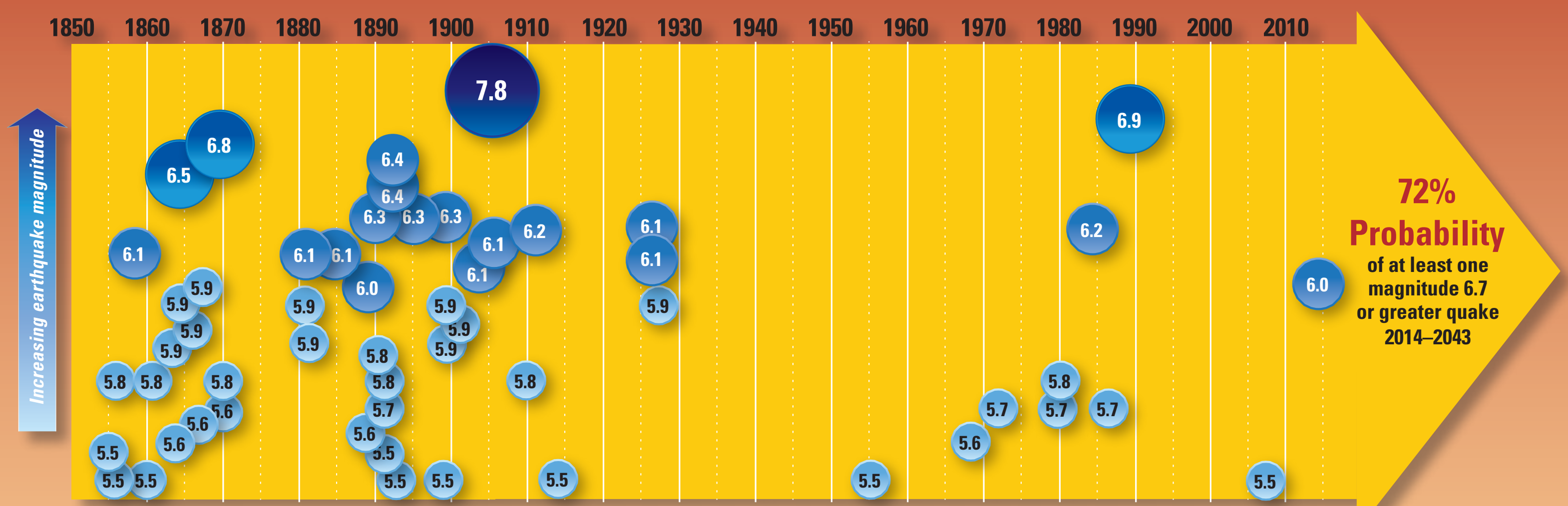
Map of known active faults in the San Francisco Bay region. The 72 percent probability of a magnitude 6.7 or greater earthquake includes the well-known major plate-boundary faults, lesser-known faults, and unknown faults. The percentage shown within each colored circle is the probability that a magnitude 6.7 or greater earthquake will occur somewhere on that fault system by the year 2043. The probability that a magnitude 6.7 or greater earthquake will involve one of the lesser-known faults is 13 percent.

Building damaged in 2014 South Napa earthquake. Photograph by Erol Kalkan, U.S. Geological Survey.

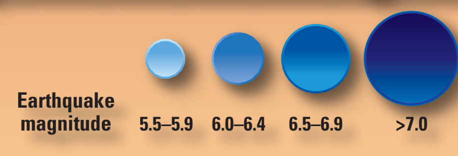
U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 2016–3020
Revised August 2016 (ver. 1.1)

San Francisco Bay Region Earthquake Timeline



1850–1966 earthquakes from Bakun, W.H., 1999, Seismic Activity of the San Francisco Bay Region: Bulletin Seismological Society of America, v. 89, p. 764–784 and 1967–2014 earthquakes from the Northern California Seismic Network.



Likelihood of at least one earthquake greater than a given magnitude in the San Francisco Bay region between 2014 and 2043.

Magnitude (*M*)	30-year likelihood of at least one earthquake in the San Francisco Bay region
$M \geq 6.0$	98 percent
$M \geq 6.7$	72 percent
$M \geq 7.0$	51 percent
$M \geq 7.5$	20 percent

Timeline of magnitude 5.5 and greater earthquakes in the San Francisco Bay region 1850–2014. In the 50 years prior to 1906, there were 13 earthquakes with a magnitude between 6 and 7, but only 6 earthquakes of similar magnitude in the 110 years since 1906. The rate of large earthquakes is expected to increase from this low level as tectonic plate movements continue to increase the stress on the faults in the region.

Earthquake Preparedness Helps

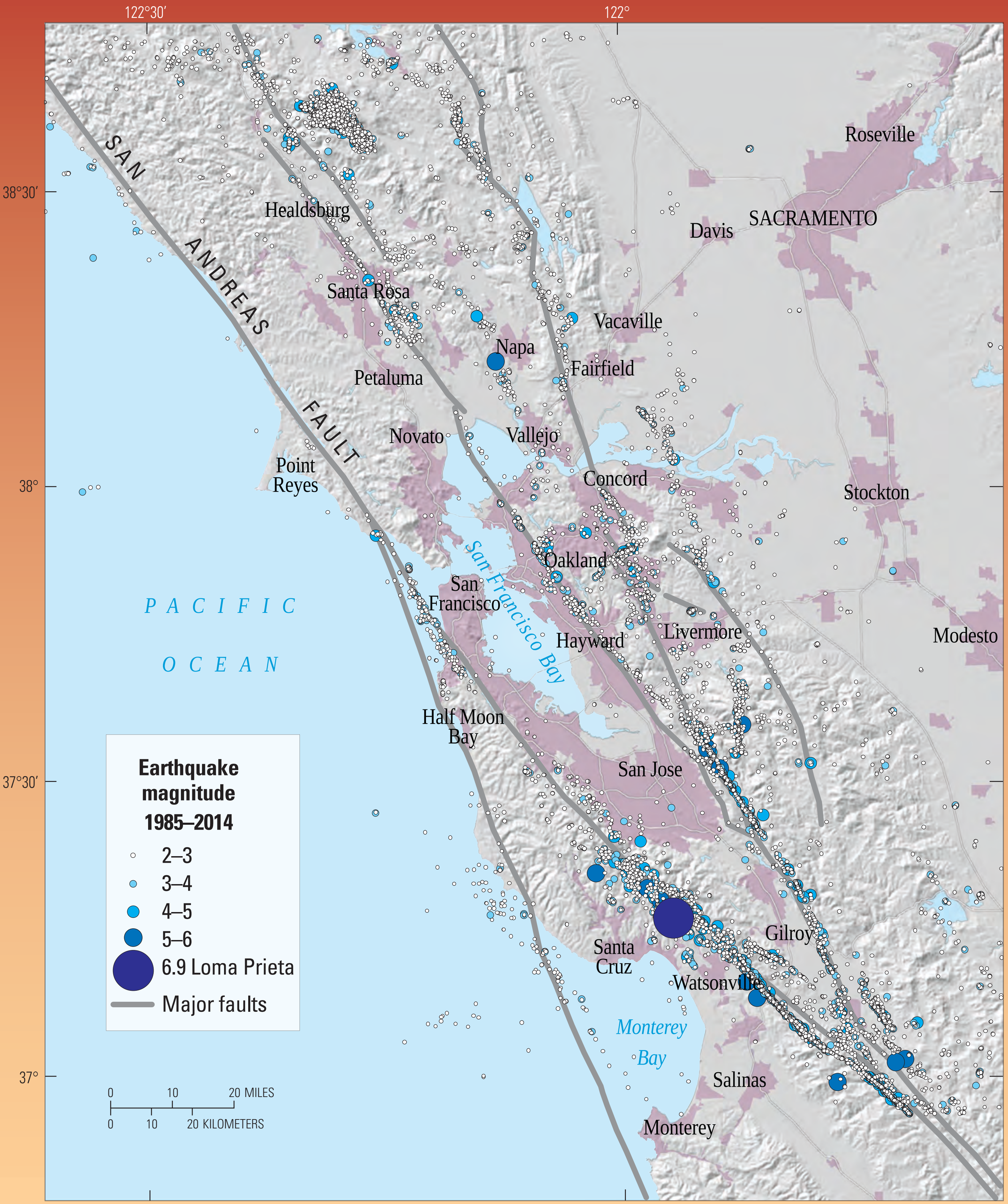
Early Sunday morning on August 24, 2014, the residents of Napa, California, were jolted awake by a strong, magnitude 6.0 earthquake. Within 30 minutes, the staff of Becoming Independent, a non-profit organization that helps adults with intellectual disabilities lead independent lives, called the people they serve in the affected area. The staff quickly visited all of the clients that needed help with cleanup and making their homes safe, a task made easier because both groups were trained in disaster preparedness and the clients had emergency kits with needed supplies on hand. The South Napa earthquake shifted houses off their foundations, damaged chimneys, started fires, and broke water mains throughout the city, causing hundreds of millions of dollars in economic losses. Many historic masonry buildings in downtown Napa were damaged. The earthquake was the largest in the San Francisco Bay region since the 1989 magnitude 6.9 Loma Prieta earthquake and a clear reminder of the seismic vulnerability of the region. The staff and clients of Becoming Independent showed that understanding and preparing for these events can improve how we live with future earthquakes.

Why Does the San Francisco Bay Region Have Earthquakes?

The same geologic process that is responsible for the San Francisco Bay region's beautiful coastlines, bays, hills, and valleys is also the primary driving force for earthquakes along faults in the region. The Bay region is located within the active boundary between the Pacific and the North American tectonic plates, where the Pacific plate slowly and continually slides northwest past the North American plate. The San Andreas Fault, on which two magnitude 7.8–7.9 earthquakes have occurred in historical time, including the 1906 San Francisco earthquake, is the fastest slipping fault along the plate boundary. Other major plate boundary faults in the San Francisco Bay region include the Hayward, Rodgers Creek, Calaveras, Maacama, San Gregorio, Concord, Green Valley, and Greenville Faults.

How Do Scientists Calculate Earthquake Probability?

Scientists rely upon a variety of techniques to help understand the rate and magnitude of past earthquakes in order to estimate the likelihood of future earthquakes. The Global Positioning System (GPS) and other land surveying and geologic techniques have allowed scientists to make more accurate measurements of how the current plate motions—totaling 1.6 inches per year across the San Francisco Bay region—distribute stress onto these individual faults. Balancing plate motions with the slip during large earthquakes and slow creep on faults allows scientists to calculate average rates of earthquake occurrence over periods of hundreds to thousands of years. (Continued on page 4)



Map of earthquakes greater than magnitude 2.0 in the San Francisco Bay region from 1985–2014. Small earthquakes occur on both major faults (shown by the gray lines) and minor faults (not shown). Because of the variability of fault geometry, earthquakes at depth do not always coincide with the mapped faults at the Earth's surface. There are sections of major faults, particularly the San Andreas Fault, with few or no small earthquakes but they will produce large earthquakes in the future. Compiled from the Northern California Seismic Network.

(Continued from page 2). A trench excavated across the Hayward Fault in Fremont revealed evidence of 12 large earthquakes over the past 1,900 years. The time interval between these earthquakes ranged from about 100 to 210 years. Historical records indicate that the most recent large earthquake on this fault occurred in 1868. However, detailed information about other past earthquakes in the San Francisco Bay region is difficult to obtain because seismograph records only go back to about 1900, historical accounts are sparse before 1850, and there are limited locations where faults can be trenched to identify and date prehistoric earthquakes.

Calculating accurate earthquake probabilities for short periods, such as 30 years, is also challenging. Although the 30-year time interval is convenient for humans, it is much less than the average time between large earthquakes on these faults, which can range from hundreds to thousands of years. The rate of large earthquakes in the San Francisco Bay region was high in the late 1800s but dropped abruptly after the 1906 San Francisco earthquake on the San Andreas Fault. Scientists believe that the post-1906 earthquake rate decreased because the large amount of slip along the San Andreas Fault in 1906 temporarily reduced the stress on many of the faults in the region. However, the ongoing motion of the tectonic plates began rebuilding stresses after the 1906 event, and earthquakes larger than magnitude 5.5 resumed during the second half of the 20th century. Future large, damaging earthquakes in the San Francisco Bay region, similar in size to the 1989 Loma Prieta and 1906 San Francisco earthquakes, may or may not be accompanied by the level of earthquake activity observed in the late 1800s.

