CHAPTER 7 – FLOOD HAZARDS: RISKS AND MITIGATION

CHAPTER CONTENT

About Chapter 7

Chapter 7 assesses hazards and risks related to flooding. Flooding is considered one of the three primary hazards in California (along with earthquake and wildfire), as explained in *Section 1.2.3* of the 2018 SHMP (see that section for a discussion of the hazard classification system and information on the criteria used for hazard risk assessments). Flood hazards discussed in this chapter include riverine, stream, and alluvial flooding and coastal flooding, erosion, and sea level rise, all of which are influenced by climate and weather. Levee and dam failure are identified as secondary hazards, because they may be triggered by primary hazard events and also by flooding and inundation resulting from tsunamis.

California's geographic diversity represents a difficult challenge to planning for flood mitigation. California has a 1,100-mile-long coastline; prominent coastal and inland mountain ranges, including the Sierra Nevada; a large riverine Central Valley; the Sacramento and San Joaquin Delta; and extensive and highly varied deserts. These geographical factors combine to create various types of floods, specifically defined in the SHMP as:

- Riverine—flooding that occurs along river and stream channels and that can range from slow-rise gradual inundation to flash floods from high velocity flows.

- Alluvial fan—flows of shallow depths and high velocities often containing sediment and rocks along uncertain flow paths on the surface and at the toes of alluvial fans.
- Coastal—inundation of locations normally above high tide, often caused by storm surge occurring with high tide and exacerbated over time with climate change-induced sea-level rise. Increased coastal erosion can also result from these conditions.
- Engineered structure failure—flooding resulting from dam or levee failure.
- Tsunami—high-speed seismic ocean waves triggered by earthquakes and underwater landslides.

For more information on the criteria and template used for hazard risk assessments and a discussion of the hazard classification system, see *Chapter 1: Introduction, Section 1.2.3*.

7.1 RIVERINE, STREAM, AND ALLUVIAL FLOOD HAZARDS, VULNERABILITY AND RISK ASSESSMENT

Floods represent the second most destructive source of hazard, vulnerability, and risk, both in terms of recent state history and the probability of future destruction at greater magnitudes than previously recorded. In addition to causing tragic loss of life, flooding in California can have a serious impact on the state's economy and environmental resources. With California representing one of the world's largest economies, a major flood here will have an unprecedented impact on the national economy as well. When California floods:

- Critical infrastructure is damaged and could be out of service for long periods
- Vital services become isolated or are closed
- Jobs are lost or put at risk when businesses are dislocated or closed
- Water supplies and water quality are affected
- Vulnerable communities are displaced and/or personal property is lost
- Natural resources and public access are damaged or eliminated.

To manage flood risk, California has a complex system of flood infrastructure consisting of approximately 20,000 miles of levees, more than 1,500 dams and reservoirs (1,250 of which are under state jurisdiction), and more than 1,000 debris basins. Federal and state facilities in the Central Valley include approximately 1,600 miles of project levees, several bypasses and appurtenant weir and control structures, seven dams, and other associated facilities.

7.1.1 IDENTIFYING RIVERINE, STREAM, AND ALLUVIAL FLOOD HAZARDS

This section addresses floods as one of three primary hazards in the classification system introduced in *Chapter 1, Section 1.2.3* and includes information identifying the following dimensions of this hazard:

- Its location within the state (i.e., geographic area affected)
- Previous occurrences within the state
- The probability of future events (i.e., chances of recurrence)

Floods represent a significant concern for the State of California for several reasons. First, California has a chronic and destructive flooding history. Second, California has widespread flooding vulnerability as indicated by the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) designations, which show flood hazard zones being common in populated areas. Third, most local governments that have FEMA-approved Local Hazard Mitigation Plans (LHMPs) have identified flooding as an important hazard.

7.1.2 PROFILING RIVERINE, STREAM, AND ALLUVIAL FLOOD HAZARDS

Every county in the state experiences floods, although the nature of these events varies due to the state's diverse climatology and geography. Disparate climatological patterns present challenges to flood mitigation planning in California. These patterns include:

- El Niño conditions
- La Niña conditions
- Desert monsoons
- Northwest coastal conditions
- Tropical storms
- Gulf of Alaska storms
- Atmospheric river patterns

Flooding, erosion, and debris flows can also occur in California in the months and years following large hot fires. High severity wildfires greatly reduce the amount of vegetation, which can reduce the amount of rainwater absorption, allowing excessive water runoff that often includes large amounts of debris. Structures located anywhere near a severe burn area are susceptible to flooding. Periods of high-intensity rainfall are of particular concern, but post-fire flooding can also occur during a normal rainy season. For more information, see: https://www.water.ca.gov/LegacyFiles/sfmp/resources/Computer_View_Highlight.pdf.

Hydrologic Regions

California's ten hydrologic regions present disparate flood mitigation planning challenges. The following is a brief description of the ten regions, shown in Map 7.A.

North Coast Hydrologic Region

The North Coast hydrologic region runs along the Pacific Coast from the California-Oregon border to the mouth of the Russian River. This region is sparsely populated, with the majority of settlement in the Humboldt Bay area. The area receives larger rain totals than any other region and has historically experienced some of the state's most spectacular and devastating flood events. Tsunamis also pose a very real threat, particularly to the community of Crescent City in Del Norte County.

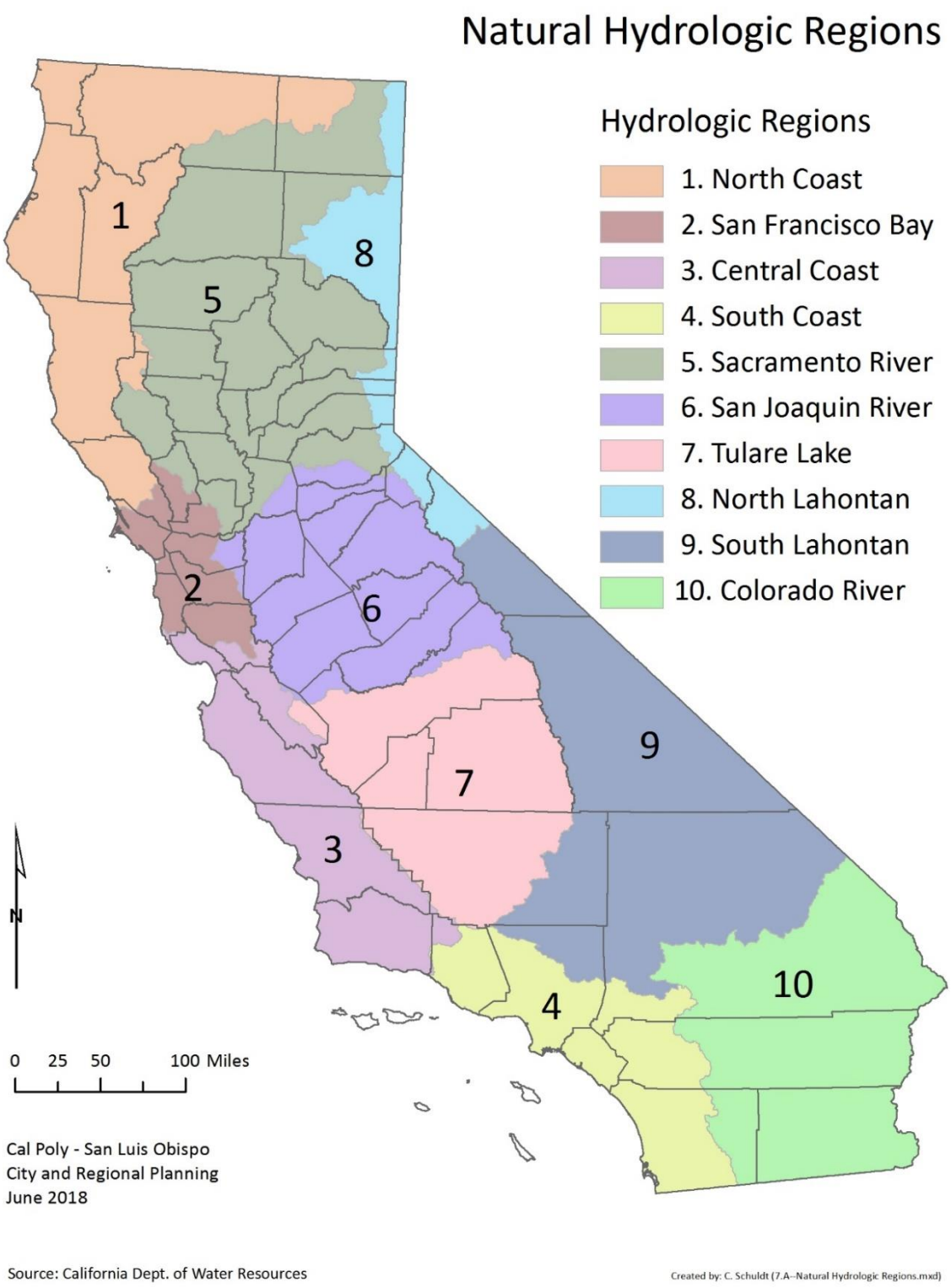
San Francisco Bay Hydrologic Region

The San Francisco Bay hydrologic region runs along the north central coast and encompasses most of the Bay Area counties. It reaches to just north of Ukiah in Mendocino County, south to the Coyote Creek watershed in Santa Clara County, and inland to just east of the Sacramento-San Joaquin Delta. The area around San Francisco Bay is heavily populated, and the entire region is marked by hills, river valleys such as those along the Russian River, and marshlands. The region is most vulnerable to classic stream flooding, landslides, and some urban flooding. Flooding along the coastal and bay shorelines can be severe when winter storms coincide with high tides. Sonoma County, most of which is located in this region, records the most National Flood Insurance Program (NFIP) repetitive losses of any area in California.

Central Coast Hydrologic Region

The Central Coast hydrologic region reaches from Año Nuevo Point in San Mateo County down the Pacific Coast to near the crest of the coast range in Santa Barbara County. The region is mountainous with very narrow strips of flat coastal plain. Generally, the mountain streams and rivers in this area run directly into the Pacific Ocean and lack significant delta areas. This region includes major agricultural areas and urban centers and is characterized by stream flooding and slides. This region is also at risk from tsunamis.

Map 7.A: Hydrologic Regions



South Coast Hydrologic Region

The South Coast hydrologic region extends north from the U.S.-Mexico border to the Tehachapi, San Bernardino, San Gabriel, and San Jacinto mountains. Nearly one-third of the area is coastal plain. This region contains major urban centers, including the counties of Los Angeles, Orange, and San Diego. Much of the flooding is sudden and severe, resulting in massive slides, debris flows, and mudflows. Typical of the flooding that occurs in this area are the 1969 winter storms that killed 47 people and resulted in $300 million in property damage. During these storms, an alluvial flood and debris flow on Deer Creek in San Bernardino County killed 11 people.

Sacramento River Hydrologic Region

The Sacramento River hydrologic region includes the northern half of the Central Valley. The Sacramento River drains through the Sacramento-San Joaquin Delta. The region is bounded by the Sierra-Nevada Mountains, Coast Range, Cascade Range, and Trinity Mountains. This is a major agricultural area, with the Sacramento metropolitan area comprising the largest concentration of population. Flooding in this region is predominantly caused by runoff from either major winter storm events or snowmelt. While massive dams and levee systems have significantly reduced this region's historic flood problems, residual risk remains a significant problem, especially for urbanizing areas within deep floodplains. The region is also vulnerable to flooding along small streams due to levee failures and in urban drain areas dependent upon pumping stations. This region includes portions of the Sacramento-San Joaquin Delta, which is vulnerable to levee failure (see *Section 7.4*).

San Joaquin River Hydrologic Region

The San Joaquin River hydrologic region encompasses the middle portion of the Central Valley. It is bounded by the Sierra Nevada Mountains and Coast Range and includes the Cosumnes, San Joaquin, and Kings River watersheds. The region also includes portions of the Sacramento-San Joaquin Delta. Although predominantly agricultural, this region has experienced increased urbanization in recent years and is subject to flooding from winter storm events and snowmelt. While many urban areas are protected by dams and levees, residual risk is significant, especially for urbanizing areas in deep floodplains.

Tulare Lake Hydrologic Region

The Tulare Lake hydrologic region comprises the extreme southern portion of the Central Valley. It bounded by the Sierra Nevada Mountains and the divide between the San Joaquin and Kings Rivers, the Coast Range, and the Tehachapi Mountains. The Kaweah, Tule, Kern, and Kings Rivers drain into the Tulare Lakebed. Through the late 1800s, Tulare Lake was of substantial size during wet periods, although its level fluctuated. A number of small reclamation districts were established in the area in the early 1900s and, over the years, built levees and reclaimed the more-than-200,000-acre lakebed for agriculture. Though now predominantly agricultural, this region contains the urban centers of Fresno, Bakersfield, Visalia, and Hanford. It is subject to flooding from winter storms and snow runoff.

North Lahontan Hydrologic Region

The North Lahontan hydrologic region lies in the extreme northeast portion of the state. It is bounded by the Sierra Nevada, Cascade, and Warner mountain ranges on the west and the Nevada border on the east and runs south to Bridgeport in Mono County. Lake Tahoe is located in the center of the region. All streams in the region terminate in lakes or playas because they have no outlet to the ocean. This region is sparsely settled with the exceptions of the communities around Lake Tahoe and in the City of Susanville. The region experiences flooding from winter rainstorms, snowmelt, and intense late spring and early fall thunderstorms.

South Lahontan Hydrologic Region

The South Lahontan hydrologic region is nestled between the Sierra Nevada, San Bernardino, and San Gabriel Mountains, the Nevada state line, Mono Lake Valley, and the northern Colorado Desert. Despite its generally dry conditions, this sparsely populated region experiences periodic winter storms and thunderstorms that often result in flash floods. Under storm conditions, the region's generally dry stream systems pose a significant threat. The Mojave River runs through three growing San Bernardino County communities: Hesperia, Victorville, and Barstow.

The desert community of Hesperia is located at the base of an alluvial fan that forms the headwaters for the Mojave River. This area experiences significant flood damage during both winter storms and summer monsoon events.

Colorado River Hydrologic Region

The dominant hydrologic features of this region are the Colorado River, which forms its eastern boundary, and the Salton Sea, which lies just shy of its western boundary. The region is marked by the San Bernardino and San Jacinto Mountains. The region is also bounded by the U.S.-Mexico border to the south and the South Lahontan region to the north. This is a mostly sparsely populated agricultural region that experiences irregular flooding. However, both common winter storm events and tropical flows from Mexico's Pacific Coast can bring massive rainstorms and flash floods. During the summer months, monsoonal flows come up over the mainland of Mexico.

Past Flood Disasters

From 1992 to February 2018, California has had 34 state-proclaimed flood emergencies and 15 federally declared flood disasters.

As shown in Table 7.A, since 1992, every county in California has been declared a federal disaster area at least once for a flooding event. The information in Table 7.A extends back to 1992 because that is the year that the California Governor's Office of Emergency Services (Cal OES) began tracking disaster recovery history information. The 1992 flood was the first federally declared flood disaster since Stafford Act implementation began in 1988.

Table 7.A: Federally Declared Flood Disasters in California, 1992-February 2018*

Disaster Number	Date	Scope (Number of Counties)	Number of Deaths	Damage in $
935-DR-CA	February 1992	6	5	$123.2 million
979-DR-CA	January 1993	25	20	$600 million
1044-DR-CA	January 1995	45	11	$741.4 million
1046-DR-CA	February 1995	57	17	$1.1 billion
1155-DR-CA	January 1997	48	8	$1.8 billion
1203-DR-CA	February 1998	40	17	$550 million
1498-DR-CA	June 2003	2	16	--[a]
1529-DR-CA	June 2004	1	0	$57 million
1577-DR-CA	February 2005	8	24	$573.1 million
1585-DR-CA	April 2005	7	0	$198.7 million
1628-DR-CA	February 2006	40	5	$327.8 million
1646-DR-CA	June 2006	16	1	$129.5 million
1884-DR-CA	March 2010	6	0	$50.6 million
4305-DR-CA	January 2017	22	**	$20.4 million
4308-DR-CA	February 2017	43	**	$260.5 million

Source: Cal OES Origins and Development - A Chronology 1917-2010; Cal OES After Action Reports; FEMA: California Disaster History, FEMA Disaster declarations for California, http://www.fema.gov/disasters/grid/state-tribal-government/77?field_disaster_type_term_tid_1=All

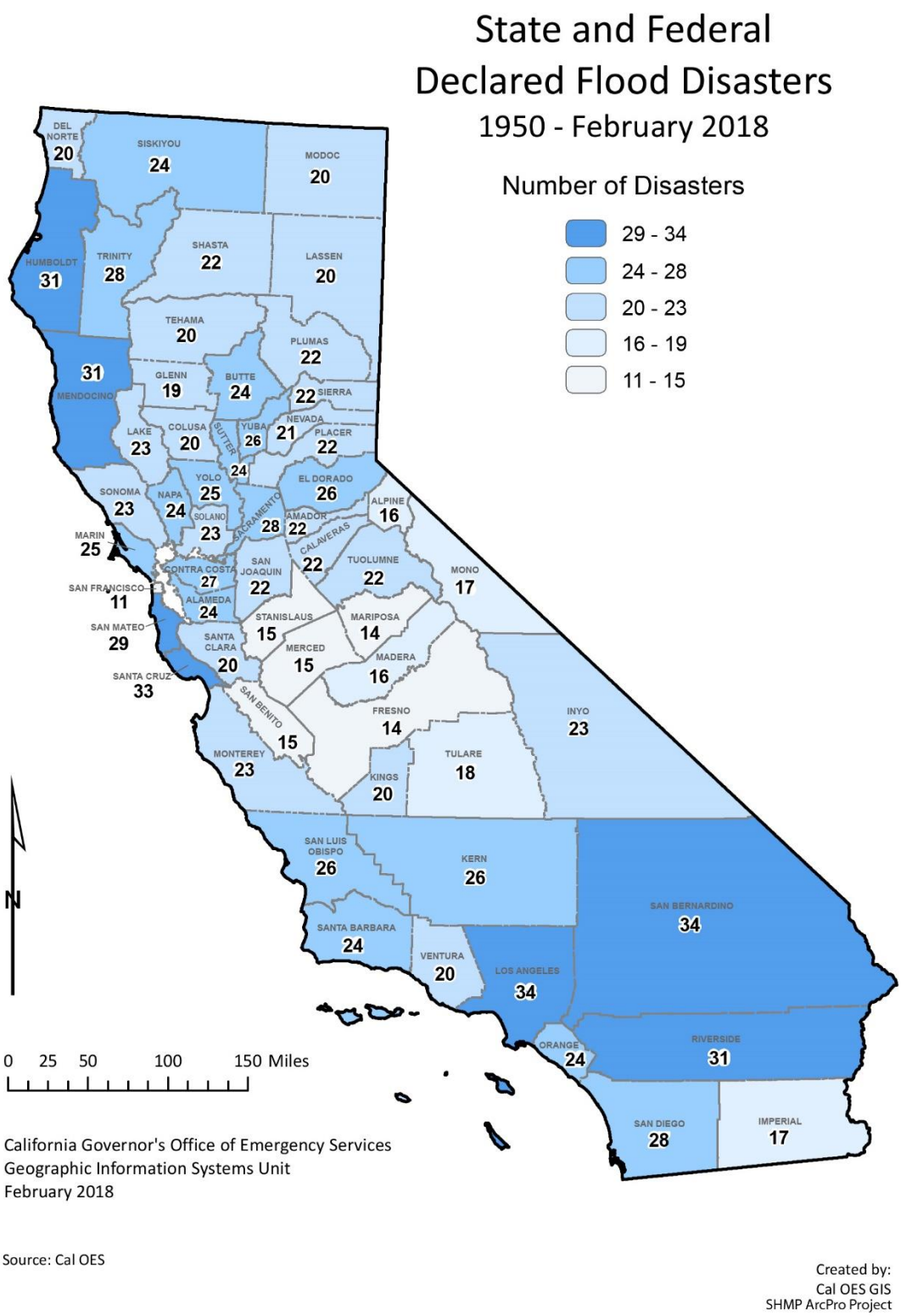
[a]DR-1428, 2003 Southern California Fires, caused the elimination of vegetation securing soils to the hillsides. In December 2003, mild flooding caused mudflows and landslides killing 16 people. The costs of the flood damages were not segregated from the fire damages.

**Disasters listed are only those designated by the Federal Emergency Management Agency (FEMA) as Flood Disasters (Storm Disasters are not included in this table).*

*** Figures pending*

Map 7.B shows the distribution of floods leading to disaster declarations from 1950 to February 2018. Some of the counties with 24 or more declared disasters during this period include Kern, Los Angeles, Riverside, San Bernardino, Orange, and San Diego in the southern portion of California; Contra Costa, Alameda, San Mateo, Marin, Napa, and Santa Cruz in the San Francisco Bay Area; Sacramento, Yolo, Sutter, El Dorado, and Yuba in the Sacramento/Sierra foothill area; and Humboldt, Trinity, Butte, and Mendocino in Northern California.

Map 7.B: State and Federal Declared Flood Disasters, 1950-February 2017



Probability of Flood Hazards

The standard references for establishing the location of flood hazards are the Flood Insurance Rate Map (FIRM) floodplains, part of a national insurance system maintained under the National Flood Insurance Program (NFIP), as described in *Chapter 1: Introduction, Section 1.4.1*. The FIRM designations not only identify the flood hazard zones for insurance and floodplain management purposes, but also provide a statement of probability of future occurrence. Map 7.C shows 1 percent chance (100-year) and 0.2 percent chance (500-year) flood zones designated by FEMA and 100-year, 200-year, and 500-year flood zones designated by the California Department of Water Resources (DWR).

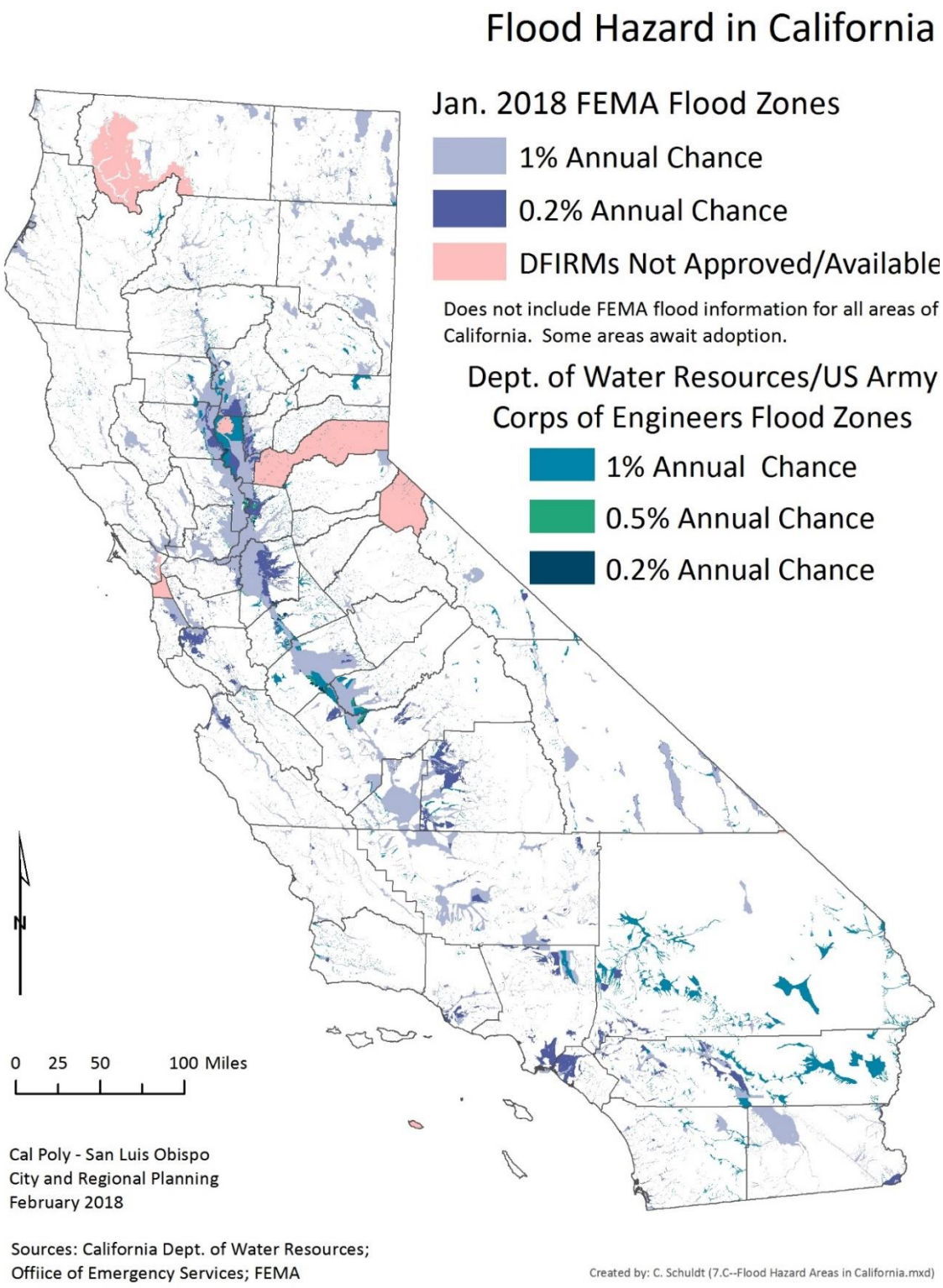
A 500-year flood has a 0.2 percent chance of occurring in any given year; a 100-year flood has a 1 percent chance, a 50-year flood has a 2 percent chance, and a 10-year flood has a 10 percent chance of occurrence. Although the recurrence interval represents the long-term average period between floods of specific magnitude, significant floods could occur at shorter intervals or even within the same year.

The FIRM designations typically identify components of the 500-year and 100-year floodplains. FEMA 100-year floodplains or areas with a 1 percent chance of a flood that size in any given year are shown in light lavender-blue in Map 7.C. High concentrations of 1 percent annual chance flood hazard areas are shown throughout the Central Valley, especially in the Sacramento-San Joaquin Delta region, as well as in selected other inland regions.

Analysis of Damage from Historic Flood Events

Damage data from California's historic flood events are useful for characterizing flood risk and identifying areas that probability-based assessments such as FIRM floodplains may miss. According to a study of population living in floodplains as of 1998, a majority of NFIP flood loss claims occur during flood events that do not rise to the level of a federal disaster declaration. Thus, the extent of flood disaster declarations alone is not a complete measure of vulnerability.

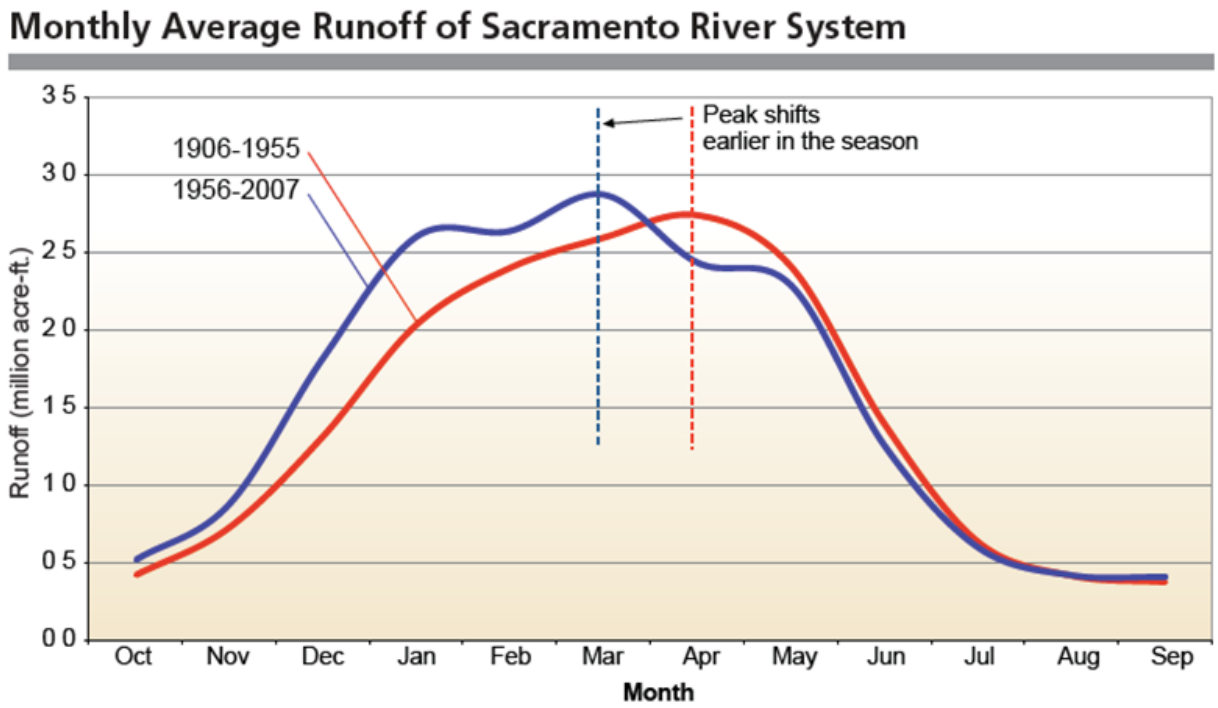
Map 7.C: Flood Hazard Areas in California



Climate Change and Flood Hazards

Climate change impacts have already been detected in temperature, precipitation, runoff, and snowpack records.[140] These changes have resulted in altered annual runoff patterns and the subsequent operation of reservoirs for flood protection. In addition, climate change not only alters annual average climate, it also increases variance.[141] As a result, regions projected to see an annual reduction in total precipitation, may experience an increase in the severity and frequency of flood events. The change of snowfall to rainfall may also contribute to an increased number and severity of flood events.

Figure 7.A: Monthly Average Runoff of Sacramento River System



Source: Department of Water Resources

An example of these effects is shown in Figure 7.A, which illustrates monthly average runoff in the Sacramento River system. The figure compares monthly average runoff for the period from 1956 to 2007 (blue line) and the period from 1906 to 1955 (red line), showing that the timing of peak runoff has shifted to earlier in the year.

Climate change impacts also interact in ways that can exacerbate the severity and frequency of flood events. For example, larger and more frequent wildfires brought on by climate change can reduce the ability of a landscape to retain rainfall, which can in turn lead to flooding and mudflows. Examples include the catastrophic mudflows that occurred in early 2018 in Santa Barbara County following heavy rainfall in an area where the 2017 Thomas Fire had denuded slopes of vegetation. In addition, sea level rise enlarges floodplains at the mouths of streams and rivers that empty into oceans and bays. Current projections indicate the following climate change trends that may affect flood hazards:

- *Precipitation:* Cal-Adapt mapping indicates a shift of precipitation events away from southern and inland hydrologic regions and toward central and northern regions.[142] However, the general decreases in annual

[140] California Department of Water Resources, California Climate Science and Data, 2015. Sacramento: author, 28 p. Retrieved on July 3,2017 from http://www.water.ca.gov/climatechange/docs/CA_Climate_Science_and_Data_Final_Release_June_2015.pdf
[141] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller eds.), 2007. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.
[142] California Energy Commission. (2017). Cal-Adapt. Retrieved on 5/30/2017 from www.cal-adapt.org.

precipitation in southern and inland regions may not be accompanied by a reduction in flooding. The increase in climate variance may result in these regions experiencing heavier, more intense, episodic rainfall and flooding events due to transport of warmer, moisture-laden air from the ocean.[143]

- *Snowpack*: Snowpack in mountainous areas (northern and coastal mountains and the Sierra) is projected to be reduced and accompanied by earlier rainfall with subsequent runoff downstream, particularly in the Sacramento River and San Joaquin River watersheds that converge in the California Delta. These trends suggest the potential for increased incidence of intense flooding in the Central Valley and the San Francisco Bay region.
- *Sea-level rise:* The State of California Sea-Level Rise Guidance 2018 Update summarizes recent scientific findings regarding global sea level rise and presents projections for California that build on data collected from a network of 12 tide gauges located along the coast (see Table 7.F and Figure 7.G in *Section 7.2*). The guidance provides sea level rise projections by decade, based on greenhouse gas (GHG) emissions scenarios. These projections serve as the basis for ways to incorporate sea level rise data into planning. An extreme scenario was also included based on rapid ice melt on Antarctica, labeled as H++. The H++ rapid loss scenario projects extreme sea level rise with a 10.2-foot increase by 2100 and a 21.9-foot increase by 2150. This increase will not only result in coastal areas experiencing increased periods and levels of inundation, but also may increase the spatial extent of floodplains near the mouths of streams and rivers emptying into marine environments. For communities located on the coast that include waterways emptying into the ocean or other marine environments, the impact of sea level rise and high tide co-occurring with rainfall events must be evaluated. Sea level rise combined with high tides will increase the frequency and severity of flood events for areas adjoining places where coastal streams and rivers empty to the ocean.

Local projections of climate change impacts on flood hazards should be made in collaboration with local experts and should rely on DWR and other state guidance, such as the DWR Climate Change Handbook for Regional Water Planning and the California Adaptation Planning Guide.

7.1.3 ASSESSMENT OF STATE FLOOD VULNERABILITY AND POTENTIAL LOSSES

This section discusses statewide vulnerability of areas susceptible to flooding. It provides an overview of state vulnerability and potential losses to flood hazards and reviews progress with respect to Repetitive Loss Communities, as well as state-owned and -leased buildings. The assessment of state vulnerability to floods uses counties as the primary unit of analysis. Included are several methods available for assessing the areas of the state that are the most vulnerable to flood hazards:

- Geographic Information Systems (GIS) risk exposure modeling
- Analysis of population in Flood Insurance Rate Map (FIRM) floodplains
- Analysis of damage from historic flood events
- Analysis of Central Valley regional and basinwide flood risk, including urban areas, small communities, and rural areas

Collectively, the results of analyses can be used to establish current and future vulnerability and potential loss with measures of space and magnitude.

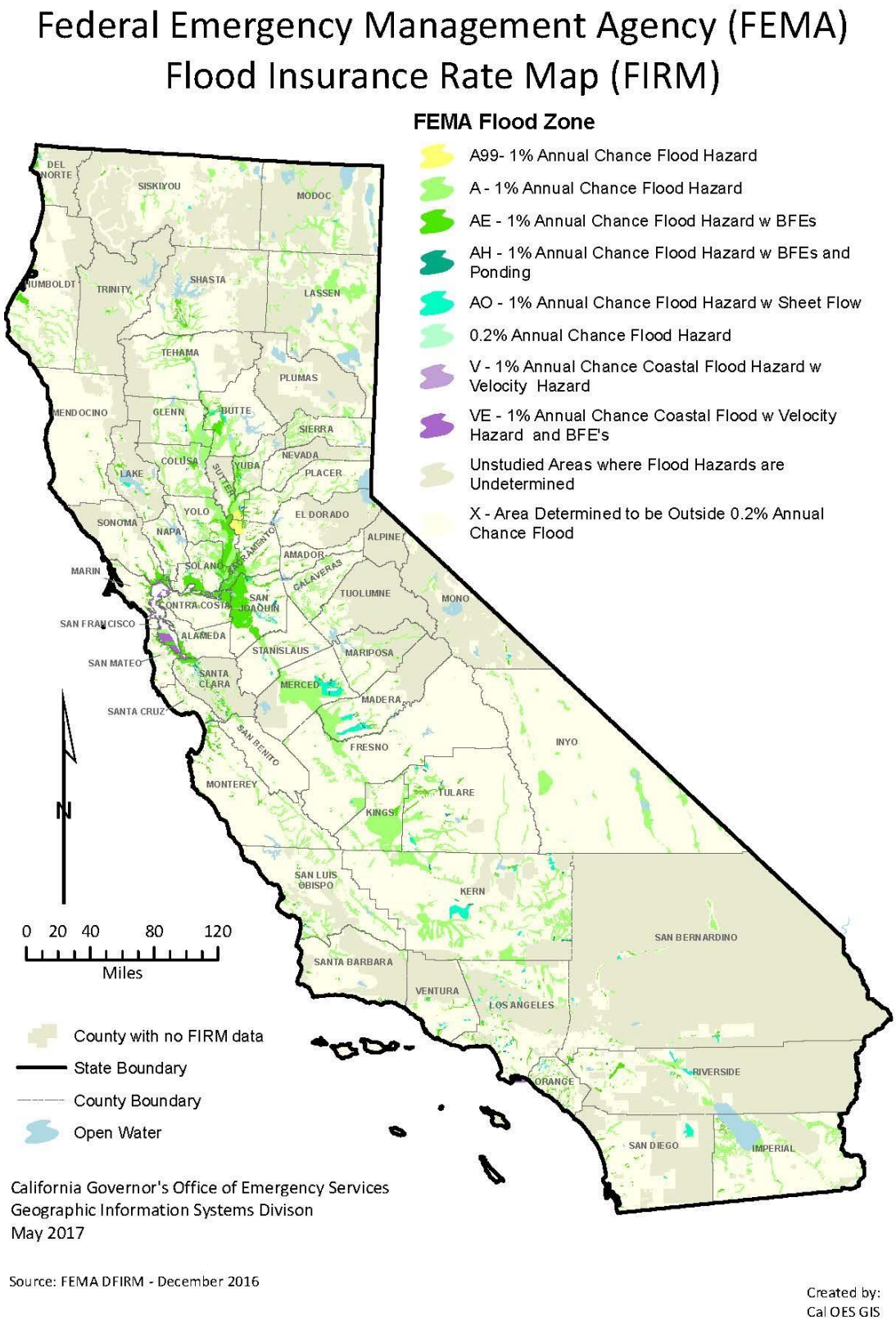
7.1.3.1 CALIFORNIA'S FLOOD EXPOSURE

Population in Flood Insurance Rate Map (FIRM) Floodplains

Flood zones are areas depicted on a Flood Rate Insurance Map (FIRM) and are defined by FEMA according to levels of risk. Zones with a 1 percent annual chance of flooding are part of the Special Flood Hazard Area (SFHA) and considered to have high risk. In communities that participate in the NFIP, mandatory flood insurance purchase requirements apply to the zones A, AE, A1-30, AH, AO, AR, A99, V, and VE or V1 through 30, as shown in Map 7.D and defined in Table 7.B.

[143] California Natural Resources Agency & California Emergency Management Agency. (2012). California Adaptation Planning Guide. Sacramento: author

Map 7.D: FEMA Flood Insurance Rate Map



For expanded definitions of the flood zones, visit the FEMA Flood Map Service Center web page: https://msc.fema.gov/portal.

It should be noted that FIRM do not provide full coverage of the state and contain inaccuracies due to changes in development and infrastructure since the original surveying. The federal government started regulatory floodplain mapping on a nationwide basis in the late 1960s. FEMA has mapped a portion of California but has substantial areas yet to map, subject to growth. Meanwhile, efforts have been under way to update some FIRMs in the state through FEMA's new Risk MAP (Mapping, Assessment, and Planning) Strategy.[144]

A Section of River Road in Modesto, Closed Due to January 2017 Floodwaters from the Tuolumne River

Source: California Department of Water Resources

According to an Analysis and Update of National Flood Hazard Layer Demographics and NFIP Policy and Claims Data report prepared for FEMA in 2012, 1,367,076 people and 506,165 housing units in California are within the Special Flood Hazard Area (SFHA).[145]

California's Flood Future: Mapping Flood Exposure

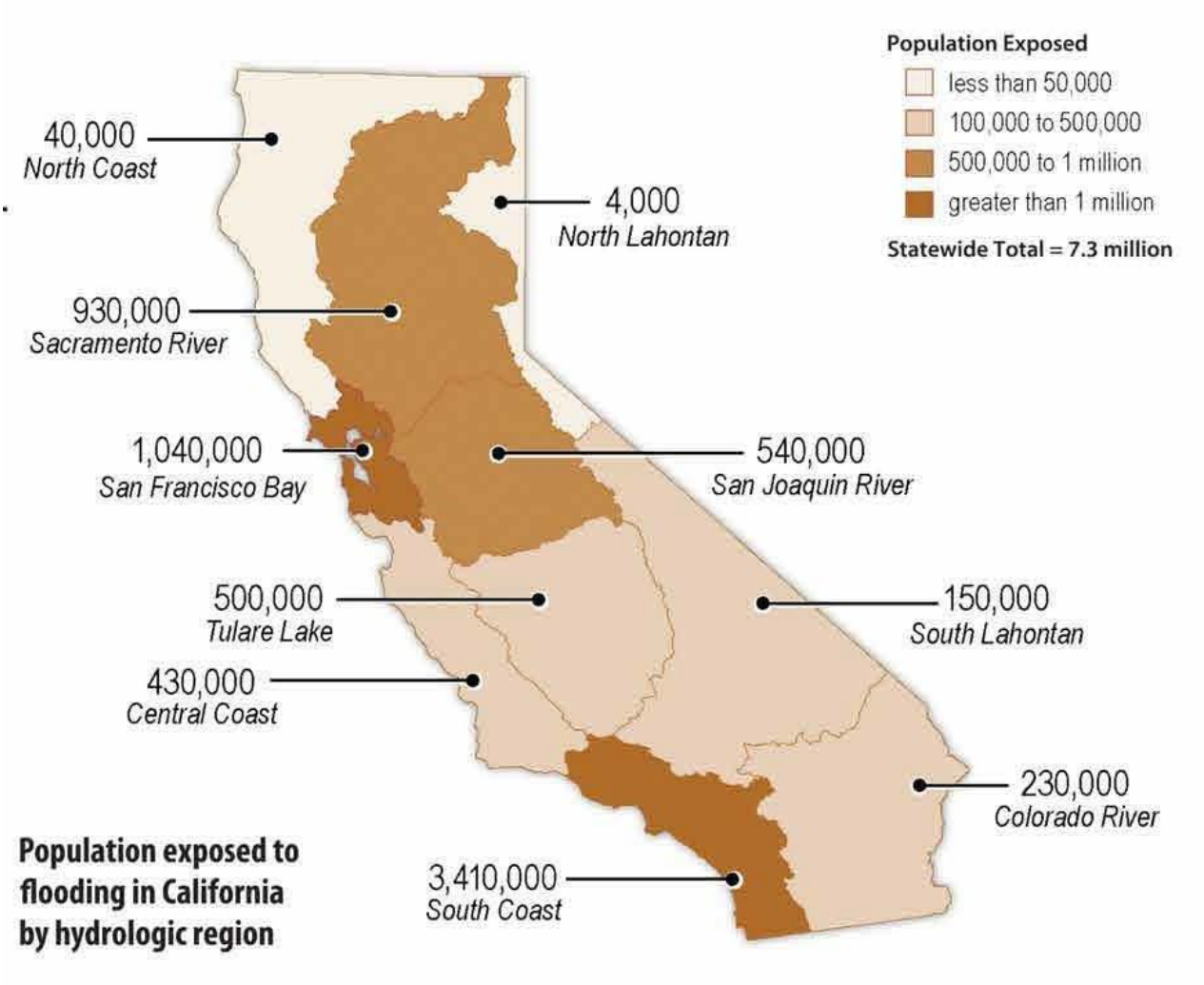
Maps 7.E and 7.F were produced as part of the California's Flood Future Report (discussed in more detail in *Section 7.1.5.2*). Map 7.E shows that one in every five Californians lives in a floodplain (500-year flood zone), and all counties have populations exposed to flooding.

As shown in Map 7.F, the statewide value of structures and contents at risk from a 500-year flood event is more than $575 billion, distributed over all regions. Los Angeles, Orange, and Santa Clara Counties lead the statistics with more than 500,000 persons, and structures and contents worth more than $70 billion, exposed to flooding.