The 2014 Uniform California Earthquake Rupture Forecast version 3 (http://pubs.usgs.gov/fs/2015/3009/) provides an updated estimate of the likelihood of large earthquakes in California over a 30-year time window from 2014 to 2043. The forecast accounts for how fast stress is accumulating on each fault due to plate motions and the time since its most recent large earthquake(s). In updating the probability calculations, scientists used a more complete set of faults for the San Francisco Bay region than those used in the previous (2008) calculations, adding 32 smaller faults to the 5 major fault systems. The new study has also incorporated more options for how multiple faults might rupture together in large earthquakes.

Probabilities of Earthquakes in the San Francisco Bay Region

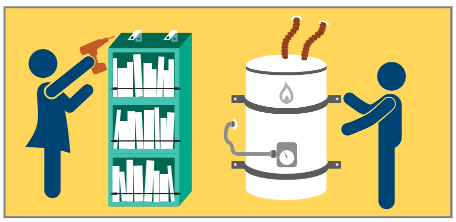
Smaller earthquakes occur more frequently than larger earthquakes. The probability that an earthquake of magnitude 6.0 or larger will occur before 2043 is 98 percent. The probability of at least one earthquake of magnitude 6.7 or larger in the San Francisco Bay region is 72 percent, and for at least one earthquake of magnitude 7.0 or larger it is 51 percent. These probabilities include earthquakes on the major faults, lesser-known faults, and unknown faults.

The probability of a large earthquake occurring on an individual fault in the San Francisco region is lower than the probability of an earthquake occurring anywhere in the region. The faults in the region with the highest estimated probability of generating damaging earthquakes between 2014 and 2043 are the Hayward, Rodgers Creek, Calaveras, and San Andreas Faults. In this 30-year period, the probability of an earthquake of magnitude 6.7 or larger occurring is 22 percent along the San Andreas Fault and 33 percent for the Hayward or Rodgers Creek Faults. Individual sections of these faults have lower probabilities for large earthquakes to occur (continued on page 6);

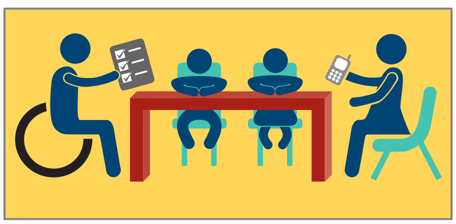
Seven Steps to Earthquake Safety

PREPARE

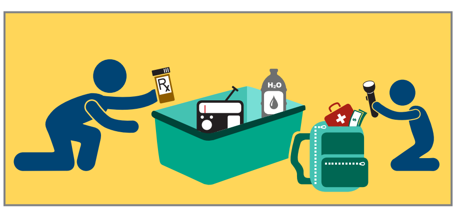
Before the next big earthquake we recommend these four steps that will make you, your family, or your workplace better prepared to survive and recover quickly:



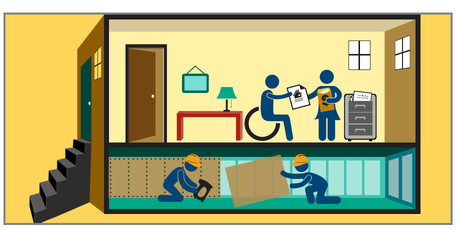
Step 1: Secure your space by identifying hazards and securing moveable items.



Step 2: Plan to be safe by creating a disaster plan and deciding how you will communicate in an emergency.



Step 3: Organize disaster supplies in convenient locations.



Step 4: Minimize financial hardship by organizing important documents, strengthening your property, and considering insurance.

SURVIVE

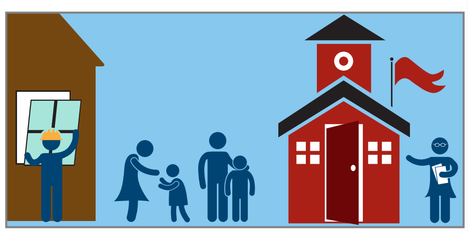
During the next big earthquake, and immediately after, is when your level of preparedness will make a difference in how you and others survive and can respond to emergencies:

Step 5: Drop, Cover, and Hold On when the earth shakes.

Step 6: Improve safety after earthquakes by evacuating if necessary, helping the injured, and preventing further injuries or damage.

RECOVER

After the immediate threat of the earthquake has passed, your level of preparedness will determine your quality of life in the weeks and months that follow:

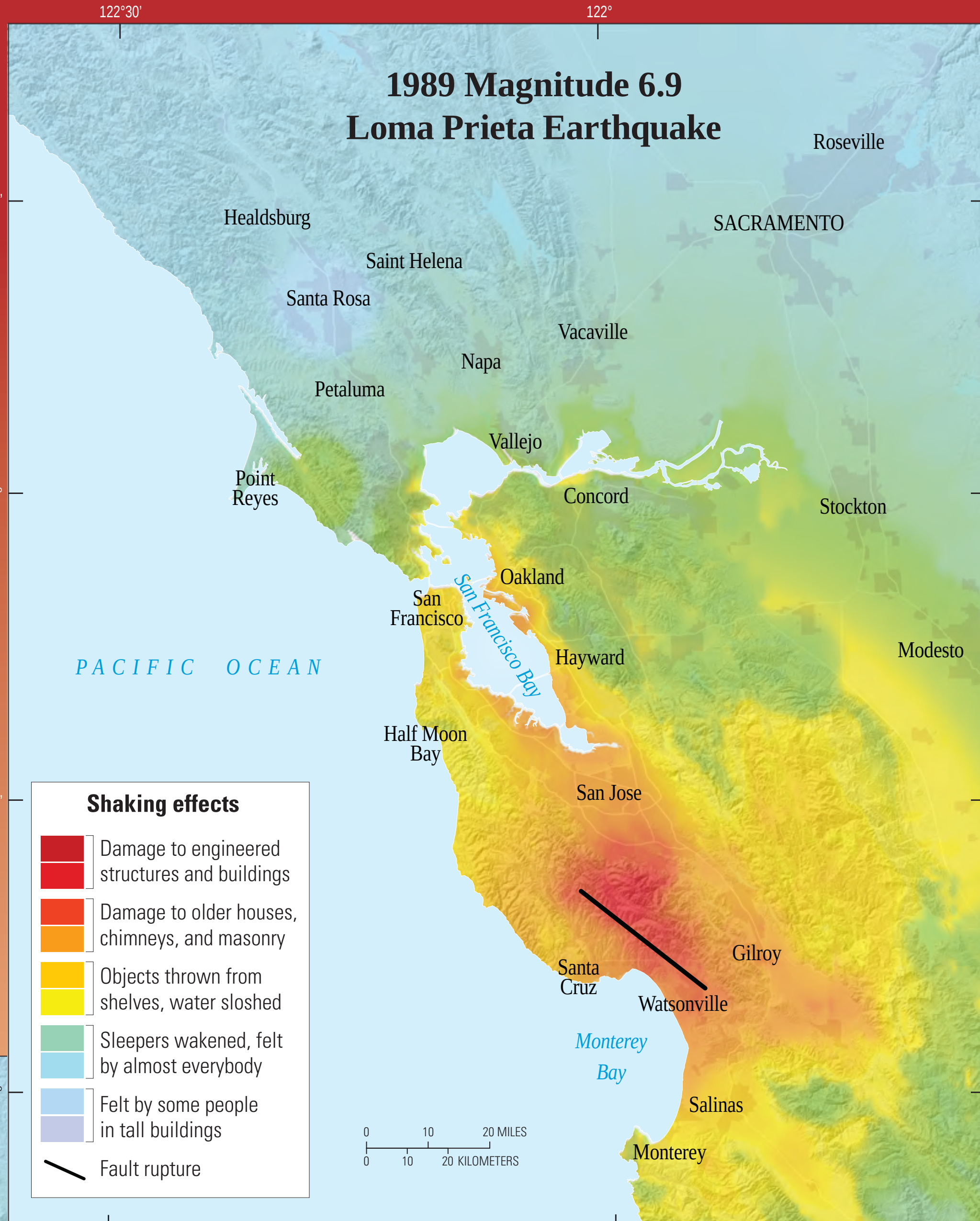


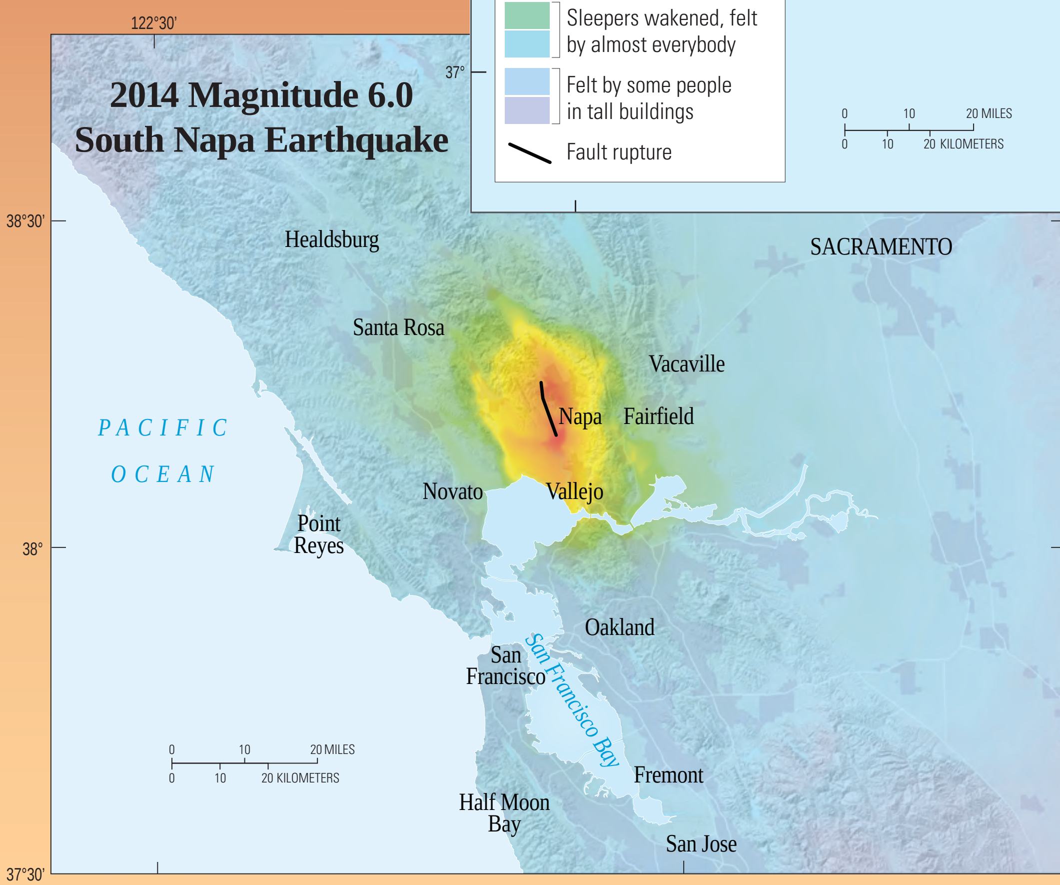
Step 7: Reconnect and Restore. Restore daily life by reconnecting with others, repairing damage, and rebuilding community.

Adapted from Seven Steps To Earthquake Safety
http://earthquakecountry.org/sevensteps/

Maps showing intensity of ground shaking for the South Napa and Loma Prieta earthquakes. The black lines show the location of fault slip at depth. The maps illustrate how the area subjected to strong shaking increases with increasing earthquake magnitude.

Road damage from the Loma Prieta earthquake. Photograph by H.G. Wilshire, U.S. Geological Survey.





Damaged building in downtown Napa. Photograph by Erol Kalkan, U.S. Geological Survey.

Additional Earthquake Resources

American Red Cross – Bay Area (http://www.redcross.org/local/northern-california-coastal)
Association of Bay Area Governments (http://resilience.abag.ca.gov/earthquakes/)
Bay Area Earthquake Alliance (http://bayquakealliance.org/)
California Earthquake Authority (http://www.californiarocks.com/)
California Geological Survey
(http://www.consrv.ca.gov/cgs/geologic_hazards/earthquakes)
Did You Feel It? (http://earthquake.usgs.gov/earthquakes/dyfi/)
Earthquake Country Alliance (http://earthquakecountry.org/)
Putting Down Roots in Earthquake Country (http://pubs.usgs.gov/gip/2005/15/)
ShakeAlert – An Earthquake Early Warning System for the United States West Coast
(http://pubs.usgs.gov/fs/2014/3083/)
ShakeMap (http://www.cisn.org/shakemap/nc/shake/index.html)
ShakeOut.org (http://www.shakeout.org/california/bayarea/)
Uniform California Earthquake Rupture Fault version 3 Fact Sheet
(http://pubs.usgs.gov/fs/2015/3009/)
United Policyholders (http://www.uphelp.org/)
USGS Real-Time Earthquakes (http://earthquake.usgs.gov/earthquakes/map/)

Damaged building in downtown Napa. Photograph by Erol Kalkan, U.S. Geological Survey.

(continued from page 5) however, an earthquake of magnitude 6.7 or larger will cause strong shaking over a broad area. Therefore, it is important to estimate the probability of a large earthquake occurring anywhere in the San Francisco Bay region.

What is the Likelihood That an Earthquake Will Affect You?

Earthquake probabilities are only one component in the evaluation of earthquake hazards. Higher magnitude earthquakes have broader areas of intense shaking and cause more damage than lower magnitude earthquakes. In a magnitude 6.0 earthquake, strong shaking and damage are confined to a localized area, as illustrated by the 2014 South Napa earthquake. In comparison, the 1989 magnitude 6.9 Loma Prieta earthquake caused damage over a region nearly 100 miles long. Local soil and geologic conditions, bedrock type, quality of building construction, and susceptibility to flooding (caused by dam or levee failure) can also affect the amount of damage at a particular site. This was dramatically demonstrated by the 1989 Loma Prieta earthquake, which devastated vulnerable parts of Oakland and San Francisco, more than 50 miles from the fault rupture.

How Can You Protect Yourself and Your Family?

Taking simple steps before and during earthquakes can help protect you and your family, as well as speed your recovery from an earthquake.

Before the next earthquake:

- Assess your home and work space, identify hazards, and secure moveable items.
- Create an emergency plan and organize disaster supplies to sustain you and your family for 72 hours or longer.
- Practice “Drop, Cover, and Hold On” to protect yourself when the ground begins to shake. Learn and practice what to do at home, work, or in school.
- Stay prepared by repeating these steps on a regular basis. For example, reassess your preparedness every year and participate in the annual Great California ShakeOut drill on the third Thursday in October.

Lack of adequate shear walls on the garage level exacerbated damage to this building at the corner of Beach and Divisadero in the Marina District, San Francisco, during the October 1989 Loma Prieta earthquake.

Brad T. Aagaard, James Luke Blair, John Boatwright, Susan H. Garcia Ruth A. Harris, Andrew J. Michael, David P. Schwartz, and Jeanne S. DiLeo

Edited by *Kate Jacques* and *Carolyn Donlin*

For more information contact:
1-888-ASK-USGS
(1-888-275-8747)

http://earthquake.usgs.gov/
http://ask.usgs.gov
https://www.facebook.com/USGeologicalSurvey
https://twitter.com/USGS

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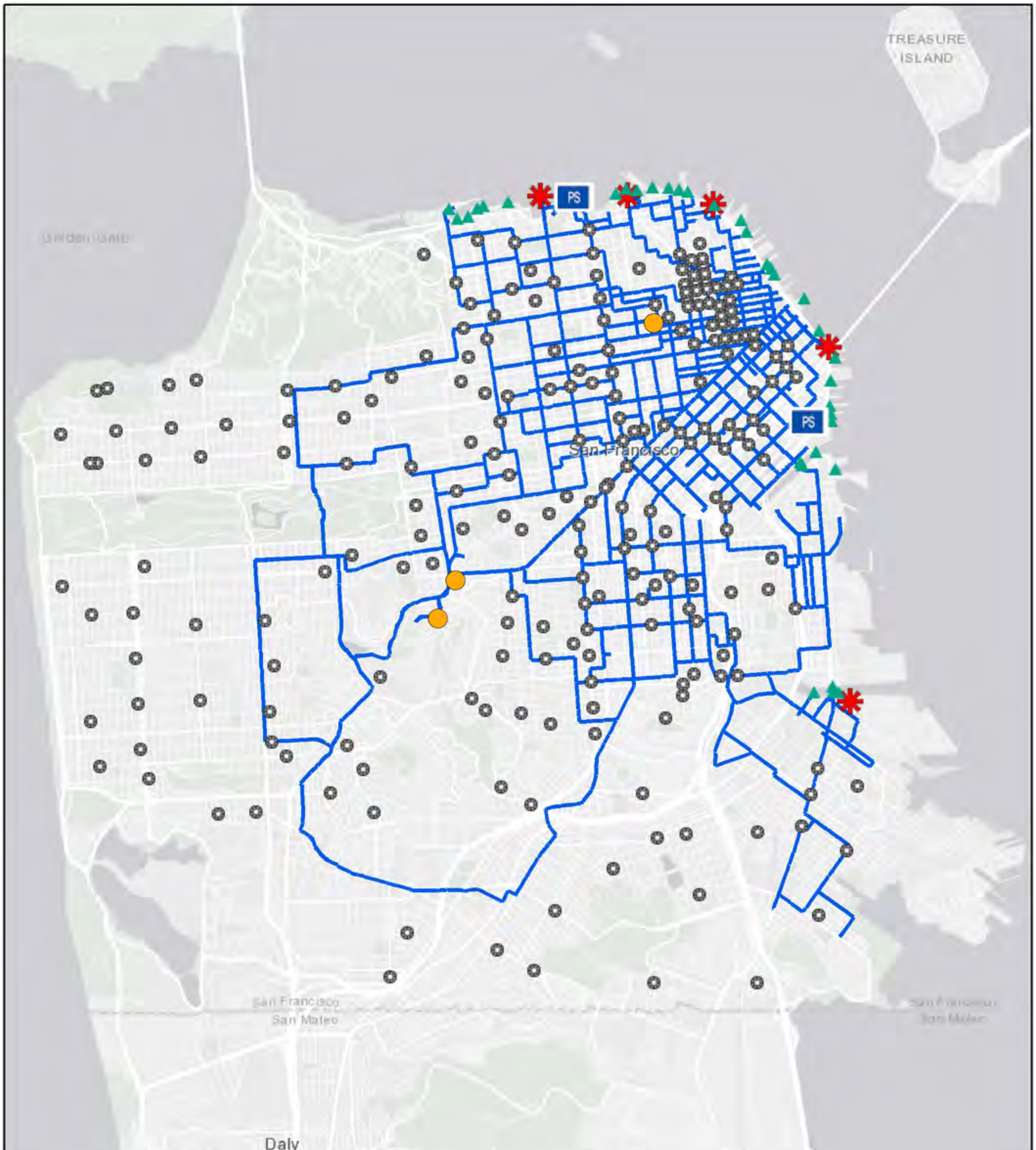
Appendix H



Existing EFWS - Assets

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

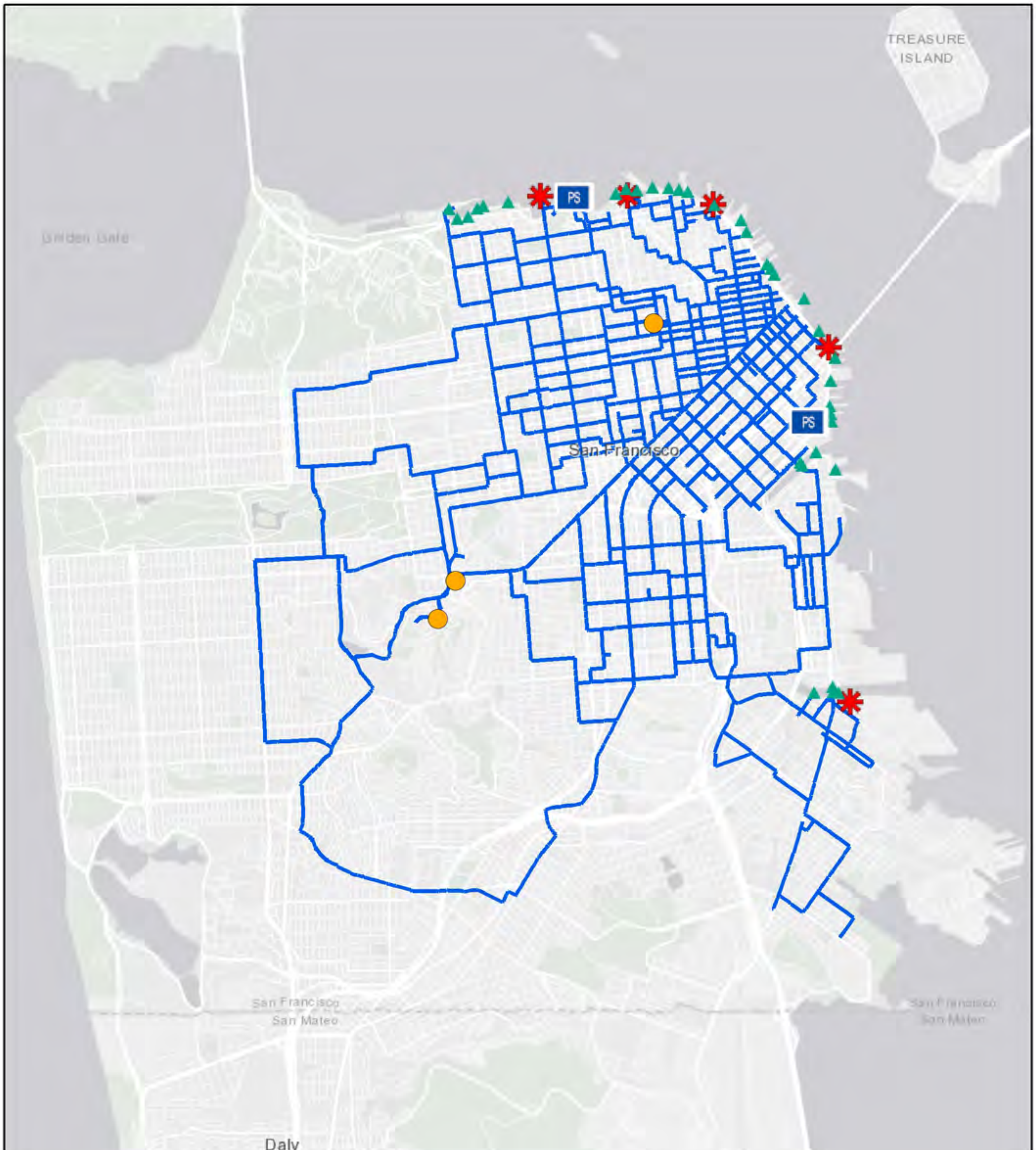
N

0 0.5 1 2 3 Miles

Legend

- PS AWSS Pump Stations
- AWSS Tank/Reservoirs
- Suction Connections
- Fireboat Manifold
- Cisterns
- AWSS Pipes

Appendix I



Existing EFWS - Pipelines

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

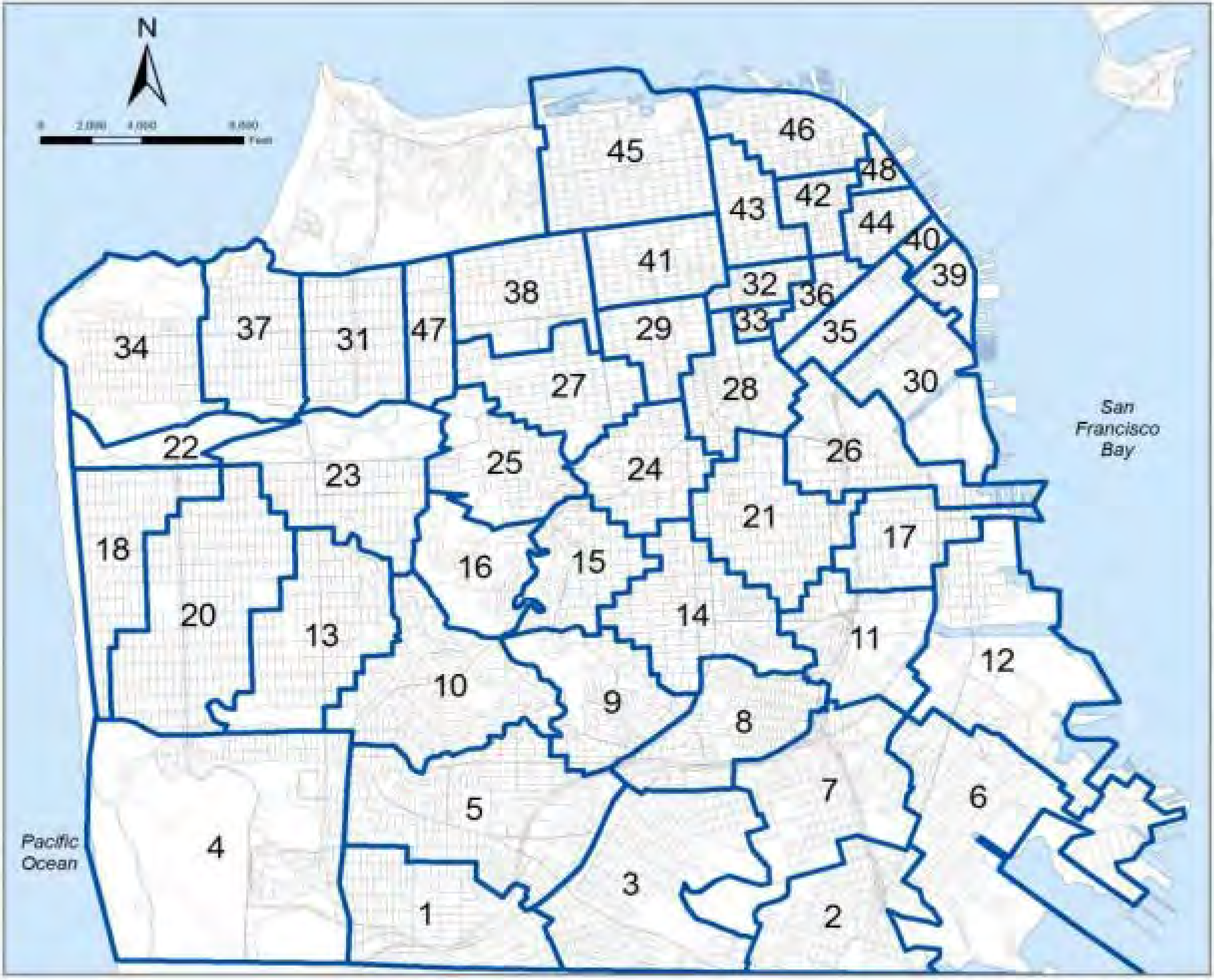
N

0 0.5 1 2 3 Miles

Legend

- PS AWSS Pump Stations
- AWSS Tank/Reservoirs
- Suction Connections
- Fireboat Manifold
- AWSS Pipes