[144] https://www.fema.gov/risk-mapping-assessment-and-planning-risk-map

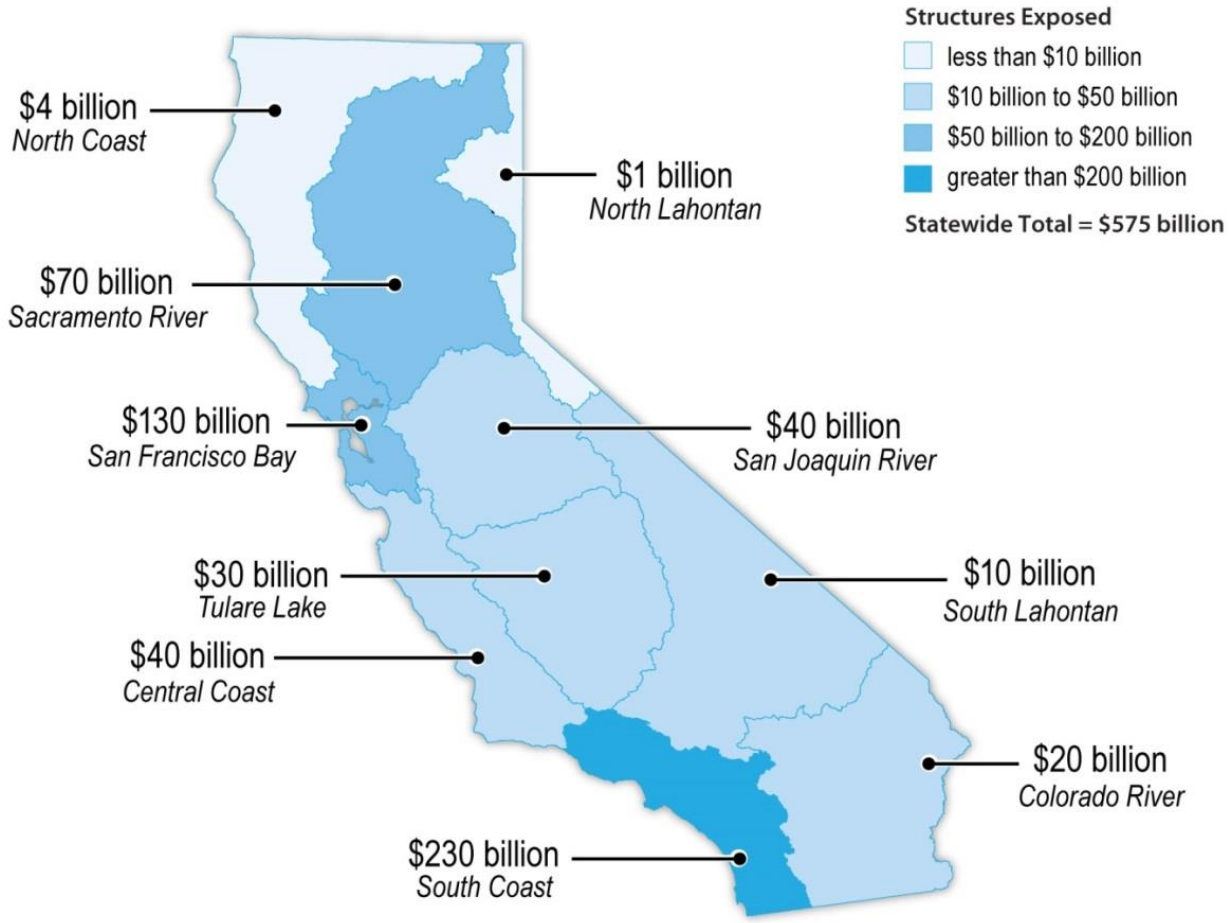
[145] Risk Assessment, Mapping, and Planning Partners (RAMPP), Project Report for Task Order#HSFEHQ-11-J-0002, Analysis and Update of National Flood Hazard Layer Demographics and NFIP Policy and Claims Data, Prepared for FEMA, October 2012.

Map 7.E: Population Exposed to 500-Year Flooding in California by Hydrologic Region



Source: California's Flood Future, http://www.water.ca.gov/sfmp/resources/Highlights_11x17_low_res.pdf

Map 7.F: Structures Exposed to 500-Year Flooding In California by Hydrologic Region



Source: California's Flood Future, http://www.water.ca.gov/sfmp/resources/Highlights_11x17_low_res.pdf

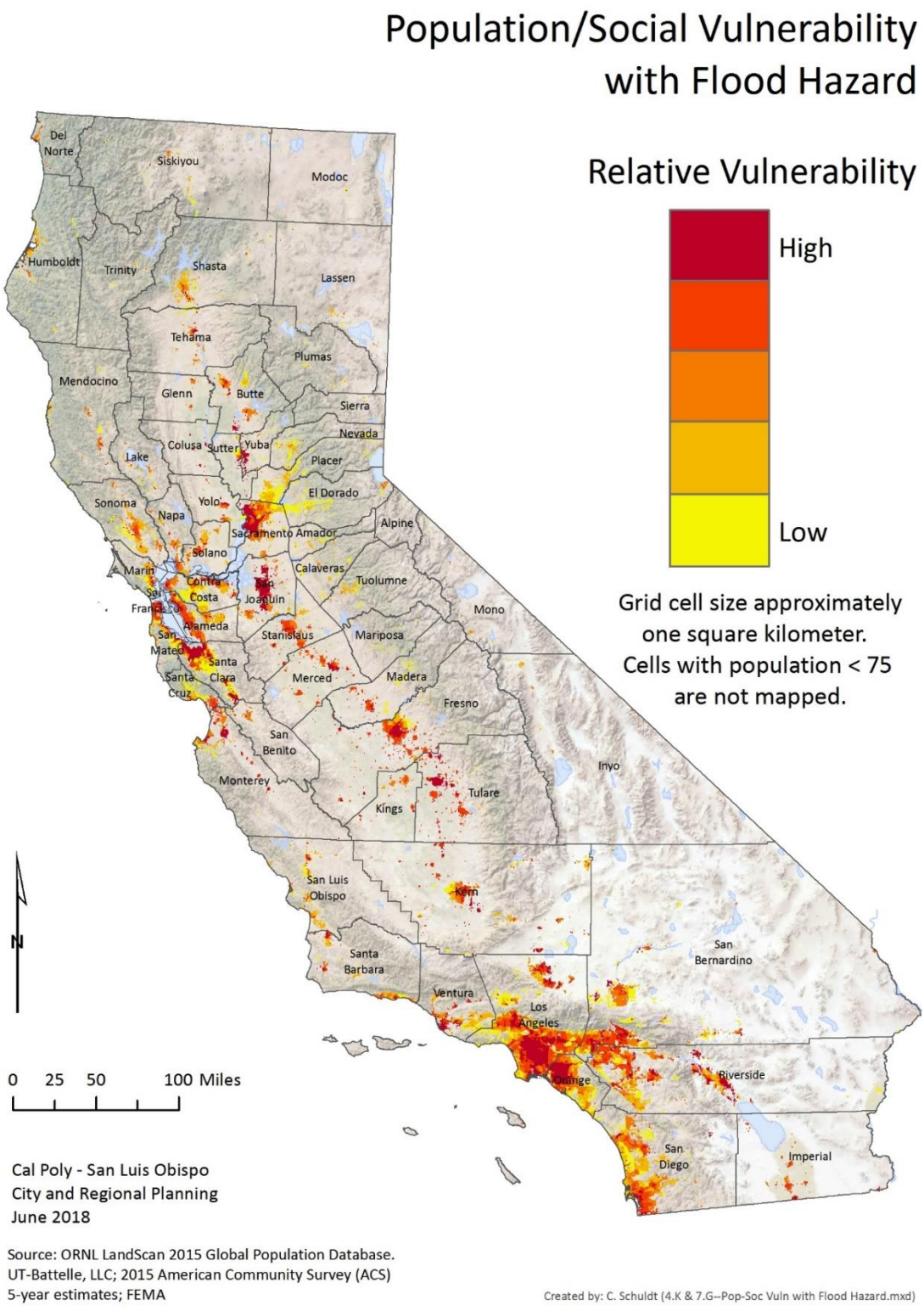
7.1.3.2 FLOOD VULNERABLE AREAS AND POPULATIONS

Flooding in California is widespread and the second most frequent disaster source. Since 1950, floods have accounted for the second highest combined losses and the largest number of deaths.

Like earthquake hazards, flooding disproportionately affects urban areas with high flood hazard potential, because these areas contain larger populations of people who are vulnerable to hazards. By comparison, uninhabited areas with high flood hazard potential are generally less vulnerable. Map 7.G shows high concentrations of socially vulnerable populations in the state's most heavily populated counties of Southern California, the Monterey Bay Area, and the San Francisco Bay Area. The color patterns shown on the map reflect the greater frequency of flooding, combined with greater social vulnerability, in portions of the Central Valley region.

Hurricane Katrina and other recent disaster events have brought to the public's attention the increased vulnerability of groups within the general population that may have fewer or differential access to resources, linguistic isolation, or less mobility than others, resulting in greater vulnerability to hazards events such as earthquakes. For an expanded discussion of social vulnerability, see *Section 4.4*.

Map 7.G: Flood Hazard and Social Vulnerability



Map 7.G shows high concentrations of population/social vulnerability (based on the index described in *Appendix N*) in areas at high risk of flood hazards within low-lying areas spread across the state. Most heavily affected counties are in the San Francisco Bay Area, the Central Valley area, and Southern California.

7.1.3.3 ESTIMATING FLOOD LOSSES TO STATE-OWNED AND LEASED BUILDINGS

Given the size and complexity of California's economy and infrastructure, the challenge of estimating potential dollar losses for state-owned facilities is substantial. As discussed in *Chapter 4*, there are over 20,000 state-owned structures in California, plus several thousand state-leased buildings, with lease terms varying in length. Table 7.B identifies a total risk exposure of $11.62 billion for buildings in areas potentially subject to the 100-year flood (Zone A).

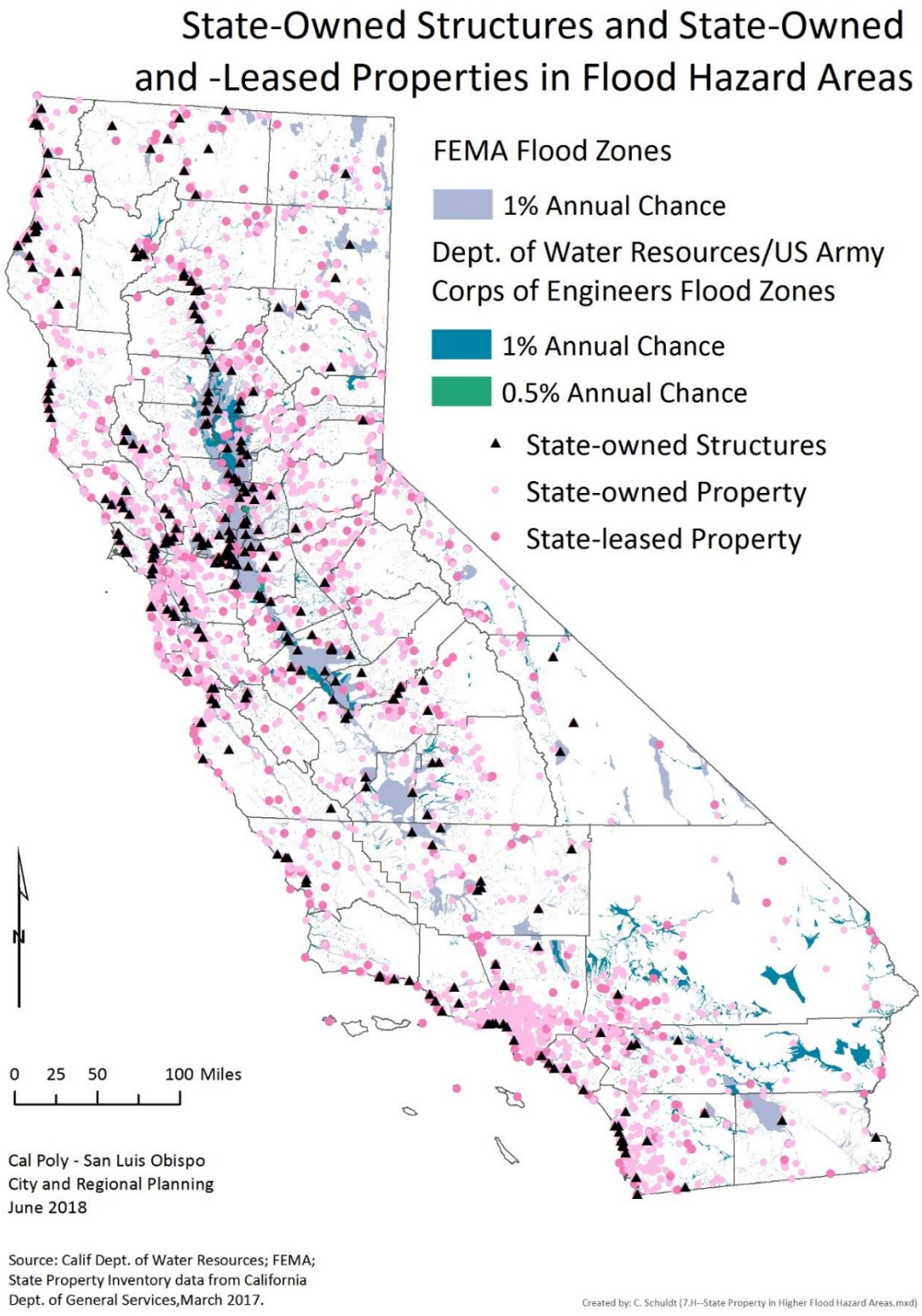
These figures tend to overstate potential losses from this hazard for two fundamental reasons: 1) flood events are centered within one region or another, and 2) only a very small portion of the building inventory within a region affected by heavy flooding would suffer substantial permanent damage.

Table 7.B: Potential Loss of State Facilities from Flood Hazards

	State Ownership Status	Number of Buildings	Square Feet	$ at Risk (billions)
FIRM 100 (Zone A)	Own	1,671	27,553,251	9.64
	Lease	433	5,657,268	1.98
	Total	**2,104**	**33,210,519**	**$11.62**
FIRM 500 (Zone X)	Own	609	5,665,724	1.98
	Lease	218	1,759,612	0.62
	Total	**827**	**7,425,336**	**2.60**
Overall Total Dollar Value at Risk				**$14.22**

Source: Department of General Services, California Governor's Office of Emergency Services (Cal OES)

Map 7.H: State-Owned Buildings in Higher Flood Hazard Areas



Map 7.H shows general locations of state-owned buildings in relation to the 1 percent Special Flood Hazard Area (SFHA) portion of the 100-year floodplain areas.

7.1.4 ASSESSMENT OF LOCAL FLOOD VULNERABILITY AND POTENTIAL LOSSES

This section addresses local flood hazard vulnerability and potential losses based on estimates provided in local risk assessments, comparing those with the state risk exposure findings presented in the GIS analysis in *Section 4.4.4* of *Chapter 4: Profiling California's Setting*.

7.1.4.1 SEVERE AND REPETITIVE FLOOD LOSS

Areas flooded in the past typically continue to be inundated repeatedly. The repetitive nature of flood damage is a cause for concern. FEMA, in coordination with the state, identifies California's top Severe Repetitive Loss (SRL) and Repetitive Loss (RL) counties. According to the University of California Davis Center for Watershed Sciences, in 2016 only 393 of the more than 30,000 RL properties are in California.[146] In 2017, RL counties in California accounted for nearly $30 million in total payments, representing 203 property losses throughout the state.

In 2017, the top 10 RL counties accounted for over 86 percent of total payments for RL counties in the state. Sonoma County is the top-ranking county in California, accounting for more than 48 percent of the total top 10 repetitive losses.

In order of losses, the top 10 Severe Repetitive Loss counties (based on grant funding amounts in 2017) are:

- Sonoma County
- Los Angeles County
- Lake County
- Marin County
- Napa County
- San Diego County
- Sacramento County
- Santa Cruz County
- Orange County
- Ventura County

In order of losses, the top 10 Repetitive Loss counties (based on grant funding amounts in 2017) are:

- Sonoma County
- Sacramento County
- Napa County
- Lake County
- Marin County
- Orange County
- Ventura County
- Santa Cruz County
- Solano County
- Monterey County

Appendices J and K provide details on 2017 losses and funding for the top 10 RL and SRL counties.

Severe and Repetitive Loss Reduction Goals

Goal 2 of the 2018 SHMP seeks to minimize damage to structures and properties. California places high priority on supporting this goal through an objective (2018 SHMP Goal 2, Objective 4) that the state and local jurisdictions use land use, design, and construction policies to facilitate reduction of severe and repetitive property losses.

[146] https://californiawaterblog.com/2016/12/14/california-flood-risk-and-the-national-flood-insurance-program/

Of the over 30,000 repetitive loss properties in the U.S., only about 1 percent are in California. However, California works to prioritize flood mitigation projects that will further reduce incidence of SRL and RL losses. California's 2013 Flood Future, developed by the California Department of Water Resources (DWR) and the U.S. Army Corps of Engineers (USACE), is a comprehensive review of statewide exposure to flood risk and includes specific tools, goals, and strategies to address barriers to improved flood management.

Additionally, Cal OES's State Hazard Mitigation Officer (SHMO) has appointed an SRL point-of-contact person who has created an account on Data Exchange, the Repetitive Loss Database. Cal OES contacts communities with SRL properties informing them of the availability of Flood Mitigation Assistance (FMA) grants and providing guidance regarding requirements. The state coordinates with the communities with the most Severe Repetitive Loss (SRL) properties to encourage them to develop and update their Local Hazard Mitigation Plans (LHMPs). The identified communities are given preference in the award of flood project grants (see *Appendices J and K*).

California is actively pursuing SRL projects to minimize future damages, as evidenced by funding issued up to December 31, 2017. As of that date, Sonoma and Los Angeles were the top SRL counties in California.

Potential Sources of Funding

In addition to receiving FMA, Pre-Disaster Mitigation (PDM), and Hazard Mitigation Grant Program (HMGP) funding, state agency flood hazard projects can be funded by local jurisdictions. County-financed flood control programs, such as Napa County's Living River project, are often funded by special funding mechanisms, such as voluntary local taxation forged through strong community coalitions. California also works to reduce flooding losses through the Community Rating System, building codes, education, and resiliency programs. The result of such efforts allow municipalities to pursue integration flood management projects specific to their local needs. Similar to Napa's efforts, Bay Area voters approved a parcel tax in 2016 to raise $500 million over the next 20 years, as a regional approach to funding sea level rise adaptation projects in the Bay Area.

The State Systemwide Investment Approach (SSIA) includes actions to improve flood protection in urban areas, small communities, and rural-agricultural areas as well as system-wide improvements, with an estimated cost of $14 to $17 billion over 25 years. Examples of a near-term system-wide action are the Yolo Bypass multi-benefit improvements that DWR is implementing. Examples of a near-term urban (regional) action are levee improvements to provide a 200-year level of protection to West Sacramento. Examples of near-term rural and small community (small-scale) actions include levee repairs and levee setbacks. The SSIA portfolio also includes investments in improved flood risk awareness, flood proofing, and land use planning. Map 7.J in *Section 7.1.5.2* shows the geographic scope of the Central Valley Flood Protection Plan (CVFPP).

Revised SSIA cost estimates now range from $17.4 to $21.3 billion, with estimated cost shares among project partners of local (8 percent), state (56 percent), and federal (36 percent). The 2017 Central Valley Flood Protection Plan (CVFPP) update includes policy and funding recommendations to support comprehensive flood management over 30 years. See *Section 7.1.5* for additional information about flood mitigation efforts.

Analysis of Effectiveness

In 2013 and 2014, Sonoma County was awarded over $5 million in two FMA grants to fund flood mitigation elevation projects. The 2013 FMA grant proposed to elevate 12 SRL homes and the 2014 FMA grant proposed to elevate 20 SRL homes. At the time of this writing, both projects are still underway, but Cal OES FMA grants specialists are coordinating with Sonoma County to determine if any preliminary information about project effectiveness is available. Sonoma County was also awarded an HMGP grant of over $660,000 to fund another flood mitigation elevation project in 2015. Work on this project is underway.

The City of Roseville in Sacramento County continues to address flood loss by obtaining PDM grant funding to acquire properties at risk of flooding. This is evidence of Roseville's commitment to addressing flood hazard and as a result of this commitment, the community holds a Community Rating System (CRS) ranking of 1. (For more discussion on the CRS, see *Section 7.1.5.8*.)

Cal OES also conducts assessments of the effectiveness of grant-funded projects through the State Mitigation Assessment Review Team (SMART) system. For more information on this system, see *Section 10.6*.

Prioritization of Funding to Address Repetitive Loss

For information about Cal OES' FMA and PDM program and funding prioritization, see *Section 10.4*. See *Appendix L* to review the PDM/FMA Project Grant NOI Consistency and Subapplication Review and Ranking Checklist with RL and SRL scoring criteria included.

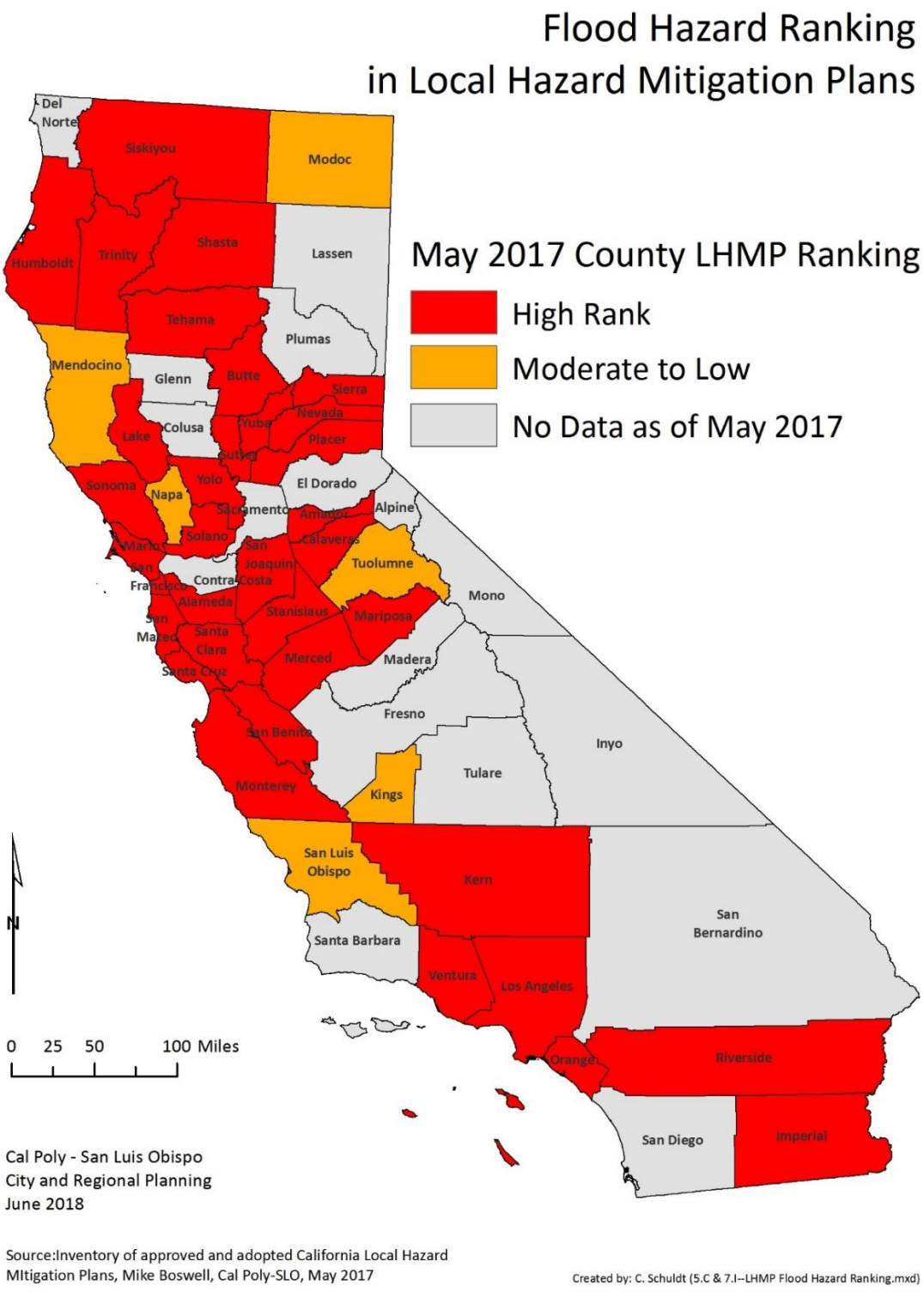
7.1.4.2 LOCAL HAZARD MITIGATION PLAN HAZARD RANKINGS

An important source of local perceptions regarding vulnerability to flood threats is found in the collection of FEMA-approved and adopted Local Hazard Mitigation Plans (LHMPs) adopted by cities, counties, and special districts as of May 2017. The most significant hazards reported in this review are earthquakes, floods, and wildfires—the three primary hazards also identified on a statewide basis by the 2018 SHMP. Including these three primary hazards, LHMPs identified over 25 distinct local hazards.

Map 7.I summarizes relative ratings of flood hazards in the May 2017 review of LHMPs. Displayed are predominant flood hazard rankings shown as high (red) and moderate to low (orange) given by at least 51 percent of the jurisdictions with LHMPs within each county. Counties shown in gray represent either jurisdictions not having a FEMA-approved and adopted LHMP, or counties where data are missing or problematic.

For a detailed evaluation of LHMPs approved as of May 2017, see *Chapter 5, California Local Hazard Mitigation Planning*.

Map 7.I: Flood Hazard Ranking in Local Hazard Mitigation Plans



As shown in Map 7.I, the 2018 LHMP review found that flood hazards are a predominant concern for most Southern California and San Francisco Bay Area counties with approved LHMPs, as well as for some Central Valley and eastern Sierra counties with approved LHMPs.

Implications for Local Loss Potential

Local hazard rankings are highly variable, responding to a wide variety of very specific local conditions. Each county has its own set of variables conditioning flood loss potential within its cities and unincorporated area. Descriptions of loss potential are very specific within individual LHMPs and are not consistently drawn up between plans, nor is there even coverage of all cities and unincorporated areas. Such variability will diminish as more cities and counties prepare LHMPs and greater standardization enables comparability of local data with statewide data.

Comparison with Statewide Vulnerability

Map 7.I reveals that most LHMPs reviewed in 2018 in Southern California, San Francisco Bay Area, and some Central Valley and eastern Sierra counties rated floods high in their hazard rankings. Overall, this finding is consistent with the patterns of flood hazards and the population/social vulnerability patterns identified in *Section 4.4.4* of the Statewide GIS Hazard Analysis presented in *Chapter 4: Profiling California's Setting*.

Robert's Island, San Joaquin County, 1996-97: A home that was required to meet Design Flood Elevation Level

Source: California Governor's Office of Emergency Services (Cal OES)

7.1.5 CURRENT RIVERINE, STREAM, AND ALLUVIAL FLOOD HAZARD MITIGATION EFFORTS

7.1.5.1 LEGISLATION

Following the devastation of Hurricane Katrina, California voters passed the Disaster Preparedness and Flood Prevention Bond Act (Proposition 1E) and the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act (Proposition 84) in November 2006, authorizing the sale of nearly $5 billion in state bonds for flood management improvements throughout the state, with $4.3 billion dedicated for repairs and improvements of flood projects in the Central Valley. Since passage of Propositions 84 and 1E, significant progress has been made in implementing levee improvements and reducing flood risk, especially in urban areas.

Furthermore, in late 2007, the California Legislature passed and the Governor signed five interrelated bills (flood legislation) aimed at addressing the problems of flood protection and liability and helping direct use of the bond funds. These were Senate Bills (SB) 5 and 17, and Assembly Bills (AB) 5, 70, and 156. A sixth bill passed in 2007, AB 162, requires additional consideration of flood risk in local land use planning throughout California.

These bills, effective January 1, 2008, collectively outline a comprehensive approach to improving flood management at the state and local levels. Major components of the 2007 legislation included the following:

- *State Planning Requirements*: The legislation required DWR and the Central Valley Flood Protection Board (CVFPB) to prepare, adopt, and collectively implement a Central Valley Flood Protection Plan (CVFPP) by 2012, then update that plan every five years. The plan must include 1) a description of existing flood risk and facilities within the State Plan of Flood Control (SPFC) area, 2) an evaluation of the improvements necessary to bring SPFC facilities up to current design standards, and 3) recommendations for improving the SPFC's performance that incorporate, wherever feasible, multiple benefits (such as to the ecosystem).

- *Local Planning Requirements*: The legislation required Central Valley cities and counties to 1) develop flood emergency response plans, and 2) amend general plans to conform to the data, policies, and implementation measures included in the CVFPP, including goals and policies intended to protect lives and property and reduce flood risk.

- *Higher Flood Protection Standards*: The legislation established 200-year flood event (a flood with a 1-in-200 or 0.5 percent chance of occurring in any year) as the minimum level of flood protection to be provided for new development in urban and urbanizing areas (i.e., areas with a population of 10,000 or more).

- *Local Zoning and Development Requirements*: The legislation required Central Valley cities and counties to amend their general plans and zoning ordinances to conform to the CVFPP, including prohibiting new development in urban areas not protected up to the 200-year flood standard. Cities and counties in the Central Valley will be required to make findings related to providing the appropriate level of flood protection or making adequate progress to achieve that protection.

- *State Mapping and Notification Requirements*: The legislation required DWR and the CVFPB to: 1) map flood risk areas in the Central Valley, 2) prepare levee flood protection zone maps, and 3) annually notify approximately 280,000 affected property owners that they live in a flood zone protected by a levee.

This flood legislation also links flood liability with local planning decisions. As of January 1, 2008, cities and counties now share flood liability with the state in the case of litigation over unreasonably approved new development in previously undeveloped areas. This requirement does not apply when the city or county has amended its general plan and zoning and otherwise makes land use decisions consistent with the CVFPP.

The State Housing Law Program of the California Department of Housing and Community Development (HCD) continuously refines the building standards to make sure they comply with new or changing laws and regulations

and develops statewide building standards for new construction of hotels, motels, lodging houses, apartments, dwellings, and buildings accessory thereto. The State Housing Law Program also develops the building standards necessary to provide accessibility in the design and construction of all housing other than publicly funded housing. The building standards are published in the California Code of Regulations, Title 24, known as the California Building Standards Code.

Progress Summary 7.A: Flood Laws

Progress as of 2018: Since 2007, multiple bills were passed by the state legislature to clarify certain aspects of the 2007 legislation relative to urban level of flood protection requirements in the Sacramento-San Joaquin Valley. These bills included Assembly Bill (AB) 1965 of 2000, Senate Bill (SB) 1070 of 2010, and SB 200 and SB 1278 and AB 1965 of 2012. AB 1965 amended the definition of adequate progress for urban level of flood protection applications and SB 1070 (2010) clarified the geographic boundaries of the Sacramento-San Joaquin Valley. SB 200 extended the state cost share for the Delta levee maintenance program to "up to 75 percent" of the costs in excess of $1,000 per levee mile.

SB 1278 (2012) and AB 1965 (2012) revised the definition of urban level of flood protection and modified the dates and timeframes for general plan amendments (July 2, 2015) and zoning ordinance updates (July 2, 2016) originally established in SB 5.

The California Department of Water Resources (DWR) has prepared three documents to inform the public and assist local governments with implementation of the legislative requirements:

DWR's 2007 California Flood Legislation Summary
This booklet provides the public with a better understanding of the roles and responsibilities of government agencies as they implement the requirements of this legislation. This booklet can be found at: http://www.water.ca.gov/legislation/2007-summary.pdf.

DWR's 2007 California Flood Legislation Companion Reference
This document is a companion to the 2007 Flood Legislation Summary that provides a listing of the code sections referenced in the flood legislation, including amendments and deletions. This booklet can be found at: http://www.water.ca.gov/legislation/2007-reference.pdf.

Local Land Use Planning: Handbook for Communities Implementing Flood Legislation - October 2010
This guidance handbook describes the new legislative requirements that affect city and county local planning responsibilities such as general plans, zoning ordinances, development agreements, tentative maps, and other actions. This handbook can be found at: http://www.water.ca.gov/floodmgmt/lrafmo/fmb/docs/Oct2010_DWR_Handbook_web.pdf.

For additional information regarding specific provisions of the aforementioned legislation, see *Annex 1, Guide to California Hazard Mitigation, Laws, Policies, and Institutions*.

7.1.5.2 FLOOD MANAGEMENT SYSTEM

Flood Management System Planning and Programs

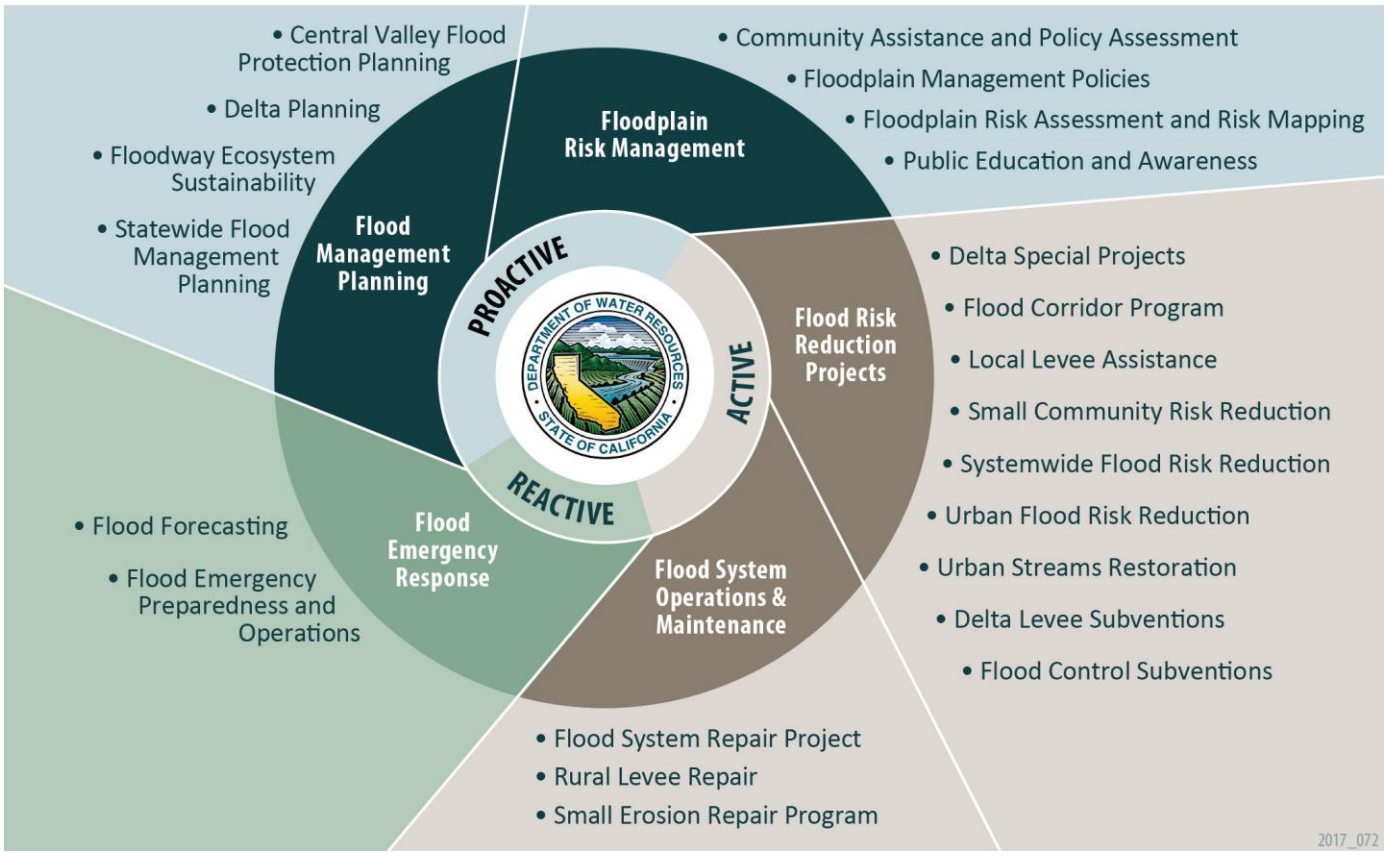
Since 2007, Propositions 1E and 84 have provided essential funding to improve flood management across the state and heighten awareness of California flood risks. Funding from these bond laws, leveraged by local and federal resources, has allowed DWR to initiate major programs to reduce flood risk in the state's communities

In addition, the funds have supported foundational work, including data collection, tools development, system evaluations, and engineering studies to identify problem areas and the improvements needed to enhance flood safety.

Progress Summary 7.B summarizes the various California flood management programs. Detailed information on accomplishments of those programs is provided in the text following the progress summary.

Figure 7.B provides a graphical representation of the inter-relationships among the flood management programs.

Figure 7.B: Inter-Relationships Among California's Flood Management Programs



Source: Central Valley Flood Protection Plan, 2017 Update.

Progress Summary 7.B: California's Flood Management Programs within the Flood Management System

Progress as of 2018: Ongoing progress in statewide floodplain management is reflected in the following significant program areas.

Flood Management Planning
These programs formulate strategies, plans, and investment priorities for implementing statewide and regional flood management projects. The two key programs are the Central Valley Flood Management Planning Program and the Statewide Flood Management Planning Program.

Floodplain Risk Management
These programs promote sound floodplain management to reduce flood risks by working closely with local agencies as well as federal agencies. Policies, guidance documents, and technical products—e.g., flood inundation models—are developed to assist communities with their strategies to manage floodplains. This area supports an additional element of successful floodplain risk management: educating the public about flood risks so people can plan, prepare, and take individual actions to reduce flood risks themselves, their families, and their property.

Flood Risk Reduction Projects
These programs coordinate with local and federal agencies to implement new flood projects; provide funding that enables local agencies to repair and improve levees and other flood management facilities statewide; provide advanced mitigation for the State Plan of Flood Control (SPFC) to aid project delivery; and enhances ecosystems associated with the flood system. A primary responsibility is to work closely with the U.S. Army Corps of Engineers (USACE), Central Valley Flood Protection Board (CVFPB), and local agencies to improve performance of SPFC facilities, as well as the Folsom Dam Joint Federal Project.

Flood System Operations and Maintenance
These programs focus on maintaining levees, pumping plants, bridges, channels, and hydraulic structures—e.g., weirs, outfall gates—to continue achieving the risk reduction benefits the SPFC was designed to provide. Local agencies carry out most of the SPFC by managing the levees and facilities for which they are responsible, while the state is required to operate and maintain those portions of the SPFC identified in California Water Code. Local agencies and the state work closely with the CVFPB, USACE, and environmental resource agencies to ensure that operation and maintenance activities promote public safety, environmental stewardship, and economic stability.

Flood Emergency Response
These programs prepare for and respond to flood threats in close coordination with local, state, and federal entities. Preparing for flood response requires continuous data collection, regular flood system inspections and evaluations, forecasts and information dissemination, annual training and exercises, preseason coordination, and replenishment of supplies and equipment.

Flood Management System: Flood Management Planning

As of 2017, work continues on two major planning efforts that will guide future state investments in both regional and statewide flood management planning activities: the Central Valley Flood Management Planning Program and the Statewide Flood Management Planning Program.

Central Valley Flood Management Planning Program

The Central Valley Flood Protection Plan (CVFPP) has guided the state's participation in managing flood risk in areas protected by the State Plan of Flood Control (SPFC) since the SPFC's adoption in 2012 pursuant to the Central Valley Flood Protection Act of 2008.

The primary goal of the CVFPP is to improve flood risk management, with supporting goals to improve operations and maintenance; promote ecosystem functions; improve institutional support, and promote multi-benefit projects.

The CVFPP is a strategic, long-range plan, and its five-year updates describe a programmatic vision for flood system improvements over time and across the Central Valley at different scales:

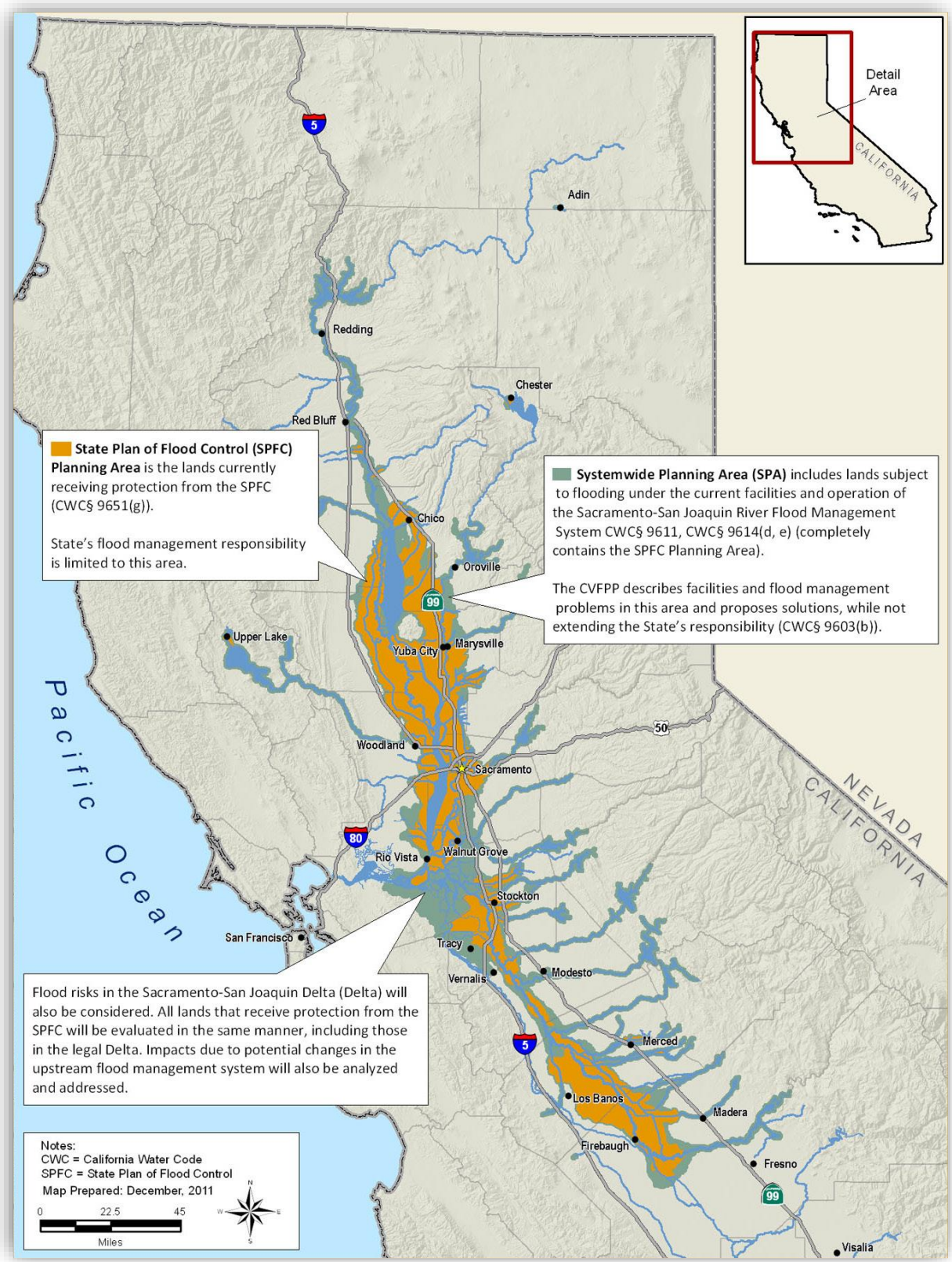
- *System-wide or large-scale:* This scale encompasses multiple regions and/or land use types up to the full extent of the flood management system in the Central Valley.
- *Regional or medium-scale:* This is the general scale of regions defined through regional flood management planning efforts according to delineation by hydrologic and administrative boundaries.
- *Small-scale:* This scale applies to local areas of limited geographic extent.

The 2012 CVFPP recommended a State Systemwide Investment Approach (SSIA), which included actions to improve flood protection in urban areas, small communities, and rural-agricultural areas as well as systemwide improvements with an estimated cost of $14 to $17 billion over 25 years. The 2012 CVFPP also recommended three major planning efforts to inform the 2017 CVFPP update:

- State-led Sacramento and San Joaquin basin-wide feasibility studies
- Six locally-led regional flood management planning studies (that involved more than 180 local entities)
- A conservation strategy

Map 7.J shows the geographic scope of the Central Valley Flood Protection Plan (CVFPP).

Map 7.J: Geographic Scope of Central Valley Flood Protection Plan



Progress Summary 7.C: Central Valley Flood Management

Progress as of 2018: Based on the results of these additional planning studies and other technical information, the 2017 Central Valley Flood Protection Plan (CVFPP) update developed a refined State Systemwide Investment Approach (SSIA) portfolio of recommended management actions that can be implemented over the near term (next 10 years) and longer term.

Examples of a near-term system-wide action are the Yolo Bypass multi-benefit improvements, which are being implemented by the California Department of Water Resources (DWR). Examples of a near-term urban (regional) action are levee improvements to provide a 200-year level of protection to West Sacramento. Examples of near-term rural and small community (small-scale) actions include levee repairs and levee setbacks. The portfolio also includes investments in improved flood risk awareness, flood proofing, and land use planning. Map 7.J shows the geographic scope of the CVFPP. Revised SSIA cost estimates now range from $17.4 to $21.3 billion, with estimated cost shares among project partners of local (8 percent), state (56 percent), and federal (36 percent). The 2017 CVFPP update includes policy and funding recommendations to support comprehensive flood management over 30 years.

Consistent with the state's climate change policies, the CVFPP has used a multi-phased approach to incorporate the latest science and data. For the 2017 CVFPP update, 2013 global climate models and 200 independent climate projections were used. Climate change is expected to contribute to an increase in the number of extreme weather events; generate more extreme floods, more seasonal rain, and less snow; raise sea levels; and increase stress on the flood management system. Results from these climate change analyses were incorporated into existing hydrologic and flood risk analyses.

More information on the CVFPP can be found at: https://water.ca.gov/Programs/Flood-Management/Flood-Planning-and-Studies/Central-Valley-Flood-Protection-Plan.

Progress Summary 7.D: Regional Flood Management Planning

Progress as of 2018: Following the Central Valley Flood Protection Board (CVFPB) adoption of the 2012 Central Valley Flood Protection Plan (CVFPP), the California Department of Water Resources (DWR) launched and funded a regionally led effort to help local agencies develop comprehensive plans that describe local flood management priorities, challenges, and potential funding mechanisms and define site-specific improvement needs.

Six Regional Flood Management Plans (RFMPs) were completed for regions in the Central Valley by 2015 and subsequently reviewed by DWR in support of the development of the 2017 update of the CVFPP. Each RFMP addressed operations, maintenance, repair, rehabilitation, and replacement; infrastructure performance; emergency management, governance; environmental compliance; regional priorities; and funding.

Together, the six RFMPs identified over 500 management actions totaling an approximate cost of $14 billion throughout the Central Valley. Despite being constrained to using existing information without new analyses or investigations, the RFMPs represent the most comprehensive thinking about local flood management challenges and opportunities and illustrate a breadth of potential flood management investments.

In addition to providing funding for the effort, DWR closely collaborated with the six regions during the development of the 2017 update of the CVFPP to reflect the contents of the RFMPs at a system-wide level. The RFMPs provided a platform for meaningful engagement and resulted in an unprecedented partnership and coordination among DWR and local and regional flood planning entities across the Sacramento River and San Joaquin River basins. DWR anticipates continuing partnership and coordination with the regions following CVFPB adoption of the 2017 CVFPP update.

For more information regarding regional flood management planning, visit: https://www.water.ca.gov/Programs/Flood-Management/Flood-Planning-and-Studies/Central-Valley-Flood-Protection-Plan.

Statewide Flood Management Planning Program

The purpose of the Statewide Flood Management Planning Program is to increase understanding of statewide flood risk, make recommendations for managing flood risk, and inform decision-makers about flood management policy and investments. In addition, the program coordinates with local, state, and federal agencies.

The Statewide Flood Management Planning Program has coordinated with the California Water Action Plan (2014 and 2016 updates), provided flood management and investment content for the California Water Plan Update 2013, coordinated and aligned content with the 2017 CVFPP update, and developed the "California's Flood Future: Recommendations for Managing the State's Flood Risk" report (2013). These documents underscore a deep commitment to the principles of Integrated Water Management (IWM).

Progress Summary 7.E: Statewide Flood Management

Progress as of 2018:

California Water Action Plan (CWAP)

In 2014, Governor Jerry Brown declared a drought emergency and issued the California Water Action Plan, which the 2017 Central Valley Flood Protection Plan (CVFPP) update and other California Department of Water Resources (DWR) programs must support. The California Water Action Plan was updated in 2016. The plan emphasizes operational and regulatory efficiency as well as sustainable and integrated funding opportunities. With regard to flood management specifically, the plan describes actions for increasing flood protection and the need for flood management projects to employ an integrated approach at a regional scale to achieve multiple benefits.

More information on the California Water Action Plan can be found at: http://resources.ca.gov/california_water_action_plan/.

California Water Plan Update (2013 CWP)

The 2013 California Water Plan Update focused on three themes: Integrated Water Management (IWM), government agency alignment, and investment in innovative and infrastructure. With regard to flood management specifically, the California Water Plan Update focuses on four general approaches: non-structural, restoration of natural floodplain functions, structural, and flood emergency management. More information on the California Water Plan Update can be found at: https://www.water.ca.gov/Programs/California-Water-Plan.

California's Flood Future: Recommendations for Managing the State's Flood Risk (California's Flood Future)

The 2013 "California's Flood Future" report provided the first comprehensive look at statewide exposure to flood risk and outlined seven recommendations for improved statewide flood risk management. Developed through a partnership between DWR and the U.S. Army Corps of Engineers (USACE), it included cooperation and information provided by more than 140 local agencies throughout California, as well as state and federal agencies. "California's Flood Future" found that more than seven million people and $580 billion in assets (crops, buildings, and public infrastructure) are exposed to flood hazards in California. It identified the immediate need for more than $50 billion to complete flood management improvements and projects statewide (including the needs identified by the 2012 CVFPP). Further, it estimated that significant additional funding—approximately $100 billion in additional capital improvements—is needed for flood management improvements and projects.

"California's Flood Future" concludes with seven recommendations for state and federal government assistance to reduce risk and consequences of flooding, provide flood risk information for policy-maker and public decisions, protect ecosystems, preserve floodplain functions, deliver multiple project benefits, improve flood management governance, identify statewide investment priorities, and provide sufficient and stable funding for flood management:

1. Conduct regional flood risk assessments to help local governments make informed decisions on land use, emergency response, ecosystem functions, and flood management projects. Strategies include identifying standard risk evaluation methods for each region, assisting local determination of risk reduction goals and acceptable residual risk, identifying opportunities to restore or maintain natural systems, and assisting local assessment of impacts of climate change and sea-level rise.

2. Increase public and policymaker awareness about flood risks to engender local, state, and federal government support for flood risk reduction actions, voter support for flood risk reduction funding, and resident support for flood preparedness efforts. For this effort state and federal government should provide consistent language and outreach program tools for increasing public awareness, provide online catalogued information about flood risk programs, grants, and related topics, promote the availability of this information, and share research data.
3. Increase support for flood emergency preparedness, response, and recovery programs to provide effective and comprehensive emergency preparedness, response, and recovery. State and federal strategy will be to provide funding and support for increased coordination, develop or improve Emergency Management Plans, conduct emergency exercises statewide, increase local participation in flood fight training, and identify data and forecasting needs.
4. Encourage land use planning practices that reduce the consequences of flooding to reduce risk to people, property, and economies in floodplains. Strategies include working with land use professionals to develop planning principles facilitating determination of flood risk, facilitating regular coordination at all levels, and linking flood project funding to use of best floodplain management practices.
5. Implement flood management from regional, system-wide, and statewide perspectives to provide multiple benefits through use of Integrated Water Management (IWM). The approach would be to identify regional flood planning areas consistent with watersheds, agency jurisdictions, and existing Integrated Regional Water Management Plan funding areas. (Integrated regional water management is the application of IWM principles on a regional basis.)
6. Increase collaboration among public agencies to foster innovative solutions, improve planning and permitting, develop high-value multiple-benefit projects, and prioritize investment needs. Strategies would be to establish regional working groups that focus on planning and implementing flood management projects, provide funding and credit for regional planning directed toward multiple-benefit or watershed-based projects, and develop a method of prioritizing and implementing flood management investments.
7. Establish sufficient and stable funding mechanisms to reduce flood risk, eliminate the backlog of identified but unfunded projects, and avoid much larger future costs for flood recovery. State and federal agencies should assess the applicability of potential funding sources, propose new funding options, develop a catalog to improve local access to information on state and federal funding sources, and increase funding for regionally based IWM flood management projects.

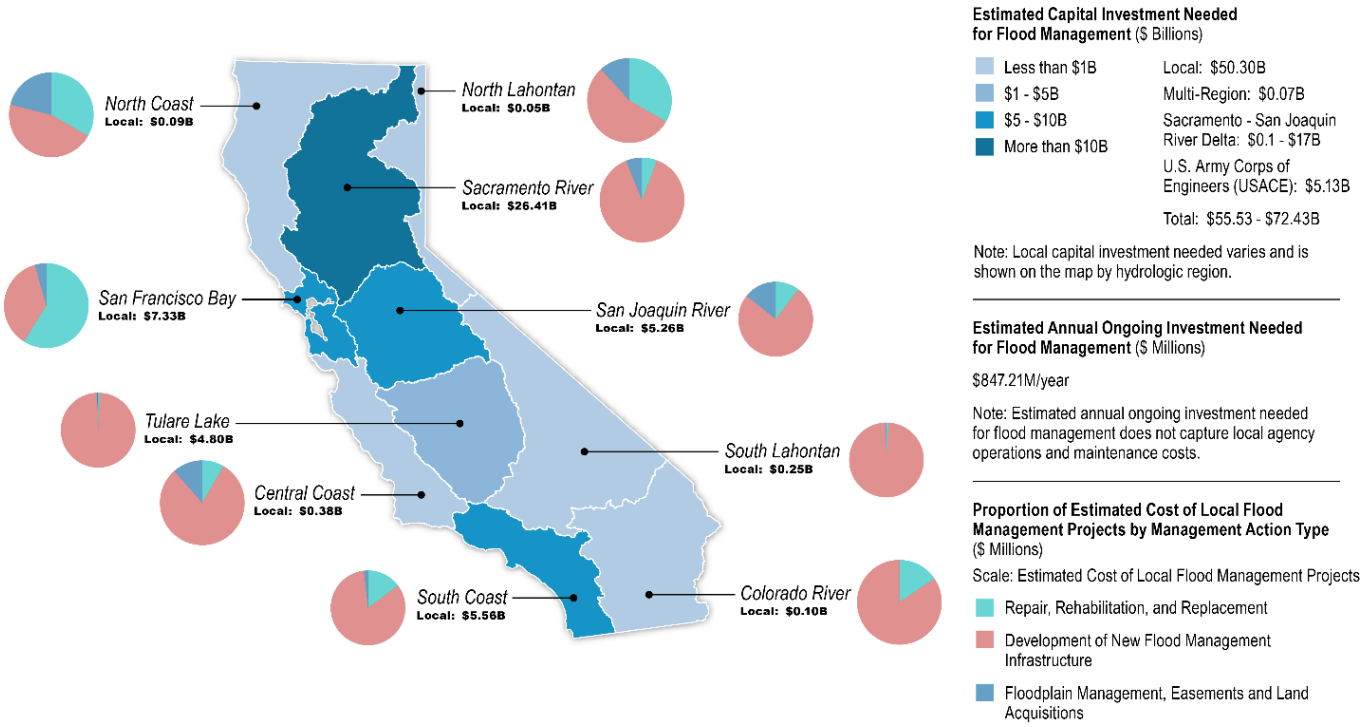
Building upon "California's Flood Future", DWR is developing a new report "Investing in California's Flood Future: An Outcome-Driven Approach to Flood Management." This new report will expand understanding related to all of the recommendations from "California's Flood Future", while describing the investment levels required to achieve the intended outcomes necessary to move the state's flood management system toward sustainability. Supporting documents for this new report will focus on establishing sufficient and stable funding mechanisms to reduce flood risk, and evaluating how public understanding of flood risk regulatory and environmental compliance processes, and agency alignment affect funding for flood management. "Investing in California's Flood Future" also outlines an outcome-driven approach for flood management.

As part of "Investing in California's Flood Future", more than 240 public agencies responsible for flood management in California were interviewed. This information gathering effort identified flood risk reduction opportunities for operations, maintenance, and capital improvements, including more than $72 billion for proposed capital flood risk reduction management actions and more than $845 million per year for ongoing flood risk reduction management action in California, as shown in Figure 7.C. Over the next decade, investments should focus on high-priority actions, such as:

- Institutional capacity, baseline operations, and routine maintenance
- Floodproofing, risk awareness, planning, studies, and mapping
- Maintenance, repair, rehabilitation, and replacement of existing infrastructure
- Development of new flood management infrastructure

More information on *California's Flood Future* can be found at: https://www.water.ca.gov/Programs/Flood-Management/Flood-Planning-and-Studies.

Figure 7.C: Flood Risk Reduction Opportunities in California



Source: Investing in California's Flood Future: An Outcome-Driven Approach to Flood Management

Flood Management System: Floodplain Risk Management

Floodplain risk management programs, with the help of government partners, develop guidance and technical tools that promote sound floodplain management to reduce the risk of flooding and educate the public about flood risk. These activities occur at a regional or statewide scale.

Through FEMA's Community Assistance Program, DWR provides technical assistance to communities participating in the National Flood Insurance Program (NFIP). This technical assistance includes about 31 Community Action Visits per year to local communities, 12 workshops, and 3,000 to 4,000 hours of technical assistance to agencies and individuals. This assistance provides support for these communities in making wise land use decisions in floodplains, which reduces flood risk and preserves the beneficial uses of floodplains (e.g., groundwater recharge, native species habitat).

Additionally, in order to geographically identify population and assets at risk from flooding, DWR has invested in several floodplain mapping efforts, including in the Central Valley, at the coast, and in alluvial fans statewide. As a result, extensive mapping and hydraulic analyses have been provided for areas protected by the SPFC, high-resolution imagery has been developed for the California coastal shoreline, and maps characterizing the geologic conditions of California's alluvial fans are available.

Flood forecasts have greatly improved California's climate data collection and evaluation, and warning efforts. Information is shared and exchanged with local, state, and federal partners and the public through the California Data Exchange Center (CDEC).

Floodplain risk management projects and programs include the following:

- Local agencies and the USACE were actively involved in DWR's evaluation of 1,914 miles of levees in urban and non-urban communities, ensuring that all partner agencies agreed on evaluation criteria and findings.

- Levee evaluation processes, analyses, reports, and points of interest are available online at a single website (http://www.dwr-lep.com/auth) for partner agencies and the public, providing easier access to this information.

- The 200-year flood information maps released in 2013 help protect over 1 million Californians and provide the technical information that urban areas require to incorporate flood management into their general plans.

- The state's first-ever high-resolution imagery of 6,145 miles of California's coast provides a tool that can lead to consistent regulatory guidance for coastal communities. This imagery can streamline identifying sensitive ecological habitats as well as approximately $40 billion in assets along the coast.

- High-resolution maps of 35,000 square miles in 10 Southern California counties help identify potential flood risk for local communities.

- Preliminary 100-year flood hazard maps developed for alluvial fan areas in Riverside and Ventura Counties can be used by local agencies to help protect the public from the flashy and unpredictable flood flows typical of alluvial fans.

- Incoming atmospheric rivers can be tracked and the amount of moisture moving into the state quantified, so state, federal, and local agencies can inform the public about potentially destructive storms in advance of their arrival.

- Information exchanged through CDEC is essential for flood management operations and effective management of hydroelectric power generation, water supplies for irrigation, municipal and industrial uses, and environmental requirements.

- Forecasts produced by DWR are used by regulatory agencies and most water suppliers to set standards statewide, as well as to determine water allocations affecting most Californians.

Flood Management System: Flood Risk Reduction Projects

Flood risk reduction projects provide funding, direction, and oversight for repairing and improving flood management facilities to reduce flood risk, using both structural and nonstructural methods. Major activities include: planning, design, and overseeing construction of flood management projects sponsored by the Central Valley Flood Protection Board (CVFPB), local agencies, and the USACE for the SPFC, as well as locally led flood management projects statewide and in the Delta.

The program includes projects that provide advance environmental mitigation for the SPFC to aid project delivery and enhance ecosystems associated with the flood system. The following projects and programs further flood mitigation efforts through inter-agency, and state and local, collaborative efforts:

- *South Sacramento Streams:* This project increases flood protection from a 50-year level to greater than a 100-year level of protection for approximately 70,000 people and a billion dollar worth of infrastructure, including a wastewater treatment plant and transportation corridors. The project will provide financial relief to property owners paying high-cost flood insurance. Partners for this project include the USACE, DWR, Central Valley Flood Protection Board, Sacramento Area Flood Control Agency, City of Sacramento, and County of Sacramento. More information on this project can be found at: http://www.safca.org/Programs_SoSacStreams.html.

- *American River Watershed Project (includes Folsom Dam Joint Federal Project, American River Common Features, and Natomas Basin):* The new auxiliary spillways at Folsom Dam will improve the ability of the dam to manage large flood events by allowing more water to be safely released in advance of a major storm event, resulting in more storage capacity remaining in the reservoir to hold back peak inflow for later use. Fish and other species will benefit from more consistent flows. The project provides at least a 200-year level of protection for 350 square miles of the greater Sacramento area.

More information on this project can be found at: http://www.spk.usace.army.mil/Portals/12/documents/civil_works/CommonFeatures/ARCF_GRR_Final_EIS-EIR_Jan2016.pdf.

- *Urban Flood Risk Reduction:* The DWR Urban Flood Risk Reduction Program was created to address state investment priorities for urban areas. The program supports the implementation of regional flood damage reduction projects for urban areas in the Sacramento and San Joaquin Valleys protected by the State Plan of Flood Control (SPFC). All projects are designed to achieve protection from a 200-year flood. The program works with urban local agencies to plan, design, and construct flood risk reduction projects. Funding for these projects is provided through Proposition 1E. Projects supported by the program, as of late 2017, include the Sutter Butte Flood Control Agency, Sacramento Area Flood Control Agency, San Joaquin Area Flood Control Agency, West Sacramento Area Flood control Agency, Three Rivers Levee Improvement Authority, City of Lathrop, City of Woodland, and RDs 537, 785, and 827 (Lower Elkhorn Basin). Total funding for these projects is about $566 million.
  More information on Urban Flood Risk Reduction Program can be found at: https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Urban-Flood-Risk-Reduction.

- *Yuba Feather Flood Protection:* The primary objective of this DWR program is to provide support to local agencies to reduce flooding and improve public safety. The program offers financial assistance to flood projects within the areas of the Yuba, Feather, and Bear Rivers, as well as Colusa Basin Drain. The program supports feasibility, design, and construction projects.

- *Flood Control Subventions:* This DWR program provides cost-share financial assistance to non-federal partners of federally authorized projects generally located outside of the Central Valley.
  More information on this program can be found at: https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Flood-Control-Subventions-Program.

- *Urban Streams Restoration:* This DWR program provides grants to local communities for projects that reduce flooding and erosion and associated property damage; restore, enhance or protect the natural ecological values of streams; and promote community involvement, education, and stewardship.
  More information on this program can be found at: https://water.ca.gov/Programs/Integrated-Regional-Water-Management/Urban-Streams-Restoration-Program.

- *Small Communities Flood Risk Reduction Program:* Created as a result of the adoption of the 2012 Central Valley Flood Protection Plan (CVFPP), the Small Communities Flood Risk Reduction Program is a local assistance program whose objective is to reduce flood risk for small communities protected by State Plan of Flood Control (SPFC) facilities, as well as for legacy communities. The Program provides State funding assistance to small communities with 200 to 10,000 residents that are protected by the SPFC, as well as to Legacy communities.

- *Flood Corridor Program:* This DWR program provides cost-share grants to local agencies and non-profit organizations throughout the state for multi-benefit projects that reduce flood risk by restoring natural floodplains and reconnecting rivers and streams to their historic floodplains.

  The Flood Corridor Program includes three flood protection grant programs:
  - Flood Protection Corridor Program authorized and funded under Propositions 13 and 84
  - Floodway Corridor Program authorized and funded under Proposition 1E
  - Central Valley Nonstructural Grants Program authorized and funded under Proposition 1E

  Any local agency or non-profit organization with interest in flood management issues is eligible to sponsor projects under Flood Corridor Program that seek to acquire, restore, enhance, and protect real property for the purposes of flood control protection and agricultural land preservation and/or wildlife habitat protection. This includes California Native American Tribes that are registered as a non-profit organization or that partner with

a non-profit or local public agency. Sponsoring agencies or other organizations that meet the criteria can partner with other types of agencies and organizations, as necessary, to ensure diverse funding sources and necessary expertise on the project team.

Fundable activities under the Flood Corridor Program include:

- Non-structural flood damage reduction projects within flood corridors
- Acquiring real property or easements in a floodplain
- Acquiring and removing of structures from flood-prone areas
- Setting back existing flood control levees or strengthening or modifying existing levees in conjunction with levee setbacks
- Preserving or enhancing flood-compatible agricultural use of real property
- Preserving or enhancing wildlife values of real property through restoration of habitat compatible with seasonal flooding
- Repairing breaches in the flood control systems, water diversion facilities, or flood control facilities damaged by a project developed pursuant to Chapter 5, Article 2.5 of the Clean Water, Watershed Protection and Flood Protection Act of 2000
- Establishing a trust fund for up to 20 percent of the money paid for acquisitions to generate interest in maintaining the acquired lands
- Paying the costs associated with the administration of projects

Funding under this program is intended to be used for acquisition, restoration, enhancement, and protection of property while preserving agriculture and enhancing wildlife habitat in and near flood corridors. More information on this program can be found at: https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Flood-Corridor-Program.

Flood Management System: Flood System Operations and Maintenance

This DWR program operates, maintains, and repairs specific levees, channels, weirs, gates, pumping plants, and bridges of SPFC facilities. Operation and maintenance of the SPFC is the joint responsibility of DWR and local maintaining agencies. The program is responsible for maintaining approximately 300 miles of SPFC levees and all Sacramento River SPFC channels. Local maintaining agencies are responsible for the remaining levees, as well as San Joaquin River SPFC channels. Flood system operations and maintenance projects and programs include:

- *Flood control facilities evaluation and rehabilitation:* This program evaluates, operates, maintains, and repairs SPFC facilities including 11 weirs, 5 gate structures, 13 pumping plants, and specific bridges associated with the SPFC.
- *Channel evaluation and rehabilitation:* This program operates, maintains, and repairs approximately 1,200 miles of SPFC channels. Specific activities include inspecting and evaluating channels and developing and using hydraulic models to identify areas within channels that require sediment or vegetation removal to maintain channel capacity and functionality.
- *Levee operations and maintenance components:* This program focuses on ongoing maintenance of specific levee structures in the SPFC to help ensure these levees will perform satisfactorily during high water events.

More information of these projects and programs can be found at: https://www.water.ca.gov/Programs/Flood-Management.

Flood Management System: Flood Emergency Response

This DWR program includes annual training; proactive preseason coordination with cooperating agencies; annual review; replenishment of supplies, thorough documentation; dedicated data collection and information dissemination; and continued efforts to improve all aspects of emergency response program performance. The program conducts functional exercises within DWR and joint exercises with local, state, and federal agencies and supports local preparedness efforts.

DWR's flood emergency response effort also provides information about the integrity of SPFC levees, channels, and structures through coordination and collaboration with local maintaining agencies and the Central Valley Flood Protection Board (CVFCB). This information improves DWR's ability to annually assess the integrity of the SPFC. The data provides valuable information for use by emergency responders and local levee maintaining agencies, as well as for flood system repair and enhancement.

The storm events of January and February 2017 caused widespread damage to a number of levees in the State Plan of Flood Control (SPFC). As described in the Central Valley Flood Protection Plan (CVFPP), local maintaining agencies and DWR, along with the U.S. Army Corps of Engineers (USACE), are responsible for maintaining the integrity of the SPFC levees, bypasses, and other facilities to continue to protect California's Central Valley. In 2017, DWR repaired 30 sites and the USACE repaired 22 sites. Additional sites are anticipated to be repaired in 2018.

Specific flood emergency response projects and programs include:

- *Hydro-climate data collection and precipitation runoff forecasting:* This program provides real-time data collection and dissemination through DWR's California Data Exchange Center (CDEC) and predicts the annual amount of runoff from Sierra snowpack that has direct implications for the state's water supply. Information collected by DWR and its partners and exchanged through CDEC is essential for flood management operations and effective management hydroelectric power generation, water supplies for irrigation, municipal and industrial uses, and environmental requirements. Forecasts produced by DWR are used by regulatory agencies and most water suppliers to set standards, as well as to determine water allocations affecting most of the population in California.

- *Real-time conditions status and warning:* This program inspects SPFC facilities to assess maintenance practices, assesses and documents the integrity and vulnerabilities of the SPFC, and provides a centralized database to store, process, and exchange real-time hydrologic information gathered by DWR inspectors and various partners throughout the state. CDEC also provides flood system conditions data and, historical information, and serves as the backbone for flood emergency response for local, state, and federal partners.

- *River forecasting and reservoir operations:* In collaboration with the National Weather Service (NWS) and the California-Nevada River Forecast Center, this program provides year-round daily forecasts of reservoir inflows, river flows, and water levels throughout California and much of Nevada. These forecasts are used by emergency responders to anticipate and prepare for flood conditions. During high water events, federal and state river forecasters work around the clock to monitor real-time changes in the larger rivers and estuaries of California's and Nevada.

  Through this program, DWR works to enhance early warning systems by improving lead time and filling-in data voids with regard to flood forecasts. In collaboration with NWS and the California Nevada River Forecast Center, this program is responsible for monitoring storms, preparing river and reservoir inflow forecasts, and issuing bulletins. Forecast-coordinated operations programs are being developed and enhanced for reservoirs in the San Joaquin and Sacramento River Basins. Coordinated operations give reservoir operators the ability to make smaller, controlled releases in advance of major storms, allowing for more water supply storage during the winter flood season. These activities help minimize the risk of exceeding river channel capacity and increase the warning times to communities along major California rivers and downstream of reservoirs.

- *Flood Emergency Response Grant Programs*: DWR offers three grants in the Flood Emergency Response Projects Grants Program. The Delta Emergency Communications Equipment Grants were awarded in 2012. The Flood Emergency Response Projects Statewide Grants (first round) were awarded in September 2013. Additional funding was made available for a second round of Statewide Grants, which were awarded in September 2015. More information on the flood grant programs can be found at: https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Flood-Emergency-Response-Projects-Grants.

- *Flood Fighting:* The Department of Water Resources (DWR) and the U.S. Army Corps of Engineers (USACE) have been using specific flood fighting methods for many years. DWR provides training in flood fighting methods to local and regional agencies throughout the state, including the California Conservation Corps and California Department of Forestry and Fire Protection (CAL FIRE). While most of these methods are designed to be used to protect levees, others have been adapted to defending homes and other structures from floodwaters and debris flows. These measures are temporary, however, and cannot be expected to last for extended periods of time.

DWR has published two instructional documents on flood fighting methods.

- For levee-oriented methods, see the "Flood Fighting Methods" document at: http://www.water.ca.gov/floodmgmt/docs/flood_fight_methods.pdf. This document is also available in Spanish.

- For home- or structure-oriented methods, see "How to Fight Flooding At Home" at http://www.water.ca.gov/floodmgmt/docs/brochure_floodfightingathome.pdf. For specific mitigation ideas related to floods, see "Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards" January 2013, prepared by FEMA, available on the FEMA website: http://www.fema.gov/library/viewRecord.do?id=6938.

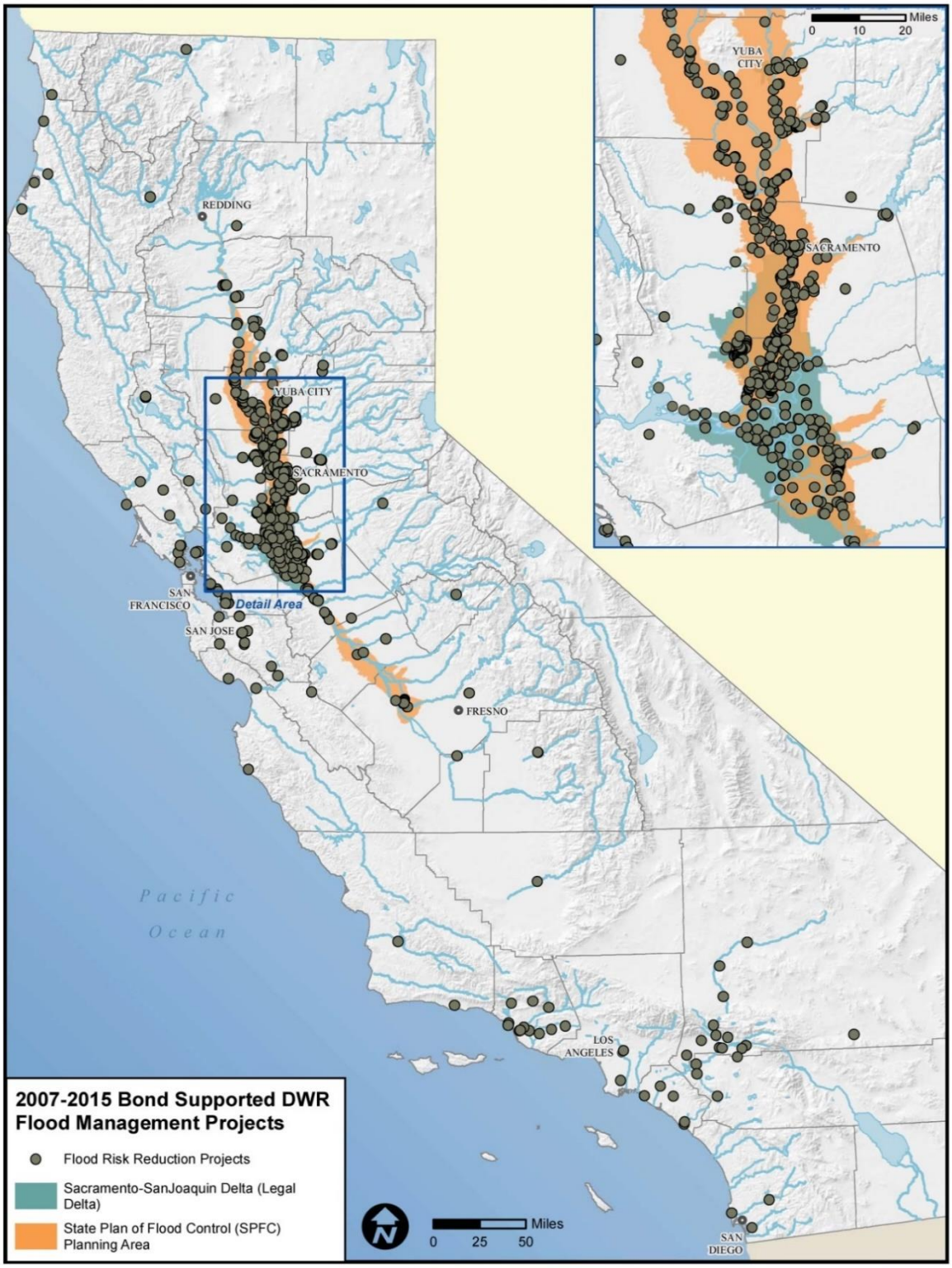
More information on these projects and programs can be found at: http://cdec.water.ca.gov.

DWR Flood Management Grant Programs

DWR administers 11 cost-sharing flood management grant programs. Benefits of DWR's grant programs in promoting flood mitigation progress include the following:

- With 12 projects completed or in progress and approximately 100 miles of levees repaired or improved to date, flood protection has increased to a 200-year level of protection for more than a half million Californians.
- Three transportation corridors (Interstate Highway 5, Interstate Highway 80, and California Highway 99) that are critical to California's economic wellbeing are now better protected from catastrophic flooding.
- Flood protection has significantly improved for Sacramento, which remains among the most at-risk cities in the country for "Katrina-like" flooding.
- With 38 projects completed or in progress and approximately 150 miles of levees repaired or improved, almost 300 square miles that include agricultural land and historic Delta communities have improved flood protection.
- Flood protection projects in the Delta that prevent saltwater intrusion into the State Water Project have helped safeguard the water supply for more than 28 million Californians.
- Flood protection has improved for approximately 100,000 Californians living in the Delta, along with native species habitat, and three key transportation corridors and utility infrastructure that cross the Delta.
- More than 27 million Californians benefit directly or indirectly from DWR grant funded projects—e.g., watershed sensor arrays that provide a broad range of data that allow local agencies to make better decisions earlier in potential flood emergencies.
- Local agencies can use the watershed sensor system to exchange information, improve emergency coordination, and communicate emergency information to the public.
- Almost 4 million people benefit directly from the interoperable communications equipment that was purchased and can be used for all emergencies, e.g. floods, fires, and earthquakes.
- Delta communities are better prepared through local flood management agencies receiving flood fight and Standardized Emergency Management System training and updated warning systems, as well as through emergency response plans.

Map 7.K: Projects of Central Valley Flood Protection Plan



Source: CA DWR, Bond and Legislative Suite Summary: Implementing Improved Flood Protection, Draft June 30, 2016

Map 7.K shows the location of DWR bond-supported flood management projects implemented from 2007 to 2015.

Investing in Flood Management

The January 2016 California Water Action Plan highlighted the continued need for broad and integrated solutions for addressing California's complex water management issues. The 2016 California Water Action Plan update provides additional guidance toward achieving sustainable flood and water management in California. It emphasizes collaboration and alignment across all levels of government, support for local and regional entities in addressing local and regional issues, and integrated-multi-benefit programs throughout the state.

Today aging built and natural flood management infrastructure, climate change with accompanying sea level rise, and growth in the floodplains create some of the pressures on the state-owned flood management system in the Central Valley and locally managed flood systems around the state. Consistent with the 2016 California Water Action Plan update, the next phase of flood management system improvement implementation will emphasize investment in:

- Expansion of the flood management system to ensure system resiliency, enabling the system to carry larger floods and manage increased runoff resulting from climate change
- Continued implementation of integrated multi-benefit projects and programs
- Increased level of protection for urban areas and small communities
- Conservation of forest and agricultural areas
- Improved operations and maintenance practices with streamlined regulatory permitting

Table 7.C summarizes flood management investments from 2007 to 2017.

Table 7.C: Flood Management Bond Expenditures by Program*

Flood Management Programs	Commitments and Expenditures, July 2006 through June 2016 ($ Millions)	Planned Investment, 2015-2017 ($ Millions)	Total Investment, 2007-2017
Flood Emergency Response	$123	$68	$191
Flood Systems Operations and Maintenance	$24	$17	$41
Flood Plain Risk Management	$116	$7	$123
Flood System Assessment, Engineering, Feasibility, and Permitting	$342	$53	$394
Flood Risk Reduction Projects			
System	$126	$251	$377
Urban	$1,170	$291	$1,461
Non-Urban	$110	$146	$256
Central Valley Total	**$2,011**	**$833**	**$2,843**
Elsewhere in the state	$754	$243	$998
Delta	$403	$116	$518
Non-Central Valley Total	**$1,157**	**$359**	**$1516**
STATEWIDE TOTAL	*$3,168*	*$1,192*	*$4,359*

**Reflects Propositions 1E and 84 only*
Source: DWR, Bond and Legislative Suite Summary: Implementing Improved Flood Protection

Flood Management Responsibilities and Infrastructure

Responsibilities for managing flood risk and responding to floods have evolved over time. In the early decades after the state's founding, flood management fell primarily to private entities. Local landowners would build levees—with varying strategies, materials, and methods—to direct and divert rivers, streams, and floodwaters. Major flood disasters in the late 1800s and early 1900s, however, spurred the state and federal governments to play greater

roles, including developing and implementing flood management policies and constructing public flood control infrastructure.

Local, state, and federal agency flood-related responsibilities, along with flood management infrastructure, are summarized below. In addition to these agency responsibilities, individual citizens also have a responsibility to plan, prepare, and take individual actions to reduce flood risks for themselves, their families, and their properties.

Local Flood Management Responsibilities

Cities, counties, and special districts (such as reclamation or flood control districts): conduct various activities including constructing, maintaining, and improving levees and flood management structures; developing land use polices; developing disaster mitigation and emergency response plans; leading emergency response and recovery efforts; and levying assessments on landowners to fund local flood management efforts.

State Agency Flood Management Responsibilities

The California Department of Water Resources (DWR) conducts flood forecasting, hydrology, and climatology studies; undertakes statewide flood management data collection and planning; inspects, oversees maintenance of, and in some cases constructs projects on State Plan of Flood Control (SPFC) levees; operates and maintains SPFC channels and other structures, as well as non-SPFC structures including dams; implements flood-related state grant programs; and helps coordinate emergency flood response operations.

The Central Valley Flood Protection Board (CVFPB) has the authority to decide whether appropriate standards are met for the construction, maintenance, and protection of SPFC facilities and floodways in the Central Valley.

The California Governor's Office of Emergency Services (Cal OES) assists counties in responding to floods and provides coordination, assistance, and funding for state-declared flood emergencies.

Federal Agency Flood Management Responsibilities

The U.S. Army Corps of Engineers (USACE) undertakes and authorizes changes to capital flood protection projects when authorized by Congress, generally in partnership with state and local agencies (including SPFC levees); periodically inspects federally constructed levees for compliance with federal standards; provides planning and assistance to state and local agencies, including during flood events; provides funding to repair eligible flood-damaged levees and structures under Public Law 84-99; provides emergency flood response when requested by the state; and establishes flood storage and release standards for certain reservoirs.

The Federal Emergency Management Agency (FEMA) operates the National Flood Insurance Program (NFIP), which includes developing flood hazard maps that define flood risk, establishing floodplain management standards, and offering federally backed insurance policies. FEMA also provides coordination, assistance, and funding for federally declared flood disasters.[147]

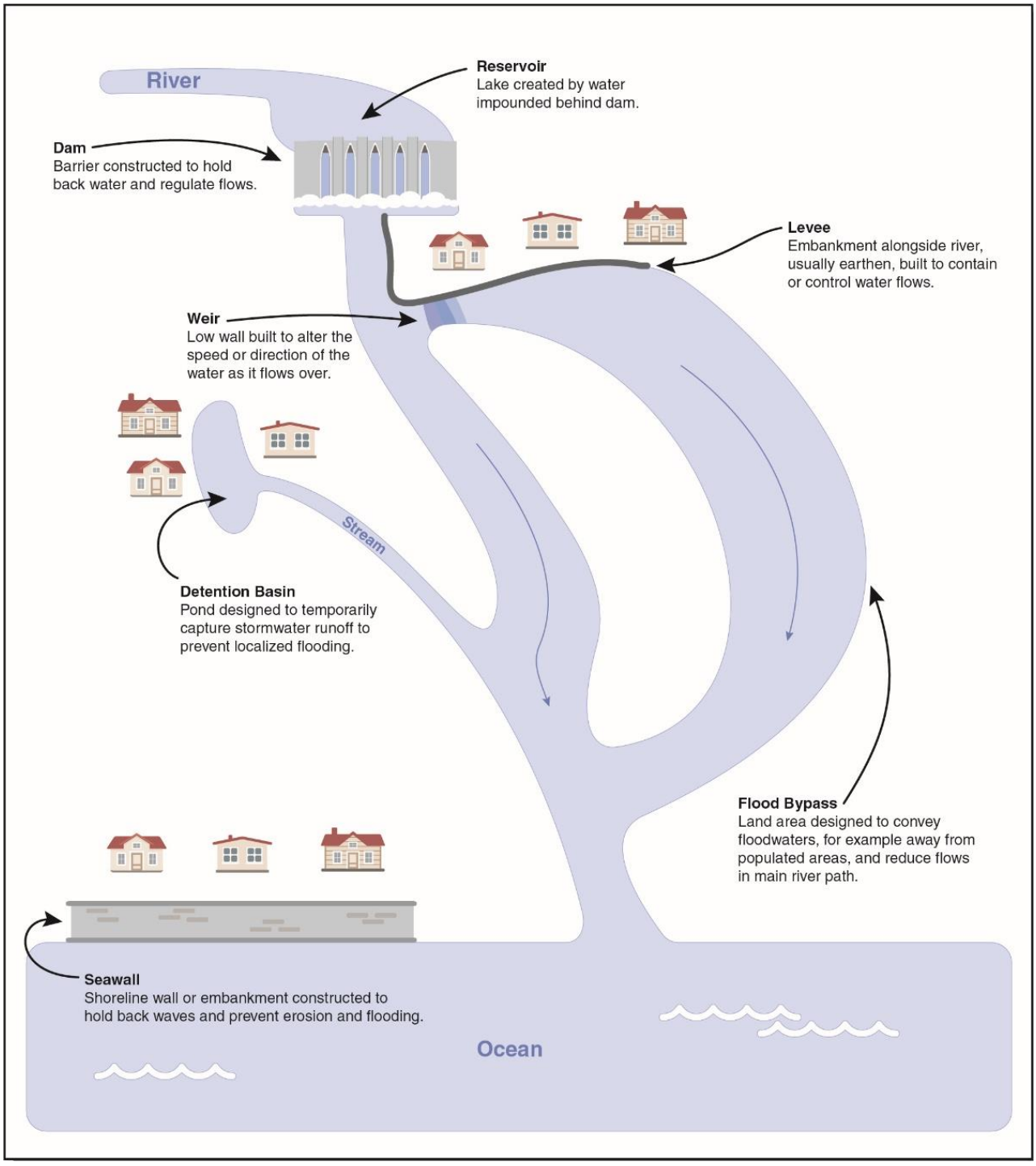
Flood Management Infrastructure

Local, state, and federal agencies have developed a variety of physical structures to convey and control water flows and floodwaters. Such structures include levees and floodwalls, channels, weirs, and culverts. Flood management infrastructure in the state includes more than 20,000 miles of levees and channels and more than 1,537 dams and reservoirs (with approximately 1,250 of these dams being under state jurisdiction). The SPFC includes about 1,600 miles of levees, five major weirs, 13 major drainage pumping plants, and seven bypasses that are used to divert water during periods of high flow. Additionally, flood management structures such as dams and reservoirs frequently are used for water supply purposes.

Figure 7.D provides a diagrammatical representation of various flood management structures and their inter-relationships. Map 7.L details the system of levees and bypasses within the State Plan of Flood Control (SPFC).