Appendix J



Legend

Fire Response Area

Appendix K

Abstract

San Francisco is at significant risk due to fire following earthquake. This report analyses fire following earthquake for San Francisco as part of a larger project undertaken by the San Francisco Department of Building Inspection entitled Community Action Plan for Seismic Safety (CAPSS). This specific report, on fire following earthquake, has been conducted with the support and assistance of the San Francisco Fire Department (SFFD).

A stochastic model for analyzing fire following earthquake for San Francisco has been developed, utilizing data received from CAPSS, SFFD and others, to assess fire following earthquake impacts due to four earthquake scenarios: magnitude 7.9, 7.2 and 6.5 events on the San Andreas fault near San Francisco, and a magnitude 6.9 event on the Hayward fault. These events cause high ground motions in San Francisco that result in ground failure in many parts of the City – ground motions are particularly high in the western part of San Francisco, which was not yet built up in 1906 and therefore is not protected by the special high pressure SFFD Auxiliary Water Supply System (AWSS). Depending on the specific earthquake scenario, these ground motions and ground failures are estimated to cause over 1,000 breaks in the potable water system, so that SFFD's AWSS and cisterns will be the only source of firefighting water in many parts of the City. The AWSS itself will sustain some damage, forcing SFFD to fall back to cisterns only in some places. At the same time, SFFD's 42 fire engines will almost certainly not be able to respond to all the post-earthquake fires, which are estimated to be about 100 on average (with a 10% chance of as many as 140) for the magnitude 7.9 San Andreas event. As a result, the methodology employed here estimates ignitions, building burnt areas and dollar losses for the four scenario events. These results are presented in Table A-1 as ranges within which losses will fall half (i.e., 50%) of the time (correspondingly, half the time the losses will be outside – that is, either more or less) than the indicated ranges: .

Table A-1
Bounds for Losses to Buildings due to Fire Following Earthquake

	25% ~ 75% Confidence Range		
	Ignitions	Loss $ billions	**Total Burnt Building Floor Area** mill. Sq. ft.
San Andreas Mw 7.9	68 ~ 120	$ 4.1 ~ $ 10.3	11.2 ~ 28.2
San Andreas Mw 7.2	52 ~ 89	$ 2.8 ~ $ 6.8	7.7 ~ 18.6
San Andreas Mw 6.5	48 ~ 70	$ 1.7 ~ $ 5.1	4.7 ~ 14.0
Hayward Mw 6.9	27 ~ 46	$ 1.3 ~ $ 4.0	3.6 ~ 11.0

For example, for the Mw 7.9 event, essentially a repeat of the 1906 earthquake, losses will on average be about $7.6 billion, and half the time will be more than $4.1 billion and less than $10.3 billion. More detailed results are presented in the report, but the significance of these results is not in their precision, but rather in their overall magnitude. The model producing these results was validated by application to the 1989 Loma Prieta event, and examined for methodological and parametric sensitivity, with satisfactory results.

A number of opportunities exist for reducing the fire following earthquake in San Francisco, including further improvements in reliability of post-earthquake water supply, further support for NERT, and greater training for this problem for SFFD officers and firefighters.

Appendix L

Fire Protection Bonds **A**

PROPOSITION A

FIRE PROTECTION SYSTEM IMPROVEMENT BONDS, 1986. To incur a bonded indebtedness of $46,200,000 for the improvement of the fire protection system within the City and County of San Francisco.

YES 273
NO 274

Analysis

by Ballot Simplification Committee

THE WAY IT IS NOW: Since the 1906 earthquake and fire, the San Francisco Fire Department has had programs to improve its fire protection system. A bond issue in 1977 paid for the most recent improvements, including an extension of the high pressure firefighting water system which operates independently from the City's domestic water supply. However, there are still parts of the City which are not served by that high pressure system.

THE PROPOSAL: Proposition A would authorize the City to borrow $46,200,000 by issuing general obligation bonds. This money would pay for improvements in San Francisco's fire protection system. These improvements would include extending the high pressure system, construction of new cisterns in residential areas, installation of a high pressure pump station at Lake Merced, construction of an emergency operations center, and other projects. The interest and principal on general obligation bonds are paid out of tax revenues. Proposition A would require an increase in the property tax.

A YES VOTE MEANS: If you vote yes, you want San Francisco to issue general obligation bonds totalling $46,200,000 to make certain improvements in the City's fire protection system.

A NO VOTE MEANS: If you vote no, you do not want San Francisco to issue bonds for these improvements in the City's fire protection system.

Controller's Statement on "A"

City Controller John C. Farrell has issued the following statement on the fiscal impact of Proposition A:

"Should the proposed Resolution be authorized and when all bonds shall have been issued on a twenty (20) year basis and after consideration of the interest rates related to current municipal bond sales, in my opinion, it is estimated that approximate costs would be:

Bond Redemption	$46,200,000
Bond Interest	38,808,000
Debt Service Requirement	$85,008,000

"Based on a single bond sale and level redemption schedules, the average annual debt requirement for twenty-two (22) years would be $3,864,000 which amount is equivalent to approximately one and twenty hundreths cents ($0.0120) in the current tax rate."

How "A" Got on the Ballot

On July 28 and August 4 the Board of Supervisors voted 8–0 in favor of the ordinance placing Proposition A on the ballot.

The ordinance was signed by Mayor Dianne Feinstein on August 6.

THE FULL LEGAL TEXT OF PROPOSITION A APPEARS ON PAGE 96

NOTE: YOUR POLLING PLACE MAY HAVE CHANGED. PLEASE REFER TO MAILING LABEL ON BACK COVER.

NO ARGUMENT WAS SUBMITTED AGAINST PROPOSITION A

A Fire Protection Bonds

ARGUMENT IN FAVOR OF PROPOSITION A

In 1906, as dawn was about to break on April 18, a giant earthquake hit the City, touching off 52 separate fires. Those downtown swiftly joined in a huge conflagration that swept westward from the waterfront, leaving much of the City in ruins.

If another major quake strikes—(and seismic experts say it will, but they can't pinpoint when), the City must be prepared.

Our firefighters must have sufficient water to fight spreading fires and quickly to control them. That's the only way our City will survive.

In 1906, water mains broke and left the City defenseless.

Proposition A will assure adequate water in every neighborhood throughout the City.

Proposition A will provide $46 million in general obligation bonds to expand and improve emergency water supplies throughout the City. Residential areas will be provided with underground cisterns, and the high-pressure water supply system will be extended. Suction hose connections to City lakes, San Francisco Bay and the Pacific Ocean will provide additional millions of gallons of water.

These emergency fire-fighting water supplies are necessary to protect our homes, schools, hospitals, churches and other structures from the threat of fire that inevitably comes with a monstrous quake.

This increased fire protection will benefit the entire City and all who live, work and vist here.

Vote Yes on Proposition A.

Dianne Feinstein, Mayor

ARGUMENT IN FAVOR OF PROPOSITION A

As a result of the earthquake and fire in 1906, San Francisco suffered great destruction and devastation from the conflagration which followed, including the destruction of 28,000 buildings.

Due to broken water mains caused by the earthquake, the San Francisco Fire Department was unable to stop the fire from getting out of control.

Proposition A will provide for the expansion of a high pressure fire-fighting water system to the residential districts of the City, which will be critical in emergency situations.

Underground cisterns also will be constructed in the outer residential districts to provide emergency water supply in areas not served by the high pressure system.

High pressure system gate valves will be motorized with emergency battery powerpacks so they can be opened and closed in an emergency when normal power is disrupted.

Suction connections will be provided to San Francisco Bay, the Pacific Ocean, and City lakes so that fire department pumpers can quickly connect and pump water from these large bodies of water to any fires.

A pumping station for the high pressure system will be constructed at Lake Merced to provide an important source of water from the western part of the City.

An Emergency Operations Center will be built to provide a command center for operations in earthquakes and other major disasters.

The recent fire and explosion in the Hunter's Point district demonstrated the critical need for water supplies in a major fire. The broken water main caused by the explosion severely hampered the Fire Department in controlling this major fire. This is an example of what can happen when normal water supplies are disrupted.

Increased earthquake activity in California demonstrates the importance of this Proposition.

The fire department can function only if an adequate water supply exists. Proposition A will provide an emergency fire-fighting water supply for the City, and ensure that fires will not get out of control due to lack of water, following an earthquake.

We urge all citizens to vote yes on Proposition A. This is protection for your home and your City.

—Submitted by the Board of Supervisors

ARGUMENT IN FAVOR OF PROPOSITION A

The Fire Commission and Chief of Department urge a YES vote on Propositon A—a $46.2 million Earthquake Preparedness Program.

This construction Program is designed to provide an updated and expanded emergency water supply system so that all areas of the City and County of San Francisco will be protected in case of a conflagration following an earthquake or other disaster.

The major components of the Program are: high-pressure water supply extensions, underground cisterns, pumping station, emergency operations center, suction hose connections to the Bay and lakes, and a study to determine fire station reconstruction needs and their earthquake safety.

Help the San Francisco Fire Department provide increased fire protection. **VOTE YES ON PROPOSITION A.**

Henry E. Berman, President, Fire Commission
Curtis McClain, Vice President, Fire Commission
Juanita Del Carlo, Commissioner, Fire Commission
Richard J. Guggenhime, Commissioner, Fire Commission
Anne S. Howden, Commissioner, Fire Commission
Emmet D. Condon, Chief of Department

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ARGUMENT IN FAVOR OF PROPOSITION A

San Franciscans will not forget, nor should they, the tragic Bayview/Hunter's Point fire on April 4, 1986. Coincidentally, two earthquakes rocked the Bay Area in the weeks following the Bayview fire.

Following the Bayview fire, I requested Board of Supervisors hearings to investigate the adequacy of San Francisco's emergency water supply in the Bayview, Ingleside, Balboa Terrace, Oceanview, Lakeside, Forest Hill, Crocker-Amazon, St. Francis Wood, West Portal, Diamond Heights, Visitacion Valley, Merced Manor, Excelsior, Portola, Silver Terrace, Miraloma Park, Forest Knolls, Inner Sunset, Lakeshore Acres, Monterey Heights, and Outer Mission neighborhoods, and to implement a program to correct deficiencies in our emergency firefighting capabilities. From these hearings and deliberations of the Fire Commission, Proposition A emerged.

VOTE YES ON A.

Proposition A is a $46,200,000 general obligation bond issue to construct a comprehensive emergency water supply system and an emergency operations center for firefighting in the event of a disaster.

That may seem like a lot of money, but it represents, in this case, a prudent, far-sighted investment in San Francisco's future. Unfortunately, we can't guarantee another Bayview-type fire won't happen. But we can be better prepared if one **does** happen, and significantly reduce the risk to life and property in the Bayview, Hunter's Point, the Outer Mission, and all of the West of Twin Peaks area.

Please vote "Yes" on A.

Quentin L. Kopp, Supervisor

ARGUMENT IN FAVOR OF PROPOSITION A

Earthquakes are a major concern to all of us who live in California, and a potential cause of disaster for San Francisco. Following a major earthquake it is highly likely that multiple fires will occur. San Francisco with its highly congested blocks of wooden buildings would face a conflagration (fire storm), if a major earthquake caused water supplies to be disrupted.