[147] Legislative Analyst Office Report "Managing Floods in California" (March 2017) http://lao.ca.gov/reports/2017/3571/managing-floods-032217.pdf

Figure 7.D: Key Flood Infrastructure Components

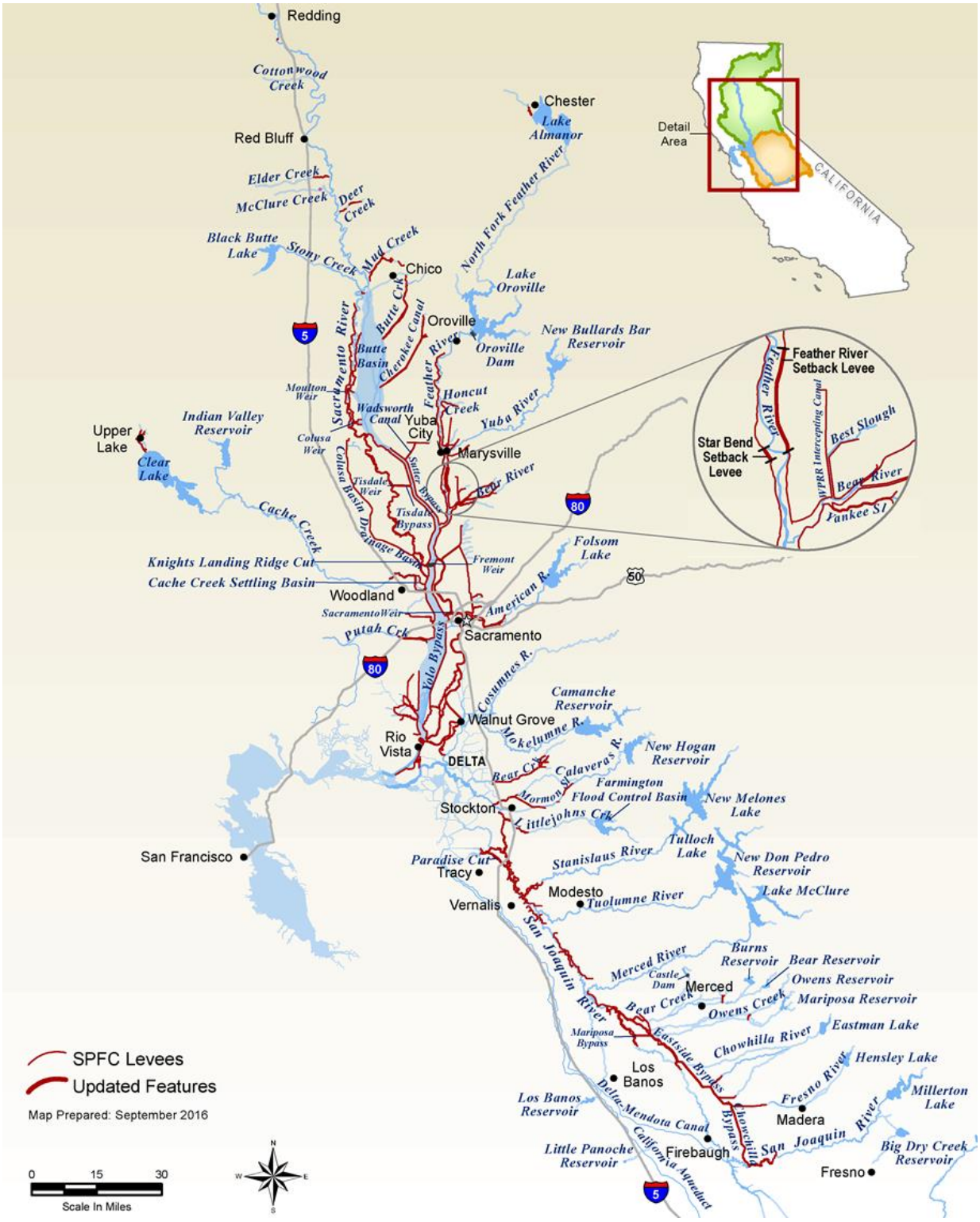


Source: California Legislative Analyst Office (http://lao.ca.gov/reports/2017/3571/managing-floods-032217.pdf)

Flood managers also use detention and retention basins, dams and reservoirs, and bypasses to collect or store water and thereby regulate flood flows. Seawalls and breakwaters are used to armor the shoreline against coastal flooding. Physical structures (e.g., levees and weirs) are also sometimes paired with non-structural approaches (e.g., wise use

of floodplains) for flood management. Additionally, flood management structures such as dams and reservoirs frequently are used for water supply purposes.

Map 7.L: State Plan of Flood Control Levees and Bypasses



Source: California Department of Water Resources

7.1.5.3 CALIFORNIA SILVER JACKETS PROGRAM

DWR continues engaging in various projects that help align federal, state, and local agencies' activities and strengthen flood mitigation efforts through communication and coordination, such as DWR's role co-leading the federally facilitated California Silver Jackets Team. The Silver Jackets Team focuses on reducing flood risk through non-structural measures and agency coordination. Goals of the Silver Jackets are to increase inter-agency cooperation in flood risk mitigation, promote flood hazard risk education and information sharing, identify and eliminate flood risk management barriers, and build on existing efforts for potential future actions. The Silver Jackets joint mission is the protection of life and property by building partnerships to work together to identify and plan for flood risk.

As a collaborative program, the California Silver Jackets program is led by the California Department of Water Resources (DWR) and empowered and supported by the U.S. Army Corps of Engineers (USACE). The program also includes the California Governor's Office of Emergency Services (Cal OES) and local California flood control/mitigation agencies.

Other federal participating agencies making up the Silver Jackets Team include FEMA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Bureau of Reclamation, the Natural Resources Conservation Service (NRCS), and the U.S. Geological Survey (USGS).

Silver Jackets Team Charter Signing Ceremony, September 2016
Source: U.S. Army Corps of Engineers photo by Terri Rorke

In 2013, California became the 40th state to join Silver Jackets, and a formal team charter with about 15 agencies or umbrella (group) organizations was signed in September 2016. The ceremonial charter signing expanded team participation and served as a formal demonstration of the team's willingness to move forward.

The improved collaboration facilitated by the Silver Jackets will help to make project implementation easier and to enable local agencies to connect directly with state and federal agencies and provide "on-the-ground" information that improves the effectiveness of state and federal Projects. Silver Jackets Team outreach efforts such as California Flood Preparedness Week help to improve public understanding of flood risk around the state.

Current and future California Silver Jackets projects are non-structural, interagency projects that reduce flood risk and can be completed in 12 to 18 months. The following is a sampling of California Silver Jackets projects:

- *Flood Risk Education Project*. This project involved several agencies, organizations, and educators, including the U.S. Army Corps of Engineers (USACE), National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS), California Department of Water Resources (DWR), California Department of Education, Sacramento County Office of Education, Water Education Foundation/Project WET (Water Education for Teachers), and Green 360. This project increases awareness of flood risk, especially among children, to enable them to prepare for and take action in case of a flood emergency. Additionally, this project also improves USACE involvement in the science, technology, engineering, and math fields, as well as Common Core and Next Generation Science Standards. The products that emerged from this project include a Simulated Water Management Model. This interactive computer model promotes critical thinking through "simulation games" that can be played by middle and high school students. This project also resulted in a children's flood preparedness activity book for younger kids.

- *Watershed University*. Silver Jackets leads Watershed University, a free event for local communities that provides education and networking opportunities, with topics including water management, emergency management, flood risk reduction, and related fields. The California Watershed University enables communities to establish local flood risk awareness events and encourage citizens to take action. Prior to 2017, Watershed University was conducted using in-person two-day annual workshops, located in outlying areas such as Redding, Atwater, and West Sacramento. Since 2017, however, Watershed University has been conducted through monthly webinars with about 75 to 100 attendees per webinar, with a break during flood season. Participants can earn Continuing Education Credits for the Certified Floodplain Manager certification for attending. Past webinar topics include HMA grant information, Floodplain Management Plans, and an overview of "California's Epic Water Year 2017." One of the future webinars will focus on NOAA's E19 historical forecast point-impact information. For more information, see. http://water.ca.gov/watershed-university/.

- *California Flood Preparedness Week*. Since 2011, DWR through California Silver Jackets has organized a California Flood Preparedness Week during which several federal, state, and local government agencies in California join together to educate citizens about California's diverse flood types and encourage them to be aware, be prepared, and take action to reduce their flood risk. Every one of California's 58 counties has had at least one federally declared flood disaster in the past 20 years, and more than $575 billion in infrastructure and $7 billion in crops are exposed to flooding. Because flooding can happen at any time, the goals of this statewide effort are to increase public awareness of flooding and improve public safety for all Californians. In a related flood risk outreach effort, California Silver Jackets has developed a series of videos focused on riverine, coastal, and alluvial fan flooding and floods after wildfires. DWR also hosts a Flood Prepare California website that provides links to flood preparedness tools, weather resources, and flood risk videos: https://water.ca.gov/What-We-Do/Flood-Preparednes.

- *Conveying flood risk:* California participated in a FEMA four-year nationwide survey to ascertain the flood risk awareness of local officials and the public. While about two-thirds of local officials surveyed identified their community as being at risk of flooding, only about one-third of the public know of a community's flood risk. See: https://www.fema.gov/local-official-survey-findings-flood-risk.

- *FEMA-Led High Water Mark Initiative*. To improve the public's awareness of flood risk and encourage actions to reduce it, FEMA and seven other federal agencies developed the "Know Your Line: Be Flood Aware" initiative. The "Know Your Line" initiative helps communities showcase their local flooding history and motivate their residents to take action by posting high water mark signs in prominent places showing how high floodwaters have risen in the past. Communities are encouraged to hold a high-profile event to announce the initiative, followed by a wide range of supporting activities to remind residents of their flood risk over time and prompt them to take steps to reduce it. In California, the Cities of Sacramento and Roseville participated in the pilot program through California Silver Jackets. Other communities may use the information to expand this program to other cities. See: https://www.fema.gov/hwm-pilot-summary-cities-sacramento-and-roseville-ca.

- *Quick Response (QR) Code—Know Your Flood Risk*. This California Silver Jackets project was accomplished in partnership with USACE, DWR, and California State Parks, with a goal of increasing public and policymaker awareness of flood risk in California. The team produced an interactive, web-based tool using free, open-source software (ESRI Story Maps) and a flyer with a quick response (QR) code to send users to the digital product. The digital product is an interactive presentation that includes photos, maps, and videos designed to educate the audience on Sacramento's flood risk and history. The QR code can be scanned with a smart phone application so that users can go directly to the website without needing a link. Based on a pilot location, the Story Map was created to be geographically specific for Sacramento and surrounding areas. However, the content of the tool can be amended and targeted to other areas, with changes to text and graphics. DWR would like to expand this program to other cities. The ESRI story map can be viewed at: https://cespk.maps.arcgis.com/apps/MapJournal/index.html?appid=8e7c54b2d9cf4c3cb8de0a093d5509e3.

- *Levee Evaluation Study.* DWR and the USACE have embarked on a major study to evaluate the geotechnical adequacy of levees in California's Central Valley (Sacramento and San Joaquin River Flood Reduction Systems). The study provides communities with information about the status of levees and information about geotechnical characteristics, which influence floodplain and flood risk management decisions. Program benefits

include improved flood risk management decision-making and flood protection. Identifying and repairing deficient levees will reduce the potential of flooding and loss of life from flood events.

- *Regional Summaries of Local Hazard Mitigation Plans (LHMPs).* This project developed a database of identified projects from FEMA approved LHMPs from 16 counties, 63 cities, and 15 districts, which will identify flood risk reduction projects that align with federal and state priorities. By developing a database of projects identified by LHMPs, both federal and state agencies will be able to leverage the information in a summarized manner to help set project priorities, provide communities with grant information (other than HMA funding), and identify opportunities for collaboration. Updates to the database will occur as resources allow.
- *California Post-Wildfire Resources Guidebook and website*. This guidebook and website will increase public awareness of flood hazards that are present in areas affected by wildfire and will provide a "one stop" compendium of resources available from agencies responsible for hazard recognition and recovery. This is modeled after the New Mexico Silver Jackets effort.

For additional updated information about Silver Jackets programs, visit: http://silverjackets.nfrmp.us/State-Teams/California and http://water.ca.gov/SilverJackets.

7.1.5.4 OTHER FLOOD-RELATED PROJECTS AND PROGRAMS

Delta Working Group

The Delta Working Group was established in 2012 as a continuation of the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force that was formed in response to Senate Bill 27, the Sacramento-San Joaquin Delta Emergency Preparedness Act of 2008.

The working group facilitates local, regional, state, and federal agency integration in addressing Delta flood issues, including coordination of preparedness and mitigation efforts. Working group participants include local maintaining agencies, Delta counties, Cal OES, the U.S. Army Corps of Engineers (USACE), the California Department of Water Resources (DWR), and others.

Alluvial Fan Task Force

In March 2007, DWR announced a partnership with the Water Resources Institute to coordinate the Alluvial Fan Task Force. The Director of DWR appointed 33 members to the task force including county supervisors, local flood managers, developers, land use/environmental groups and representatives of state and federal agencies.

Most recently the task force was charged with developing a model ordinance and local planning tools that would provide a framework to guide decisions regarding future land use on alluvial fans. Such guidance would be non-prescriptive and flexible allowing local governments to adapt it to local conditions and each development.

The model ordinance and local planning tools are aimed at ensuring public health, safety, and general welfare and minimizing public and private losses and damages that may result from the flood risks and related hazards posed by development located on alluvial fans while giving consideration to the beneficial floodplain area and other values that enhance the sustainability of watersheds.

Alluvial fans are created by the deposition of sediment moving from higher to lower elevations and they are common throughout Southern California. Alluvial fans tend to be popular places to build, but risks may be present including alluvial fan flooding, landslides, fires and other hazards that have long-ranging consequences for local governments.

In response to an Alluvial Fan Task Force recommendation, a study assessing post-fire runoff was conducted by the California Geological Survey (CGS) in collaboration with DWR, resulting in CGS Special Report 234 entitled "Assessment of Post-Fire Runoff Hazards for Pre-Fire Mitigation Planning – Southern California." This report is discussed in more detail in *Section 6.2.4* of the Landslide Hazard Risk Assessment.

To view the final reports and obtain additional information about the Alluvial Fan Task Force, visit: http://aftf.csusb.edu/.

Alluvial Fan Floodplain Evaluation and Delineation

The Alluvial Fan Floodplain Evaluation and Delineation (AFFED) project is one component of the California DWR FloodSAFE Initiative. As of late 2017, the AFFED project study area is limited to the 10 Southern California counties that participated in the Alluvial Fan Task Force. The AFFED project goals support the overall FloodSAFE goals. These include reducing flood risk to residents of California, their homes and property, the state's infrastructure, and public trust resources; developing a sustainable flood management system for the future; and reducing the adverse consequences of floods when they do occur.

To achieve these goals, the project will create preliminary maps of flood hazard boundaries for all alluvial fans within the 10-county study area. The mapping will rely on a methodology that includes the use of two-dimensional computer modeling techniques for the estimation of flooding extents.

Watershed Emergency Response Team

Post wildfire evaluation work on non-federal lands in California has been conducted by the California Department of Forestry and Fire Protection (CAL FIRE) in numerous ways over the past 60 years, beginning with Emergency Watershed Protection (EWP) assessments identify and mitigate hydrologic and geologic risk following wildfire. In 2007, CAL FIRE Watershed Protection Program staff developed a draft prioritization form for use in identification of fires that could present the highest risk to lives and property from post-fire hazards.

This approach was revisited in 2015, and has become the basis for the Watershed Emergency Response Team (WERT). WERTs are assembled with staff from primary agencies and other agencies and deployed to better coordinate local assistance to ensure a rapid response in identification of life safety and property downslope or downstream of burn areas at risk from post-fire flood or debris flows. For more information about WERT see *Section 6.2.4.*

Flooding at Discovery Park, Near Downtown Sacramento, During the January 2017 Winter Storms

Source: California Department of Water Resources

7.1.5.5 WATER MANAGEMENT AND ENVIRONMENTAL INITIATIVES

California Water Plan

The California Water Plan serves as the state's blueprint for integrated water management and sustainability. It details initiatives to ensure reliable water supplies and foundational actions for sustainable water use. It also provides an investment guide for the water community with an array of strategies to achieve multiple goals and benefits; integrates state government initiatives, objectives, and strategies; and incorporates consideration of uncertainties, risks, and resource sustainability into water and flood planning for the future.

The 2013 update was developed by DWR and other agencies through rigorous public involvement and state and federal agency coordination processes to build on the contents of the previous 2009 update. That update provided a strategic plan, a suite of resources management strategies, reports on California's hydrologic regions, and reference and technical guides and will introduce a number of key additional and enhancements in response to stakeholder recommendations and evolving decision-making information needs.

More information the California Water Plan and the in-progress 2018 California Water Plan update are available at: https://water.ca.gov/Programs/California-Water-Plan.

Delta Stewardship Council

The Delta Reform Act of 2009 created the Delta Stewardship Council (DSC), an independent state agency. The goals of the DSC are to provide a more reliable water supply for California and protect, restore, and enhance the Delta's ecosystem. These goals must be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place. In 2012, the DSC developed a comprehensive management plan for the Delta (Delta Plan), which will include the Bay Delta Conservation Plan (BDCP) providing it is approved by state regulatory agencies and meets certain additional criteria. More information on the Delta Stewardship Council can be found at: http://deltacouncil.ca.gov/.

Bay Delta Conservation Plan/California WaterFix

The Bay Delta Conservation Plan (BDCP) is a 50-year, ecosystem-based plan designed to restore fish and wildlife species in the Delta in a way that also protects California's water supplies while minimizing impacts on Delta communities and farms. The BDCP is a multiyear collaboration effort among local water agencies, environmental and conservation organizations, state and federal agencies, and other interest groups. It serves as a natural community conservation plan (NCCP) under state law and a habitat conservation plan (HCP) under federal law which will support the issuance of permits from California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS).

The California Department of Water Resources (DWR), the Bureau of Reclamation, and those state and federal water contractors seeking to take authorizations for activities covered under the BDCP will have ultimate responsibility for compliance with the provisions of the BDCP and the associated regulatory authorizations. This group is referred to as the Authorized Entities and will work with the fish and wildlife agencies to implement the BDCP.

More information on the BDCP can be found at; http://baydeltaconservationplan.com/Home.aspx.

Progress Summary 7.F: Water Plans and the Delta

Progress as of 2018:

California Water Plan (2018 Update)

The 2018 California Water Plan update is in development, with ongoing Policy Advisory Committee and Tribal Advisory Committee meetings that are open to the public. The final 2018 update is planned for release in December 2018. A Tribal Water Summit held in April 2018 included topical material supporting the 2018 California Water Plan update. Tribal summits support integration of federal, state, and tribal mitigation planning.

More information on the progress of the California Water Plan update is available at: https://www.water.ca.gov/Programs/California-Water-Plan/Water-Plan-Updates.

Delta Stewardship Council

The Delta Stewardship Council (DSC) recently added a web page called the "Delta Plan Administrative Performance Measures Dashboard" that tracks implementation of programs recommended by the Delta Plan. The dashboard is sorted by agency, allowing the viewer to review progress for each agency. To view the Delta Plan Administrative Performance Measures Dashboard, go to: http://admin-measures-dashboard.deltacouncil.ca.gov/.

Bay Delta Conservation Plan/California WaterFix

The California WaterFix planning process began in 2006 when updates to the State Water Project (SWP) and coordinated operations of the Central Valley Project (CVP) were initially proposed as the Bay Delta Conservation Plan (BDCP). The BDCP envisioned updating the SWP by adding new points of diversion in the north Delta and complying with state and federal environmental regulatory processes through a 50- year habitat conservation plan.

In December 2013, the California Department of Water Resources (DWR), U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS) released the BDCP draft state and federal environmental regulatory documents.

In July 2015, DWR and the U.S. Bureau of Reclamation issued supplemental regulatory documents that included three additional alternatives that would update the SWP without the large-scale conservation efforts initially identified. These alternatives were proposed to achieve regulatory compliance through a different means that does not include the 50-year habitat conservation plan.

The lead agencies proposed that one of these new alternatives, known as California WaterFix (Alternative 4A), be identified as the preferred alternative in replacement of the previously identified alternative. In addition, the state proposed a separate program, California EcoRestore, to provide restoration efforts for species conservation independent of the SWP facility upgrades.

The California WaterFix Project consists of new water conveyance facilities with three new diversion points in the north Delta, tunnel conveyance and ancillary facilities, operational elements, and habitat restoration and other environmental commitments to mitigate construction- and operation-related impacts of the new conveyance facilities.

The BDCP final environmental review documents issued in December 2016 describe the alternatives, discuss potential environmental impacts, and identify mitigation measures that would help avoid or minimize impacts. They also provide responses to all substantive comments received during public review of the draft documents. In July 2017, DWR issued a Notice of Determination for the BDCP EIR, which identified Alternative 4a (California WaterFix) as the preferred alternative. Permitting efforts and full design work will occur through the end of 2018, with construction anticipated to begin in late 2018.

More information on this program can be found at: http://baydeltaconservationplan.com/FinalEIREIS.aspx. More information on the BDCP can also be found at: http://baydeltaconservationplan.com/default.aspx.

7.1.5.6 FLOOD HAZARDS MAPPING

Senate Bill (SB) 5 (2007) authorized the California Department of Water Resources (DWR) to develop the Best Available Maps displaying 100-year (1 percent annual chance) and 200-year (0.5 percent annual chance) floodplains for areas located within the Sacramento-San Joaquin Valley watershed. SB 5 (2007) requires that these maps contain the best available information on flood hazards and be provided to cities and counties in the Sacramento-San Joaquin Valley watershed. This effort was completed by DWR in 2008.

DWR has expanded the Best Available Maps to cover all counties in the state and to include 500-year floodplains. The 100- year (1 percent annual chance), 200- year (0.5 percent annual chance), and 500-year (0.2 percent annual chance) floodplains are displayed on a web viewer, found at http://gis.bam.water.ca.gov/bam/. The web viewer allows users to view a particular area and identify potential flood hazards.

Progress Summary 7.G: Senate Bill 1278—200-Year Floodplain Maps and General Plan Amendments

Progress as of 2018: As mandated by Senate Bill (SB) 1278 (2012), the California Department of Water Resources (DWR) developed and released 200-year informational floodplain maps for 10 urban communities within the Sacramento-San Joaquin Valley. The development of the maps met the legislative deadline of July 2, 2013. The maps provide information on the water surface elevation of flooding in urban areas in the event of failure of the State Plan of Flood Control (SPFC) facilities during a 200-year event.

The 10 urban communities are the following:

- Chico
- Yuba City and Marysville
- Woodland and Davis
- Merced
- Sacramento Metropolitan Area (Sacramento and West Sacramento)
- Stockton Metropolitan Area (Stockton and Lathrop)

SB 1278 (2012) also extended the date for cities and counties to amend their general plans and zoning ordinances to include certain floodplain information. The legislation required that general plans must be amended no later than July 2, 2015. The general plan amendments must include data and analysis contained in the 2012 Central Valley Flood Protection Plan (CVFPP), including the location of the facilities of the SPFC and locations of real property protected by those facilities. Additionally, general plans must include the locations of flood hazard zones mapped by the Federal Emergency Management Agency (FEMA) and flood hazard locations mapped by local flood agencies or flood districts. Cities and counties had an additional 12 months after their general plan amendments (or until July 2, 2016) to update their zoning ordinances to be consistent with the general plan amendments.

After these amendments (required to be completed no later than July 2, 2016), cities and counties will be required to make findings on whether they have achieved the level of flood protection stipulated in California Government Code Sections 65865.5, 65962, and 66474.5, or are making adequate progress using criteria developed by DWR. DWR has developed criteria in collaboration with cities, counties, other state entities, federal agencies, and associated professional organizations. For more information visit: https://water.ca.gov/Work-With-Us/Grants-And-Loans/Urban-Flood-Risk-Reduction.

7.1.5.7 CODES AND STANDARDS

Progress has been made on the incorporation of standards for flood-resistant construction in the 2015 International Building Code and International Residential Code. Incorporation of standards for flood-resistant construction in these codes is a major step forward in implementing floodplain management at the local level.

For example, Section 1612.4 of the International Building Code states that the design and construction of buildings and structures located in flood hazard areas, including coastal high hazard areas and coastal A zones, shall be in accordance with Chapter 5 of ASCE/SEI 7-16, Minimum Design Loads for Buildings and Other Structures and with ASCE/SEI 24-14 Flood Resistant Design and Construction, which provides minimum requirements for flood-resistant design and construction of structures located in flood hazard areas.

The International Residential Code requires dwellings in floodways to be designed in accordance with ASCE 24-14 and includes an alternative that allows communities to require homes in any flood zone to be designed in accordance with ASCE 24-15. Highlights of ASCE 24-14 that complement the NFIP minimum requirements include provisions that address building performance; flood-damage resistant materials; utilities and service equipment and siting considerations.

The provisions of ASCE 24-14 are consistent with FEMA's NFIP performance requirements, and meet or exceed NFIP regulations. In comparison with NFIP requirements, ASCE 24: provides more specific requirements, incorporates the Coastal A Zone with foundation requirements; requires new construction and substantial improvement/damage construction to incorporate freeboard; and, requires dry floodproofing to include human intervention requirements.

For any FEMA-funded flood retrofitting project, complete compliance with ASCE 24 is preferred. Some requirements of ASCE 24 may be satisfied via a "deemed to comply" approach meeting the spirit of ASCE 24. Hazard Mitigation Assistance (HMA) funded elevation and dry floodproofing projects must comply with ASCE 24 regardless of whether they were "substantially damaged or they trigger substantial improvement." Additionally, any mitigation reconstruction projects proposed under HMA funding qualify as new construction and therefore must fully comply with ASCE 24.

7.1.5.8 PARTICIPATION IN NATIONAL FLOOD INSURANCE PROGRAM (NFIP)

U.S. Congress established the National Flood Insurance Program (NFIP) with the passage of the National Flood Insurance Act of 1968. The NFIP is a program administered by the Federal Emergency Management Agency (FEMA) enabling property owners in participating communities to purchase insurance as protection against flood losses in exchange for state and community floodplain management regulations that reduce future flood damages. In California, approximately 97 percent of California communities participate in the NFIP. For broader training, DWR provides statewide NFIP workshops annually.

California communities participate in the NFIP Community Rating System (CRS), which was implemented in 1990 as a voluntary program for recognizing and encouraging community floodplain management activities exceeding the minimum NFIP standards. Any community in full compliance with the minimum NFIP floodplain management requirements may apply to join the CRS. More information on DWR's management of California's NFIP and Community Rating System (CRS) can be found at: https://www.water.ca.gov/Programs/Flood-Management/Community-Resources/National-Flood-Insurance-Program.

As of 2017, there are 527 NFIP-participating communities throughout the state.[148] Also as of 2017, California had one of the largest NFIP policy counts in the nation, with over 238,000 NFIP flood insurance policies covering more than $68 billion of insured assets (not including other commercial coverage).[149] This policy count has increased by over 40,000 since 2013.[150] Table 7.D provides data on top 10 counties by number of NFIP policies. Coverage by county ranges from a low of 59 total policies to a high of over 53,000.

Table 7.D: Top 10 California Counties with NFIP Policies

	County	Number of National Flood Insurance Program (NFIP) Policies	Flood Insurance Rate Map (FIRM) Zone A Policies	Flood Insurance Rate Map (FIRM) Zone V Policies
1	Sacramento	53,859	23,384	0
2	Los Angeles	20,004	7,244	285
3	Orange	15,570	7,725	10
4	Santa Clara	15,508	12,883	0
5	San Diego	9,750	4,478	7
6	San Joaquin	8,263	1,755	0
7	Marin	8,262	4,726	107
8	Sutter	8,100	309	0
9	Tulare	7,472	3,592	0
10	Ventura	7,144	3,322	73

Source: Federal Emergency Management Agency, NFIP Insurance Report: California April 6, 2018

DWR provides the following services in support of the NFIP:

- Provides technical assistance, guidance, and NFIP training to local communities, other NFIP stakeholders, and federal and state agencies
- Acts as a resource for flood maps, technical data, and other general NFIP information
- Assists local floodplain administrators in maintaining community compliance and wise land use decision-making
- Supports the Community Rating System (CRS) and provides guidance and opportunities for communities to join and increase their participation
- Participates as an active partner in FEMA's Risk MAP Program
- Provides assistance to local communities and state agencies on FEMA grants
- Writes and edits white papers addressing floodplain management and other NFIP topics
- Provides assistance to the Cal OES and local communities on Local Hazard Mitigation Plans (LHMPs), general plans, and emergency management plans
- Pursues leadership roles and actively participates in national, state, and local floodplain management associations and organizations
- Coordinates with state and local agencies on flood management issues statewide
- Provides pre- and post-disaster support to federal, state, and local agencies and the general public[151]

Community Rating System Participation

The Community Rating System (CRS), part of the National Flood Insurance Program (NFIP), is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. This is done by providing flood insurance premium discounts to property owners in communities participating in the CRS program. Credit points are earned for a wide range of local floodplain management activities; the total number of points determines the amount of flood insurance premium discounts to policyholders.

[148] FEMA, 2017
[149] FEMA NFIP Policy and Claims Report, dated April 5, 2108
[150] FEMA Data Library, 2018
[151] Five-Year Floodplain Management Strategic Plan 2009-2013

Under CRS, communities that obtain a rating or 9 or better are awarded a premium discount ranging from 5 to 45 percent. For a CRS rating of 1, properties within the community receive a 45 percent discount on NFIP insurance premiums. Communities with a CRS rating of 5 are awarded a 25 percent discount. Under the CRS, flood insurance premium rates are discounted to reward community actions that meet the three goals of the CRS: 1) reduce flood damage to insurable property, 2) strengthen and support the insurance aspects of the NFIP and 3) encourage a comprehensive approach to floodplain management.

In California, eight communities have a CRS rating of 5 or better. Each built a floodplain management program tailored to its own particular hazards, character, and goals. Under these programs, each community carries out numerous and varied activities, many of which are credited by the CRS. The average discount in policyholder premiums varies according to a community's CRS rating, as described above, and the average amount of insurance coverage in place. According to FEMA, the "Best of the Best"[152] communities that hold the highest CRS ratings include two California communities: the City of Roseville and Sacramento County.

The City of Roseville in Placer County has the distinction of being the only community in the United States to achieve a CRS Class 1 rating, thus entitling policyholders to a 45 percent reduction in flood insurance premiums for properties located in Special Flood Hazard Area (SFHA). Floods in 1995 spurred Roseville to strengthen its floodplain management program. Today the city earns points for almost all CRS-creditable activities. The average premium discount for policies in the SFHA is $963.

Sacramento County, has steadily improved its rating since joining the CRS in 1992. Now a CRS Class 2 rating, the County's more significant activities are diligent public outreach on protecting waterways, purchasing flood insurance, and preparing for floods. The average premium discount in the SFHA is $395. The City of Sacramento has a CRS Class 5 rating, resulting in an NFIP discount of 25 percent.

As summarized in Table 7.E, in 2011, there were 173,922 NFIP flood insurance policies in CRS communities in California, representing a total of $124,209,085 in premiums paid by policyholders who realize $14,550,271 in savings from their communities' participation in the CRS. In 2017, the number of NFIP flood insurance policies increased by 65,029. Total premiums paid were reduced $34,617,217 from premiums paid in 2011, and savings resulting from CRS participation exceeded that of 2011. This is strong evidence of positive local-level flood management practices.

Table 7.E: Increases in Premium Savings Resulting from CRS Participation, Between 2011 and 2017

Year	National Flood Insurance Program (NFIP) Policies in Force	Total Premiums Paid by California Policyholders	Premium Savings as a Result of Community Rating System (CRS) Participation
2011	173,922	$124,209,085	$14,550,271
2017	238,951	$89,591,868	$14,749,350

Source: State CRS Summary: California, January 2012, https://water.ca.gov/LegacyFiles/floodmgmt/lrafmo/fmb/fas/nfip/crs/Links/doc/241_2012_California_State_Profile.pdf; FEMA Policy and Claim Statistics for Flood Insurance, https://www.fema.gov/policy-claim-statistics-flood-insurance

Of the top California Repetitive Loss (RL) and Severe Repetitive Loss (SRL) communities, the majority participate in the CRS program. The state encourages all RL and SRL communities to participate in the CRS program.

For a list of California communities participating in the CRS program, see "Table 3: Community Rating System Eligible Communities Effective October 1, 2016" in the following report: https://www.fema.gov/media-library-data/1476294162726-4795edc7fe5cde0c997bc4389d1265bd/CRS_List_of_Communites_10_01_2016.pdf.

[152] https://www.fema.gov/media-library-data/1507029324530-082938e6607d4d9eba4004890dbad39c/NFIP_CRS_Fact_Sheet_2017_508OK.pdf

Federal Strategy for Mitigating Severe Repetitive Loss Properties

By creating the Severe Repetitive Loss (SRL) program, the Flood Insurance Reform Act of 2004 provided a new opportunity for state governments to mitigate the most flood-prone properties. On July 6, 2012, President Obama signed the Biggert-Waters Flood Insurance Reform Act of 2012. In response to outrage over the increase in flood insurance premiums resulting from the Biggert-Waters Act, the Homeowners Flood Insurance Affordability Act passed in 2014 with the intent of reducing the financial burden for policyholders. This 2014 legislation moved the SRL funding into the FMA program and created a combined National Flood Mitigation Fund. This resulted in administrative changes to how SRL projects are funded.

Approximately 9,000 insured properties have been identified with a high frequency of losses or a high value of claims. As these policies come up for renewal, they will be transferred to the National Flood Insurance Program (NFIP) Servicing Agent's Special Direct Facility. SRL properties with renewal dates of January 1, 2007 or later will be afforded coverage (new business or renewal) only through the Special Direct Facility.

For guidance on Severe Repetitive Loss properties, visit:
https://www.fema.gov/pdf/nfip/manual201205/content/20_srl.pdf.

For an overview of Homeowners Flood Insurance Affordability Act modifications to the Biggert-Waters Flood Insurance Reform Act, visit: https://www.fema.gov/media-library/assets/documents/93074.

Participation in FEMA's Risk MAP Program

FEMA works with federal, state, tribal, and local partners to identify and promote informed planning and development practices through the Risk Mapping, Assessment, and Planning (Risk MAP) program. Through the Risk MAP program, various NFIP maps are in the process of being updated. As a part of this effort, Risk MAP program staff are working with local jurisdictions around the state and federal and state agencies, such as Silver Jackets and the California Department of Water Resources (DWR), to determine local priorities for flood mitigation planning related to the map update efforts.

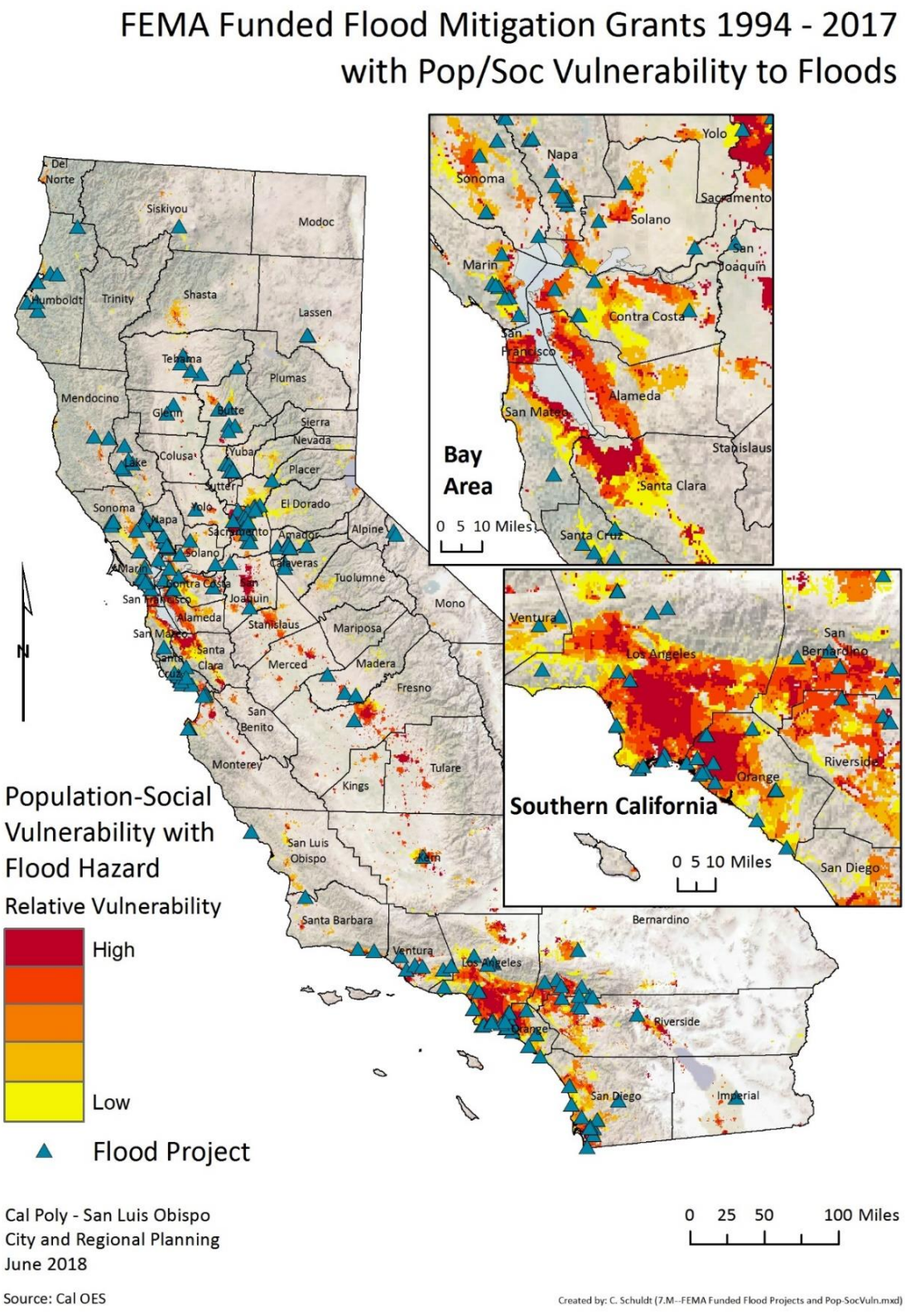
7.1.5.9 FEMA-FUNDED FLOOD HAZARD MITIGATION PROJECTS

The FEMA Flood Mitigation Assistance (FMA) program assists states and local communities in implementing flood hazard mitigation measures before a major disaster occurs. The program targets NFIP communities with numerous Repetitive Loss (RL) structures. The program offers two types of grants to local communities: planning grants and project grants. To be eligible for FMA grant funding, a community must have a FEMA-approved Floodplain Management Plan or a Local Hazard Mitigation Plan (LHMP), as long as the LHMP includes a flood assessment and mitigation strategy and has been FEMA-approved according to Section 201.4 or Section 201.5 of 44 Code of Federal Regulations (CFR). See *Chapter 10, Section 10.4.3* for more information regarding the FMA grant funding.

A community has two years to develop a Floodplain Management Plan and three years to complete a project with FMA funds. The FMA program only permits planning sub-applications that support the flood hazard portion of state, tribal, or local mitigation plans to meet the requirements outlined in 44 CFR Part 201 Mitigation Planning. Funds are only available to support communities participating in the National Flood Insurance Program (NFIP). The total planning grant funding made available in any fiscal year to any state, including all communities located in the state, cannot exceed $300,000. Project grant funding during any five-year period cannot exceed $10 million to any state or $3.3 million to any eligible community. States also receive technical assistance grants to administer the FMA program. The total assistance grants in any fiscal year during a five-year period cannot exceed $20 million.

Map 7.M shows the distribution of flood-related hazard mitigation projects in relation to vulnerable populations in high flood hazard areas. More projects are in the San Francisco Bay Area, Central Valley, and Northern California than in Southern California, coinciding with areas of higher population and social vulnerability to flood hazards.

Map 7.M: FEMA-Funded Flood Mitigation Projects and Population Vulnerability



Cal Poly - San Luis Obispo
City and Regional Planning
June 2018

Source: Cal OES

Created by: C. Schuldt (7.M--FEMA Funded Flood Projects and Pop-SocVuln.mxd)

7.1.5.10 LOCAL FLOOD MITIGATION SPENDING

According to California's Legislative Analyst's Office, as primary responsibility for managing flood risk rests with local governments, the majority of funding for flood management activities is generated and spent at the local level. DWR/USACE estimated that local funding for flood-related activities averaged $2 billion annually between 2000 and 2010.[153]

7.1.6 ADDITIONAL FLOOD HAZARD MITIGATION OPPORTUNITIES

7.1.6.1 FUTURE HAZARD MITIGATION ASSISTANCE GRANT FUNDING OPPORTUNITIES

This risk assessment describes several programs for which DWR would consider requesting future FEMA Hazard Mitigation Assistance (HMA) funding. These are either new programs that DWR is considering implementing or current successful programs that DWR would like to continue and/or expand. These potential HMA-funded programs include the following.

Central Valley Flood Management Planning

The Central Valley Flood Protection Plan (CVFPP) is California's strategic blueprint to improve flood risk management in areas of the Central Valley protected by the State Plan of Flood Control (SPFC) updated on a five-year planning cycle. The 2017 CVFPP update developed a refined State Systemwide Investment Approach (SSIA) that includes a portfolio of recommended management actions—both structural and non-structural—aimed at reducing flood risk. These refinements are summarized for areas of interest (system-wide, urban, rural, and small communities) and by management action category in Table 3-2 in Chapter 3 of the 2017 CVFPP update. Refinements to physical and operational elements of the SSIA are also provided in Chapter 3 (pages 3-5 through 3-7) of the 2017 CVFPP update. The actions are also justified by various supporting documents.[154]

System-Wide Actions – Bypasses, including Flood Structure Improvements

Yolo Bypass Multi-benefit Improvements

The Yolo Bypass expansion would increase the overall capacity of the Sacramento River flood management system to convey large flood events benefiting urban, small community, and rural-agricultural areas. The Yolo Bypass Multi-Benefit Improvements would also increase habitat acreage for sensitive species and expand opportunities for recreation and open space.

The expansion would increase system performance over current conditions to better withstand hydrologic uncertainty, climate change, sea level rise, and other stressors. In addition, operational changes have been developed to accompany the future bypass expansion. Once funding is available, the Yolo Bypass expansion is expected to take 15 to 20 years. The 2017 CVFPP update refinements are as follows:

- An approximately 1.5-mile expansion of the Fremont Weir and expansion of the Yolo Bypass in multiple locations with levee setbacks where feasible, including consideration of the use of the Sacramento Deep Water Ship Channel to convey flood flows
- An approximately 1,500-foot expansion of the Sacramento Weir and Bypass (including consideration of automation)
- Multi-benefit improvements to the Cache Creek Settling Basin for sediment management and sediment remediation

[153] http://lao.ca.gov/reports/2017/3571/managing-floods-032217.pdf
[154] http://cvfpb.ca.gov/cvfpp/

Paradise Cut Multi-benefit Improvements

The Paradise Cut Multi-Benefit Improvements would provide public safety benefits reducing stage and the probability of levee failure along the San Joaquin River. The Paradise Cut Multi-Benefit Improvements would also increase habitat acreage for sensitive species. In addition, operational changes have been developed to accompany the future bypass expansion. Key implementation actions, such as land acquisition, are expected over the next few years. The 2017 CVFPP update includes an approximately 1,000-foot-long weir and associated levee setbacks.