Proposition A, as an Earthquake Preparedness measure, is very important for San Francisco. It will provide for Emergency Water Supply necessary for fire fighting.

We urge all citizens to **VOTE YES ON PROPOSITION A.**

Bruce Bolt, Professor of Seismology
Karl V. Steinbrugge, Past Chairman
California Seismic Safety Commission
Charles Scawthorn, Structural Engineer
Joe J. Litehiser, Seismologist
Donald H. Cheu, M.D., Vice Chairman
Governor's Earthquake Task Force

ARGUMENT IN FAVOR OF PROPOSITION A

We support this important Earthquake Preparedness Program.
VOTE YES ON PROPOSITION A.

Willie L. Brown, Jr., Speaker of Assembly
Michael Hennessey, Sheriff
Morris Bernstein, President, Airports Commission
Douglas Engmann, Commissioner, Board of Permit Appeals
E. L. Friend, President
Anne Halstead, Commissioner, Port Commission
Thomas E. Horn, President, War Memorial Board of Trustees
Melvin D. Lee, Commissioner, Redevelopment Commission
Robert J. McCarthy, Vice President, Board of Permit Appeals
Al Nelder, Commissioner, Police Commission
Michael Salarno, Member, S.F. Parking Commission
William K. Coblentz, Attorney
Gordon J. Lau, Attorney
Steven L. Swig, Attorney

ARGUMENT IN FAVOR OF PROPOSITION A

Fire Protection for San Francisco's neighborhoods is a vital factor. Emergency Water Supplies for fire fighting are necessary so that the Fire Department can provide ample protection to our homes in the event an earthquake damages water mains as occurred in 1906.

Proposition A will expand and improve the Fire Department's Emergency Water Supplies.

- Suction hose connections for pumpers will be provided to City lakes, S.F. Bay and Pacific Ocean.
- Underground cisterns will be provided in residential areas.
- The High-Pressure System will be extended to outer residential districts.

The cost of Proposition A is .0120 cent per $100 valuation on the property tax; this means a home valued at $150,000 would pay $17.16 per year for this protection. This is highly cost effective insurance for our homes.

We urge all citizens to **VOTE YES ON PROPOSITION A.**

Marguerite A. Warren
James J. Walsh, Jr.
Dorothy Agnes McDougall
Andrew Jones
George L. Newkirk
Jess T. Esteva
Dolph Andrews
Norman V. Wechsler

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A Fire Protection Bonds

ARGUMENT IN FAVOR OF PROPOSITION A

Fire Protection and Earthquake Preparedness concern all school officials in San Francisco.

Proposition A is an important program that will provide **Emergency Water Supplies For Fire Fighting** throughout the City.

When a major earthquake strikes, the Fire Department must have a dependable water supply to protect our families, homes and schools.

Earthquakes cannot be stopped, but we must have water to stop the fires that will occur.

We ask all citizens to join us and **VOTE YES ON PROPOSITION A.**

Myra A. Kopf, President, Board of Education
A. Richard Cerbatos, Vice President, Board of Education
Libby Denebeim, Member, Board of Education
JoAnne Miller, Member, Board of Education
Benjamin Tom, Member, Board of Education
Sodonia M. Wilson, Member, Board of Education
Rosario Anaya, Member, Board of Education
Ernest C. Ayala, President, S.F. Community College Board
Al Vidal, Principal, Washington High School

ARGUMENT IN FAVOR OF PROPOSITION A

Improved and expanded Emergency Water Supplies for fire fighting in San Francisco are a necessary factor to prevent another conflagration (fire storm) from sweeping the City as occurred in 1906.

Our central business and financial districts are the economic heart of the City, the residential districts contain the homes of our citizens.

Proposition A provides increased fire protection to our high-rise buildings and our homes.

Earthquake preparedness and protection from the ravages of fire concern us all. As civic leaders of San Francisco we urge all citizens to **VOTE YES ON PROPOSITON A.**

Lee Dolson, General Manager, Downtown Association
James R. Bronkema, President, Embarcadero Center

ARGUMENT IN FAVOR OF PROPOSITION A

We can bet that most of you have seen the circles of bricks encompassing certain intersections in some neighborhoods in San Francisco. These circles mark underground water cisterns that were constructed "after" the devastating earthquake and fire in 1906. Many neighborhoods in San Francisco built after 1912 are NOT serviced by this alternate water system.

Proposition A would provide a City-wide emergency water supply system to protect our homes and neighborhoods.

We cannot prevent earthquakes but we can take precaution against fire. . .the biggest threat to San Francisco.

We urge a **YES** vote on Proposition A. . . fire protection for our families no matter where they may be in our City.

Nancy Honig
Roxanne Mankin
Jane McKaskle Murphy
Bernice E. Ayala
Cheryl Arenson
Gina Moscone
Jonnie B. Johnson

ARGUMENT IN FAVOR OF PROPOSITION A

Earthquake Preparedness and increased fire protection are of vital concern to all citizens of San Francisco.

VOTE YES ON PROPOSITION A.

Robert Bacci
Michael Bernick
Susan Bierman
Frank T. Blackburn
Rev. Dr. Amos C. Brown
Sally Brunn
Stafford Buckley
Michael Chan
Charles D. Cresci
Rosemary DeGregorio
Todd Dickinson
H. Welton Flynn
Ron Huberman
Ralph Hurtado
David Jenkins
Agar Jaicks
Carole Migden
Polly V. Marshall
Alicia Wang
Thomas F. McDonough
Tony Kilroy
Leroy King
David Looman
Christopher Martin
Peter Mezey
Marilyn Miller
Jeff Mori
Sandy Mori
Yoshio Nakashima
Mitchell Omerberg
Edward J. Phipps
Linda Post
Thelma Shelley
Robert J. Tully
Yori Wada
Evelyn Wilson
Pansy Ponzio Waller
Bruce W. Lilienthal
Jim Wachob

ARGUMENT IN FAVOR OF PROPOSITION A

Pure self interest dictates that we provide an abundant and surplus supply of "fire protection" water for EVERY part of San Francisco, not just half of it! VOTE YES!

W. F. O'Keeffe, Sr., San Francisco Taxpayers Association

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ARGUMENT IN FAVOR OF PROPOSITION A

Emergency water supplies for fire fighting are vital for San Francisco. On April 4, 1986, an explosion and fire occurred in the Bayview District, causing nine deaths. The disrupted water supply caused by the explosion, severely hampered the Fire Department in controlling this fire.

In the event of a major earthquake it is highly likely that water mains will be damaged throughout San Francisco. Proposition A will provide for 94 underground cisterns to be built in residential areas where few emergency water supplies now exist. The Bayview fire demonstrated the need for emergency water supplies for fire fighting.

Protect your neighborhood and home.

VOTE YES ON PROPOSITION A.

Concerned Citizens for Improved Fire Protection

Michael Frew, Chairman
John Holt
Robert L. Kreuzberger
Ed F. Patterson
Michael S. Newman
Mel S. Newman
Jack R. Brower
August J. Nevolo

ARGUMENT IN FAVOR OF PROPOSITION A

San Franciscans remember what happened in 1906. The fires that occurred after the earthquake swept the City and left many thousands of people homeless.

Proposition A is a common sense program to provide **Emergency Water Supplies for Fire Fighting** throughout the City. This would ensure that fires would not get out of control due to lack of water supply.

This $46.2 million bond issue needs a two-thirds vote. As a former member of the Board of Supervisors and neighborhood businessman, I urge all citizens to vote for this important program. It is protection for your family, home and city at a very low cost; it makes sense in both human and economic terms.

VOTE YES ON PROPOSITION A.

John Barbagelata, Realtor

ARGUMENT IN FAVOR OF PROPOSITION A

Proposition A assures San Francisco residents of on-going preparation which is the best defense against a major disaster—earthquake, conflagration, or an explosion.

San Francisco Fire Fighters regard this measure as the first-step in the earthquake preparedness program.

Control disaster with expanded fire protection!

San Francisco Fire Fighters urges a **YES** vote on Proposition A.

James T. Ferguson, President,
San Francisco Fire Fighters Local 798

ARGUMENT IN FAVOR OF PROPOSITION A

Fire Protection is a serious concern for all citizens of San Francisco. We, the working Fire Chiefs of San Francisco are well aware of what happened in 1906, when fires occurring after the great earthquake burned thousands of buildings and left over 200,000 homeless.

The quake caused hundreds of breaks in water mains and the lack of water supplies prevented the Fire Department from controlling the fire.

We do not want this to happen again.

Proposition A will provide **Emergency Water Supplies for Fire Fighting.** The following installations will be placed in our neighborhoods to protect our homes.

- 94 underground cisterns will be built.
- 56 suction hose connections for pumpers will be provided to City lakes, S.F. Bay and Pacific Ocean.
- The High-Pressure System will be extended to residential areas.
- Improvements to tanks, reservoirs, pump stations, including a new pump station at Lake Merced and an Emergency Operations Center.

The recent fire in the Bayview District that took nine lives demonstrated how important water supplies can be. The damaged water supply caused by the fire and explosion seriously hampered Fire Department efforts to control this major fire.

We as the working Fire Chiefs who actually run the day-to-day field operations in San Francisco urge all citizens to support this important measure.

VOTE YES ON PROPOSITION A.

John W. Flaherty
President, The San Francisco Fire Chiefs Association
Gary J. Torres
Secretary, The San Francisco Fire Chiefs Association

ARGUMENT IN FAVOR OF PROPOSITION A

Fire safety can be improved by voting FOR Proposition A and AGAINST BART director Eugene Garfinkle. BART's a fire trap.

Tom Spinosa, BART Board candidate

A Fire Protection Bonds

ARGUMENT IN FAVOR OF PROPOSITION A

Earthquake Preparedness and Fire Protection are vital factors for all citizens.

VOTE YES ON PROPOSITION A.

A. Cecil Williams, Glide United Methodist Church
Bob Barry, President, S.F. Police Officers Association
William Corvin, President, California Steam Company
J. M. Eaneman, President, AMC Cancer Research Board of Directors
George Foos, Chairman, Great Western Value Centers
Rev. John L. Green, Chaplain, S.F. Fire Department
Albert S. Samuels, Jr., Past President, Market Street Project
Harvey Matthews, Bayview-Hunter's Point Democratic Club
Arthur Goedewaagen, President, Sunset-Parkside Education & Action Committee

ARGUMENT IN FAVOR OF PROPOSITION A

Prior to the Great Earthquake and Fire of 1906, San Francisco Fire Chiefs had always insisted the City was not prepared for a major disaster. History proved them correct. Today, 80 years later, San Francisco's preparation is still not adequate.

When each of us was Chief of Department, we emphasized the need for the additional preparedness necessary to prevent a sweeping fire storm or catastrophic disaster. That state of preparedness has yet to be attained. However, Proposition A offers a once-in-a-life opportunity to protect life and property, through preparation, at an extremely minimal cost. This opportunity should not be missed.

Proposition A will provide the necessary water supplies vital to preventing another conflagration of the 1906 magnitude!

Proposition A will expand the high-pressure firefighting water supply system beyond the commercial areas into the residential neighborhoods!

Proposition A will greatly improve fire defenses not only in the western part of San Francisco but City-wide as well!

Proposition A will ensure that San Francisco is no longer one of the few remaining major cities with a sub-standard Emergency Operations Center for command and control during disasters and earthquakes!

As former San Francisco Fire Chiefs, we urge you to **VOTE "YES" ON PROPOSITION A.**

William F. Murray, Chief, San Francisco Fire Department, Retired
Keith P. Calden, Chief, San Francisco Fire Department, Retired
Andrew C. Casper, Chief, San Francisco Fire Department, Retired

ARGUMENT IN FAVOR OF PROPOSITION A

- Yes on Proposition A.
- Local fire chiefs have warned about grave BART fire catastrophe dangers. End disregard of public safety.

—San Franciscans for BART Safety

ARGUMENT IN FAVOR OF PROPOSITION A

This is a vital issue for San Francisco. **Emergency Water Supplies for Fire Fighting** must be provided throughout the City.

Many fires will occur if a major earthquake strikes San Francisco.

The Fire Department needs a water suply to prevent a conflagration (fire storm) from occurring again, as it did in 1906.

Earthquakes are a geologic fact of life and cannot be prevented, but we can prepare for the fires that will occur, this makes sense for all citizens.

VOTE YES ON PROPOSITION A.

Philip S. Day, Jr.
Director, San Francisco Office of Emergency Services
Richard Eisner, Earthquake Preparedness Consultant
Jelena Pantelic, Chairperson, Disaster Preparedness Committee
Joe Posillico, Emergency Services, Salvation Army
Peter Ashen, Disaster Director, American Red Cross

ARGUMENT IN FAVOR OF PROPOSITION A

San Francisco Council of Civic Organizations endorsements:
Proposition A—YES
Proposition M—YES

Terence Faulkner
President, San Francisco Council of Civic Organizations

ARGUMENT IN FAVOR OF PROPOSITION A

Earthquake Preparedness and providing Emergency Water Supplies for Fire Fighting are of vital importance to San Francisco.

VOTE YES ON PROPOSITION A.

Donald J. Birrer, Director of Public Works
Frank M. Jordan, Chief of Police
Dean Macris, Director of Planning
Rudy Nothenberg, General Manager, Public Utilities
William Stead, General Manager, Municipal Railway
David Werdegar, M.D.M.P.H., Director of Public Health
James D. Cooney, General Manager, S.F. Water Department

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Appendix M

FIRE COMMISSION

City and County of San Francisco

Gavin Newsom, Mayor

Victor Makras, *President*
Stephen A. Nakajo, *Vice President*
George Lau, *Commissioner*
Andrea Evans, *Commissioner*

698 Second Street
San Francisco, CA 94107
Telephone 415.558.3451
Fax 415.558.3413
Monica Quattrin, *Commission Secretary*

SAN FRANCISCO FIRE COMMISSION
RESOLUTION 2010-01

ENCOURAGING THE FIRE DEPARTMENT TO PURSUE GRANT FUNDING IN THE AMOUNT OF $9.785 MILLION FROM THE FEDERAL GOVERNMENT, TO EXPAND THE DEPARTMENT'S PORTABLE WATER SUPPLY SYSTEM.

WHEREAS, The uniformed employees of the San Francisco Fire Department (SFFD) respond to approximately 100,000 incidents a year; and,

WHEREAS, It is the responsibility of the SFFD and its members to protect the lives and property of the citizens of San Francisco from the effects of natural disasters; and,

WHEREAS, The United States Geological Survey has issued increasingly frequent warnings of the high probability of a potentially catastrophic earthquake in the San Francisco Bay Area during the next thirty years; and,

WHEREAS, World renowned scientists, whose area of expertise is the modeling of the destructive effects of earthquakes on underground infrastructure, have identified the domestic water system of San Francisco as highly vulnerable to catastrophic failure in the event of a major Bay Area earthquake; and,

WHEREAS, World renowned scientists, whose area of expertise is the modeling of the spread of fire following earthquakes in modern urban settings, have predicted that there is a high likelihood that San Francisco will be subject to multiple simultaneous conflagrations following a major Bay Area earthquake; and,

WHEREAS, The assessed value of the real estate in San Francisco subject to property taxation exceeds $100 billion; and,

WHEREAS, The spread of fire following earthquakes in a modern urban setting typically is responsible for as much as 75% of the total dollar loss that results; and,

WHEREAS, Loss of life following an earthquake in a modern urban setting is greatly exacerbated by the effects of resultant fires in buildings where occupants have been trapped by structural collapse; and,

WHEREAS, The Auxiliary Water Supply System does not cover the entire geographic areas of the City and County of San Francisco; and, WHEREAS, The SFFD's Portable Water Supply System has been proven effective in the above-ground transmission of water for fire fighting purposes; and,

WHEREAS, The Portable Water Supply System works in conjunction with and can supplement the existing Auxiliary Water Supply System, and therefore the Portable Water Supply System is capable of partially mitigating the possible lack of domestic water system availability following a major earthquake; and,

WHEREAS, the number of units currently comprising the SFFD's existing Portable Water Supply System is not adequate to supply all areas of San Francisco where the Auxiliary Water Supply System does not extend; and

WHEREAS, the proposed design for expanding the Portable Water Supply System has been shown to be a highly cost effective and functionally adaptable method of providing the means by which firefighters can attack multiple conflagrations simultaneously;

WHEREAS, the SFFD is working with Senator Dianne Feinstein and Speaker of the House Nancy Pelosi in seeking these grant funds, now therefore, be it

RESOLVED, That the Fire Commission encourages the Fire Department to actively pursue grant funds in the amount of $9.785 million from the Federal government, to expand the Portable Water Supply System and train SFFD uniformed members, the Fire Reserve, and other members of the community who may assist the SFFD in times of disaster.

Adopted at the Regular Meeting of the San Francisco Fire Commission on January 14, 2010.

Ayes: 4 (Makras, Nakajo, Lau, Evans)
Nays: 0

Monica Quattrin

Monica Quattrin, Commission Secretary

Appendix N

Frequently Asked Questions - Fire Suppression Water Systems

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

1) What is the Auxiliary Water Supply System, and what is its primary function?

The Auxiliary Water Supply System (AWSS) is a non-potable fire-suppression water system that was built the decade following the catastrophic 1906 San Francisco earthquake. The purpose of the AWSS is to provide the San Francisco Fire Department (SFFD) with a high-pressure fire suppression water system that can be utilized during large fires. The system is vital for protection against the loss of life, homes, and businesses from fire following an earthquake and non-earthquake multiple-alarm fires.

There are two aspects of the AWSS that are critical to its success:

1. Distribution infrastructure: The AWSS consists of over 135 miles of high-pressure pipeline and hydrants. The system utilizes approximately 30 seismically-reliable motorized valves, allowing the SFPUC to valve off sections of the system, to ensure that pressure is maintained in areas where fires are occurring.
2. The water supply that feeds into the AWSS distribution infrastructure. The primary source of the AWSS is the SFPUC's Hetch Hetchy Water System.

The original AWSS system consisted of three reservoirs and two seawater pumping stations. Their capacities:

- 10.5 million gallon Twin Peaks Reservoir,
- 0.5 million gallon Ashbury Heights Tank, and
- 0.75 million gallon Jones Street Tank.
- Seawater pump station #1: 10,000 GPM (located in SOMA)
- Seawater pump station #2: 10,000 GPM (located near Aquatic Park)

In 2010, the management of the AWSS was transferred to the San Francisco Public Utilities Commission (SFPUC). A shared goal of the SFPUC and SFFD is doing the following to expand and improve the reliability of the water supply serving the AWSS. The agencies have undertaken the following to do so:

- 95% completion of the $4.8 billion Water System Improvement Program (WSIP), providing robust seismic upgrades to the pipelines, reservoirs, and infrastructure that supply water to San Francisco and the greater Bay Area;
- Added a larger pipe to increase the speed of re-filling the Twin Peaks reservoir from the 11 million gallon Summit Reservoir;
- Connecting the 70 million gallon South Basin of the University Mound Reservoir to AWSS (expected completion in 2018);
- Replaced the engines and installed remote control capabilities for Seawater pump station #1 to allow for remote operation;
- Structural and seismic upgrades of Seawater pump station #2 (expected completion in 2020);
- Designing the installation of a pump station at Lake Merced to feed into the AWSS in the future if funding is available;

- Analyzing the usage of the 90 million gallon North Basin of Sunset Reservoir as a water Supply for a Potable AWSS in the Sunset and Richmond Districts; and
- Investigating the installation of a seawater pump station at Ocean Beach to serve as a secondary source of water for fire suppression for the Sunset and Richmond Districts.

In addition to the AWSS, the SFPUC's low-pressure drinking water system and its low-pressure hydrants, as well as approximately 180 cisterns throughout San Francisco, can be pumped and utilized by SFFD Fire Trucks for fire-suppression.

2) Is the AWSS located throughout San Francisco? If not, why?

The AWSS was built after the 1906 earthquake, and its location, primarily in the northeast portion of San Francisco, corresponds to the location of the central business district and the majority of the city's population at that time.

The San Francisco Public Utilities Commission (SFPUC), SFFD, and San Francisco Public Works (SFPW) are committed to increasing fire protection throughout San Francisco. Since the passage of the Earthquake Safety and Emergency Response Bond in 2010, the three agencies have been implementing projects to improve the system's seismic reliability and range of coverage. The three agencies will continue to implement projects utilizing new and proven technologies that improve upon the original system design. There have been many advancements in earthquake resistant pipeline design and materials, hydrants, and seismic valves since the early 1900s, and the SFPUC intends to use the best possible technology available to meet the performance standards of the SFFD. Please standby for future updates to the SFPUC webpage for images, graphics, and maps showcasing the original AWSS system, recent upgrades, and future projects.

3) Who manages the AWSS, the SFPUC or the SFFD? How does the SFFD know that the AWSS system is being adequately and reliably maintained?

The SFFD owned and managed the AWSS and the fire hydrants on the potable water system from the early 1900s until 2010. During this time the SFFD collaborated with staff from San Francisco Public Works (SFPW) to implement upgrades to the system. In 2010, the AWSS was transferred to the SFPUC, the City's experts in water supply piping systems. By bringing in the SFPUC to work with SFFD and SFPW, City leaders created an interagency team with all of the expertise needed to manage, operate, and update the AWSS.

The SFFD is considered the end user of the system, and therefore system improvements and expansion completed by SFPUC must meet the rigorous and high-quality standards of the SFFD. The SFFD and SFPUC meet monthly to discuss operations of the AWSS, report on maintenance activities, review capital and developmental project design and status, and communicate on policies and procedures that affect both departments.

This partnership presents the best of both worlds for San Franciscans. The women and men of SFFD are internationally-recognized for their expertise, experience, and bravery in fighting fires. Similarly, the SFPUC, with its Hetch Hetchy Water System, is recognized as one of the top water agencies in the world. The SFPUC has hundreds of engineers that are experts in designing, expanding, and improving water systems. Additionally, the SFPUC has over 80 plumbers and dozens of construction management experts in-house that are dedicated to providing high-quality maintenance and oversight of the construction projects needed to keep the AWSS functioning for the SFFD's use.

With the two agencies working together, in partnership with SFPW, the City of San Francisco has the experts it needs to successfully operate, expand, and improve the AWSS.

4) What are the SFPUC and SFFD doing to increase fire protection in the areas of the City that do not have the AWSS?

When the SFPUC took over control of the system, the agency worked with SFFD to complete a review of all existing facilities and a comprehensive Planning Study.

The analysis modeled the hydraulic reliability of the existing AWSS after a major earthquake. In this context of this study, hydraulic reliability is defined as the percentage of the water needed by SFFD to fight fires that would be met by the AWSS and other sources after a 7.8 earthquake on the San Andreas Fault.

Our analysis showed that the 2010 AWSS 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 given project serves and 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.

The following projects have been completed utilizing the funds from the 2010 and 2014 bonds:

- Installation of 30 new cisterns (with 15 of these cisterns installed in the Sunset and Richmond districts);
- Reliability upgrades at the three primary source supplies – Twin Peaks Reservoir, Ashbury Heights Tank, and Jones Street Tank;
- Added a larger pipe to increase the speed of re-filling the Twin Peaks reservoir from the 11 million gallon Summit Reservoir;
- Replaced the engines and installed remote control capabilities for Seawater pump station #1 to allow for remote operation;
- 6 pipeline and tunnel projects.

The following projects are in construction and/or design phase:

- Connecting the 70 million gallon South Basin of the University Mound Reservoir to AWSS (expected completion in 2018);
- 16 pipeline and tunnel projects;
- Motorizing critical seismically-reliable valves for remote control, and improving the electronic control system of the valves; and
- Structural and seismic upgrades of Seawater pump station #2 (expected completion in 2020);
- Designing the installation of a pump station at Lake Merced to feed into the AWSS in the future if funding is available;
- Preliminary analysis for a Potable AWSS for the Sunset and Richmond Districts. *Additional information on that system can be found in questions 6-11.*

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%.

5) Who makes decisions about the selection and implementation of AWSS projects? Who reviews the progress and implementation of AWSS capital projects?

Overseeing the selection and implementation of AWSS projects is the Management Oversight Committee consisting of SFPUC General Manager Harlan Kelly, SFFD Chief Joanne Hayes-White, SFPW Director Mohammed Nuru, and SFPUC Assistant General Manager of Water Steve Ritchie.

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 AWSS capital projects. Capital Planning Committee meetings are open to the public. Please find more info at the Committee's webpage.

6) Are the SFPUC and SFFD looking at something called a Potable AWSS for fire suppression on the Westside of San Francisco. What is a Potable AWSS? How does it function? How is it different from the existing AWSS?