Feather River – Sutter Bypass Multi-benefit Improvements

The Feather River-Sutter Bypass Multi-Benefit Improvements are not expected to be implemented until 2030 or later, after the Yolo Bypass Multi-Benefit Improvements are complete. Nevertheless, a range of potential system-scale improvements are subject to further study in close coordination with local and regional partners. One consideration is upgrade and modification of the Colusa and Tisdale Weirs.

Butte Basin

To improve system-wide flood risk management, levee repair and infrastructure improvements for Butte Basin flood relief structures (rural) are being considered.

New Bullards Bar Dam

To improve system-wide flood risk management, a lower level outlet at New Bullards Bar Dam with capacity of approximately 20,000 cubic feet per second is being considered.

Rural Levee and Infrastructure Improvements

To improve system-wide flood risk management, completion of structural upgrades to identified rural infrastructure is being considered.

System-Wide Actions – Reservoir Storage and Operations

Overview

A range of reservoir flood storage and operations actions would significantly reduce flood risk near downstream urban areas. In addition, floodplain storage actions, pursued on a willing-seller basis and consistent with local land use plans, would reduce flood risk by providing transitory storage. There are also opportunities to reduce flood risk through groundwater banking from recharge and conjunctive use operations, particularly in the San Joaquin River Basin. The 2017 refinements are as follows:

- Study of potential changes to Calaveras River and Tuolumne River reservoir operations
- Continued state support for the Folsom Dam Raise
- Further study and refinement of reservoir and floodplain-related storage actions in the Calaveras and Tuolumne River watersheds
- Four transitory storage sites identified at Dos Rios, Three Amigos, Oroville Wildlife Area, and Conaway Ranch
- Multiple benefit opportunities (e.g., conjunctive use and groundwater recharge) identified at Madera Ranch and in western Madera County to reduce future subsidence and provide water supply benefits

DWR Forecast-Coordinated Operations

The DWR Forecast-Coordinated Operations program focuses on flood control reservoirs in the Central Valley to mitigate flood impacts downstream. Core partner agencies include DWR, the National Oceanic Atmospheric Administration (NOAA), and the U.S. Army Corps of Engineers (USACE). The core partners work with and coordinate with all reservoir operators to improve downstream flood protection without affecting the water supply of upstream reservoirs. This coordination is important to help reduce flood peaks and provide longer lead time for emergency responders. Information about reservoir operations and reports, as well as dam conditions, can be found at the California Data Exchange Center (CDEC) at: http://cdec.water.ca.gov/reservoir.html.

Urban Actions – Capital Improvements

Based on urban levee improvements in the preceding five years, remaining necessary urban improvements to achieve a 200-year level of protection are outlined by local, state, and federal agencies. The intent is to preserve urban development opportunities within specific boundaries without inducing broader urban development that increases aggregate economic and life safety risk. At present, the following urban areas are being considered: the City of Chico, Yuba City and the City of Marysville, the Sacramento metropolitan area, the Cities of Woodland and Davis, the City of Merced, and the Stockton metropolitan area. Other areas may be included in the future.

Rural Actions – Capital Improvements

Levee and Infrastructure Repairs: Site-specific rural-agricultural repairs are being considered, including potential levee repairs on the Eastside Bypass to replace capacity lost due to local subsidence.

Small Communities Actions – Capital Improvements

Levee and Infrastructure Repairs: Study and implementation of small community levee and infrastructure repairs to achieve protection from 100-year (1 percent annual chance) flood events are conducted through the Small Communities Flood Risk Reduction program. This program may include levee repairs and infrastructure improvements, levee setbacks, land acquisition, and habitat restoration.

Refinements to physical and operational elements in the State Systemwide Investment Approach (SSIA) call out residual risk management actions that are fundamental to the overall flood risk management approach in the CVFPP. They include emergency management (system-wide); routine maintenance (system-wide); risk awareness, floodproofing, and land use planning (urban, rural, and small communities); and land acquisitions and easements (rural).

Residual Risk Management

Emergency Management (System-Wide)

Enhanced emergency management would increase warning and mitigation times and would improve life safety and reduce property damages throughout the Central Valley. Specific activities planned for implementation to reduce the vulnerability of people and property in high risk areas are as follows:

- Improved all-weather roads on levee crowns for quick response to flood emergencies
- Continued maintenance of strategically located stockpiles of flood fight materials
- Enhanced flood information collection, forecasting, and notification
- Enhanced local flood emergency response planning with technical and financial assistance to local agencies to help develop local flood preparedness and response plans for communities, conduct local and regional flood exercises, and engage local responders to improve flood emergency readiness
- Improved rural post-flood recovery assistance program
- • Development and training of staff on the use of the Flood Emergency Management System for the state-federal joint flood operations center to manage, track, and report the flood emergency management and flood fight activities.

Routine Maintenance (systemwide)

A robust routine maintenance program underpins effective flood risk management. The 2017 CVFPP update acknowledges that funding for flood system maintenance over time has been insufficient and that significantly greater expenditures would be justifiable in the future. This justification comes from the "Flood System Long-Term Operations, Maintenance, Repair, Rehabilitation, and Replacement Cost Evaluation" Work Group effort. (For a summary of the effort, see Understanding the True Cost of OMRR&R box, 2017 CVFPP update, page 4-5.) Routine maintenance includes the following:

- Routine levee and channel maintenance, such as rodent control, vegetation control, encroachments and pipe maintenance, bank erosion and repair, and sediment removal

- Maintenance of minor structures, such as stop log or gated closure structures, pumping plants, monitoring and flood relief wells and piezometers, retaining walls and floodwalls, pipe penetrations, and encroachments
- Maintenance of

The state will carry out the following activities for SPFC facilities:

- Maintain all-weather levee crown roads for quick response to potential flood threats
- Assist local maintaining agencies in fixing sites requiring critical repairs in rural-agricultural areas
- Enhance inspection and maintenance of the levees and channels
- Ensure that sites identified as requiring maintenance actions during spring inspections are properly maintained and repaired by fall, prior to flood season
- Coordinate inspection and timely maintenance of the levees under jurisdictions of the local maintaining agencies
- Provide timely repair facilities that are the responsibility of the state and that are identified during an inspection as having deficiencies
- Develop strategies for long-term system management and maintenance, such as improving the efficiency of permitting routine maintenance activities and addressing legacy system issues such as encroachment and pipe penetrations

The state will also consider providing implementation grant funding to partner local agencies to ensure proper operation and maintenance of the SPFC

Risk Awareness, Floodproofing, and Land Use Planning (Urban, Rural, and Small Communities)

Risk Awareness

The 2017 CVFPP update includes a recommendation to promote activities that manage residual risk, such as public awareness campaigns and flood risk notifications. The goal of public awareness campaigns is to motivate people to take individual actions to protect themselves, such as developing personal evacuation plans, preparing supplies and provisions for a flood emergency, and insuring themselves against flood damages. Public awareness campaigns, flood risk notifications, and flood emergency preparedness and response programs offer opportunities to empower communities and individuals to take steps to further reduce residual risk. Awareness campaigns can also increase overall willingness to support flood system improvements.

Floodproofing

Non-structural flood risk management actions related to floodproofing reduce flood risk. They include:

- Raising and waterproofing structures and building berms
- Purchasing and relocating homes in floodplains

Land Use Planning and Floodplain Management

Other critical non-structural actions include land use and floodplain management. As stated in the 2012 CVFPP and reaffirmed in the 2017 CVFPP update, the state encourages policies and actions that avoid, to the extent feasible, creating new flood risks for people and property that are not presently at risk. Recommended future land use/floodplain management actions include the following:

- Establish a DWR Floodplain Management Strategic Implementation Plan to track what recommendations have been implemented from earlier endeavors (e.g., the 2002 California Floodplain Management Task Force) and propose a strategy for implementing the remaining recommendations
- Ensure state implementation of floodplain management actions by promoting internal efforts to facilitate implementation of measures prioritized in the update to the Floodplain Management Strategic Implementation Plan
- Evaluate the feasibility of a supplemental state insurance program
- Continue to work with the Agricultural Floodplain Ordinance Task Force
- Seek establishment of a post-disaster agricultural recovery program

- Seek support for a post-disaster habitat recovery program
- Partner with FEMA to increase investments in non-structural actions
- Track land use changes and flood management system improvements to assess whether life loss and property damage risks are increasing or decreasing

Land Acquisitions and Easements (Rural)

Agricultural and conservation easements are considered for their potential to reduce flood risk. These include potential flowage easements in the vicinity of the Eastside Bypass to replace capacity caused by local subsidence.

7.1.6.2 REGIONAL FLOOD MANAGEMENT PLANNING

As part of the 2017 CVFPP update, DWR launched and funded a regionally led effort to help local agencies develop comprehensive plans that describe local flood management priorities, challenges, potential funding mechanisms, and site-specific improvement needs. The site-specific improvement needs have been collected into a database of about 630 Regional Flood Management Plan (RFMP) projects in the Sacramento and San Joaquin River Basins. These projects include a wide variety of objectives, such as improving emergency response, constructing ring levees, repairing erosion, developing and maintaining all-weather levee crown roads, and improving reservoir operations. A subset of these projects was subsequently identified to inform the 2017 CVFPP update planning process. Local project HMA funding would be pursued by the responsible local agency pursuant to its Local Hazard Mitigation Plan (LHMP).

7.1.6.3 STATEWIDE FLOOD MANAGEMENT PLANNING

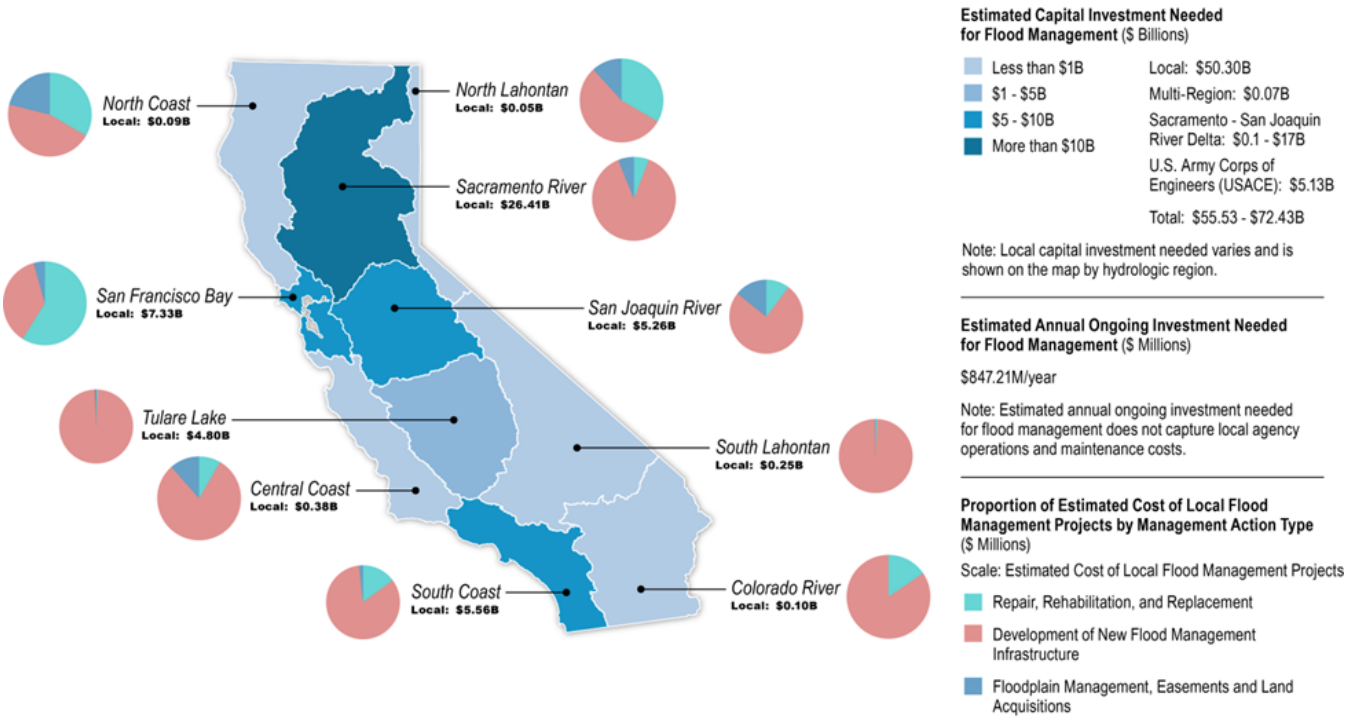
Building upon the "California's Flood Future" report, DWR is developing a new report titled "Investing in California's Flood Future: An Outcome-Driven Approach to Flood Management." This new report will expand understanding related to all of the recommendations from "California's Flood Future," while describing the investment levels required to achieve the intended outcomes necessary to move the state's flood management system toward sustainability.

As part of "Investing in California's Flood Future," more than 240 public agencies responsible for flood management in California were interviewed. This information gathering effort identified flood risk reduction opportunities for operations, maintenance, and capital improvements, including more than $72 billion for proposed capital flood risk reduction management projects and more than $845 million per year for ongoing flood risk reduction needs in California. Over the next decade, investments should focus on high-priority actions, such as:

- Institutional capacity, baseline operations, and routine maintenance
- Floodproofing, risk awareness, planning, studies, and mapping
- Maintenance, repair, rehabilitation, and replacement of existing built and natural infrastructure
- Development of new flood management infrastructure

Figure 7.E illustrates estimated flood management investment needs by hydrologic region and type of management action as identified by the "Investing in California's Flood Future" report. More information on the "California's Flood Future" report can be found at: https://www.water.ca.gov/Programs/Flood-Management/Flood-Planning-and-Studies and https://www.water.ca.gov/Programs/Flood-Management.

Figure 7.E: Flood Risk Reduction Opportunities in California



Source: California's Flood Future: An Outcome-Driven Approach to Flood Management

7.1.6.4 OTHER FLOODPLAIN MANAGEMENT PROGRAMS

In the wake of the devastating effects of Hurricanes Harvey, Irma, and Maria in 2017, it is apparent that the nation must be better prepared for storms larger than those experienced in the past. This preparedness includes hazard mitigation planning beyond the NFIP Special Flood Hazard Areas (SFHAs). In addition to the ARkStorm scenario planning described above, other floodplain management programs that may be considered by DWR in the near future to broaden its flood hazard mitigation planning include the following:

- Update FEMA maps for State Plan of Flood Control (SPFC) protected areas
- Complete Central Valley Flood Evaluation Delineation (CVFED) goals of developing 100-year (1 percent annual chance), 200-year (0.5 percent annual chance), and 500-year (0.2 percent annual chance) maps
- Improve flood insurance coverage in levee protected areas
- Investigate a supplemental California flood insurance program for structures located outside SFHAs
- Develop a flood risk phone application that will inform people of their approximate flood risk by parcel
- Revisit building codes, especially concerning evacuation locations for schools and care facilities
- Update DWR's Awareness Floodplain Maps, which identify 100-year flood hazard areas not yet mapped by FEMA using approximate assessment procedures
- Update California hazard disclosure law to reflect state and federal flood maps, not just NFIP maps
- Work with communities to promote Integrated Community Resilience (ICR), which includes evacuation planning, accurate flood maps, improved warning systems, strong penetration of flood insurance, family emergency planning, vulnerable population identification, and school safety
- Incorporate dam safety into flood planning by modeling big releases due to large floods
- Integrate dam safety into local public safety agency emergency plans

An overall objective of the above programs is to put flood information in the hands of the people so that they can make better-informed decisions regarding their own flood hazard planning.

7.1.6.5 THE ARKSTORM SCENARIO

Cooperative planning efforts addressing severe storm events hold promise for future mitigation of potential catastrophic flooding and related impacts. Initiated by the USGS and other agencies, including Cal OES, a severe storm scenario has been developed in a manner similar to the 2008 Southern California ShakeOut Scenario.

The USGS Multi-Hazards Demonstration Project's second product, called ARkStorm, addresses massive U.S. West Coast storms analogous to those that devastated California in 1861-1862. Scientific studies of offshore deposits in Northern and Southern California indicate that storms of this magnitude and larger have occurred about as often as large earthquakes on the southern San Andreas Fault. Over the last decade, scientists have determined that the largest storms in California are the product of phenomena called atmospheric rivers, and so the Multi-Hazards Demonstration Project storm scenario is called the ARkStorm, for Atmospheric River 1,000 (a measure of the storm's size). Such storms are projected to become more frequent and intense as a result of climate change.


K Street, Sacramento, looking east, 1861-1862

For the ARkStorm scenario, experts designed a large, scientifically realistic meteorological event followed by an examination of the secondary hazards (e.g., landslides and flooding), physical damages to the built environment, and social and economic consequences. The hypothetical ARkStorm would be similar to the intense winter storms of 1861-1862 that left California's Central Valley impassible. Storms far larger than the ARkStorm, dubbed megastorms, have also hit California at least six times in the last two millennia.

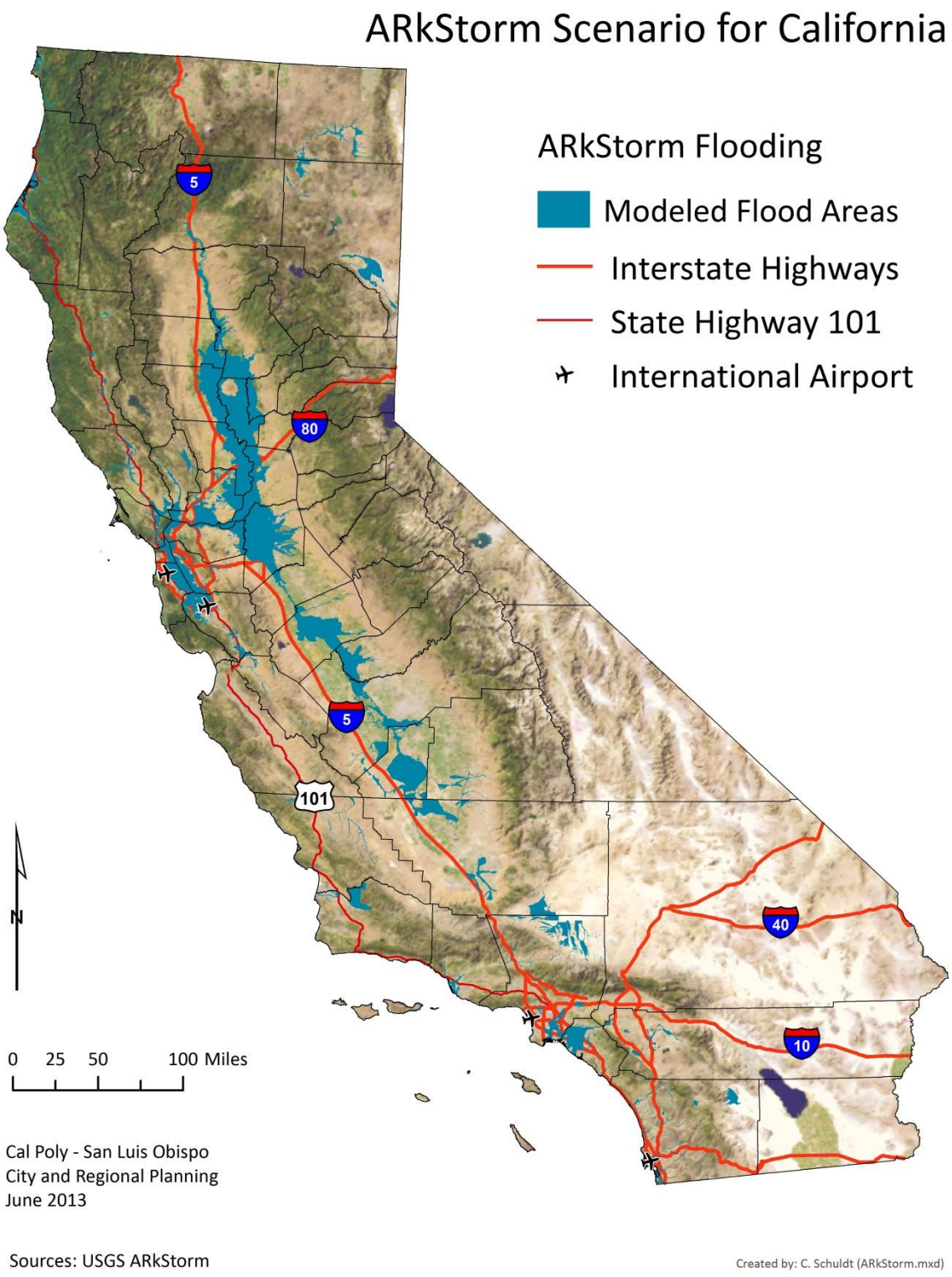
The ARkStorm produces precipitation in many places exceeding levels experienced on average every 500 to 1,000 years. Extensive flooding in many cases overwhelms the state's flood protection system, which is at best designed to resist 100-year (1 percent annual chance) and 200-year (0.5 percent annual chance) flows. (Many flood protection systems in the state were designed for smaller runoff events.) The Central Valley experiences widespread flooding. Serious flooding also occurs in Orange County, Los Angeles County, San Diego, the San Francisco Bay Area, and other coastal communities. In some places, winds reach hurricane speeds, as high as 125 miles per hour. Hundreds of landslides occur, damaging roads, highways, and homes. Property damage exceeds $300 billion, most of it from flooding. Agricultural losses and other costs to repair lifelines, dewater flooded islands, and repair damage from landslides bring the total direct property loss to nearly $400 billion, of which only $20 to $30 billion would be recoverable through public and commercial insurance. Power, water, sewer, and other lifelines experience damage that takes weeks or months to repair. Flooding evacuation could involve over one million residents in the inland region and Delta counties.

A storm of ARkStorm's magnitude has important implications: 1) it raises serious questions about the ability of existing national, state, and local disaster policy to handle an event of this magnitude; 2) it emphasizes the choice between paying now to mitigate, or paying a lot more later to recover; 3) innovative financing solutions are likely to be needed to avoid fiscal crisis and adequately fund response and recovery costs; 4) responders and government managers at all levels could be encouraged to conduct self-assessments and devise table-top exercises to exercise their ability to address a similar event; 5) the scenario can be a reference point for application of FEMA and Cal OES guidance connecting federal, state, and local natural hazards mapping and mitigation planning under the NFIP and Disaster Mitigation Act of 2000; and 6) common messages to educate the public about the risk of such an extreme event could be developed and consistently communicated to facilitate policy formulation and transformation.

The ARkStorm report was published in January 2011. To download the ARkStorm report, visit: http://pubs.usgs.gov/of/2010/1312/.

The ARkStorm scientific effort resulted in a plausible flood hazard scenario to be used as a planning and preparation tool by hazard mitigation and emergency response agencies to direct potential hazard mitigation and training efforts.

Map 7.N: Projected ARkStorm Flooding in California (Based on Modeled Scenario)



Map 7.N depicts an ARkStorm modeled scenario showing the potential for flooding in the Central Valley as the result of a large storm. *(Online or download viewers can zoom in for a closer view of the information on this map.)*

7.2 SEA-LEVEL RISE, COASTAL FLOODING, AND EROSION HAZARDS, VULNERABILITY AND RISK ASSESSMENT

7.2.1 IDENTIFYING SEA-LEVEL RISE, COASTAL FLOODING AND EROSION HAZARDS

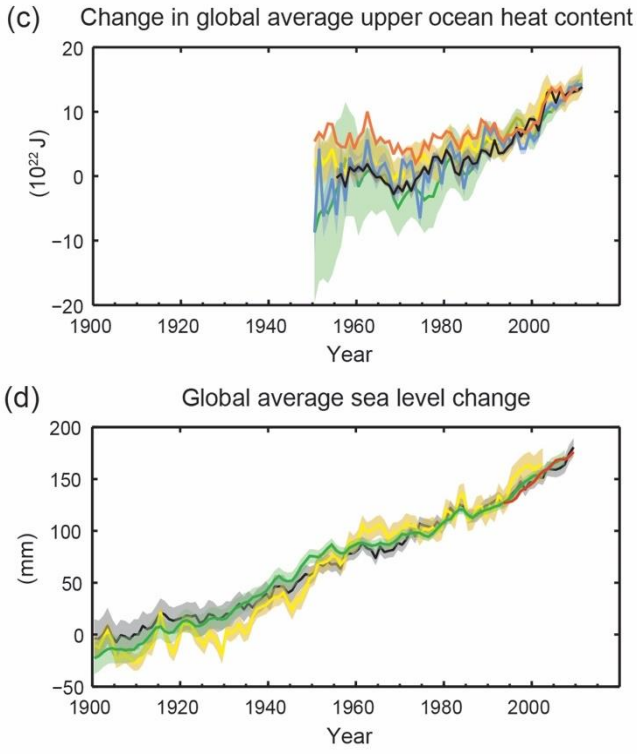
Coastal erosion is a natural geomorphic process. In California, coastal erosion can be accelerated or exacerbated through a combination of factors, including winter storms, tidal action, wind-generated high surf, wave action, and rising sea levels. High tides may coincide with heavy rain causing coastal flooding, coastal bluff erosion, and landslides, such as were experienced during the 1998 and 2016 El Nino storms.

As discussed in *Section 4.3*, climate change will result in sea-level rise and may increase the frequency of severe weather and winter storms. These changes will exacerbate existing coastal hazards, including flooding and erosion, and will have severe impacts along the California coast.[155]

It is important to distinguish between sea-level rise at the global scale and the regional/local scale and to identify the different contributing factors. Increases in global sea-level result from two primary causes: ocean thermal expansion (when water warms, it expands) and the melting of land-based ice, including mountain glaciers, ice caps, and the polar ice sheets of Greenland and Antarctica. Thus far, the largest contributor to sea-level rise is thermal expansion, but the rate of ice loss from both the Greenland and Antarctic ice sheets is accelerating.[156, 157] If the current rate of loss for the Greenland and Antarctic ice sheets continues, the contribution from the ice sheets will become the dominant source of sea-level rise.[158] As shown in Figure 7.F, changes in sea-level have been occurring for at least the last 100 years and are projected to continue. The rate of sea-level rise is increasing, meaning the amount of increase is higher in more recent decades than in preceding decade, and this trend is projected to continue.

While global mean sea-level is rising, it is relative sea-level—the local difference in elevation between the height of the sea surface and the height of the land surface at any particular location—that affects coastal communities and ecosystems at risk from coastal flooding. Future changes in relative sea-level will vary along the length of the California coastline.

Figure 7.F: Global Upper Ocean Heat Content and Sea-Level Change Since 1900



Source: IPCC: Climate Change 2013

[155] California Coastal Commission Staff Sea-level Rise Team. California Coastal Commission Sea-level Rise Policy Guidance. San Francisco: California Coastal Commission, 2015, 293 p.

[156] IPCC: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013, 1535 pp.

[157] Griggs, G, Árvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust, April 2017.

[158] Griggs, G, Árvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust, April 2017.

Generally, sea-level rise progressively worsens the impact of high tides and wind-driven waves associated with severe storms. Coupled with increased frequency, severity, and duration of high tide and storm events related to climate change, sea-level rise will exacerbate these extreme events along the coast. These events may expose the coast to severe flooding and erosion; damage to coastal structures, real estate, public access, and coastal habitats; and seawater intrusion into delta areas and coastal aquifers.[159] El Niño events exacerbate storms and coastal inundation above that already occurring due to sea-level rise and normal coastal weather and tidal patterns.[160]

California's land mass includes more than 1,100 miles of outer coast with features like bluffs, beaches, and wetlands, in addition to bay shorelines and the Delta. The San Francisco Bay shoreline alone is approximately 300 miles, not including the Delta. The coast also supports varying levels of development and land use, including recreational, agricultural, industrial, commercial, and residential uses. The continued rise in sea-level increases the risk of inundation in low coastal areas. Near-shore wave heights and wave energy will increase, intensifying the potential for storm damage, beach erosion, and bluff retreat. Under sea-level rise scenarios, development adjacent to shoreline areas will be at increased risk of damage from everyday tidal conditions as well as storm events.

Sea-level rise impacts on marine transportation include potential difficulties shipping into and out of the ports of Sacramento and Stockton, along with higher winter flows in the Sacramento River. Increased siltation from storm runoff would necessitate more frequent dredging of channels across California. Harbors could suffer wave damage, siltation, and other navigation and safety challenges. Sea-level rise will also create difficulties for ports and harbors by affecting cargo transfer capability as ships ride higher along docks and also by affecting transfer between roads or railways and docks (e.g., agriculture coming from Central Valley to be shipped out of the Port of Oakland).

Sea-level rise also impacts the environment. If beaches, wetlands, and other coastal habitats are unable to migrate inland, because of pace, sediment availability, or inland development as sea-levels rise, which is particularly likely in places where shoreline armoring or other development blocks natural migration, they can be lost to permanent inundation or degraded by salt water intrusion with resulting impacts related to land subsidence, loss of habitat for fish and wildlife, and loss of aesthetic, recreational, and commercial uses. Such loss would also mean the loss of important ecosystem services. For example, intact wetlands serve as a buffer to flooding events by increasing flood capacity, recharging groundwater, protecting water quality, and providing water supply reliability.

7.2.2 PROFILING SEA-LEVEL RISE, COASTAL FLOODING AND EROSION HAZARDS

The State of California Sea-Level Rise Guidance Document, initially adopted in 2010 and updated in 2013, provides guidance to state agencies for incorporating sea-level rise projections into planning, permitting, investment, and other decisions. The 2013 version of the guidance was based on the 2012 National Research Council report, which provided regionally specific scenario-based projections of sea-level rise across the West Coast. Since that time, there have been advances in the understanding of sea-level rise modeling (namely, improved methods for providing probabilities or likelihoods of local sea-level rise change) and the scientific understanding of potential ice loss from the Greenland and Antarctic ice sheets, warranting an update to the state's sea-level rise guidance to reflect the best available science. Additionally, increased policy and legislative directives and mandates focused on improving climate adaptation and resiliency in California at both the state and local level have necessitated an update to the guidance to help cities, counties, and state entities prepare for and adapt to sea-level rise.

In April 2017, at the request of the California Ocean Protection Council (OPC), a working group of the OPC's Science Advisory Team released a report entitled "Rising Seas in California: An Update on Sea-Level Science " that synthesizes the state of sea level rise science. The Rising Seas report provides the scientific foundation for the 2018 update to the state's sea-level rise guidance, led by the OPC in coordination with the California Natural Resources Agency (CNRA), the Governor's Office of Planning and Research (OPR), and the California Energy Commission (CEC). The State of California Sea-Level Rise Guidance 2018 Update was adopted by the OPC in March 2018. The updated 2018

[159] California Natural Resources Agency. 2009 California Climate Adaptation Strategy. Sacramento: author, 2009, 200 p. Retrieved on August 24, 2017 from http://resources.ca.gov/docs/climate/Statewide_Adaptation_Strategy.pdf.

[160] Barnard, P. L. et al. Extreme oceanographic forcing and coastal response due to the 2015–2016 El Nino. Nat. Commun. 8, 14365, 2017. Retrieved on August 28, 2017 from https://www.nature.com/articles/ncomms14365.pdf.

policy guidance provides direction on how to select appropriate sea-level rise projections based on geographic location, project lifespan, impacts, and adaptive capacity, as well as recommendations for planning and adaptation strategies to safeguard California's people, places, and natural environment.

The State of California Sea-Level Rise Guidance 2018 Update summarizes recent scientific findings regarding global sea-level rise and presents projections for California that build on data collected from a network of 12 tide gauges located along the coast, shown in Figure 7.G.

Figure 7.G: Locations of Tide Gauges Used as the Basis for Sea-Level Rise Projections

Source: State of California Sea-Level Rise Guidance 2018 Update; http://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/

The guidance explains the rapid advancement of scientific understanding of sea-level rise and provides sea-level rise projections by decade, based on greenhouse gas (GHG) emissions scenarios (See Table 7.F). These projections serve as the basis for ways to incorporate sea-level rise data into planning. To complement the comprehensive probabilistic approach to projecting sea-level rise, an extreme scenario, labeled as H++, was also included based on rapid ice melt on Antarctica.

The H++ rapid loss scenario projects extreme sea-level rise with a 10.2-foot increase by 2100 and a 21.9-foot increase by 2150. The H++ rapid loss scenario is also detailed in the 2017 OPC report titled "Rising Seas in California: An Update on Sea-Level Rise Science."

Table 7.F: Projected Decadal Sea-Level Rise (in Feet) for San Francisco

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)					H++ scenario (Sweet et al. 2017) *Single scenario
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE	
		50% probability sea-level rise meets or exceeds...	66% probability sea-level rise is between...		5% probability sea-level rise meets or exceeds...	0.5% probability sea-level rise meets or exceeds...	
				Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions	2030	0.4	0.3 -	0.5	0.6	0.8	1.0
	2040	0.6	0.5 -	0.8	1.0	1.3	1.8
	2050	0.9	0.6 -	1.1	1.4	1.9	2.7
Low emissions	2060	1.0	0.6 -	1.3	1.6	2.4	
High emissions	2060	1.1	0.8 -	1.5	1.8	2.6	3.9
Low emissions	2070	1.1	0.8 -	1.5	1.9	3.1	
High emissions	2070	1.4	1.0 -	1.9	2.4	3.5	5.2
Low emissions	2080	1.3	0.9 -	1.8	2.3	3.9	
High emissions	2080	1.7	1.2 -	2.4	3.0	4.5	6.6
Low emissions	2090	1.4	1.0 -	2.1	2.8	4.7	
High emissions	2090	2.1	1.4 -	2.9	3.6	5.6	8.3
Low emissions	2100	1.6	1.0 -	2.4	3.2	5.7	
High emissions	2100	2.5	1.6 -	3.4	4.4	6.9	10.2
Low emissions	2110*	1.7	1.2 -	2.5	3.4	6.3	
High emissions	2110*	2.6	1.9 -	3.5	4.5	7.3	11.9
Low emissions	2120	1.9	1.2 -	2.8	3.9	7.4	
High emissions	2120	3	2.2 -	4.1	5.2	8.6	14.2
Low emissions	2130	2.1	1.3 -	3.1	4.4	8.5	
High emissions	2130	3.3	2.4 -	4.6	6.0	10.0	16.6
Low emissions	2140	2.2	1.3 -	3.4	4.9	9.7	
High emissions	2140	3.7	2.6 -	5.2	6.8	11.4	19.1
Low emissions	2150	2.4	1.3 -	3.8	5.5	11.0	
High emissions	2150	4.1	2.8 -	5.8	5.7	13.0	21.9

Source: State of California Sea-Level Rise Guidance 2018 Update; http://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/

The State of California Sea-Level Rise Guidance 2018 Update also provides the probability that sea-level will meet or exceed particular heights for each decade from 2030 to 2150, as shown in Table 7.G. To further bolster the planning response to sea-level rise and complement the probability estimates in Table 7.G, efforts have been made to estimate the projected rate of sea-level rise.

Taken together, this information provides communities the ability to identify priorities for the most vulnerable locations and populations, keeping in mind that sea-level rise affects other coastal hazards such as erosion and flooding, as well as processes located a distance inland (see Tables 7.G and 7.H).

Tables 7.F, 7.G, and 7.H provide the sea-level rise data for San Francisco as an example of the sea-level rise projections provided in Appendix 3 of the State of California Sea-Level Rise Guidance 2018 Update for the remaining 11 tide gauge locations along the California Coast. Under these projections from the State of California Sea-Level Rise Guidance 2018 Update, California can expect to lose hundreds of feet of shoreline along its entire coastline over the next century.

Table 7.G: Probability that Sea-Level Rise Will Meet or Exceed a Particular Height (in Feet) in San Francisco

SAN FRANCISCO - High emissions (RCP 8.5)

	Probability that sea-level rise will meet or exceed... (excludes H++)									
	1 FT.	2 FT.	3 FT.	4 FT.	5 FT.	6 FT.	7 FT.	8 FT.	9 FT.	10 FT.
2030	0.1%									
2040	3.3%									
2050	31%	0.4%								
2060	65%	3%	0.2%	0.1%						
2070	84%	13%	1.2%	0.2%	0.1%					
2080	93%	34%	5%	0.9%	0.3%	0.1%	0.1%			
2090	96%	55%	14%	3%	0.9%	0.3%	0.2%	0.1%	0.1%	
2100	96%	70%	28%	8%	3%	1%	0.5%	0.3%	0.2%	0.1%
2150	100%	96%	79%	52%	28%	15%	8%	4%	3%	2%

SAN FRANCISCO - Low emissions (RCP 2.6)

	Probability that sea-level rise will meet or exceed... (excludes H++)									
	1 FT.	2 FT.	3 FT.	4 FT.	5 FT.	6 FT.	7 FT.	8 FT.	9 FT.	10 FT.
2060	43%	1.4%	0.2%							
2070	62%	4%	0.6%	0.2%	0%					
2080	74%	11%	2%	0.4%	0.2%	0.1%				
2090	80%	20%	3%	1.0%	0.4%	0.2%	0.1%	0.1%		
2100	84%	31%	7%	2%	0.8%	0.4%	0.2%	0.1%	0.1%	
2150	93%	62%	31%	14%	7%	4%	2%	2%	1%	1%

Source: State of California Sea-Level Rise Guidance 2018 Update; http://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/

Table 7.H: Projected Average Rate of Sea-Level Rise (millimeters/year) for San Francisco

	Probabilistic Projections (mm/yr) (based on Kopp et al. 2014)				H++ scenario (Sweet et al. 2017) *Single scenario
	MEDIAN	LIKELY RANGE	1-IN-20 CHANCE	1-IN-200 CHANCE	
	50% probability sea-level rise meets or exceeds...	66% probability sea-level rise is between...	5% probability sea-level rise meets or exceeds...	0.5% probability sea-level rise meets or exceeds...	
		Low Risk Aversion		Medium - High Risk Aversion	Extreme Risk Aversion
High emissions 2030-2050	6.7	4.5 - 9.3	12	17	26
Low emissions 2060-2080	5.3	3.1 - 8.2	12	22	
High emissions 2060-2080	9.5	6.4 - 13	17	28	42
Low emissions 2080-2100	5.2	2.3 - 9.1	14	28	
High emissions 2080-2100	11	6.0 - 16	22	37	55

Source: State of California Sea-Level Rise Guidance 2018 Update; http://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/

In the context of rapidly evolving science, communities developing strategies to address sea-level rise impacts should choose sea-level rise projections based on best available science at the time, and in alignment with recommendations from California's sea-level rise guidance. California's key sea-level rise guidance documents, as of July 2018, include:

- The Ocean Projection Council's State of California Sea-Level Rise Guidance 2018 Update and 2017 Rising Seas in California: Update on Sea-Level Rise Science: http://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/

- The California Coastal Commission's Sea-Level Rise Policy Guidance (*2018 update pending*): https://www.coastal.ca.gov/climate/slrguidance.html

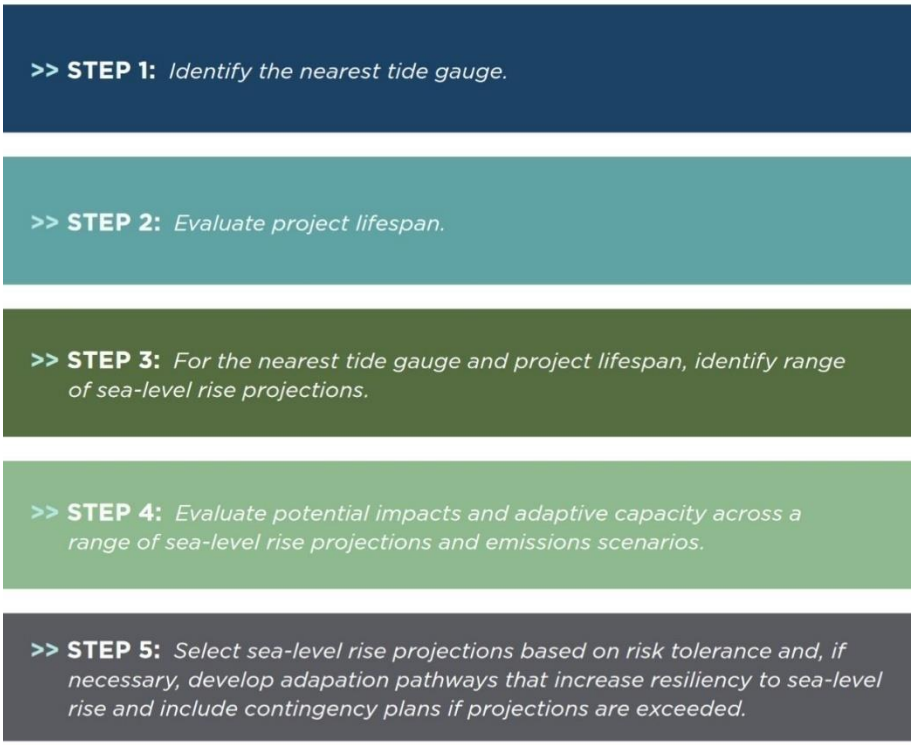
The 2015 California Coastal Commission Sea Level Rise Policy Guidance also provides a background on sea level rise science, recommendations for addressing sea level rise in Local Coastal Programs (LCPs) and Coastal Development Permits, and information on adaptation options. In particular, the California Coastal Commission (CCC) guidance recommends using best available science to determine appropriate sea level rise projections for the planning horizon; identifying the physical impacts associated with sea level rise, including changes in erosion and flooding; assessing impacts on coastal resources and development; and identifying and implementing adaptation options to minimize risks.

The CCC is in the process of updating its 2015 guidance to incorporate the newest science and will align its projections with the State of California Sea-Level Rise Guidance 2018 Update, which includes the best available science from the 2017 "Rising Seas in California: An Update on Sea-Level Science" report. The 2018 Draft Science Update of the 2015 California Coastal Commission Sea Level Rise Policy Guidance is available for review and public comment closes in early September 2018.

An important component of the State of California Sea-Level Rise Guidance 2018 Update, which can assist communities in determining the sea level rise scenario most applicable to their sea level rise planning and adaptation efforts, is the step-wise approach outlined in the section entitled "Guidance on How to Select Sea-Level Rise Projections," starting on page 21 of the document.

The step-wise approach provides a decision framework that can be used to guide the selection of applicable sea level rise projections and develop adaptation pathways. Decisions about which sea-level rise projections to select—and the necessary adaptation pathways and contingency plans to ensure resilience—will be based on factors including location, lifespan of the given project or asset, sea level rise exposure and associated impacts, adaptive capacity, and risk tolerance/aversion. Figure 7.H illustrates the step-wise approach.

Figure 7.H: Step-Wise Approach to Selecting Sea-Level Rise Projections



Source: State of California Sea-Level Rise Guidance 2018 Update; http://www.opc.ca.gov/updating-californias-sea-level-rise-guidance/

The State of California Sea-Level Rise Guidance 2018 Update expands on each step in detail, providing considerations and justifications for potential scenario selections, as well as a risk decision framework outline (in Appendix 4; built on the work of the Governor's Office of Planning and Research [OPR] in response to Executive Order B-30-15) to assist state, tribal, and local government decision-makers' evaluation efforts. The framework should be used to guide selection of appropriate sea level rise projections and, if necessary, develop adaptation pathways that increase resiliency to sea level rise and include contingency plans if projections are exceeded or prematurely reached.