The word "potable" is defined as "safe to drink". The Potable AWSS currently under analysis will connect to the 90 million gallon North Basin of the Sunset Reservoir, and will provide a high-pressure firefighting system for the SFFD to fight fires in the Richmond and Sunset Districts. **The Potable AWSS will meet the same rigorous standards required by SFFD to fight large fires, and will utilize the same earthquake resistant pipes, seismically-reliable valves, hydrants, and components utilized by the AWSS, and therefore will be designed to function at the high-pressure level required by SFFD.** The Potable AWSS project is currently in the planning and analysis phase. The SFPUC will work with SFFD to design the system with operational capabilities and design criteria standards equal to or exceeding the existing AWSS.

The Potable AWSS will also have roughly 5 connections to potable water pipes in the Sunset and Richmond districts. **These connections will utilize the same valves as the 30 valves the existing AWSS currently uses to isolate sections of the AWSS to maintain system pressure.** Additionally, these 5 valves will be tested at the same schedule as the existing valves to ensure their performance during an incident. During non-fire events, the Potable AWSS pipeline will be one of many pipes supplying drinking water to the Richmond and Sunset districts.

In the event of a major fire, the approximately five isolation valves will be closed automatically, remotely, or manually, which are the same methods that the 30 valves on the existing AWSS utilize. These five isolation valves will be closed so that the Potable AWSS will be disconnected from the City's low-pressure water system and therefore can provide reliable high-pressure water for fire-fighting. If the Potable AWSS is isolated for firefighting use, homes and businesses will continue to be served by other redundant low-pressure drinking water distribution pipes, assuming that those low-pressure pipes have not incurred numerous breaks and leaks during the earthquake.

An additional benefit of the Potable AWSS is that it will be designed and constructed to meet required AWSS performance standards, and the system will be rated to meet drinking water standards. This means that after firefighting following an earthquake, the Potable AWSS will be able to provide drinking water to the Sunset and Richmond Districts even if the City's low-pressure drinking water distribution system incurs numerous breaks and leaks.

7) Does the Potable AWSS provide an equivalent amount of fire suppression when compared to the existing AWSS? Does the Potable AWSS provide the water pressure and supply of water needed by SFFD to fight small and large fires?

Yes. The Potable AWSS will be designed to meet all SFFD performance requirements. The SFFD will not reduce or lower their robust performance standards, and therefore the SFPUC must design, construct, maintain, and operate the Potable AWSS system to meet these standards. The SFPUC is currently working in conjunction with SFFD to design a system that will have pressure and performance capabilities equal to or exceeding AWSS.

8) Does the Potable AWSS use the same type of earthquake resistant piping and valves as the AWSS?

Yes. The Potable AWSS will use earthquake resistant piping that is equal or better than the current AWSS piping design standard. Additionally, the Potable AWSS will utilize the same seismically-reliable valves as the 30 existing valves currently utilized by the AWSS to isolate sections of the system to ensure supply reliability in areas with fires. The hydrants utilized will also be the same as the existing AWSS. All of these components will be able to property function at the high-pressure levels required by SFFD.

9) The Potable AWSS relies on automatic valves to boost the water pressure to the level needed to fight big fires. What if the automatic valves fail, will SFFD be without the water they need to fight big fires? Does the existing AWSS rely on these automatic valves to fight fires? Does the Potable AWSS rely on more of these valves than the existing AWSS?

The potable AWSS will be isolated after an earthquake from the remainder of the distribution system by seismically-reliable motorized valves using the same method and equipment as current AWSS valves. All valves, future and existing, have redundant safeguards and a maintenance program that will ensure their performance. The valves can be operated manually if the valve actuators fail, just like the existing AWSS motorized valves. The valves are utilized by the existing AWSS and the future Potable AWSS to isolate sections of pipe to ensure that the systems provide the water supply and pressure needed by SFFD to fight big fires.

The quantity of the motorized valves on the future Potable AWSS will be dependent on the length of the Potable AWSS pipeline constructed, but is anticipated to be approximately 5 valves.

10) Are there other cities that have implemented a Potable AWSS? Or do other cities utilize systems similar to the existing AWSS?

Only one other city in the world, Vancouver, B.C. Canada, has been identified as having an isolated secondary firefighting system similar to the existing AWSS. Vancouver's system is less than 10 miles in length, while ours has over 135 miles.

To our knowledge, all other cities rely on their low-pressure potable water system and hydrants for fire-fighting. In Japan, a country that has similar seismic risk to that of San Francisco, cities utilize a system similar to the proposed Potable AWSS. The Japanese system is designed similar to our proposed Potable AWSS – for fighting a large fire after an earthquake, seismically-reliable water transmission mains and hydrants are isolated from the rest of the distribution system using seismically-reliable valves. This allows the Japanese's seismically reliable mains to be increased in pressure and used for fire-fighting. After the fires are suppressed, the Japanese system is used to provide drinking water to residents and businesses.

Recently a team of Japanese water engineers came to San Francisco to showcase the success of their piping system and their experience using Kubota pipes to SFPUC and SFFD staff. The Japanese team highlighted the success of their system and its piping in its utilization after earthquakes to fight fires.

Japan's successful implementation and use of a system similar to the proposed Potable AWSS showcases that the approach and technology do work in fighting fires after a major earthquake.

11) Is the SFPUC is proposing to fill the Potable AWSS from Sunset Reservoir. How much water is in Sunset Reservoir?

The North and South Basins have a combined capacity of 176 million gallons. The North Basin, with a capacity of 90 million gallons, will be connected to the Potable AWSS. The North Basin recently underwent a $64 million seismic upgrade, and is designed to withstand a 7.9 San Andreas Fault earthquake. It can be isolated from the South Basin, and therefore all 90 million gallons could be used for firefighting purposes.

12) Can Sunset Reservoir provide enough water for SFFD and civilian use during a fire? How long will the water in Sunset Reservoir last if it the reservoir is unable to be re-filled by the SFPUC's Hetch Hetchy Water System, the SFFD is utilizing the Potable AWSS to fight a fire, and civilians are utilizing the reservoir?

If firefighting requires a flow of 14,000 gallons per minute for the Sunset and Richmond districts, the 90 million gallon water supply in the North Basin of Sunset Reservoir will last for 4.5 days. This assumes that no additional water is added from the Hetch Hetchy Water System, which is **very** unlikely. Please see question #12 for additional info.

During an emergency situation, the South basin of Sunset Reservoir will be isolated from the North Basin, allowing the North Basin to be used solely for firefighting purposes. The 86 million gallon South Basin will still be connected to the City's low-pressure drinking water distribution piping system so that residents and businesses can receive drinking water while fires are being fought. In an Earthquake situation, residents and businesses may not receive continuous drinking water from the South Basin as fires are being fought, if there are breaks and/or leaks in the low-pressure drinking water pipes that connect to the South Basin. After the fires are put out, the Potable AWSS, connected to the North Basin, will be able to provide drinking water to the Sunset and Richmond Districts, even if the City's low-pressure drinking water distribution system incurs numerous breaks and leaks.

13) Will Sunset Reservoir be able to function after an earthquake? How long will it take for the water supplying Sunset Reservoir to arrive to the reservoir if there is a major earthquake?

In 2008, seismic improvements to the North Basin of Sunset Reservoir were completed for $64 million under the SFPUC's Water System Improvement Program (WSIP). Also under the WSIP, seismic improvements were made on the pipelines leading to Sunset Reservoir. **Thus, it is anticipated that the reservoir can be replenished from the Hetch Hetchy Water System within 24 hours of a major seismic event. Therefore, the Hetch Hetchy Water System will be able to re-fill the North Basin of the Sunset Reservoir prior to the Potable AWSS draining it after 4.5 days of use.**

The Hetch Hetchy Water System consists of 9 reservoirs, capable of supplying up to 265 million gallons of water per day. The WSIP includes $4.8 billion in upgrades to the system, increasing its seismic reliability and ability to provide water to the Bay Area after a large earthquake.

14) The Pacific Ocean is right next to the Westside of San Francisco. Why aren't we filling the Potable AWSS from there? Doesn't the AWSS use Bay Water?

The primary water source for the existing AWSS is the 10 million gallon Twin Peaks Reservoir, 0.5 million gallon Ashbury Heights Tank, and 0.75 million gallon Jones Street Tank. As part of the AWSS bond-funded projects, the Summit Reservoir, with its 11 million gallons of storage, can now be better used by the AWSS. This reservoir serves as a back-up, and would only be utilized by the AWSS during a large fire.

If additional water sources are needed, there are 2 seawater pump stations on the east side of San Francisco that can be utilized to supply a back-up water supply to the AWSS. There have been no known uses of these 2 stations during a fire since their installation in the early 1900s.

The Sunset Reservoir North Basin, with its large capacity and seismic reliability, provides an excellent, existing supply that can be used for the proposed Potable AWSS at no additional cost to rate payers. This reservoir is nine times larger than the existing Twin Peaks reservoir, the primary source utilized by the AWSS.

In the future, an existing SFPUC pump station at Lake Merced will be modified to pump Lake Merced water into new AWSS pipelines that will be installed by the Park Merced development project. Eventually, the Park Merced AWSS pipeline could be connected to the existing AWSS pipeline near Ocean Avenue. Current work will connect the 140 million gallon University Mound Reservoir to the existing AWSS.

The SFPUC is also analyzing new seawater pump stations that could be developed along Ocean Beach and by Hunters Point Shipyard, and will provide updates to the public as the analysis is completed. These future pump stations could serve as back-up supplies for the AWSS and Potable AWSS. Please note that the Potable AWSS would have to be converted to an AWSS if seawater was used, which would cause the system to lose the benefit of being a seismically reliable potable water distribution system for the Sunset and Richmond Districts.

15) How long will it take to install the Potable AWSS in the Sunset and Richmond District? I want fire-suppression in the Westside of San Francisco ASAP.

The Potable AWSS is in the planning phase. Pipeline construction could begin in 2019 if the Management Oversite Committee gives direction to proceed with this project. SFPUC is requesting approval for funding of one mile of pipeline per year at $10 million per mile. Depending on the final length of Potable AWSS pipeline, the construction could be completed in four to eight years. A four-mile pipeline would take four years, while an eight-mile pipeline would take eight years. Each mile of pipeline installed provides significantly greater firefighting protection.

Please note that because the Potable AWSS option provides potable water benefits to the Sunset and Richmond Districts, bond funding **and** SFPUC rate payer funds could be used to pay for its implementation.

The same is not true if a traditional AWSS is deployed in the Sunset and Richmond Districts. Traditional AWSS systems can only utilize bond funding. Due to this distinction, a traditional AWSS would likely have a longer implementation timeline than a Potable AWSS because there is not enough bond funding in place to complete a traditional AWSS at this time. A Potable AWSS project could begin implementation more quickly using SFPUC rate payer funds.

16) How do population growth and new buildings affect firefighting reliability, and will AWSS be expanded to growing areas of San Francisco, such as new development areas in the east and southeast areas of San Francisco?

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 AWSS capacity requirements, both within the new developments and in the City as a whole. The SFPUC and SFFD are working together to specify new AWSS piping and hydrants required within the new developments. Additionally, developers are required to contribute financing towards, or construct, AWSS 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.