7.2.3 ASSESSMENT OF SEA-LEVEL RISE, COASTAL FLOODING, AND EROSION VULNERABILITY AND POTENTIAL LOSS

Sea level rise threatens many aspects of the coastal economy, as well as California's broader economy, including coastal-related tourism, beach and ocean recreational activities, transfer of goods and services through ports and transportation networks, coastal agriculture, and commercial fishing and aquaculture facilities.[161]

Statewide Assessment

In addition to potential losses in revenue, Heberger et al. (2009) estimate that $100 billion worth of property is at risk of flooding during a 100-year coastal flood with 4.6 feet (1.4 meters) of sea level rise (the amount projected to occur by the year 2100 in their Pacific Institute study). This at-risk property inventory includes seven wastewater treatment plants, commercial fishery facilities, marine terminals, coastal Highway 1, 14 power plants, residential areas, and other important development and infrastructure. Sea level rise also poses environmental justice and social equity challenges. This is particularly true for communities that may be dependent on at-risk industries, are already suffering from economic hardship, or have limited capacity to adapt, including lower-income, linguistically isolated, elderly, and other vulnerable populations.

The potential impacts of sea level rise are substantial. Areas vulnerable to inundation in 2100 have a population of about 475,000 and property values estimated at approximately $100 billion.[162] According to the Pacific Institute study, critical infrastructure now threatened by increased risk of inundation includes:

- 140 schools
- 34 police and fire stations
- 55 health care facilities
- 330 hazardous waste facilities and sites
- 3,500 miles of roads and highways and 280 miles of railways
- 30 coastal power plants, with a combined capacity of 10,000 megawatts
- 28 wastewater treatment plants (including both treatment plants along the open ocean coastline and along bay coastlines)
- San Francisco and Oakland International Airports

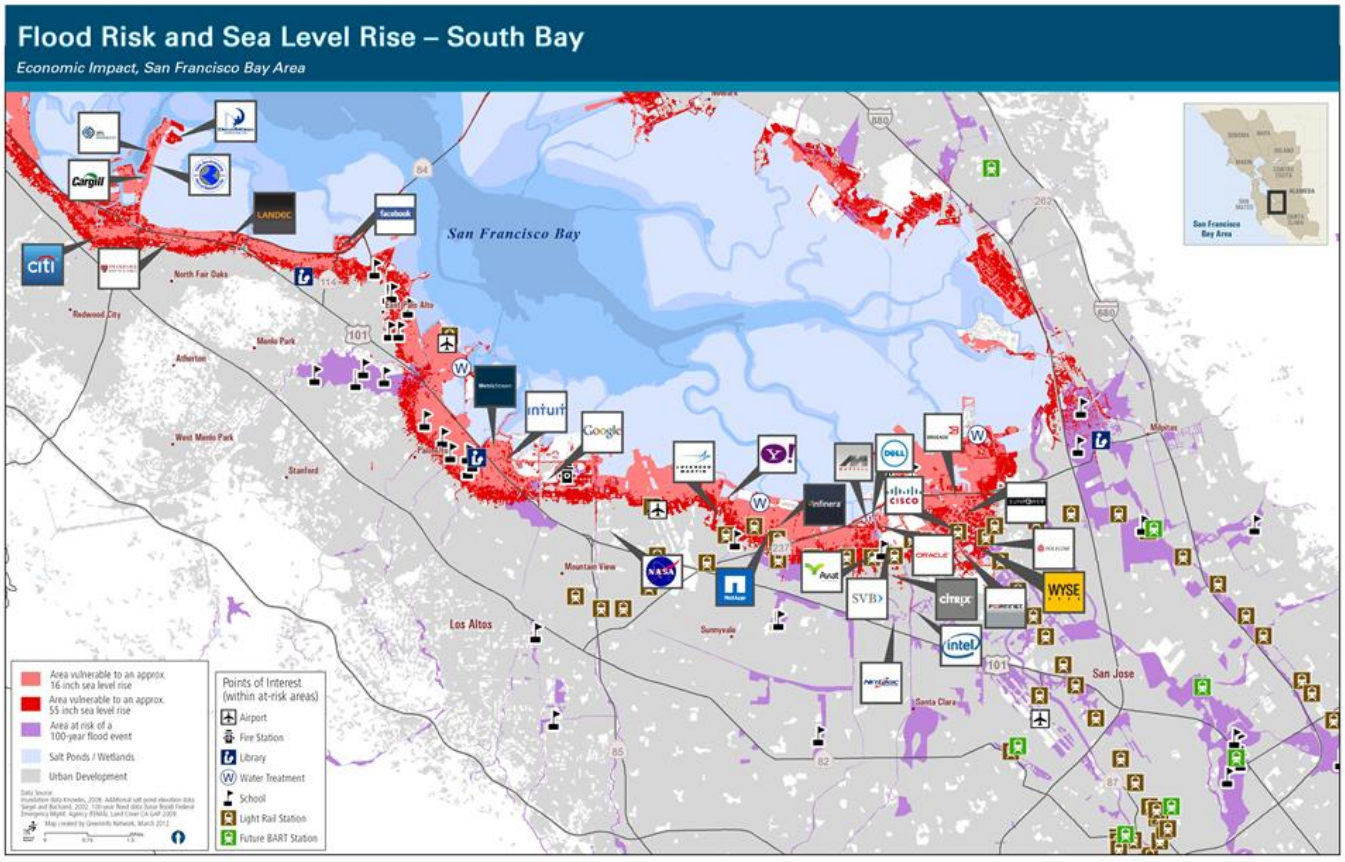
The study estimates that $100 billion worth of property (in year 2000 dollars) is at risk from a 100-year flood event with a 4.6-foot (1.4-meter) sea level rise and no adaptation. The study also notes that two-thirds of the vulnerable property is in the San Francisco Bay Area. Most of the bayfront north, east, and south of San Francisco and Oakland, including both San Francisco and Oakland International Airports, will require some form of adaptive action, such as sea walls, elevated and low-impact development, or managed retreat through acquisition and wetlands restoration. In addition, the occupants of these coastal areas include many businesses that would experience both physical damage and economic disruption due to the rising sea levels. See Map 7.O, which was prepared as part of the South San Francisco Bay Shoreline Project, showing locations of businesses in Santa Clara County vulnerable to sea-level rise.

While the Pacific Institute study is no longer a new assessment, it still offers a reasonable statewide view of sea-level rise vulnerability. What is new since the 2009 publication is the development of many local and regional assessments of sea-level rise vulnerability by jurisdictions, agencies, and organizations, which lend more region-specific detail to sea-level rise vulnerability analysis and support subsequent development of local or regional adaptation plans.

[161] https://documents.coastal.ca.gov/assets/slr/guidance/August2015/0_Full_Adopted_Sea_Level_Rise_Policy_Guidance.pdf

[162] Gleick, P. The Cost of Adaptation to Sea-level Rise along the California Coast and in the San Francisco Bay. California Climate Change Center, October 2008, pp. 42-47

Map 7.O: Businesses Vulnerable to Sea-Level Rise in the San Francisco South Bay



Source: THE SOUTH SAN FRANCISCO BAY SHORELINE STUDY AND PROJECT; summarized by Richardson 2016, http://www.lhc.ca.gov/sites/lhc.ca.gov/files/Reports/239/WrittenTestimony/RichardsonOct2016.pdf

Local and Regional Assessments

Since the 2009 Pacific Institute study, most sea-level rise assessments have been either focused at a regional or jurisdictional level and are prepared with greater detail and depth of analysis than is typically found in a statewide assessment. These area-specific vulnerability assessments review local hazards and climate exposure and assess what may be affected as a necessary first step in developing local mitigation and adaptation actions. This local/regional focus allows a jurisdiction or group of jurisdictions to evaluate the results and implications of the assessment; educate the public about sea level rise hazards and vulnerability in their communities; identify possible adaptation strategies; incorporate information and actions into climate adaptation, land use and hazard mitigation plans; and build solutions into other ongoing programs.

Many coastal communities vulnerable to sea level arise along the length of California have undertaken site and sector specific analyses of the potential impacts of sea-level rise to their communities, infrastructure, critical facilities, economies, environments, and social vulnerabilities. Some recent examples include (from north to south):

- *Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment*: The Humboldt Bay Shoreline Inventory, Mapping, and Sea Level Rise Vulnerability Assessment (2013) inventoried and mapped existing shoreline conditions on Humboldt Bay; assessed existing shoreline vulnerability to breaching or overtopping under current tidal and climatic conditions; assessed existing shoreline vulnerability to sea-level rise; and, identified land uses and infrastructure that could be affected if the existing shoreline fails to retain the tides. The assessment was performed for six separate hydrologic units and for ten types of shoreline structures

within each of those hydrologic units. The study results may be found at: http://scc.ca.gov/projects/north-coast/ and http://scc.ca.gov/webmaster/ftp/pdf/humboldt-bay-shoreline.pdf.

- *Marin Bay Waterfront Adaptation and Vulnerability Evaluation*: The Marin Bay Waterfront Adaptation and Vulnerability Evaluation (BayWAVE) (2017) presents potential consequences of sea-level rise for a variety of assets, including parcels and buildings, transportation networks, utilities, working lands, natural resources, recreational assets, emergency services, and cultural resources for 8 municipalities and 19 unincorporated jurisdictions within the County. Additionally, asset profiles include economic, environmental, equity, and management considerations related to sea-level rise vulnerability. For additional details regarding BayWAVE, go to: https://www.marincounty.org/main/marin-sea-level-rise/baywave/vulnerability-assessment.

- *San Francisco Sea Level Rise Action Plan*: The San Francisco Sea Level Rise Action Plan (2016) outlines a comprehensive path toward building a sea-level rise adaptation and implementation plan. An ongoing phase in the process is completing the sea-level rise vulnerability assessment. Asset categories are being continuously added and, when completed, will provide the basis for asset prioritization to guide adaptation strategies. To view the action plan, visit: http://sf-planning.org/sea-level-rise-action-plan.

- *County of San Mateo Sea Level Rise Vulnerability Assessment*: The County of San Mateo's Sea Level Rise Vulnerability Assessment (Sea Change SMC) (2018) documents potential impacts to 15 cities and the unincorporated portions of San Mateo County based on three different sea-level rise scenarios and one erosion scenario. This risk-based vulnerability assessment uses best available existing data. Vulnerability profiles were developed for 29 assets. The vulnerability assessment report serves as the first step of the Sea Change SMC Initiative. For additional information about the vulnerability assessment and Sea Change SMC, see Best Practices Highlight 7.A and visit: http://seachangesmc.com/.

- *County of Santa Barbara Sea Level Rise & Coastal Hazards Vulnerability Assessment*: The County of Santa Barbara's Sea Level Rise & Coastal Hazards Vulnerability Assessment (2017) addressed two separate zones of the unincorporated coastline (North County and South County). Risk and exposure to coastal erosion, coastal flooding, and tidal inundation of assets within the unincorporated areas of the County were modeled. The vulnerability assessment evaluated the impact of up to 5 feet of sea-level rise by the year 2100 and additional impacts associated with large wave storm events. County assets were divided into eight sectors: hazardous materials and minerals, roads and public transportation, land use, public facilities, public access and recreation, environmentally sensitive habitats, and wastewater and water supply. The document also includes an extensive discussion of the current planning landscape for context. The Assessment can be found at: http://longrange.sbcountyplanning.org/programs/Coastal%20Resiliency%20Project/coastalresiliency.php.

- *City of Los Angeles Sea Level Rise Vulnerability Study*: The City of Los Angeles Sea Level Rise Vulnerability Study (2013) provides an assessment of the potential vulnerabilities the City may face due to rising sea levels. It draws attention to potentially vulnerable City assets, possible building-related economic losses, and indicators of social vulnerability to begin to identify the most vulnerable communities in the City. A regional stakeholder working group was established early in the process to provide critical input to the study as well as suggestions on how to: 1) move forward in adaptation planning, 2) expand the study in future iterations, and 3) communicate the findings to wider audiences.
  The full report may be found at: http://www.adaptationclearinghouse.org/resources/sea-level-rise-vulnerability-study-for-the-city-of-los-angeles-california.html.

- *San Diego County Economic Vulnerability to Sea Level Rise*: The San Diego County Economic Vulnerability to Sea Level Rise (2018) report, published by the San Diego Regional Climate Collaborative, seeks to identify whether important parts of the economic base of the region (the industries which sell outside the region) are vulnerable and where adaptation strategies may be needed to sustain commercial and industrial activity. The analysis uses six different scenarios combining sea-level rise and storm intensity. Results indicate that commercial and industrial properties in San Diego County face significant risks to their economic well-being from sea-level rise-related flooding. The largest industries in terms of vulnerabilities include tourism and recreation, shipbuilding, and professional and technical services, each of which is an important part of the economic base of the County.

For additional details, go to: https://www.sdclimatecollaborative.org/single-post/2018/04/02/San-Diego-Regional-Climate-Collaborative-Publishes-Regional-Economic-Vulnerability-to-Sea-Level-Rise-Report.

The above examples provide a sampling of the various approaches individual communities have taken to assess their vulnerability to sea level rise. It should be noted that in most cases, conducting the vulnerability assessment is an incremental process which begins with collecting existing data and is supplemented over time with additional categories and more detailed analysis. Many of the jurisdictions described above, along with many other vulnerable coastal communities, continue to enhance their assessment and adaptation efforts.

Recent funding support for some of these efforts has been provided through the California Coastal Commission Local Assistance Grant Program which placed an emphasis on sea-level rise and climate change in both the 2016-2017 and 2017-2018 funding cycles (see Progress Summary 7.J). The California Department of Transportation (Caltrans) also supports enhancing transportation related vulnerability assessments to inform adaptation planning through the SB 1 Adaptation Planning Grant program (three funding cycles, ending in 2019). For more information about SB 1, see http://www.dot.ca.gov/hq/tpp/grant_files/FY_18-19/7.FY18-19_AP_AwardList.pdf.

Best Practices Highlight 7.A: San Mateo County's Sea Change Program and Sea Level Rise Vulnerability Assessment

San Mateo County faces a somewhat unique risk in that it is exposed to sea-level rise along its western Pacific Ocean coastline as well as its eastern shoreline which fronts the southern portion of the San Francisco Bay. In December 2013, the County held a conference that focused on addressing the challenges facing the County from the threat of sea-level rise. The conference identified the need for more specific information about the impact of sea-level rise on San Mateo County communities. Further action was taken in 2015 when the County established the Office of Sustainability and launched the "Sea Change SMC" initiative. The first two tasks for Sea Change SMC included initiating a community engagement process to build support for cross-jurisdictional collaboration and commencement of the San Mateo County Sea Level Rise Vulnerability Assessment. The primary goals of the vulnerability assessment were to:

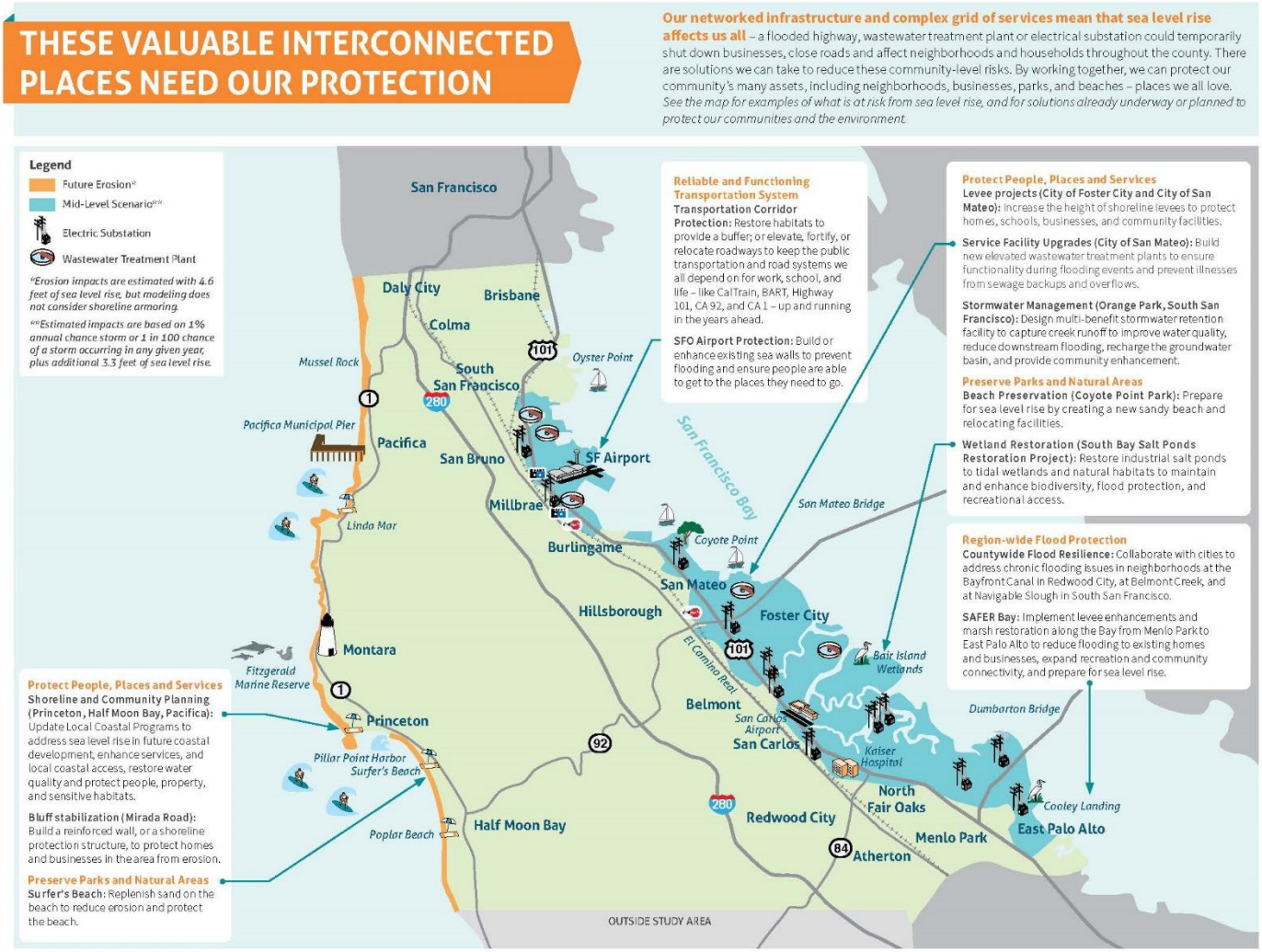
- Assess the overall vulnerability of the County to the impacts from sea-level rise, including permanent inundation, temporary flooding, erosion, and saltwater intrusion
- Identify potential consequences of hazards associated with sea-level rise, if no actions are taken
- Provide useful information to lead to actionable outcomes and lay the foundation for future, more detailed analyses to be conducted by the County or its cities
- Create an awareness of the need to prioritize nature-based solutions and to reduce impacts to socially vulnerable communities
- Build a collaborative network throughout the County on which to plan future efforts assess vulnerability, identify impacts of flooding and erosion on people, places, and critical infrastructure, and provide a menu of protective solutions

The assessment used existing data projecting sea level rise hazards to understand the geographic extent to which the County could be exposed to inundation and erosion. Three sea-level rise scenarios and one scenario for coastal erosion were developed based on best available scientific data.

Key steps in the vulnerability assessment process included: producing maps and inventories of built and natural assets exposed, as well as an assessment of communities in areas at risk from current and future inundation; analyzing short and long-term impacts of sea-level rise, storm related impacts and the potential long-term implications of inaction; developing 30 Asset Vulnerability Profiles (AVPs) for a representative set of assets across geography and asset categories; preparing a menu of adaptation options; engaging multiple stakeholders to discuss the challenges associated with sea-level rise; and, preparing a roadmap for future efforts to increase resiliency through suggested adaptation strategies.

The assessment report identifies built and natural assets vulnerable to sea-level rise, explores public health and risks from cascading impacts, and discusses what these factors mean for policy and planning purposes. The report findings highlight that many of the assets have cross-cutting vulnerabilities and may have more than one point of exposure to sea level rise. Additionally, issues such as "governance vulnerability" resulting from the complexity of multiple governing agencies and asset ownership, and the potential for increased social vulnerability as a result of sea level rise are discussed. Specific details of the vulnerability assessment methodology, results, and community process, and next steps in the sea level adaptation planning process may be found at: http://seachangesmc.com/vulnerability-assessment/.

Figure 7.I: Graphic from San Mateo County's Sea Level Rise Vulnerability Assessment



Source: County of San Mateo Sea Level Rise Vulnerability Assessment, http://seachangesmc.com/wp-content/uploads/2018/03/SLR_VA_Highlights_v12_web-spread.pdf

Key Resources and Guidance for Sea-Level Rise Vulnerability Assessments and Adaptation Planning

Sea level projections are the basis for assessing vulnerability to sea level rise and planning adaptation strategies. The ability for communities to visualize the local assets threatened by sea level rise is critical for developing adaptation strategies.

Many federal and state agencies and other organizations have developed support resources for local, regional, and tribal jurisdictions. Table 7.I includes a listing of best available sea level rise resources and guidance as of July 2018, including interactive mapping tools intended to aid communities in assessing and planning for sea level rise impacts. This table includes many of the SLR resources available as of August 2018, but is not an exhaustive list. Other resources may be available, or be developed in the future, that are valuable assessing or planning for SLR.

Table 7.I: Sea-Level Rise Resources and Guidance

Sea Level Rise Resource/Guidance	Description
Guidance and General Resources	
Ocean Protection Council (OPC) State of California Sea-Level Rise Guidance 2018 Update	OPC's updated 2018 guidance recommends how to include sea-level rise projections in decisions and recommends strategies for risk evaluation and adaptation. The 2018 guidance should be consulted for the most current sea-level rise projections. http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf
OPC 2017 Rising Seas in California: Update on Sea-Level Rise Science	This report synthesizes the state of sea level rise science and provides the scientific foundation for the 2018 update to the State of California's sea level rise guidance. http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf
California Coastal Commission Sea-Level Rise Policy Guidance	This document is an overview of sea-level rise science and recommended methodology for addressing SLR in planning and regulatory actions. It is intended to serve as a multi-purpose resource for a variety of audiences and includes a high level of detail on many subjects. Supplemental sea-level rise guidance materials can be found on the Coastal Commission website. https://www.coastal.ca.gov/climate/slrguidance.html
Governor's Office of Planning and Research (OPR) Integrated Climate Adaptation and Resiliency Program (ICARP) Adaptation Clearinghouse: Ocean and Coast Topic Area	The Adaptation Clearinghouse serves a centralized source of information to guide planning and implementation of adaptation projects. For the clearinghouse start page, visit: http://opr.ca.gov/clearinghouse/adaptation/ The Clearinghouse's "Ocean and Coast" topic area provides a comprehensive listing of resource information, including sea-level rise planning documents, adaptation plans, policies, guidance, science and research, case studies, and funding sources. For the ocean and coast topic page of the clearinghouse, visit: https://resilientca.org/topics/ocean-and-coast/
OPC Sea-Level Rise Planning Database	Assembly Bill 2516 (2014) requires OPC to develop and maintain a sea-level rise Planning Database biannual surveys of sea-level rise planning information to catalog California's efforts to prepare for rising seas. OPC is working with OPR to provide the resources listed in the databased through the Adaptation Clearinghouse Ocean and Coast Topic area. http://www.opc.ca.gov/planning-for-sea-level-rise-database/

Sea Level Rise Resource/Guidance	Description
National Oceanic and Atmospheric Administration (NOAA) Digital Coast	Portal to local, state, and federal data, tools, and training for resilience and other coastal issues. NOAA developed the website in partnership with stakeholders who are the website's primary users. These contributing partners include federal, state, local, and regional governments, and non-governmental, academic, and private sector organizations. https://coast.noaa.gov/digitalcoast/
Adapting to Rising Tides Portfolio	The San Francisco Bay Conservation Development Commission (BCDC) Adapting to Rising Tides (ART) program offers planning guidance, engagement and planning tools for conducting a community adaptation planning process, and resources addressing sea-level rise, specific to counties in the San Francisco Bay Area. http://www.adaptingtorisingtides.org/
California State Coastal Conservancy	The Coastal Conservancy's Climate Ready Program is helping natural resources and human communities along California's coast and San Francisco Bay adapt to the impacts of climate change, such as rising sea levels, beach and bluff erosion, extreme weather events, flooding, increasing temperatures, changing rainfall patterns, decreasing water supplies, and increasing fire risk. http://scc.ca.gov/climate-change/
California State Coastal Conservancy /The Nature Conservancy	The Nature Conservancy in California and the California State Coastal Conservancy collaborated to produce the first statewide, comprehensive assessment of the vulnerability of California's coastal habitats, imperiled species, and conservation lands to sea level rise. http://coastalresilience.org/project/conservation-assessment/
California State Lands Commission	The California State Lands Commission works to facilitate sea-level rise preparedness with an emphasis on protecting California's public trust lands and the public's right to access and enjoyment of these lands. The Commission partners with the California legislature and federal, state, and local agencies on efforts to mitigate the impacts of sea-level rise on the lands and natural resources entrusted to its care. http://www.slc.ca.gov/Programs/Sea_Level_Rise.html
Coastal Plan Alignment Compass	Developed through a multi-agency partnership, The Compass focuses on California coastal communities, which are responsible for developing a suite of local plans that include local coastal programs, local hazard mitigation plans, and general plans. https://resilientca.org/topics/plan-alignment/
California Natural Resources Agency	The California Natural Resources Agency leads and coordinates the administration's climate adaptation policy and its natural resources climate policy. http://resources.ca.gov/climate/
California Climate Change Portal	The State of California hosts this web page offering sea level rise resources for local governments. http://www.climatechange.ca.gov/adaptation/local_government/sea_level_rise.html
OPR General Plan Guidelines	OPR updated General Plan Guidelines provide guidance to local governments on how to incorporate climate change into general plans. http://opr.ca.gov/planning/general-plan/
Sea-Level Rise Mapping Tools	
Cal-Adapt Climate Change Mapping Tools	This tool offers state climate data for multiple hazard and is interactive with the General Plan Guidelines Data Mapping Tool (see description below). Mapping data includes water depth based on various sea-level rise scenarios. http://cal-adapt.org/tools/slr-calflod-3d/

Sea Level Rise Resource/Guidance	Description
NOAA Office for Coastal Management Sea Level Rise Viewer	This web mapping tool assisting in visualizing community-level impacts from coastal flooding or sea-level rise (up to 6 feet above average high tides). It also provides photo simulations of how future flooding might affect local landmarks, as well as data related to water depth, connectivity, flood frequency, socio-economic vulnerability, wetland loss and migration, and mapping confidence. https://coast.noaa.gov/slr/
Sea the Future: Sea Level Rise and Coastal Flood Web Tools Comparison Matrix	This matrix compares sea-level rise visualization tools to apply to local questions. The matrix was created to provide the planning and coastal management communities with an expandable chart to compare the functions and methods of publicly available sea level rise and coastal flood web tools. The matrix was originally developed as part of California's "Lifting the Fog" workshop, which sought to provide guidance to end users interested in using modeled sea level rise projections in coastal planning. http://sealevel.climatecentral.org/matrix/
CoSMos	The Coastal Storm Modeling System (CoSMoS) is a dynamic modeling approach that has been developed by the United States Geological Survey in order to allow more detailed predictions of coastal flooding due to both future sea-level rise and storms integrated with long-term coastal evolution (i.e., beach changes and cliff/bluff retreat) over large geographic areas. https://walrus.wr.usgs.gov/coastal_processes/cosmos/index.html
Hazard Exposure Reporting and Analytics: HERA	Developed by USGS, HERA can be used in conjunction with CoSMoS to evaluate sea-level rise impacts on demographics, economics, land cover, and infrastructure. HERA provides mapping results in chart and table formats. https://www.usgs.gov/apps/hera/
Our Coast Our Future (OCOF), Online Viewer for the CoSMoS Tool	Our Coast, Our Future (OCOF) is a collaborative, user-driven project focused on providing coastal California resource managers and land use planners with locally relevant, online maps and tools to help understand, visualize, and anticipate vulnerabilities to sea-level rise and storms. http://data.pointblue.org/apps/ocof/cms/
The Nature Conservancy Coastal Resilience California	This tool visualizes sea-level rise to identify vulnerabilities along the California coast, compares economic impacts of nature-based adaptation approaches, and identifies potential mitigation pathways for coastal habitats. http://maps.coastalresilience.org/california/
Surging Seas Risk Finder	This tool provides local information on se-level rise and coastal flooding down to the neighborhood level. http://sealevel.climatecentral.org/
General Plan Guidelines Data Mapping Tool	This tool maps various data sets (including sea-level rise projections) that may be useful to local, regional, and tribal planners. Data are grouped by general plan category and by common themes. http://opr.ca.gov/planning/general-plan/data-mapping-tool.html
State of California Geoportal	Many of the state's hazards mapping tools, along with many other Geographic Information Systems (GIS) tools are accessible on the State of California Geoportal website. http://portal.gis.ca.gov/geoportal/catalog/main/home.page

Additionally, some agencies such as California State Lands Commission have also developed internal resources regarding sea-level rise. For example, the California State Lands Commission's Sea-Level Rise Viewer is a web-mapping application developed to assist staff in sea-level rise planning and lease area review.

For other mitigation and adaptation planning resources see Tables 5.J and 5.K in *Section 5.3.2*.

7.2.4 CURRENT SEA-LEVEL RISE, COASTAL FLOODING, AND EROSION HAZARD MITIGATION EFFORTS

Mitigating the impacts of sea-level rise requires action at all levels of government. A global effort is needed to reduce greenhouse gas (GHG) emissions that are leading to climate change, but GHG emission reduction will not be able to blunt sea-level rise in the near term. In addition, GHG emissions remain in the atmosphere for periods ranging from decades to centuries. As a result, ocean waters will continue to warm and the polar ice caps and continental glaciers will continue to melt even as GHG emission reduction programs occur.

Since sea-levels will continue rising, communities must implement a variety of adaptation strategies to reduce impacts from sea-level rise. Appropriate land use planning and regulation are needed at the federal, state, and local levels. Many statewide guidance documents provide information related to adaptation options. For example, the Coastal Commission's draft Residential Adaptation Policy Guidance document discusses climate adaptation for residential development to help communities with residential land use planning.[163]

Often, the first step in developing mitigation strategies is assessing vulnerability, because it is through the vulnerability assessment that areas in need of mitigation are identified. In some cases, specific assessment methods are used to inform mitigation actions and are classified as part of the mitigation strategy. Thus, some sea-level rise vulnerability assessment efforts being undertaken by state agencies, considered to be precursors to development of priority mitigation and adaptation actions, are included in this section.

Adaptation Efforts by State Agencies

In California, multiple agencies are pursuing efforts to address sea-level rise and development decisions affecting coastal areas are regulated at state, regional, and local levels. While not a regulatory agency, the Ocean Protection Council (OPC) is responsible for updating the State of California's sea-level rise guidance document to ensure that state and local planning, permitting and investment decisions are based on the best available science and are protective of vulnerable communities, infrastructure, and coastal habitats. This guidance is integrated into regulatory and funding decisions of the state's coastal management agencies. The California Coastal Commission regulates development to ensure protection of coastal resources and calls for preparation of Local Coastal Programs (LCPs), which carry out state Coastal Act policies (subject to review and approval by the Coastal Commission). Similarly, the Bay Conservation and Development Commission (BCDC) prepares and implements plans that determine development along San Francisco Bay.

The State Department of Parks and Recreation has jurisdiction over more than 300 miles of California coastline and implements a Coastal Erosion Policy to avoid construction of new structures or coastal facilities in areas subject to ocean wave erosion, sea cliff retreat, and unstable cliffs.

The California State Lands Commission regulates the construction of marine oil terminals (Chapter 31F Marine Oil Terminals, Title 24 Part 2, California Building Code). It regulates the construction of liquid natural gas (LNG) marine terminals through a building code in pre-draft stage and will oversee the construction of oil platforms on state lands. In addition, California State Lands Commission oversees public trust lands. As sea levels rise, the public trust boundary will move inland, affecting areas of development not currently serving public trust interests (e.g. private residential development). Community responses to sea-level rise and hazards will be affected by how the California State Lands Commission addresses public trust lands over time.

While several state agencies are in the process of evaluating and responding to potential effects of sea-level rise, four agencies have substantial focus on the issue. The Ocean Protection Council (OPC), California Coastal Commission, and San Francisco Bay Conservation and Development Commission (BCDC) are actively engaged in an ongoing evaluation of sea-level rise and related hazards such as erosion and coastal flooding. In addition, the

[163] California Coastal Commission. Draft Residential Adaptation Policy Guidance. 2017. Retrieved on August 30, 2017 from https://www.coastal.ca.gov/climate/slr/vulnerability-adaptation/residential/

California Department of Transportation (Caltrans) has responsibility for extensive transportation infrastructure potentially at risk and has been assessing the vulnerability of these transportation systems.

Continued efforts are also underway to facilitate coordinated understanding of the latest science regarding climate impacts on oceans. These efforts help to integrate adaptation work between federal, state, regional, and local jurisdictions.

Fourth Climate Change Assessment

The Fourth Climate Change Assessment is the first inter-agency effort to implement a substantial portion of the Climate Change Research Plan that was released in 2015. The California Natural Resources Agency, in collaboration with the Governor's Office of Planning and Research (OPR), the California Energy Commission (CEC), and the Climate Action Team (CAT) Research Working Group, has developed a proposed portfolio of projects for California's Fourth Climate Change Assessment.

Among the portfolio of projects being undertaken in the fourth Climate Change Assessment are several that address coastal issues, sea-level rise, and ocean ecosystems, including:

- Assessing and Communicating the Impacts of Climate Change on the California Coast
- Identification of Natural Infrastructure Options for Adapting to Sea-Level Rise
- California Mussels as Bio-Indicators of the Ecological Consequences of Global Change: Temperature, Ocean Acidification, and Hypoxia
- Multi-Scale Infrastructure Interactions with Intermittent Disruptions: Coastal Flood Protection Infrastructure, Transportation, and Government Networks
- Strategies for Adapting to Long-Term Sea-Level Rise in the San Francisco Bay Area

Final reports for the projects listed above are planned for release in August 2018.

Best Practices Highlight 7.A: Natural Infrastructure for Adapting to Sea Level Rise

In November 2017, the Fourth Climate Change Assessment in coordination with other federal and state agencies published "Case Studies of Natural Shoreline Infrastructure in Coastal California: A Component of Identification of Natural Infrastructure Options for Adapting to Sea Level Rise." The report features five case studies of projects along the state's coastline that address adaption to sea level rise through green and/or natural shoreline infrastructure methods. Natural shoreline infrastructure is an alternative to engineered structures that is more likely to preserve the benefits of coastal ecosystems while also maintaining coastal access.

A Technical Advisory Committee was charged with selecting a set of projects to highlight as case studies of natural shoreline infrastructure, and was composed of 34 representatives from local, state, and federal government agencies, non-governmental organizations, and environmental consulting firms.

For each featured case study, a summary is provided along with a list of "Key Lessons for Success" that can be used by other coastal jurisdictions. The case studies were designed to be useful examples for coastal planners, local governments, and others working on solutions and making decisions regarding climate-related coastal hazards.

To download the report, visit: http://coastalresilience.org/wp-content/uploads/2017/11/tnc_Natural-Shoreline-Case-Study_hi.pdf.

Safeguarding California Plan: 2018 Update

In the 2018 update to the Safeguarding California Plan strategies are organized into 10 sectors with five for social systems and the built environment and five for natural and managed resource systems and an additional sector, new to the 2018 update, for "Parks, Recreation, and California Culture."[164] The "Parks, Recreation, and California Culture" sector is categorized under both systems, as it deals with social systems, the built environment, and natural resources. Climate justice recommendations, also new to the 2018 update, are included in all policy sectors. (For more information on the Safeguarding California Plan: 2018 Update, see *Section 4.3.6.4*).

Within the natural and managed resource systems grouping is the "Ocean and Coast" Sector. For this sector, recommendations with associated next steps and ongoing actions are listed. These recommendations (and their associated steps and actions) address sea-level rise and adaptation. For more information, visit the California Natural Resources Agency website: http://resources.ca.gov/climate/safeguarding/.

California Coastal Commission: Planning and Regulatory Process

There are a number of ways the California Coastal Commission addresses sea-level rise in its planning and regulatory process. The potential impacts of sea-level rise fall directly within the Coastal Commission's planning and regulatory responsibilities under the Coastal Act, which mandates the protection of public access and recreational opportunities, coastal habitats, and sensitive resources, and requires the minimization of coastal hazards for all coastal development.

The Coastal Commission implements these policies through the review and certification of Local Coastal Programs (LCPs) (which allow local governments to implement the Coastal Act at the local level) and through direct review of certain projects (either through an appeal of a local agency decision or review of projects located in areas of the Coastal Commission's retained jurisdiction). Since its inception, the Coastal Commission and local governments have addressed coastal hazards that will be exacerbated by sea-level rise through actions such as requiring hazard and site stability analyses, ensuring that development is setback or otherwise designed to avoid or minimize hazards, and requiring that any measures taken to address hazards will minimize impacts on coastal habitats.

The Coastal Commission is working to implement the state's sea level rise policy guidance through a number of avenues. These includes outreach and training for Coastal Commission staff, local governments, and other interested parties; and coordination with state and federal agencies such as NOAA, FEMA, USGS, Caltrans, the California State Lands Commission, OPC, and others. Notably, the Coastal Commission has emphasized (and devoted significant funding to) working with local governments to update their LCPs to better address sea level rise.

The impacts of sea level rise will be felt at the local level, and therefore local responses are a critical component of effective management of these impacts. To that end, the Coastal Commission (leveraging funding from both OPC and the State Coastal Conservancy) developed a grant program that funds local jurisdictions to update LCPs with the goal of updating or developing policies to ensure that adaptation occurs in a way that protects both coastal resources and public safety and allows for sustainable economic growth. To date, over 30 local governments have received grants to complete vulnerability assessments, technical studies, and adaptation plans, and to develop updated land use and adaptation policies that better address sea level rise.

[164] California Natural Resources Agency. (2017). Draft Report Safeguarding California Plan: 2017 Update. Sacramento: author, 183 p., p. 4.

Progress Summary 7.H: California Coastal Commission Sea-Level Rise Policy Guidance

Progress as of 2018: In August 2015, the Coastal Commission adopted the "California Coastal Commission Sea-level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits" document. It provides background on sea level rise science, recommendations for addressing sea level rise in Local Coastal Programs (LCPs) and Coastal Development Permits, information on adaptation options, and a discussion of the legal context of adaptation planning. Communities should check the Coastal Commission website for updates to the guidance as science evolves.

The 2015 document provides six steps for addressing sea level rise in LCPs and other plans:

1. Determine the range of sea level rise projections relevant to the LCP planning area
2. Identify potential physical sea level rise impacts in the LCP planning area
3. Assess potential risks from sea-level rise to coastal resources and development
4. Identify LCP adaptation strategies to minimize risks
5. Draft an updated or new LCP for certification by the Coastal Commission
6. Implement the LCP and monitor and revise as needed.

Sea level rise and the changing climate present management challenges of a new magnitude, with the potential to significantly threaten many coastal resources. As sea levels rise, beaches, wetlands, and other coastal habitats will be drowned and eventually lost if they are backed by fixed development and unable to naturally migrate inland over time. This constraint, commonly referred to as "coastal squeeze," also affects public access and recreation and presents a significant environmental justice issue if private residents adjacent to the shoreline continue to enjoy shoreline access while the general public access is blocked.

The "coastal squeeze" phenomenon requires the implementation of adaptation strategies like beach nourishment and managed retreat to ensure the continued protection of coastal resources as mandated by the Coastal Act. To better address these challenges, the Coastal Commission developed its Sea Level Rise Policy Guidance, which was unanimously approved in August 2015. This document provides a set of guiding principles and recommendations for how to address sea level rise within the context of the Coastal Act. It provides step-by-step processes for how to develop or update LCPs to respond to sea level rise and how to address sea level rise in Coastal Development Permit applications.

The guidance also includes information of sea level rise science, a library of adaptation strategies, and background on the legal context of adaptation planning. In 2018, the Coastal Commission released a draft science update to the Sea Level Rise Policy Guidance intended to better align the CCC guidance with the Ocean Projection Council's State of California Sea-Level Rise Guidance 2018 Update and 2017 Rising Seas in California: Update on Sea-Level Rise Science documents.

Visit the California Coastal Commission website to download the Sea Level Rise Policy Guidance document: https://www.coastal.ca.gov/climate/slrguidance.html.

Progress Summary 7.I: Local Coastal Resources Grant Program

Progress as of 2018: The California Coastal Commission's Local Coastal Program/Local Assistance Grant Program provides funds to support local governments in completing or updating Local Coastal Programs (LCPs) consistent with the California Coastal Act, with special emphasis on planning for sea level rise and climate change.

Four rounds of LCP local assistance grants have been awarded. To date, $5 million has been awarded to 34 different local governments to complete a variety of vulnerability assessments, technical studies, and adaptation plans, to conduct public outreach, and to develop or update LCP policies to better address sea level rise. In the fourth round of grant funding, a total of $546,685 of California State Coastal Conservancy funds were awarded to jurisdictions working on sea level rise and climate change planning. The fifth round of grant funding is planned to be awarded in the fall of 2018.

More information on the Coastal Commission grant program, including links to completed grant deliverables from local jurisdictions, can be found at: https://www.coastal.ca.gov/lcp/grants/.

More information on the Coastal Commission's continued sea level rise work can be found on the Coastal Commission's sea level rise [165] and LCP local assistance grant program web page: https://www.coastal.ca.gov/lcp/grants/.

Caltrans – Sea Level Rise Assessment and Adaptation Planning, Permitting, Highway Design

In February 2009, Caltrans prepared a report titled "Vulnerability of Transportation Systems to Sea-level Rise: A Preliminary Assessment," which concluded that a 4.58-foot (1.40-meter) rise in sea level would have substantial impacts on various transportation systems, including flooding of tunnels and airport runways, washouts of coastal highways and rail lines, and submersion of dock and port facilities. These would have strategic security implications, as well as transportation and economic implications.

By 2100, sea level rise could put at risk about 350 miles of major state highways located along coastal, delta, and interior waterways. Freight transportation that involves ports, rail lines, local streets, highways, and pipelines also faces the potential for major disruption. The impacts of sea level rise could endanger an estimated 3,500 miles of roads and 280 miles of railways that would be vulnerable to a 100-year flood event in 2100.

Building on the initial evaluation in 2009, Caltrans released "Guidance on Incorporating Sea-level Rise" in 2011. The 2012 Caltrans Director's Policy 30 bolstered these efforts by mandating the consideration and integration of climate change into departmental decisions and activities. In 2013, "Caltrans Activities to Address Climate Change" was released.[166] This document summarizes GHG reduction as well as adaptation needs and strategies for California's transportation system.

Caltrans' initial vulnerability assessment and adaptation studies are detailed in the 2014 "District 1 Climate Change Vulnerability Assessment and Pilot Studies FHWA Climate Resilience Pilot Final Reports."[167] This study effort created a process for vulnerability evaluation of Caltrans assets and a means to assess adaptation strategies. Vulnerability assessment and pilot study efforts are planned for the remaining districts within the next year, with District 4 expected to release a draft report in 2017.

The climate change impacts studied include sea level rise, storm surge, precipitation change, high temperatures, and wildfires. The vulnerability assessment studies complete four steps:

- Project future climate scenarios (2050, 2070, 2100)

[165] https://www.coastal.ca.gov/climate/slrguidance.html
[166] Caltrans. Caltrans Activities to Address Climate Change, 2013. Retrieved on 8/25/17 from http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/Caltrans_ClimateChangeRprt-Final_April_2013.pdf.
[167] Caltrans. (2014). District 1 Climate Change Vulnerability Assessment and Pilot Studies. Retrieved on 8/25/17 from http://www.dot.ca.gov/hq/tpp/offices/orip/climate_change/documents/ccps.pdf.

- Quantify and map impacts of climate change stressors
- Identify transportation assets as risk (roads, bridges, culverts)
- Develop strategies and guidance to address vulnerable assets in Caltrans planning programming, and project development

Senate Bill 1, the Road Repair and Accountability Act of 2017, includes accounting for projected climate change impacts such as sea level rise as a condition for projects receiving funds. The bill also establishes a funding program to support climate adaptation planning. For more information on Senate Bill 1, see *Section 4.3.6.2* or visit: http://www.dot.ca.gov/hq/tpp/grant_files/FY_18-19/7.FY18-19_AP_AwardList.pdf.

Best Practices Highlight 7.B: Caltrans Incorporating Sea-level Rise into Corridor Planning for State Route 37

State Route 37 (SR 37) constitutes a major regional east-west vehicular transportation corridor in the northern San Francisco Bay Area. Caltrans selected this corridor for a case study to understand adaptive transportation planning in the face of sea-level rise. The case study, initiated in 2014, was designed to implement a four-stage process:

- Involve stakeholders in a multi-way discussion of future scenarios
- Model potential risks to SR 37 and associated shoreline
- Develop conceptual diagrams, costs, and visualizations of adaptive structures
- Share text resources, data, and project findings through a web-system

The results of the case study were released in 2016 as the State Route 37 Integrated Traffic, Infrastructure, and Sea-level Rise Analysis report, also known as the SR 37 Stewardship Study. The University of California, Davis, in partnership with Caltrans District 4, conducted the study in conjunction with key stakeholders including congestion management agencies from Napa, Solano, Sonoma, and Marin Counties; the Metropolitan Transportation Commission; North Bay county resource conservation districts; state and federal resource and permitting agencies; the Sonoma Ecology Center; the Sonoma Land Trust; and numerous others.

The study provided crucial information on the expected impacts of sea-level rise on State Route 37 and developed high-level cost estimates for three potential highway reconstruction options to mitigate the impacts of sea-level rise, while also addressing environmental considerations. The results of the study will help shape long-range planning for State Route 37 by informing the updates of the Transportation Concept Report. District 4 will also use this study as the foundation for future decision-making in potential follow-up studies, including a hydraulic study and a transit opportunities assessment. The full report and technical appendices may be accessed at: http://scta.ca.gov/wp-content/uploads/2018/02/SR-37-Corridor-Plan-with-appendix.pdf.

The State Route 37 Integrated Traffic, Infrastructure, and Sea Level Rise Analysis study, as well as other preceding research efforts provided a basis for an additional regionally based sea-level rise planning effort. The SR 37 Transportation and Sea Level Rise Corridor Improvement Plan was released in June 2018. Also a collaborative effort between Caltrans, the Metropolitan Transportation Commission, and the four North Bay Transportation Authorities, this corridor plan encompasses three broad goals:

- Integrate transportation, ecosystem, and sea-level rise adaptation into one design
- Improve mobility across all modes and maintain public access
- Increase corridor resiliency to storm surges and sea-level rise

The most critical issues for the study corridor are recurrent traffic congestion, vulnerability to flooding (including sea-level rise), and potential impacts of sea-level rise on highly sensitive environmental resources adjacent to the corridor. The corridor plan developed and evaluated three potential strategies to maintain Highway 37 in the context of the existing corridor and identified adaptive mitigation strategies to address the key corridor issues and develop resiliency to sea-level rise. An Implementation Plan is also included which outlines specific projects to be completed in the near-, mid-, and long-term. Further details may be found at: http://scta.ca.gov/wp-content/uploads/2018/02/SR-37-Corridor-Plan-with-appendix.pdf.

Department of Water Resources

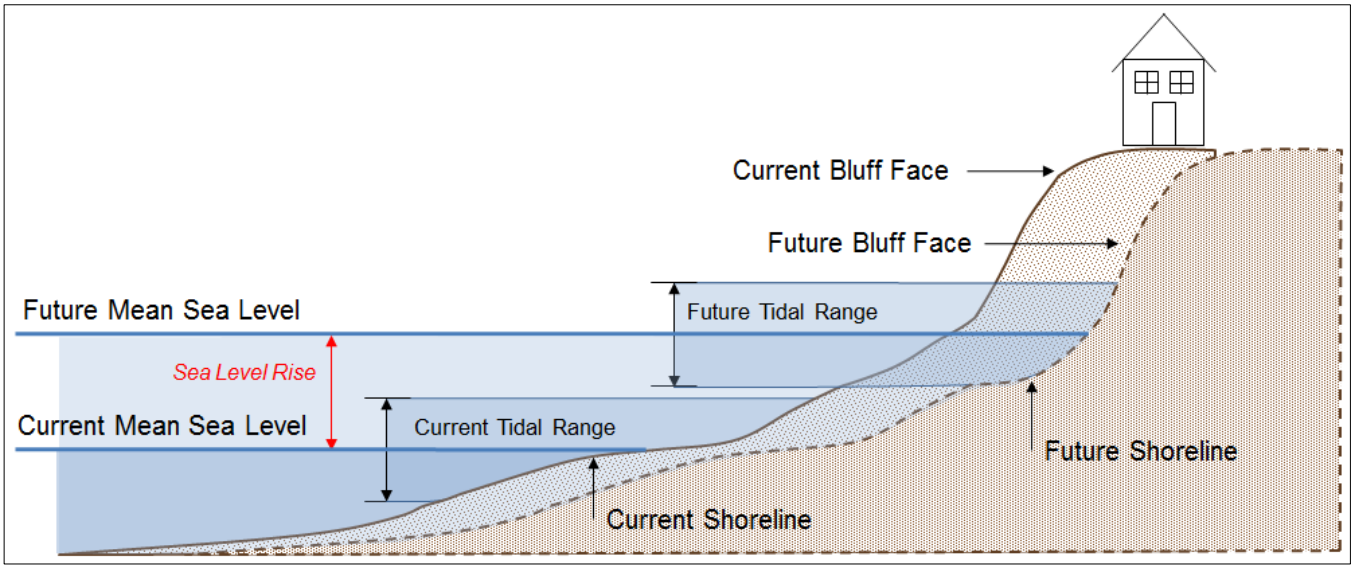
The California Department of Water Resources (DWR) produced the California Quick Guide in 2007 with a focus on "existing condition" flood hazards. In October 2016, DWR published an appendix to the Quick Guide titled "The National Flood Insurance Program in California Quick Guide Coastal Appendix: Planning for Sea-Level Rise" to provide information to floodplain managers, planners, and community leaders who need to understand the effects of future sea level rise in order to enhance their communities' mitigation plans and take action to better protect their citizens. The appendix provides information and resources on regulatory and non-regulatory FEMA mapping efforts, general approaches for mapping sea level rise in coastal areas, and guidance to communities on how to plan for sea level rise.

Figure 7.J illustrates information provided in DWR's Quick Guide. To download the California Quick Guide Coastal Appendix document, visit: http://water.ca.gov/floodmgmt/lrafmo/fmb/docs/QGCoastalAppendix_FINALDRAFT_2016dec02.pdf.

For more information about California's climate change adaptation initiatives, see *Section 4.3.6*.

(Note: DWR's Quick Guide information has not yet been updated to incorporate the sea level rise projections from the 2017 "Rising Seas in California: An Update on Sea-Level Science" report and the State of California Sea-Level Rise Guidance 2018 Update, which are considered the best available science for sea level rise projections in California, as of 2018.)

Figure 7.J: Sea-level Rise Planning Guidance



Source: California Department of Water Resources, The National Flood Insurance Program in California: Quick Guide Coastal Appendix: Planning for Sea-level Rise, October 2016.

Adapting to Rising Tides: Addressing Vulnerability to Sea-level Rise in San Francisco Bay

The Bay Conservation and Development Commission (BCDC) focuses on sea level rise in San Francisco Bay and development within the first 100 feet of the waterfront. The document titled "Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline" was released in 2011. Building on this effort, BCDC supports the Adapting to Rising Tides (ART) program. This program offers includes guidance, examples, and many other resources to support regional and local efforts (see Figure 7.K).

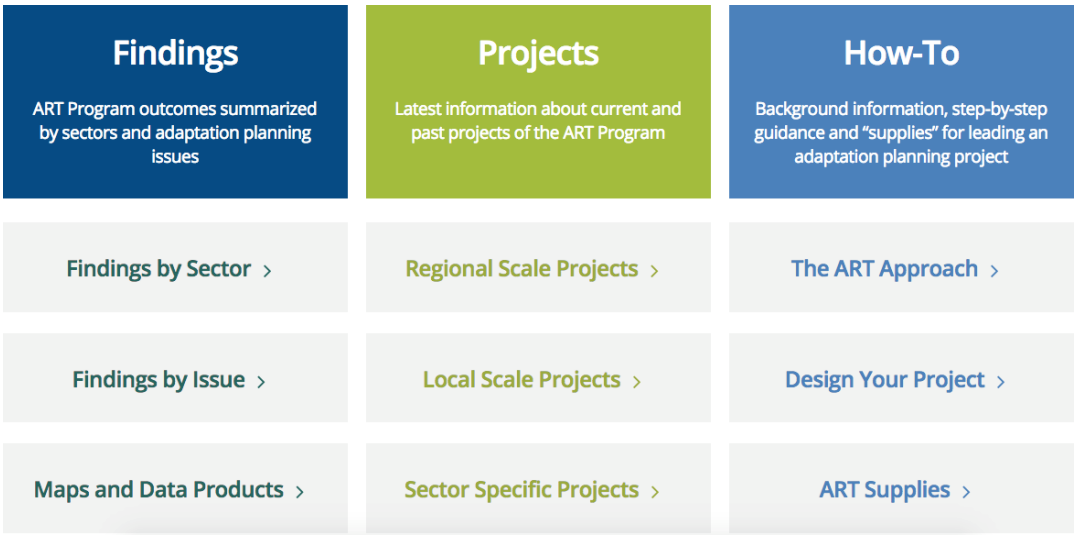
Progress Summary 7.J: San Francisco Bay Conservation and Development Commission

Progress as of 2018: The San Francisco Bay Conservation and Development Commission (BCDC) has been working to support local and regional sea level rise adaptation efforts with guidance, improved science, and educational programs. Since 2010, these efforts have been housed within the Adapting to Rising Tides (ART) program.[168]

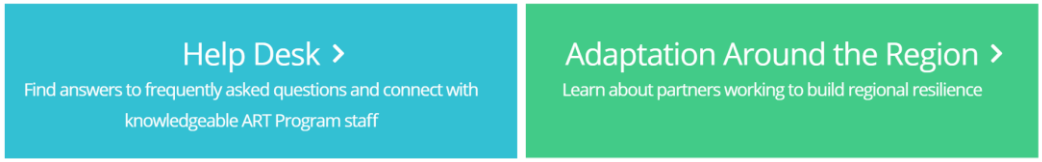
BCDC's efforts continue to expand in scope, detail, complexity, and setting. These efforts (including several implemented projects) will continue to foster adaptation efforts in the Bay Area.

For more information about BCDC's Adapting to Rising Tides (ART) program, visit: www.adaptingtorisingtides.org/.

Figure 7.K: Bay Conservation and Development Commission (BCDC) Adapting to Rising Tides Program – Resource Organization



Source: www.adaptingtorisingtides.org



Source: www.adaptingtorisingtides.org

Two valuable aspects of the ART program are the "Help Desk" and "Adaptation Around the Region" features. For more information about these features, visit: www.adaptingtorisingtides.org.

[168] San Francisco Bay Conservation and Development Commission (BCDC). 2017. Adapting to Rising Tides. Retrieved on 8/28/17 from http://www.adaptingtorisingtides.org/

Local and Regional Adaptation Planning and Efforts

Many local and regional jurisdictions have pursued sea level rise planning and adaptation efforts. The following best practices highlight planning efforts and projects completed since 2013 can be used as examples by other jurisdictions.

Best Practices Highlight 7.C: The Adapting to Rising Tides Project: Collaborative Adaptation Planning on the Shoreline of Alameda County

The Adapting to Rising Tides (ART) project is a collaborative planning effort led by San Francisco Bay Conservation and Development Commission (BCDC) and the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management. The ART program seeks to answer two key questions:

1) How will climate change impacts of sea level rise and storm events affect the future of Bay Area communities, infrastructure, ecosystems, and economy?
2) What strategies can we pursue, both locally and regionally, to reduce and manage these risks?

For its pilot project, the ART team worked with an active and engaged group of local, county, regional, state, and federal agency staff to evaluate the vulnerability and risk of a portion of the Alameda County shoreline from Emeryville to Union City. The first step in this process was an impacts assessment that identified local climate impacts associated with sea level rise and storm events, and characterized the existing conditions of community land use, transportation, utility, and shoreline assets in the project area (the ART sub-region). The impacts assessment set the stage for a comprehensive evaluation of vulnerability based on exposure and sensitivity to sea level rise and storm events, and the capacity to accommodate or adjust to these impacts. With input from the working group and other experts, the project also broadly evaluated the social equity, economic, environmental, and governance consequences of sea level rise and storm event impacts.

Based on the assessment of vulnerability and risk, the ART project developed a suite of adaptation responses to mitigate the risk of future sea level rise and storm events by improving the resilience of community land use, transportation, utility, and shoreline assets at the sub-regional scale. With the working group, the project is evaluating the sub-regional adaptation responses, which include a number of possible actions that can be taken together or individually by interested stakeholders to strategically address identified vulnerabilities. The adaptation response also included options for local, regional, and statewide implementation, including the processes, partners, and triggers for initiation.

In addition to developing adaptation responses at the sub-regional scale, the ART project is evaluating the issues of inter-related vulnerabilities and risks, including infrastructure inter-dependencies, which need to be addressed at scales smaller than the sub-region. These efforts will help the region better understand the potential mitigation options to address cross-cutting, the multi-hazard risk that the shoreline will face in light of sea level rise, existing coastal hazards, and other future pressures. While the documents for Alameda County were completed in January 2014, the ART staff continue to work with asset managers within the project area on more focused assessment and adaptation planning.

The initial ART program has expanded into BCDC's "ART Portfolio" program, which includes a range of ongoing local- and regional-scale projects and sector-specific projects, such as ART Bay Area, the Contra Costa County ART Project, the Capitol Corridor Passenger Rail project, and many others.

To learn more, see: http://www.adaptingtorisingtides.org/project/art-subregional-project/.

Best Practices Highlight 7.D: Sea-Level Rise Adaptation in the San Francisco Bay Area – Mission Creek Sea-level Rise Adaptation Study

San Francisco is one of many coastal cities threatened by the impacts of sea level rise. The lowest-lying part of the city is the eastern waterfront surrounding Mission Creek Canal and Mission Bay. Projections for San Francisco Bay presented in the State of California Sea-Level Rise Guidance 2018 Update anticipate a 2.4- to 3.4-foot increase in tide levels by 2100 (based on low to high emissions scenarios in the likely range), which could flood neighborhoods, historic bridges, and other critical infrastructure.

To address the hazards posed by rising sea level in Mission Creek, several City and County of San Francisco agencies conducted a $200,000 adaption study in collaboration with experts from the Netherlands, San Francisco Bay Area Planning and Urban Research Association (SPUR), San Francisco Bay Conservation and Development Commission (BCDC), and other stakeholders. The report preparation effort sets an example of collaborative efforts among agencies and private sector partners. The Mission Creek Sea Level Rise Adaptation Study provides a set of multi-purpose design alternatives to promote a more resilient waterfront community around Mission Creek Canal and Mission Bay. The purpose of the study was to generate a range of solutions through an imaginative and collaborative process, rather than a list of policy recommendations commensurate with a "preferred" alternative. The rationale behind this method is to ensure that the discussion of sea level rise adaptation includes all possibilities and perspectives.

The process resulted in seven possible adaptation strategies, three for the creek and four for the bay shoreline, and separate adaptation concepts for the historic piers in the area. The alternatives include protecting the perimeter shoreline, providing tidal control, damming or leveeing the creek as a barrier against the greater San Francisco Bay, providing a multi-purpose levee, elevating streets, and creating a new waterfront. Priorities for the development of these alternatives included the integration of flood protection into the urban fabric for an attractive and economically viable city, natural ecosystem and habitat development, and future adaptability. The report can be downloaded from the SPUR website at the following link: http://www.spur.org/sites/default/files/publications_pdfs/Mission_Creek_Sea_Level_Rise_Adaptation_Study.pdf.

Best Practices Highlight 7.E: City of Del Mar Sea-level Rise Adaptation Plan

The City of Del Mar, located in San Diego County, has committed to actively planning for sea level rise to protect its coastal resources. With grant funding from the California Ocean Protection Council, California State Coastal Conservancy and California Coastal Commission, in addition to its own supplemental funding, the City committed to prepare a vulnerability and risk assessment of local hazards (sea level rise, storm-surge, and coastal flooding), a long-term sea level rise Adaptation Plan, and Local Coastal Program (LCP) amendment with new land use policies and implementing regulations.

Del Mar's City Council approved the Adaptation Plan in May 2018 and is scheduled to adopt the plan in September 2018. The plan recognizes the threat of sea level rise to city resources and its role in worsening storm surge and coastal flooding and erosion. Of significance is the City's coordinated planning effort with the goal of integrating the Adaptation Plan into the LCP via an LCP amendment. This effort serves as an example of successful integration of adaptation and hazard mitigation planning with general planning. Figure 7.L, taken from the Adaptation Plan, shows the steps used by the City of Del Mar to evaluate, select, and plan for adaptation options.

The guiding principles for developing, evaluating, and analyzing adaptation measures in the plan include the following:

- Limit the risk of extreme coastal and river flooding to less than 5 percent
- Maintain a walkable beach for recreational use and economic benefit
- Maintain horizontal coastal access and vertical water access points to North and South Beach
- Maintain San Dieguito Lagoon wetland habitat functions

The plan combines accommodation, protection, and retreat approaches to sea level rise adaptation with triggers for various strategies in the plan. The plan evaluates "acceptable risk," which it defines as a risk with a less than 5 percent chance of occurring. Five particular areas affected by sea level rise were identified:

- Vulnerable City assets and public resources throughout the City
- San Dieguito Lagoon wetland (River Valley and Del Mar Fairgrounds)
- San Dieguito River flooding (North Beach, River Valley, and Del Mar Fairgrounds)
- Erosion of bluffs and adjacent beaches (South Bluffs, Powerhouse Park, and North Bluffs)
- Erosion and flooding for North Beach (15th Street north to the San Dieguito Lagoon mouth)

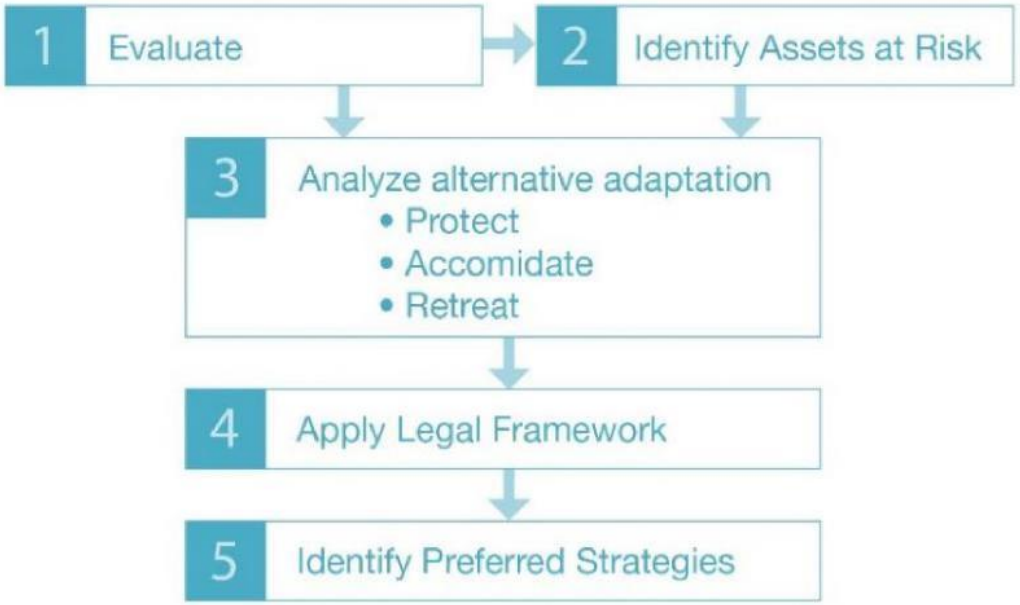
In addition to the five areas mentioned above, three areas were listed as having high priority for sea level rise adaptation needs. Adaptation measures include relocating the City's fire station and public works yard and flood proofing a sewer lift station.

For each of the five areas listed above, vulnerability was assessed and a phased set of adaptation strategies were identified, with triggers (e.g., sea level or beach width) for when each strategy should be pursued. Each measure is described with both benefits and constraints identified. For example, North Beach adaptation measures include the following:

- Beach and dune nourishment
- Raise/improve sea walls and revetments
- Sand retention measures
- Raise structures
- Relocate public infrastructure

More information about the City of Del Mar's Adaptation Plan and LCP Amendment can be found at: http://www.delmar.ca.us/498/Sea-Level-Rise-Local-Coastal-Program-Ame.

Figure 7.L: Del Mar's Process for Evaluating, Selecting, and Sea Level Rise Adaptation Options



Source: City of Del Mar. Approved City of Del Mar Sea-level Rise Adaptation Plan, May 2018. Retrieved on July 23, 2018 from http://www.delmar.ca.us/498/Sea-Level-Rise-Local-Coastal-Program-Ame

7.3 TSUNAMI AND SEICHE HAZARDS, VULNERABILITY AND RISK ASSESSMENT

Although tsunamis and seiches are rare events, the consequences can be high. They can quickly put the lives of millions of coastal residents, businesses, and visitors in jeopardy. The impacts on people and property in the wake of the 2004 Indian Ocean tsunami (230,000 fatalities in 14 countries) and 2011 Japan tsunami (18,000 fatalities in Japan alone; costliest modern natural disaster at $235 billion) emphasize the need to improve tsunami preparedness, mitigation, and recovery planning efforts in California.

A recent study indicated that a large tsunami event originating from the Aleutian Islands could cause coastal flooding that would result in extensive damage and lead to years of recovery, costing the state billions of dollars. However, this study also found that 80 to 90 percent of the damage could be prevented with detailed response, mitigation, land use, and recovery planning efforts. This is the type of work coordinated through the California Tsunami Program, among all levels of government, led by the California Governor's Office of Emergency Services (Cal OES) and the California Geological Survey (CGS).

7.3.1 IDENTIFYING TSUNAMI AND SEICHE HAZARDS

Tsunami

A tsunami is a wave triggered by any form of land displacement along the edge or bottom of an ocean or lake. Land displacement can be in the form of submarine landslides or submarine dip-slip faults. These types of faults cause ruptures that result in seafloor uplift or down-drop. This mass movement translates to a tsunami or gravity wave within the overlying water at the surface. A good general description for understanding tsunamis can be found in Chen and Scawthorn (2003).

Tsunamis travel radially outward from the area of initiation. The size of a tsunami is proportional to the mass that moved to generate the tsunami. As a tsunami approaches the shore and the depth of the water column decreases, the energy in the wave pushes the wave crest above the water surface resulting in a larger wave height. Wave run-up is the elevation above mean sea level on dry land that a tsunami reaches. Run-up is what causes inundation of coastal areas that are below the run-up height.

There are two types of source regions for tsunamis—resulting in local and distant source tsunamis as viewed from the affected shoreline. Local tsunamis are typically more threatening because they afford at-risk populations only a few minutes to find safety. California is vulnerable to, and must consider, both types. Identifying tsunami hazards requires 1) evaluating the potential for submarine mass movement both locally and at great ocean distances, and 2) identifying coastal regions within the direct or indirect path of a potential tsunami wave that are below the run-up height.

Tsunamis can travel at speeds of over 600 miles per hour in the open ocean and can grow to over 50 feet in height when they approach a shallow shoreline, potentially causing severe damage to coastal development. Tsunami hazards that affect both harbors and communities include coastal flooding, seiches (standing waves in an enclosed or partially enclosed body of water), strong damaging currents, extreme water-level fluctuations, eddies (circular currents), and sedimentation/scour. Once coastal areas become flooded and/or damaged, additional subsequent, tsunami-induced hazards can include free-floating debris and environmental contamination from spills.

Seiche

Although less common, seiches can also affect coastal and lake shorelines. A seiche is caused by resonances in a body of water that has been disturbed by wind, atmospheric pressure variations, seismic activity, or even tsunamis. The vertical harmonic motion produces an impulse that travels the length of the water basin and reflects off the other end or sides. These reflected waves can then interfere with each other and create amplified standing waves. Seiches can occur in large bays or lakes as well as large, odd-shaped harbors. Natural basins like Lake Tahoe or man-made basins like the Ports of Los Angeles and Long Beach can be locations where seiches occur in California.

Although seiche activity can be captured by numerical tsunami models, little work has been performed exclusively on seiches in the state.

7.3.2 PROFILING TSUNAMI HAZARDS

Numerous studies have documented historical tsunamis recorded along California's coast. In 1700, an earthquake estimated at Magnitude 9.0 ruptured along the Cascadia Subduction Zone, which stretches from along the coasts of British Columbia, Washington, and Oregon to offshore of California north of Cape Mendocino. Though there were no local written accounts, scientists originally recognized the event from geological evidence and oral histories from the Native American people in the area. This information was eventually cross-referenced with Japanese documents that described an "orphan" tsunami that was not accompanied by a large earthquake in Japan. The exact date and time of this earthquake are known because of a combination of tsunami deposit evidence, carbon-14 and tree-ring dating, tsunami modeling, and historical Japanese records.

The Cascadia Subduction Zone is the most significant local tsunami source for the California coast north of Cape Mendocino. Geological evidence indicates that large Cascadia earthquakes and associated tsunamis have occurred at least 19 times over the past 10,000 years, with event recurrence varying from 200 years to more than a thousand years over that 10,000-year period.

The California Seismic Safety Commission report, the Tsunami Threat to California Findings and Recommendations on Tsunami Hazards Risks, published in December 2005, indicates that over 80 tsunamis have been observed or recorded along the coast of California in the past 150 years. The report includes findings that tsunamis generated either locally or from events elsewhere in the Pacific Basin pose a significant threat to life and property in California, and that tsunamis present a substantial risk to the economy of the state and nation primarily through the impact on ports.

The National Centers for Environmental Information (NCEI) provides a database cataloging all tsunami occurrences. The database can be used to evaluate past tsunami events at a particular site. As shown in Table 7.J, there have been eight tsunamis known to have caused damage to ports and harbors or coastal inundation in California since 1946. In 1964, a tsunami caused by a Magnitude 9.2 earthquake offshore from Alaska resulted in 13 deaths in California and destroyed portions of downtown Crescent City. More recently, a 2006 tsunami (originating in the Kuril Islands region north of Japan) caused approximately $20 million in damage to Crescent City harbor. A 2010 tsunami (originating offshore from Chile) caused millions of dollars in damage to ports and harbors in the state.

Table 7.J: Summary of Tsunami Damage Along the California Coast Since 1946

Date	Event	Magnitude	Cost of Damage [a]	Deaths
March 11, 2011	Offshore Japan Earthquake	9.0	$100 million	1
February 27, 2010	Offshore Chile Earthquake	8.8	$3 million	0
November 15, 2006	Kuril Islands Region Earthquake	8.3	$20 million	0
March 28, 1964	Offshore Alaska Earthquake	9.2	$20 million	13
May 22, 1960	Chile Earthquake	9.5	$1 million	2
March 9, 1957	Aleutian Islands Earthquake	8.6	<$1 million	0
November 4, 1952	Kamchatka Earthquake	9.0	<$1 million	0
April 1, 1946	Aleutian Islands Earthquake	8.8	<$1 million	2

Source: California Geological Survey
a: "Cost of Damage" represents reported damage at the time of the tsunami; not all damage may be accounted for in early events.

A tsunami in 2011 (caused by a Magnitude 9.0 earthquake offshore of Japan) killed one person at the mouth of the Klamath River and caused up to $100 million of damage to 27 ports, harbors, and marinas throughout the State.[169] The most damage occurred in Crescent City, Santa Cruz and Moss Landing harbors and a federal disaster was declared in Del Norte, Santa Cruz, and Monterey Counties. Both Crescent City and Santa Cruz harbors sustained

[169] Wilson et al., 2012

damage to all docks, and oil spills and water/sediment contamination that resulted from sunk or damaged boats. Because recovery efforts in these two harbors took several years to complete, both harbors incurred business/economic losses that have been difficult to recapture.

Post -Tsunami Damage to Crescent City Harbor, March 2011

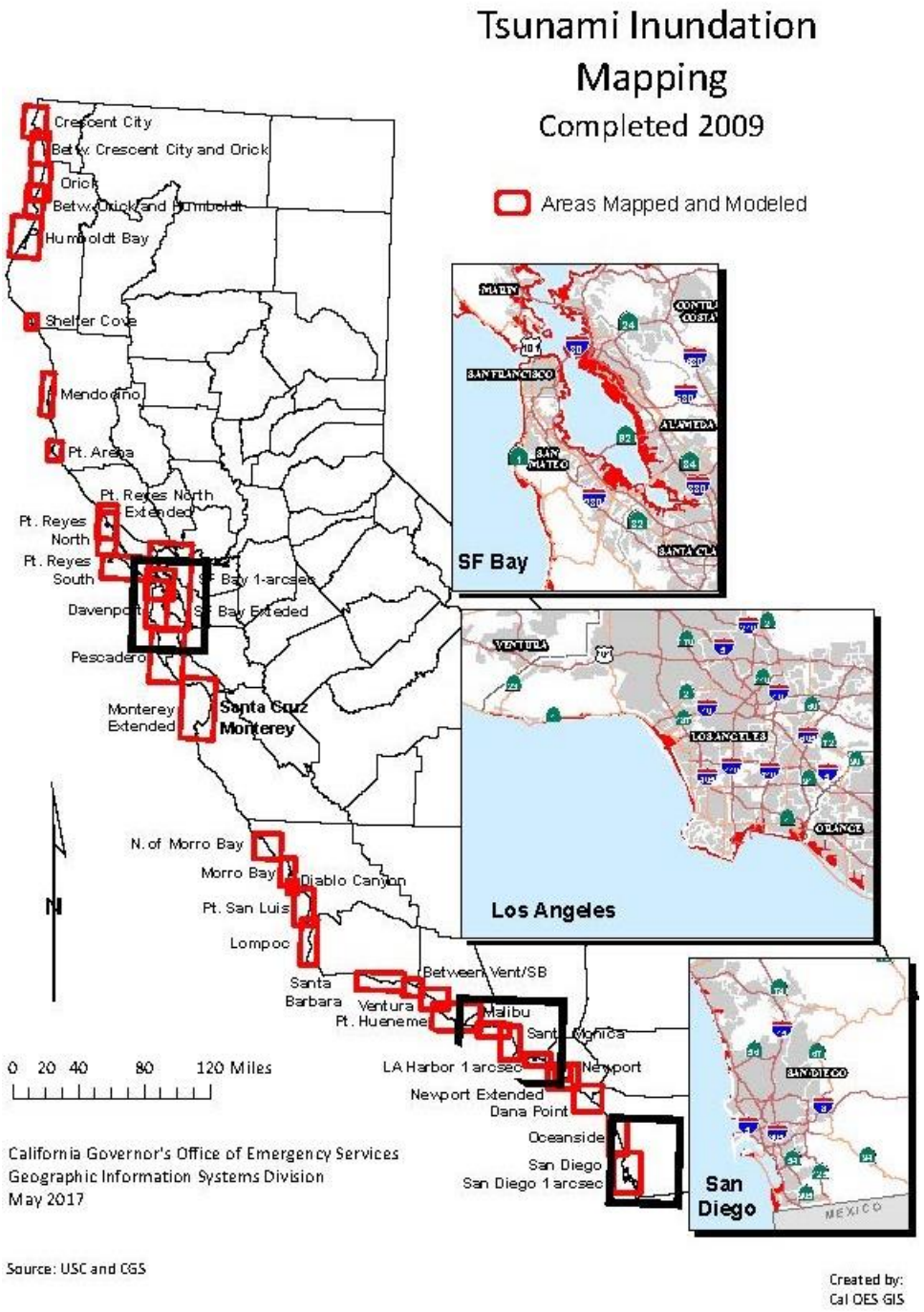
In 2009, the California Tsunami Program, along with the Tsunami Research Center at the University of Southern California (USC) completed statewide tsunami inundation maps appropriate for evacuation planning (see Maps 7.P and 7.Q). These maps were a composite of numerical tsunami inundation model runs from a suite of large, realistic tsunami sources both local and distant.

Projections of tsunami flooding varied by source and location along the coast but, in general, maximum tsunami flood elevations varied from 25 to 50 feet along the coast north of Cape Mendocino, from 15 to 30 feet along the coast from Cape Mendocino to Point Conception, from 3 to 12 feet within the San Francisco Bay, and from 5 to 15 feet south of Point Conception[170]. As previously mentioned, the Cascadia Subduction Zone provides the largest tsunami hazard for the area north of Cape Mendocino because it could generate large tsunami surges onshore within minutes after an earthquake. The most significant tsunami source region for the entire state from a distant-source event would be from the subduction zone off the coast of the eastern Aleutian Islands.

As was evident during the 2010 and 2011 Japan tsunami, California's ports, and harbors are also prone to damage from strong tsunami currents. The 2010 version of the Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS), codified as the 2010 California Code of Regulations Title 24, Part 2, California Building Code, Chapter 31F Marine Oil Terminals, became effective in 2011. It includes a study by Borrero et al. (2006) that provides maximum credible tsunami water levels and current speeds for marine oil terminals in the San Francisco Bay Area.

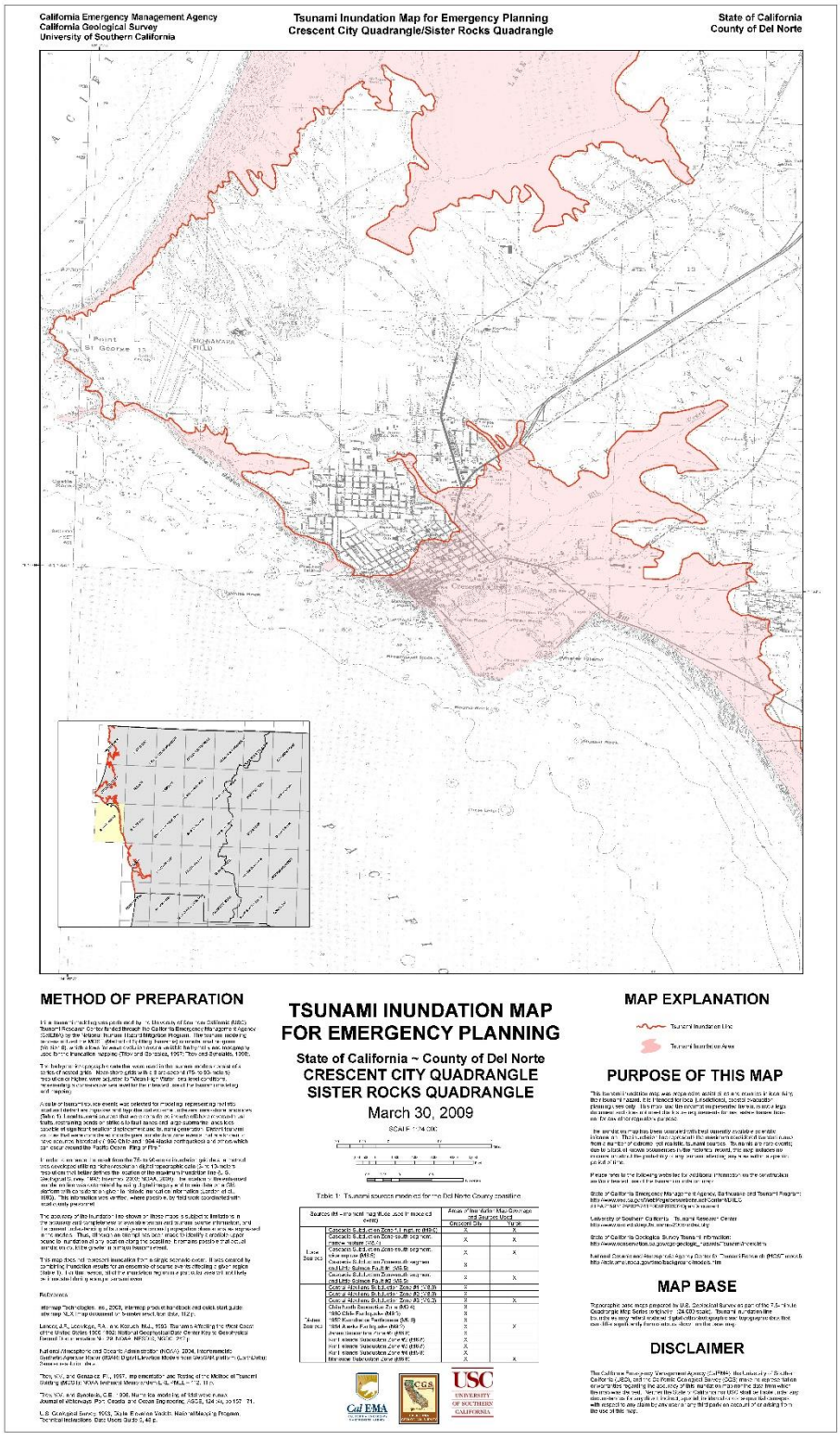
[170] Wilson et al., 2008; Uslu, 2008; Barberopoulou et al., 2009

Map 7.P: Tsunami Inundation Mapping Completed, 2009



Map 7.P provides a generalized statewide index to local areas covered by California Geological Survey (CGS) tsunami modeling and mapping. CGS, in cooperation with Cal OES and the Tsunami Research Center at the University of Southern California (USC), has undertaken modeling of tsunami hazards to produce statewide tsunami inundation maps. These local maps are developed for all populated areas at risk to tsunamis in California and represent a combination of the maximum considered tsunamis for each area.

Map 7.Q: Tsunami Inundation Map – Crescent City



Map 7.Q shows a local area tsunami inundation map prepared by the CGS. For more detailed information on areas within the future tsunami run-up areas, see: http://www.conservation.ca.gov/cgs/geohazards/tsunami/maps.

Progress Summary 7.K: Understanding Tsunami Probability

Progress as of 2018: There have been a number of new studies and strategies that have continued to improve the understanding of tsunami hazards in California through the coordinated research and resultant work of various government, university, and private partners. This work directly benefits tsunami preparedness, mitigation, and policy development in California.

Historical/Pre-Historical Tsunamis. A statewide assessment for geological evidence of tsunamis was conducted, including a reconnaissance of 20 coastal marshlands through site visits and coring of shallow surface sediments to determine if evidence for past tsunamis existed.[171]

Conclusive evidence of tsunami deposits was not found at most of the sites evaluated. Geologic evidence consistent with tsunami inundation was found at two locations: three marshes in the Crescent City area for the 1700 and 1964 tsunamis, and Pillar Point Marsh near Half Moon Bay from the 1946 Aleutian Islands event. Potential tsunami deposits were also evaluated at the Carpinteria Salt Marsh Reserve in Santa Barbara County.

The state also worked with Humboldt State University to complete a tsunami deposit database cataloging data from the statewide study and other studies, especially past studies which have found tsunami deposits in Northern California from pre-historic Cascadia events.[172] Although tsunami deposit information is useful for studying the area of flooding and the recurrence of past tsunamis, it should be noted that the absence of evidence of tsunami deposits is not indicative that large inundating tsunamis have not occurred. Rather that the conditions may not have been ideal for creating and preserving tsunami deposits, for instance, extensive coastal development leaving little undisturbed area for preserving tsunami records at the coast.

Probabilistic Tsunami Hazard Analysis (PTHA). The State Tsunami Program is working with other scientists to complete new tsunami hazard maps based on a probabilistic analysis.[173] These maps, some of which will be completed by the end of 2018, will be available for various land-use and mitigation applications, discussed in more detail in *Section 7.3.5: Current Tsunami Hazard Mitigation Efforts* below.

The PTHA maps identify areas of expected flooding for various risk levels, including 100-, 200-, 475-, 975-, 2,475-, and 3,000-year average return periods. Because the probabilistic approach includes uncertainties in the sources, modeling, and mapping, projected flooding from the higher return periods (2,475 year average return period and over) where uncertainties can be high is more extensive. Initial evaluation of the PTHA products indicate that the 2009 state inundation maps are similar in their flood potential to the 975-to-3,000 year range of return periods in different parts of the state.

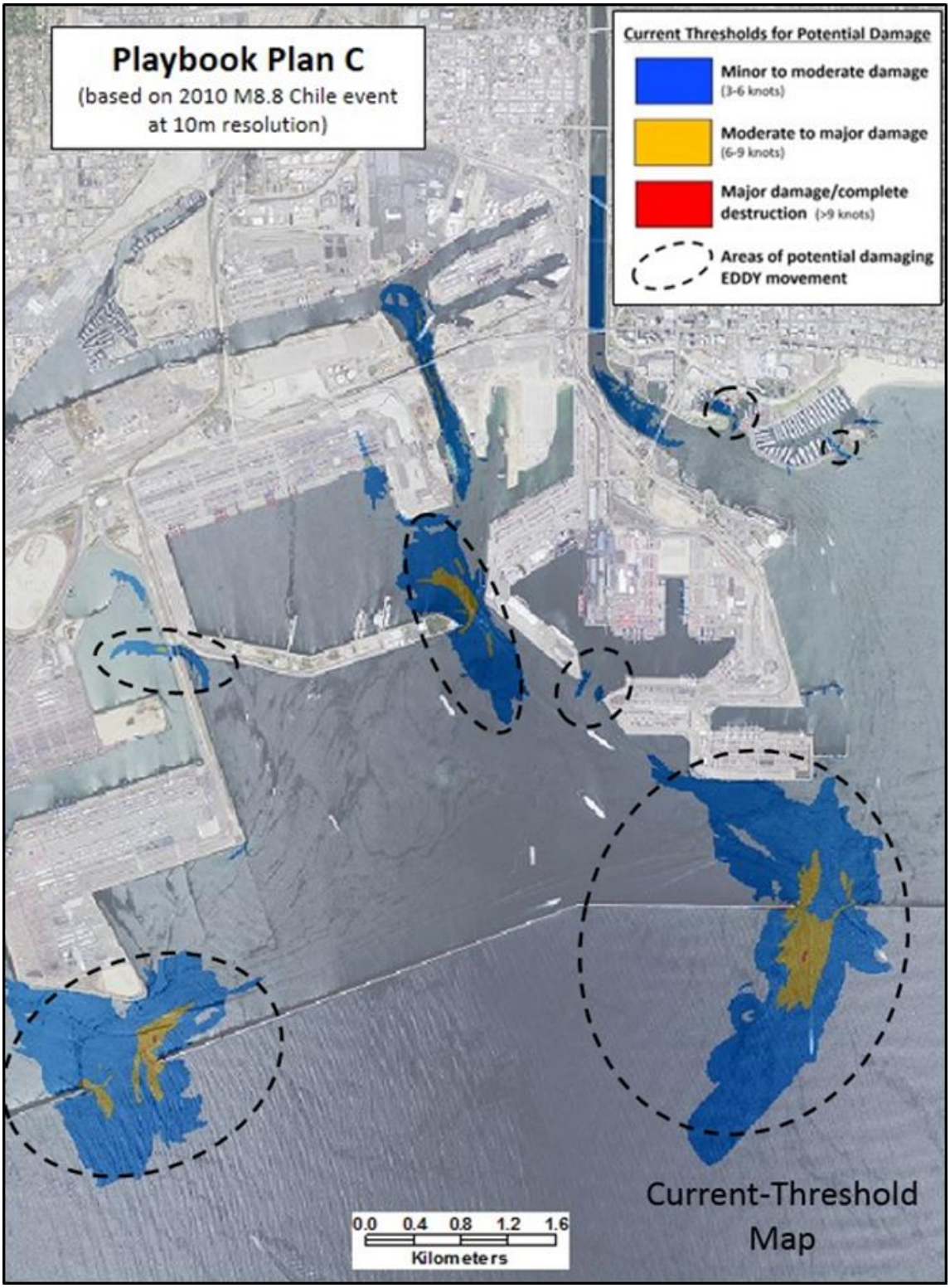
Maritime Hazards. With regard to strong currents, more recent studies by the California Governor's Office of Emergency Services (Cal OES), California Geological Survey (CGS), and the University of Southern California (USC) focus on the impacts of currents within harbors statewide.[174] Thirty-three Maritime Tsunami Response Playbooks have been developed covering over 70 ports, harbors, and marinas to provide harbor officials with information about where strong currents and damage could occur during various distant-source tsunami scenarios.