Appendix O

Project Name	Planning	Design	Procurement or Bid/Award	Construction	Substantial Completion	Final Completion	Cancelled	Postponed	Complete	Total	SFPW Construction Contract
Cisterns	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**30**	**30**	
Physical Plant	**3**	**0**	**0**	**2**	**0**	**0**	**0**	**1**	**4**	**10**	
Ashbury Tank									1		
Jones Street Tank									1		
Lake Merced Pumping Station - conventional AWSS	1										
Lake Merced Pumping Station - potable AWSS	1										
Pumping Station 1				1							
Pumping Station 2				1							
Twin Peaks Reservoir									1		
Twin Peaks Reservoir Joint Sealing									1		
Sunset Reservoir Pumping Station - potable AWSS	1										
University Mound Pumping Station - conventional AWSS								1			
Pipelines & Tunnels	**1**	**2**	**2**	**3**	**0**	**0**	**5**	**6**	**9**	**28**	
4th Street Connection							1				
Clarendon Supply			1								
Control System									1		
Fillmore & Haight								1			✓
Fort Mason Pier 2 Seawater Manifold								1			
Jones Street Tank Valves									1		
Pipeline Repairs									1		
Planning Study (CS-199)									1		
Pumping Station 1 Tunnel								1			
Seawater Fireboat Manifolds Evaluation									1		
Seawater Suction Connections									1		
Street Valve Motorization								1			
Twin Peaks Reservoir 16" Supply									1		
19th Avenue Pipeline			1								✓
Ashbury Bypass Pipeline				1							✓
Candlestick Point - Carroll Avenue									1		
Columbus & Green Pipeline									1		✓
FWSS - Lake Merced							1				
FWSS - McLaren Park Tanks							1				
FWSS - Street Crossings							1				
FWSS - Sunset Reservoir							1				
Ingleside Pipeline								1			
Irving Street Pipeline				1							✓
Lake Merced Pipeline		1									
Mariposa TFB Pipeline				1							
TFB Mission Rock - South Pipeline		1									
Westside Potable AWSS Pipeline	1										
University Mound East Pipeline								1			
Assessments	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**12**	
Ashbury Heights Valve House Evaluation									1		
Jones Street Tank Generator Foundation Evaluation									1		
Jones Street Tank Retaining Walls Assessment									1		
Jones Street Tank Valve House Evaluation									1		
ESER 2014 Project Recommendations									1		
Pipeline Network Surge Analysis									1		
Pumping Station 1 Foundation & Well Evaluation									1		
Pumping Station 1 Tunnel Evaluation (PS1 to bay)									1		
Pumping Station 2 Discharge Tunnels Evaluation									1		
Pumping Station 2 Well Evaluation									1		
Twin Peaks Reservoir Forebays Evaluation									1		
Twin Peaks Reservoir Tunnel Evaluation									1		
	4	**2**	**2**	**5**	**0**	**0**	**5**	**7**	**55**	**80**	

	Planning	Design	Procurement or Bid/Award	Construction	Substantial Completion	Final Completion	Cancelled	Postponed	Complete	Total	SFPW Construction Contract

Appendix P

Candidate EFWS Projects

5/8/2019

	Projects	Project Cost ($M) (2018 $)	No. of FRA's Directly Benefited	Hydraulic Power (MW)	Project Cost/MW ($M)	Scaling Factor to Lowest $/MW
Pipeline Projects						
1	Conv. AWSS PL - Diamond Street	4	1	0.7	6	1.0
2	Westside Seawater Supply PL	TBD				
3	Conv. AWSS PL - Lake Merced	4	1	0.1	25	4.2
4	Conv. AWSS PL - College Hill Supply	34	0	0.8	43	7.1
5	PEFWS	195	8	4.1	44	7.3
6	Conv. AWSS PL - Ingleside (Phase 1)	6	1	0.1	53	8.8
7	Conv. AWSS PL - Stanford Heights Supply	18	0	0.3	60	10.1
8	Conv. AWSS PL - University Mound East	23	4	0.4	67	11.2
9	Conv. AWSS PL - Ingleside (Phase 2)	14	1	0.2	78	13.0
10	Conv. AWSS PL - University Mound West	19	2	0.2	112	18.7
Subtotal Pipeline Projects		**317**		**6.8**		
Supply Projects						
1	Potable EFWS - Lake Merced PS	40	8	4.6	9	1.3
2	Conv. AWSS Lake Merced PS	10	2	1.5	7	1.0
3	Potable EFWS - Sunset PS	34	8	4.6	7	1.1
4	Conv. AWSS University Mound PS	20	10	2.6	8	1.2
5	Conv. AWSS Manifold - Pier 33-1/2	5	0	0.4	13	1.9
6	PS1 Well	2	0	0.1	13	2.1
7	Westside Seawater PS	TBD				
8	Conv. AWSS Manifold - Fort Mason Pier 1	8	0	0.4	21	3.1
9	Conv. AWSS College Hill Supply PS	25	0	1.0	25	3.8
10	Twin Peaks Forebays	6	0	0.2	26	3.9
11	Twin Peaks Tunnel	8	0	0.2	34	5.2
12	PS1 Tunnel (Phases 1 and 2)	13	0	0.3	43	6.6
13	Conv. AWSS Stanford Heights Supply PS	26	0	0.6	43	6.6
14	PS2 Discharge Tunnels	5	0	0.1	67	10.3
15	PS2 Well	4	0	0.04	89	13.7
Subtotal Supply Projects		**206**		**16.8**		
Infirm Zone Projects						
1	Conv. AWSS PLs - Infirm Zone 7	16	1	0.21	79	1.0
2	Conv. AWSS PLs - Infirm Zone 9	10	1	0.03	320	4.1
3	Conv. AWSS PLs - Infirm Zone 3, 4, 5	33	3	0.05	666	8.5
4	Conv. AWSS PLs - Infirm Zone 1, 2	32	2	0.04	790	10.1
5	Conv. AWSS PLs - Infirm Zone 6	18	1	0.00		
6	Conv. AWSS PLs - Infirm Zone 8	7	1	0.00		
7	Conv. AWSS PLs - Infirm Zone 10	19	1	0.00		
Subtotal Infirm Zone Projects		**135**		**0.3**		
Other Projects						
1	Conv. AWSS PL - PIPE - Bryant & 11th	16	0	0.15	104	1
2	Conv. AWSS PL - PIPE - Dolores & 20th	9	0	0.05	197	1.9
3	Conv. AWSS PL - PIPE - Brannan St.	36	0	0.04	953	9.2
4	Conv. AWSS PL - PIPE - Market St.	28	0	0.03	871	8.4
5	Ashbury Valve House	5	0			
6	Jones St Generator Foundation	1	0			
7	Jones St Valve House	5	0			
8	PS2 Remote Operation and Engine Repl.	12	0			
9	Miscellaneous Repairs	15	0			
10	Conv. AWSS PL - Surge Protection	4	0			
11	Conv. AWSS PL - Valve Renovation	6	0			
Subtotal Other Projects		**136**		**0.3**		
Development Projects						
1	Potrero PL	14	1			
2	Southern Area Supply Projects	166	5			
Subtotal Development Projects		**180**				
Grand Total		**974**		**19**		

1) MW=Hydraulic power (MW)
(1 MW = 1,341 hp)
2) S=Scaling factor to lowest $/MW

Appendix Q

I/San Francisco Independent/January 31, 1990 N.S.W.C

Fire Dept.'s Ace in the Hole

By Jim Castleberry

The night of the Oct. 17 earthquake was not the first time the San Francisco Fire Department had to call on its Portable Water Supply System, but it was by far the most important.

When firefighters responded to a blaze in the Marina District, they were horrified to learn that *all the water lines in a 40 square block area surrounding the fire were broken and useless.*

With no water pressure, firefighters could only watch as the fire raged out of control and threatened to explode into the largest blaze in the city since 1906.

But the city had one more card to play – its ace in the hole.

Division Chief Harry Brophy issued the call for the Fireboat Phoenix and the department's Portable Water Supply System (PWSS).

For Assistant Chief Frank Blackburn, who developed the PWSS, and his fellow firefighters, it was the test they had been waiting for. The one that would determine once and for all if the PWSS, hailed as ingenious by some and a boondoggle by others, really worked. "I told the guys that this was the Super Bowl," Blackburn said.

Fortunately for the city, the PWSS performed perfectly.

As the Phoenix pumped water from the Bay, firefighters set up portable hydrants on Divisadero Street that allowed them to stretch hoses all the way to the fire at Beach Street.

Within an hour after the system was hooked up, the fire had been brought under control.

San Francisco's Board of Supervisors rewarded Blackburn with a commendation, thanking him not only for the development of the system but his quick work in putting it to use on Oct. 17.

"Without those portable hydrants, along with the fireboat, the city probably would have burned to the ground," Supervisor Terrance Hallinan said. "Blackburn knew where all the hydrants were and as soon as it hit, he rounded them up and set them into operation. It was a key to turning that whole situation around."

The key to the PWSS is the portable hydrant designed by Blackburn from old Gleeson pressure-reducing valves and other spare parts lying around the department's repair shop. Using the hydrants, firefighters can pump from the Bay, a lake or underground cistern and lay a grid of hose covering several blocks.

The portable hydrants not only allow water pressure to be maintained, they also let firefighters hook up pumper trucks or fire hoses along the line so fires in multiple locations can be battled.

"Say there was a fire on Van Ness Avenue and all the water mains were broken," Blackburn said. "The PWSS would let you pump water from the Bay, all the way up Van Ness. People say it can't work, but it does. We proved it on Oct. 17."

Blackburn didn't start working on the portable hydrants and PWSS until 1984. By 1985 a prototype was ready and they were in regular use by 1986.

The PWSS helped put out a five alarm fire at First and Townsend street in 1987 and was also used at Hetch Hetchy later that year to protect buildings threatened by a fire burning in Yosemite National Forest.

"We drafted water from the Tuolumne River for that one," Blackburn said. "It's amazing. All you need is a body of water."

"It's something that San Francisco should really be proud of," said Dr. Charles Scawthorn, a researcher who has done extensive study of the risk posed to San Francisco by fire.

In 1987 Scawthorn wrote a report for the insurance industry on the conflagration risk in San Francisco following a major earthquake similar to 1906.

His report foresees widespread destruction with billions of dollars in property losses and dozens of major fires – similar in size to the Marina fire – after a magnitude 8.3 or larger quake.

"Everything that happened on Oct. 17 confirmed my findings," he said. "But the PWSS is obviously going to greatly improve the chance of the city surviving 'The Big One.' It won't save it entirely but at least we'll be able to limit the losses."

The Portable Water Supply System includes:

-- Four hose wagons that carry 4,000 to 5,000 feet of large, five inch diameter hose that connect to the portable hydrants (normal firehose is only three inches in diameter.

-- Underground cisterns located throughout the northern and eastern sections of the city that can be filled with water to supply trucks along the way.

-- Portable hydrants that allow water to flow freely for long distances at a very high pressure.

Scawthorn recommends a large-scale expansion of the PWSS.

"If there are only four hose wagons, you can only fight fires in four locations," Scawthorn said. "After a big quake there will be fires breaking out all over the city."

The Fire Commission has indicated its desire to expand the system and cleared the way for building of more cisterns in the outer Sunset and Richmond residential neighborhoods.

Plans are also underway to purchase more large-diameter hose, if the money can be found.

Blackburn calls it the best defense a city like San Francisco can have against fire following an earthquake.

"When a major quake occurs and water mains are broken, the answer is the PWSS," he said. "If you don't have it, you won't put the fires out."

1990 article on the Portable Water Supply System, an adjunct to the AWSS, and its use during the post-earthquake fires in October 1989.

Appendix R

Figure 5-1. Preferred Alternative Planning Level Schedule

ID	Task Name	Duration	Start	Finish
1	Alternative B	1 day	Mon 6/3/13	Mon 6/3/13
2	+ Motorization & addition of seism	720 days	Tue 6/4/13	Mon 3/7/16
6	+ 4th Street Hose	576 days	Tue 6/4/13	Tue 8/18/15
10	+ PS1 Tunnel upgrade	1296 days	Tue 6/4/13	Tue 5/22/18
14	+ Jones St. Tank Bypass Valves	624 days	Tue 3/8/16	Fri 7/27/18
18	+ Repair suction connections	1372 days	Tue 3/8/16	Wed 6/9/21
22	+ SCADA improvements	720 days	Fri 2/16/18	Thu 11/19/20
26	+ FB Manifold R&R	672 days	Fri 2/16/18	Mon 9/14/20
30	+ Pipe Investigation and Repair	1050 days	Tue 6/4/13	Mon 6/12/17
34	+ Sutro Connection and PS	1488 days	Tue 6/4/13	Thu 2/14/19
38	2014 Bond	1 day?	Mon 6/1/15	Mon 6/1/15
39	+ Reliability Upgrades at Facilities	1296 days	Tue 6/2/15	Tue 5/19/20
43	+ Cistern Construct 46 New Cister	1432 days	Fri 7/8/16	Mon 1/3/22
47	2021 Bond	1 day?	Wed 6/1/22	Wed 6/1/22
48	+ Pipeline Replacement Program	2548 days	Thu 6/2/22	Mon 3/8/32
52	+ Silver Extension	1508 days	Thu 6/2/22	Mon 3/13/28
56	2027 Bond	1 day?	Thu 6/1/28	Thu 6/1/28
57	+ University Mound Connection an	864 days	Fri 6/2/28	Wed 9/24/31
61	+ Sunset Extension	1528 days	Thu 12/21/28	Mon 10/30/34
65	+ Sunset Rezoning	708 days	Wed 7/11/29	Fri 3/26/32
69	2033 Bond	1 day?	Thu 6/1/34	Thu 6/1/34
70	+ Lake Merced Pump Station	864 days	Fri 6/2/34	Wed 9/23/37
74	+ Sunset Connection and PS	864 days	Thu 12/21/34	Tue 4/13/38
78	2039 Bond	1 day?	Fri 6/1/40	Fri 6/1/40
79	+ Pipeline Replacement Program	2432 days	Mon 6/4/40	Tue 9/28/49
83	2045 Bond	1 day?	Fri 6/1/46	Fri 6/1/46
84	+ Richmond Extension	935 days	Mon 6/4/46	Fri 12/31/49
88	+ Alemany Extension	791 days	Fri 12/21/46	Fri 12/31/49
92	+ Geneva Extension	647 days	Thu 7/11/47	Fri 12/31/49