Map 7.R is the Maritime Tsunami Playbook Current-Threshold map for the Port of Long Beach.

The results of this project indicate that all open coast and most Bay Area harbors are prone to damage from tsunamis of various sizes and source locations.

[171] Wilson et al., 2014
[172] Hemphill-Haley et al., in press
[173] California Probabilistic Tsunami Hazard Analysis Work Group, 2015; Thio, in press
[174] Wilson et al., 2016

Map 7.R: Example Maritime Tsunami Playbook Current-Threshold Map for the Port of Long Beach



Source: California Geological Survey. Refer to CGS Special Report 241 for more information

7.3.3 ASSESSMENT OF STATE TSUNAMI VULNERABILITY AND POTENTIAL LOSSES

Spurred by the catastrophic tsunami in Sumatra,[175] and Japan,[176] the tools to perform vulnerability assessments are now available and being used to assess the California coast. The USGS has completed a vulnerability analysis based on the current state tsunami inundation maps. The study titled "Community Exposure to Tsunami Hazards in California" provides first responders, state and local emergency planners and other stakeholders, with valuable, new information about the people who live in, work in, and visit each of the 20 counties, 94 incorporated cities and 83 unincorporated communities located in a tsunami inundation zone.[177] The study found that the 2009 state tsunami inundation zone contains 267,347 residents, 15,335 businesses, and 168,565 employees. In addition, millions of non-residents also visit areas within the tsunami inundation zone during the summer months.

In January 2012, the Multi-Hazards Demonstration Project evolved into an ongoing project known as Science Application for Risk Reduction (SAFRR) that has a similar mission and national purview. Under SAFRR's coordination auspices, the USGS, Cal OES, CGS, and other entities teamed to develop a Pacific Basin Tsunami Scenario (Ross et al., 2013). This scenario modeled physical tsunami characteristics of inundation, currents, and scour to estimate the impacts of damage and resultant, necessary restoration of the built environment. This also included environmental, social, and economic impacts that would result from a large, hypothetical, but plausible distant source tsunami affecting the west coast of the United States, Alaska, and Hawaii.

Like previously studied disaster scenarios, the SAFRR Pacific Basin Tsunami Scenario sought to apply science to explain and understand the impacts of natural disasters, in this case, tsunamis. Some of the findings of the California statewide analysis included the following:

- The largest economic impacts on the state pertain to damage and incapacitation of the ports and harbors, and damages to coastal properties, resulting in billions of dollars in losses.
- One third of the boats could be damaged or sunk, and two thirds of the docks damaged or destroyed.
- 8,500 residents who live in the scenario inundation zone would likely need shelter because of damage to their homes.
- Although tsunami travel time could take four to six hours, timely, completed evacuations would be a challenge for certain areas with limited access and dependent-care populations.

For more information on SAFRR, visit: https://www2.usgs.gov/natural_hazards/safrr/projects/tsunamiscenario.asp.

As previously discussed, by early 2018 the State Tsunami Program expects to have completed maps that will use a PTHA for California.[178] These maps will be used for numerous applications including identifying potential tsunami hazard "zones of required investigation" under the Seismic Hazards Mapping Act and will assist state and local agencies in making land use planning decisions. They will also help regional and state planners understand the flood potential from tsunamis representing different risk levels.

7.3.4 ASSESSMENT OF LOCAL TSUNAMI VULNERABILITY AND POTENTIAL LOSSES

Community exposure to tsunamis in California varies considerably—some communities may experience great losses that reflect only a small part of their community and others may experience relatively small losses that devastate them.

Among the 94 incorporated communities and 83 unincorporated areas of the 20 coastal counties, the communities of Alameda, Oakland, Long Beach, Los Angeles, Huntington Beach, and San Diego have the highest number of people and businesses in the tsunami inundation zone. The communities of Belvedere, Alameda, Crescent City, Emeryville, Seal Beach, and Sausalito have the highest percentages of people and businesses in this zone. On the basis of a

[175] Iwan et al., 2006
[176] Wilson et al, 2012
[177] Wood et al., 2013
[178] Thio, in press

composite index, the cities of Alameda, Belvedere, Crescent City, Emeryville, Oakland, and Long Beach have the highest combinations of the number and percentage of people and businesses in tsunami-prone areas.

The communities that are most vulnerable to injury and life safety issues exist within Del Norte and Humboldt counties due their close proximity to the Cascadia Subduction Zone. To download the Community Exposure to Tsunami Hazards in California report visit the USGS website: http://pubs.usgs.gov/sir/2012/5222/.

Information related to community vulnerability and loss assessments may be found in Local Hazard Mitigation Plans (LHMPs) and Local Coastal Programs (LCPs) that help guide planning for coastal communities under the California Coastal Act.

Progress Summary 7.L: Assessing Tsunami Hazards and Potential Losses

Progress as of 2018: New products and tools are available or are being produced that can help assess community-level, regional, and statewide vulnerability and potential losses. Using these products and tools together will result in the most comprehensive vulnerability and loss potential analysis possible.

HAZUS Tsunami Module. FEMA has developed a new tsunami loss estimation module for HAZUS using existing numerical model results for tsunami inundation, flow depth, velocity, and force. This HAZUS module allows new capability for estimation of casualties, economic losses, structural functionality, and site-specific analysis, content losses, casualties, infrastructure damage, and evacuation time, and a range of losses based on safe zones and community preparedness levels. It performs independent (non-repetitive) calculation of the earthquake and tsunami results. This is a huge step forward as there was previously no method to systematically compute losses from tsunamis. With the production of new probabilistic tsunami analysis maps, the use of the tsunami HAZUS module will improve the state's ability to compare tsunami casualties and physical and economic impacts to those of other hazards, including earthquakes.

PTHA Maps and Products. As previously discussed, the State Tsunami Program is completing a set of Probabilistic Tsunami Hazard Analysis (PTHA) maps representing risk levels from 100-year to 3000-year average return periods. Analysis using these probabilistically based products will allow for a more common platform for comparison to other seismic and flood probabilistic analyses.

Tsunami Loads in Building Design. The American Society of Civil Engineers Subcommittee 7-16 on tsunami load forces has completed analysis and design standards that have been adopted by the International Building Code. These standards address structural response to tsunami wave loading, tsunami wave-loading forces for design purposes, non-structural element response to wave loading, and dynamic effects of tsunami wave travel throughout a built environment. If adopted by the state during the next building code cycle (2019), these tsunami design load standards will be applied to critical and essential buildings (Risk Category 4 and 3) and may apply to some other high-occupancy structures (Risk Category 2).

Maritime and Pier Mitigation Plans. The State Tsunami Program is working with engineers at the University of Southern California (USC) and the California State Lands Commission to complete Harbor and Pier Improvement Reports for all at-risk harbors and piers. These products are based on deterministic (scenario-based) and probabilistic (recurrence interval based) methods and provide site-specific harbor and pier improvements and engineering recommendations as well as a cost-benefit assessment for each mitigation activity based on new tsunami damage potential analyses and evaluation of other potential hazards from storms, high tides, and sea-level rise. The partners will also help harbor and pier officials obtain Federal Emergency Management Agency (FEMA) and California Governor's Office of Emergency Services (Cal OES) pre-disaster hazard mitigation funds and/or other grants and loans to help make the recommended improvements.

Tsunami Evacuation and Maritime Response "Playbooks". Instead of an all-or-nothing approach to evacuation and response, Playbooks provide communities and harbor officials with tsunami-specific maps and guidance about what areas to evacuate or avoid during distant source events.[179] Using a sports analogy, the Playbook approach provides the best coastal defensive "play" (or plan) against a tsunami of a particular size and source origin location.

Reducing the number of people and businesses that have to evacuate can reduce costs of business closures and vulnerability of evacuees to other hazards during evacuation (e.g., large storms or earthquake hazards during local events). For example, Wood et al (2016) indicated that using the Playbook approach instead of the worst-case evacuation zones during a large distant source tsunami scenario, with enough lead time to implement this approach, could result in 1) 178,646 fewer residents and 159,271 fewer employees having to evacuate; and 2) a $122 million reduction in business disruptions statewide. See Map 7.R for an example Playbook Map.

Tsunami Evacuation Time Analyses: The State Tsunami Program has partnered with the U.S. Geological Survey (USGS) to evaluate pedestrian and car-based tsunami evacuation times. Area-specific studies have been completed for Balboa Island in Newport Beach[180] and the City of Alameda.[181] Playbook scenario and full evacuation lines were evaluated in these studies. The results of these studies have helped the above communities determine the best evacuation routes and modes of transportation to use during future tsunami events. By early 2018, a statewide analysis of evacuation times will be completed using the new probabilistic tsunami hazard maps. This information can help identify the most vulnerable population centers for both local- and distant-source tsunamis.

Tsunami Recovery Guidance: The State Tsunami Program is developing recovery guidance for communities.[182] Integrating a recovery planning strategy can help identify where the most vulnerable populations and community assets are located. For example, it took Crescent City Harbor years to fully recover from the combined damage from the 2006 and 2011 tsunamis. Although the harbor is improved and fully functional, a large number of fishing fleet vessels have found homeports elsewhere because of the delays in harbor recovery. To reduce this problem after future tsunamis, the harbor installed larger piles and deflection docks in order to reduce impacts and recovery times.

[179] Lynett et al., 2014; Wilson and Miller, 2014; Wilson et al., 2016)
[180] Henry et al., 2016
[181] Peters et al., 2016
[182] Johnson et al., in press

Map 7.S: Example Harbor Cleat Failure Potential Analysis in the Draft Harbor Improvement Report for Oceanside Harbor

Zone	Case ID				
	Alaska	Cascadia	Chile 2010	Chile North	Japan 2011
1	Moderate	Moderate	Moderate	Moderate	Moderate
2	Moderate	Low	Low	Low	Low
3	Moderate	Low	Low	Low	Low
4	Moderate	Low	Moderate	Moderate	Low
5	Moderate	Low	Moderate	Moderate	Moderate
6	Moderate	Low	Low	Moderate	Low
7	Low	Low	Low	Low	Low
8	Low	Low	Low	Low	Low
9	Low	Low	Low	Low	Low

Source: University of Southern California

7.3.5 CURRENT TSUNAMI HAZARD MITIGATION EFFORTS

State Tsunami Program Coordination with Federal Programs

Most tsunami hazard preparedness and mitigation planning efforts are conducted through the State Tsunami Program and its Steering Committee comprised of representatives from the 20 coastal and Bay Area counties and the four coastal-region National Weather Service (NWS) offices. Based on the analysis of recent events, the California Tsunami Program is enhancing existing products and developing new products that will improve tsunami preparedness and mitigation. These planning efforts and products help 1) the maritime community better understand tsunami hazards within their harbors and determine if and where mitigation activities should be implemented; 2) emergency managers not only prepare for significant tsunami events, but develop evacuation plans for relatively small ''Warning'' level events where extensive evacuation is not required, and 3) land-use planners and building designers better understand the probabilities of tsunami hazard and the effects over the lifetime of construction and development.

The state program cooperates with NOAA and other states within the National Tsunami Hazard Mitigation Program (NTHMP) through federal grants, and FEMA Region IX through a Co-operative Technical Partnership to fund preparedness and mitigation planning efforts. The primary structural and financial support for the NTHMP comes from the 2017 Tsunami Warning, Education, and Research Act. The State Tsunami Program relies exclusively on federal funding sources, which at times are limited or in jeopardy due to real and potential federal budget cut decisions.

A report issued by the California Seismic Safety Commission in 2005 states that "tsunamis, generated either locally or from events elsewhere in the Pacific Basin, pose a significant threat to life and property in California" and points out that losses from tsunamis can be reduced in four ways: 1) engineering standards creating more damage-resistant buildings and port structures, 2) public education training Californians to recognize tsunami alerts and providing instruction on what to do, 3) warning systems alerting a population to a tsunami coming from a distant source, and 4) effective evacuation planning.

More recently, the California Tsunami Policy Work Group (2014) completed a report titled "California's Tsunami Risk: A Call for Action," providing direction to the state tsunami program and other state and federal partners through 47 recommendations. The 2013 version of the state hazard mitigation plan (SHMP) recognized that the California Tsunami Policy Work Group would be completing this document to "…help guide, develop, and improve future tsunami preparedness and mitigation activities…," which the state program is actively working to initiate. The 47 recommendations cover the following broader topics:

- Comprehensively assess tsunami hazard likelihood and severity
- Improve our understanding of tsunami risk and ways to reduce it
- Establish a framework to more effectively communicate tsunami warnings
- Capitalize on national efforts to reduce tsunami risk
- Condition development in areas exposed to tsunami hazards
- Implement tsunami resilient building codes
- Consider tsunami hazards in land-use decisions
- Enhance multi-jurisdictional planning for tsunami hazard
- Increase the effectiveness of tsunami hazard warnings
- Address regional preparedness, response, and recovery issues
- Prepare the maritime sector for tsunami hazards

Tsunamis cannot be prevented, but early warning and evacuation can dramatically reduce their threat to human safety. Modern warning networks can sense tsunamis hundreds, or even thousands, of miles from their location of impact and issue warnings to potentially threatened communities. For example, NOAA's Tsunami Program operates the National Tsunami Warning Center (NTWC) in Palmer, Alaska, which monitors seismographs and deep-ocean

buoys and provides tsunami alerts to coastal communities in California. Cal OES and CGS work with the NTWC and the coastal National Weather Service (NWS) offices to provide real-time tsunami information to the communities through the State and Regional Emergency Operations Centers. Such warning systems, coupled with well-designed evacuation plans and a public educated about how to respond, can remove people from harm's way.

Federal and state programs continue to educate local emergency response agencies and the public. As discussed in previous sections, the State Tsunami Program completed a statewide set of tsunami inundation maps in 2009 for use in evacuation planning. These maps, made with the assistance of the Tsunami Research Center at the University of Southern California, are available to the public through the CGS tsunami web page at www.tsunami.ca.gov and Cal OES MyPlan and MyHazards web pages at http://myplan.calema.ca.gov/ and http://myhazards.calema.ca.gov/.

Local Jurisdiction Efforts

Municipalities are undertaking their own planning efforts specifically directed toward this hazard. For example, Tsunami Safety Plans and related brochures have been prepared for communities in Humboldt County with the assistance of the Redwood Coast Tsunami Working Group. For more information, visit: http://www.humboldt.edu/rctwg/. Many other communities are taking an active role in tsunami preparedness and response activities, such as: holding community education and preparedness events, installing tsunami hazard and evacuation signs, and running tsunami tabletop exercises and evacuation drills. The state is also helping to support this work and encouraging other coastal regions of the state to develop similar types of tsunami work groups and enhance their preparedness events.

Other State Tsunami Program Efforts

Other tsunami hazard mitigation activities of the State Tsunami Program include: 1) offering guidelines for local emergency managers to use for reviewing geotechnical and utility-disruption hazards as they relate to evacuation from a local tsunami event; 2) assisting coastal communities to become TsunamiReady®, a federal designation indicating that the community has fully prepared to respond to a tsunami emergency; 3) conducting tsunami workshops and exercises with local communities; and 4) providing communities with educational materials they can use for their outreach activities.

Maritime communities in California were challenged and affected first and foremost during the 2010 and 2011 tsunamis. Although millions of dollars were lost during these two events, the eyewitness accounts and video information collected after each event provided an excellent resource for improving tsunami hazard analysis in harbors and bays. Through the aforementioned partnership developed between the state and FEMA, observed strong tsunami currents and damage were used to validate and calibrate numerical tsunami model currents to produce in-harbor hazard maps included in Maritime Response Playbooks.[183] These products identify offshore safety zones for potential boat evacuation when a tsunami "Warning" is issued for a distant source event.

As previously discussed, Harbor Improvement Reports are also being created to provide harbor-specific mitigation measures that can be directly integrated into Local Hazard Mitigation Plans (LHMPs). The State Tsunami Program has developed educational information for boaters and harbormasters alike, including a new brochure for boaters with tsunami education information and advice on what to do and what not to do during a tsunami. Ultimately, harbor-specific guidance has been created to help maritime communities better prepare for, respond to, and recover from future tsunamis.

As also noted previously, a majority (80 to 90 percent) of the losses from future large tsunami events can be reduced by implementing effective response, mitigation, and recovery strategies. One of the key tools required to make these efforts successful are the regulatory zone maps prepared by the GS. "Zones of required investigation" have been and are being prepared for surface fault rupture, soil liquefaction, and earthquake-induced landslide hazards in California.

183

Evacuation Drill for King Salmon, Humboldt County, 2012

Source: Rick Wilson, California Geologic Survey

Although hazard maps are typically associated with only with hazard identification, these regulatory maps constitute mitigation through their requirement for site-specific investigation of relevant hazards at development sites, and mitigation plans approved by the lead agency before permits are issued. CGS has used federal funding and external partners to advance the science behind tsunami hazard mapping to the point where the State Geologist determined that regulatory zones for tsunami hazards can now be prepared, as stipulated in the 1990 Seismic Hazard Mapping Act.

Progress Summary 7.M: Probabilistic Tsunami Hazard Analysis Mapping Linkage to Mitigation Activities

Progress as of 2018: In addition to being used for the Seismic Hazard Mapping Act, Probabilistic Tsunami Hazard Analysis (PTHA) products are being produced for other mitigation activities to protect coastal residents and infrastructure in California. The California Geological Survey (CGS) is working with a number of organizations to help them incorporate the PTHA products into their response, mitigation, and construction planning:

C*alifornia Building Standards Commission (CBSC):* A new section in the California Building Code addressing tsunami loads on critical and essential facilities is set to be included in the 2019 update of the code. The original Tsunami Design Zone maps created for this update by the American Society of Civil Engineering are not of a suitable detail and quality for making design and construction decisions. For example, these existing maps show tsunami flooding traveling too far inland and overflowing river levees and other structures where they should not. The PTHA maps produced by the CGS will be of much higher quality and accuracy. The CGS plans to work with the CBSC to replace the existing maps with the new, more accurate maps when they become available.

As previously mentioned, if adopted by the state during the next building cycle, these tsunami design load standards will be applied to critical and essential buildings (Risk Category 4 and 3) and may apply to some other high-occupancy structures (Risk Category 2). PTHA maps representing 2475-year average return periods will apply to Risk Category 4 structures, whereas the 2,475-year average return period minus 3 feet of flow depth will apply for Risk Category 3 and possibly Risk Category 2 structures.

California Governor's Office of Emergency Services (Cal OES): The CGS has been a long-time partner of Cal OES through the State Tsunami Program and its Steering Committee. Cal OES plans to use the PTHA maps for a number of projects when they become available:

1. Cal OES and the CGS will use the PTHA maps to verify and update the accuracy of the 2009 tsunami inundation maps for evacuation planning, most likely replacing the 2009 maps with the new maps.
2. Cal OES will use the PTHA maps in developing vertical evacuation structures in several coastal communities to protect vulnerable populations that have no safe, high ground immediately available for evacuation before a local-source tsunami arrives.
3. The PTHA maps and the related products (hazard potential maps; sediment/debris model results; etc.) will help Cal OES and the Federal Emergency Management Agency (FEMA) work with harbors and ports to obtain local hazard mitigation funding to implement mitigation measures in the most hazardous parts of the harbors.
4. PTHA maps will be used to set the foundation of local and state tsunami recovery planning guidance being developed by Cal OES and the CGS.

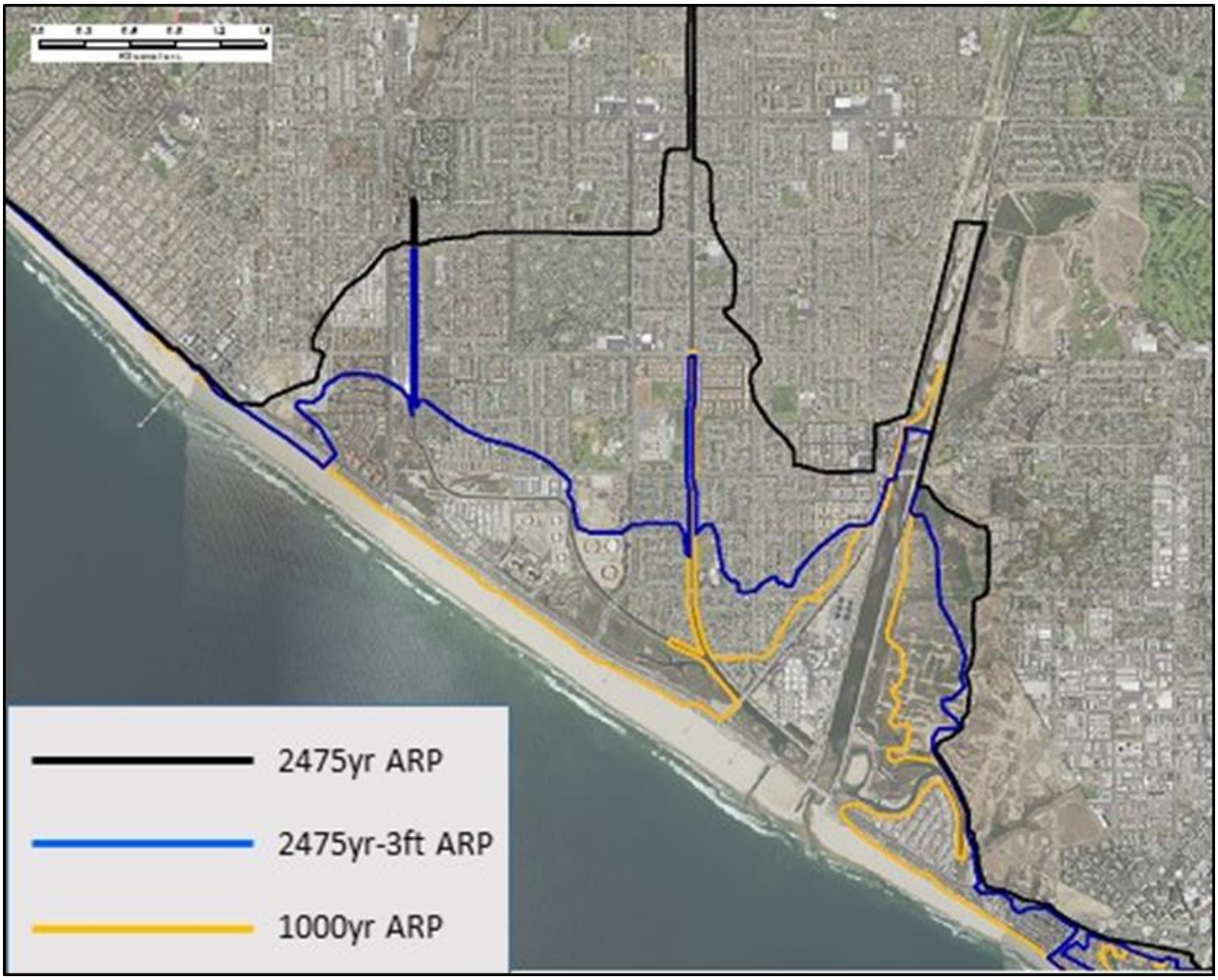
California Coastal Commission (CCC): At present, the California Coastal Commission uses the 2009 tsunami inundation maps for evacuation planning for Local Coastal Programs (LCP). As previously stated, the 2009 maps are based on deterministic scenarios and the State Geologist has determined that these maps are not appropriate for making land use decisions. The PTHA maps will provide the Coastal Commission with a more appropriate set of maps for community-level land use planning through LCPs.

FEMA: There are a number of programs within FEMA which plan to utilize the results from the PTHA products:

1. PTHA maps will be created and included in FEMA's RiskMAP program, which provides flood hazards maps to the public outside of the existing Flood Insurance Rate Map (FIRM) program.
2. PTHA maps will be compared to existing FEMA FIood Insurance Rate Maps to determine if and how they should be merged into the existing FIRMs that restrict new development in flood prone areas.

At present, the California Coastal Commission uses the 2009 tsunami inundation maps for evacuation planning for Local Coastal Programs (LCP). As previously stated, the 2009 maps are based on deterministic scenarios and the State Geologist has determined that these maps are not appropriate for making land use decisions. The PTHA maps will provide the Coastal Commission with a more appropriate set of maps for community-level land use planning through LCPs.

Map 7.T: Draft PTHA Inundation Lines for a Portion of Huntington Beach



Note: Lines represent Probabilistic Tsunami Hazard Analysis (PTHA) risk levels of 2,475-year and 1,000-year average return periods (ARPs), as well as the 2,475-year ARP minus 3 feet of flow depth.
Source: California Geological Survey

Caltrans: At present, Caltrans does not consider tsunami loads in their analysis of their highways and bridges. The PTHA maps and related products will be used in the retrofitting of existing bridges and highways and the design and construction of future bridges and highways. This will produce a more resilient infrastructure during tsunamis.

Harbors/Ports/Piers: The PTHA maps and related products covering a range of risk levels will be integrated into Harbor and Pier Improvement Reports that cover recommended mitigation activities of maritime and pier facilities and related infrastructure.

Local Communities: The PTHA maps which cover a range of risk levels can be used for improving land-use plan decision-making through Local Coastal Plans and risk-reduction measures through the Local Hazard Mitigation Plans.

Life and property loss from tsunamis and seiches can also be reduced by limiting development along low-lying coasts and designing structures to allow swift water to flow around, through or underneath without causing collapse.

In 2011, FEMA released the National Disaster Recovery Framework—the first statement of national recovery policy—which specifically identifies an approach for multi-level government coordination and local empowerment and partnership in planning and managing disaster recovery. It also emphasizes the importance of recovery planning, both before and after disasters, focuses on community outcomes, and defines measures of recovery success. The State of California has followed suit and is in developing the California Disaster Recovery Framework that defines the roles and responsibilities of state-level agencies and partners in supporting community recovery.

Based on the immediate and long-term tsunami recovery issued faced by Japan and even California's harbors, the State Tsunami Program and its partners are developing a community-level tsunami recovery guidance document. This guide is being developed to assist staff and local officials of California coastal cities and counties, particularly those with a significant level of risk, to initiate planning for community recovery following a tsunami disaster. Community recovery following a major disaster is a complex process that can take years and even decades to complete. Local governments have an important leadership role in community recovery because of their ability to mobilize resources and technical assistance from state, federal, and non-governmental partners, and to support and even catalyze the actions of residents, businesses, and other affected organizations.

7.3.6 ADDITIONAL TSUNAMI HAZARD MITIGATION OPPORTUNITIES

The State Tsunami Program and its federal and community partners are working together to mitigate the impacts of tsunami hazards. The primary goal for coastal California is to identify which regions are vulnerable to tsunami hazards and to prepare those communities accordingly.

Probabilistically based tsunami hazard maps allow for a rational risk-based approach to hazard and mitigation decisions. Other products, such as evacuation and maritime response Playbooks, Harbor and Pier Improvement Reports, and recovery guidance, will greatly assist local harbors and communities enhance their real-time and long-term hazard mitigation activities. Addressing multiple hazards at once, such as tsunami, storms, tides, and sea level rise, will augment the effectiveness of mitigation activities for communities in the future. This newly available, vetted information must be comprehensively integrated into community resilience documents like Local Coastal Programs (LCPs), Local Hazard Mitigation Plans (LHMPs), and related planning efforts.

Considering the advances in tsunami hazard mitigation and planning, there are a number of enhanced mitigation activities to consider for the future work:

- Develop and enhance existing educational materials to increase public knowledge of potential tsunami risk in their community and ways to reduce this impact.
- Continue to address the recommendations outlined in the California Tsunami Policy Work Group report.
- Assist federal, state, and local entities in the application of new PTHA products.
- Develop an overarching tsunami planning guidance document that incorporates the use of new PTHA maps, maritime and pier mitigation reports, evacuation time analyses, and the recovery guidance.
- Work with harbor districts and community planners to integrate new products into their LCPs, LHMPs, and related land use planning documents.
- Assist harbor and community officials with applying for and obtaining hazard mitigation funds and loans to implement risk-reduction strategies.
- Use the tsunami HAZUS tsunami module to evaluate local, regional, and statewide impacts of the PTHA results and significant scenario events.
- Improve numerical tsunami modeling for evaluating tsunami currents and forces within the onshore built environment.
- Work with harbor districts and community planners to improve community preparedness and response activities, such as using the "blue-line" project to identify the extent of tsunami flooding on roads.

- Develop guidance for communities to evaluate the use of existing buildings for vertical evacuation during local tsunami events.
- Complete and update Tsunami Evacuation Playbooks for all communities statewide, and continue to evaluate and enhance the real-time response recommendation process using the FASTER flood prediction approach.
- Enhance and maintain the coastal web-camera network, and improve the ability to use this network in real time during future tsunami events.
- Develop tsunami response guidance for large vessels, such as tankers, container ships, and cruise ships.
- Improve evaluation, planning, and implementation of tsunami hazard mitigation efforts as they related to non-tsunami hazards, such as extreme storm and tidal events, coastal erosion and sedimentation, and sea level rise.
- Evaluate the tsunami and seiche risk within large, deep-water lakes and reservoirs like Lake Tahoe and Clear Lake, and work with communities around those lakes to develop tsunami planning strategies.
- Continue to participate in and work through the National Tsunami Hazard Mitigation Program (NTHMP) to develop national guidance and standards to ensure consistent, accurate, and cost-effective products and planning efforts across state lines.

7.4 LEVEE FAILURE AND SAFETY, VULNERABILITY AND RISK ASSESSMENT

7.4.1 IDENTIFYING LEVEE HAZARDS

Millions of people and billions of dollars of assets in California are protected by levees. Levees in California protect land from peak flood levels and/or protect land that is below sea-level. The first type of levee is intended to withstand peak flood levels that are caused by intense rainfall or rapid snow melt within the watershed. Examples are the levees along the Russian River or the Sacramento River near Sacramento. The second type of levee is intended to withstand nominal water levels on a continuous basis as well as peak flood levels. Examples are the levees throughout Sacramento-San Joaquin Delta.

The San Francisco Bay-San Joaquin-Sacramento Delta region (a.k.a. "the Delta" or "the Bay-Delta") contains levees critical for delivering irrigation water to 3 million acres and drinking water to over 23 million people. A failure in one of the Delta levees in 1972 interrupted the state and federal water supply systems and required approximately 500,000 acre-feet of fresh water to restore export water to acceptable quality.[184] Recent studies indicate the levees in the Delta are susceptible to damage from close or more distant seismic events.

History of Levees in California

The construction of levees in California's Central Valley started in the 1850s to protect or claim floodplains including islands in the Delta, for agricultural purposes. In many cases, soil was either scraped from adjacent land or dredged from adjacent channels and placed onto existing natural levees. Central Valley and Delta soils allow for one of the most agriculturally productive regions in the world and a significant economic benefit for California. The soil was rich for growing crops as a result of river-deposited silts or river-nourished backwater peats in these locations, but these types of soils generally make poor foundation material for levees.

During the same time period, hydraulic mining occurred in the mountains at the headwaters of the rivers that feed the Delta and huge amounts of sediment were flushed downstream raising riverbeds and causing increased flooding. To prevent buildup of this sediment, levees were built and/or heightened to increase flows through the low-lying areas to aid in moving the sediment pulses through the Delta.

The levees have been augmented since then to produce the current system. After several devastating floods the U.S. Army Corps of Engineers (USACE) started modifying and constructing levees as early as the early 1900s using sediment from adjacent rivers and channels. Levees were also constructed by others in the 1900s in areas subject to coastal influences, such as in San Francisco and San Pablo Bays. Until about the 1940s to 1950s, most levees were not engineered and frequently failed.

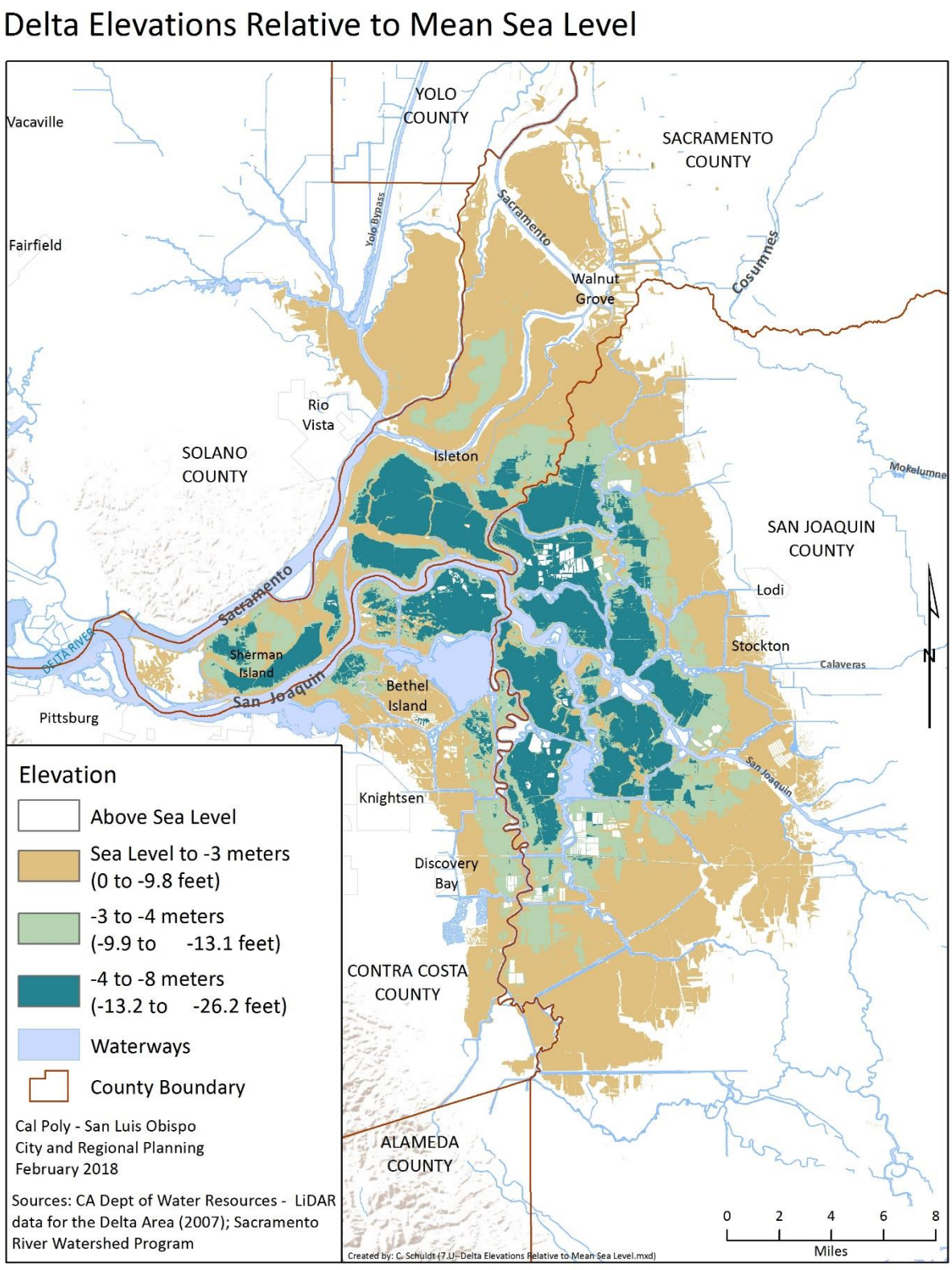
Increasing Risk and Consequences

Some of the areas protected by these levees were originally intended to have land use compatible with agriculture but have subsequently become urban. Some of the levees in California have been augmented in recent years but many remain as originally constructed or have deteriorated. Changes in climate affecting hydrologic patterns in California, as well as sea-level rise, are bringing additional loading to levees.

With the reclaimed floodplains not being replenished with new sediment and the drying out of some of the boggy areas, the land protected by the levees began to drop in elevation via subsidence and wind erosion of topsoil. Land behind the levees will continue to drop in elevation with the addition of potential sea-level rise exacerbating the situation.

[184] Senate Hearings on the 1972 Levee Failure at Brannan- Andrus Islands

Map 7.U: Delta Elevations Relative to Mean Sea-Level



Map 7.U shows the general configuration of levees and waterways in the Delta area. Most levees in California are in the Bay-Delta and, for the most part, protect land that is at or below sea-level. As can be seen in Map 7.U, there

are vast areas in the Delta that are already below sea-level. In California, levees protect farmland, ranchland, rural residential areas, urban residential areas, and infrastructure such as roads, highways, and waterways or canals. The Bay-Delta is a complex system in which there are three rivers bring in fresh water and tidal fluctuations cycle in salt water or brackish water.

Water projects carry fresh water to millions of citizens in Central and Southern California. Approximately 60 percent of the water supply of the San Francisco Bay Area is also extracted from or passes through the Delta. In addition to facing risks to its water system from Delta levee failures, the Bay Area also has numerous substandard levees protecting both low-lying and below-sea-level urban areas and infrastructure, including the Oakland International Airport.

Levee Stability

The stability of levees is a function of several variables. Three main loading functions related to levee failure are water level changes, ground shaking, and static loading.[185] Water level changes can be due to peak flood levels or rapid drawdown; both are known to adversely affect the stability of levees. Other hydrostatic influences known to affect levee stability are constant load, cyclical influx of seawater from bay (tidal changes), and reverse flows in some areas. Ground shaking is a function of earthquakes in and around the levees but can occur up to 100 kilometers or more away and still affect levee performance. Static loading represents the nominal loading conditions that regularly exist, but documented levee failures have occurred with no adverse conditions other than static loading. The Jones Tract failure in 2004 is an example of a failure without adverse conditions. The type of foundation the levee is constructed upon (such as peat or alluvium) or the composition of the levee itself (such as loose sand) will influence a levee's performance during a seismic event or under certain static loading conditions. Many levees in the Delta are designed nominally to 100-year design flood levels.

Levee Failure Mechanisms

Six main failure mechanisms are a function of the three loading functions. The six mechanisms are bearing failure, sliding failure, slump or spreading failure, seepage failure, erosion failure, and overtopping, which may be described as follows[186]:

1. A bearing failure in levees is typically deep-seated and can be induced by seismic ground shaking or a loss of soil shear strength. Failure can be triggered by a seismic event that either causes a loss of soil strength or produces destabilizing inertial loading conditions.

2. A sliding failure may occur if the foundation soil has a weak or brittle zone resulting in a preferred failure plane. Both seismic-induced inertial loading and high water levels can cause sliding failures.

3. Slumping and spreading can be generated by two loading conditions. Cyclic loading from earthquakes may generate increased pore pressures and reduced soil strength, leading to volumetric and/or deviatoric strains in the foundation. The same results can also occur due to increased pore pressures from high water levels and increased seepage.

4. Seepage is one of the most common failure mechanisms in levees. Levees are built in fluvial depositional environments, and it is common to find levees with an existing sandy layer beneath the foundation. The sandy layer can be a conduit for flow underneath the levee, resulting in critical conditions at the landside toe of the levee. This can lead to erosion of the foundation during high water or a consistent weakening of the foundation over a long period of time, both eventually leading to failure. Biogenic agents can also lead to destabilizing seepage. These can include rodent holes, tree roots, or other biological activity that create conduits for seepage. Some of the materials used in the construction of levees historically are also susceptible to through seepage. This through seepage can also result in a failure.

[185] Moss and Eller, 2007
[186] Moss and Eller, 2007

5. High-velocity flows can erode material from the outboard or waterside of the levee, which may lead to instability and failure. Erosion can occur at once or over time as a function of the storm cycle and the scale of the peak storms.

6. The failure mechanism of overtopping occurs when high water exceeds the elevation of the levee crest. The water energy is then concentrated at the landside toe of the levee, leading to soil erosion and decreased levee stability. Once overtopping starts, the erosion can quickly lead to a large failure. Some areas in California have experienced land subsidence due to groundwater depletion or other reasons. Land subsidence can cause overtopping to occur in areas that have not had overtopping risk in the past.

Re-Engineering the Levees

Federal, state, and local agencies have been endeavoring to re-engineer the older levees and to build new levees to increasing design standards. One of the biggest issues of the existing levee system, particularly in the Bay-Delta, is the quality of the foundation material on which the levees are founded, as well as the material composition of the levees themselves. Two seismic concerns related to California levees are liquefaction potential of sandy levees and levees founded on granular or sandy soils, and cyclic failure and post-cyclic deformations of levees founded on peaty organic soils. Some non-seismic concerns related to California levees are ensuring sufficient levee height to withstand peak flows, armoring levees against toe or face erosion, preventing detrimental seepage through and beneath levees, and mitigating against degradation of levee integrity due to biological agents or time-based strength degradation of levee materials.

One of the important lessons learned from the New Orleans levee failures[187] was that levees can be designed and built to appropriate standards, but the juncture where two levees abut or join or where a levee abuts or joins a floodwall must also be designed and built to the same standards to avoid failure. A number of failures in and around New Orleans can be attributed to this juncture or interface between different levees built at different times using different designs or under different jurisdictions. Regardless of how well built each levee was, the interface or connection was sub-standard and failure occurred at that location. In engineering terms, levees are considered a series system, a chain of connected engineered components. Levee hazard mitigation must be conducted on a system-wide basis, and a levee system, as with any series system, is only as strong as the weakest “link” in the chain.

7.4.2 PROFILING LEVEE HAZARDS

In parts of California, both the chances and the consequences of flooding are ranked the highest in the nation. Many of the levees in California are intended to protect against a storm that as a 1 percent chance of occurring in any year. Some areas have an even lower level of protection. For perspective, the levee system protecting the city of New Orleans was intended to protect against a storm that has a 0.4 percent of occurring in any year (a 250-year level of protection) but failed in 2005 due to Hurricane Katrina.

A list of significant levee failures in the Bay-Delta from 1900 to the present is shown in Table 7.K. This list documents the spatial and temporal variability of levee failure but does not attribute the failures to a particular loading function or failure mechanism.

[187] Seed, et al., 2006

Table 7.K: San Francisco Bay-San Joaquin-Sacramento Delta Levee Failures, 1900-2017

Delta Island/Tract	Total Acres Flooded	Year Flooded
Andrus Island	7,200	1902, 1907, 1909, 1972
Bacon Island	5,546	1938
Bethel Island	3,400	1907, 1908, 1909, 1911, 1972, 1981, 1983
Big Break	2,200	1927
Bishop Tract	2,100	1904
Bouldin Tract	5,600	1904, 1907, 1908, 1909, 1972
Brack Tract	2,500	1904
Bradford Island	2,000	1950, 1983
Brannan Island	7,500	1902, 1904, 1907, 1909, 1972
Byron Tract	6,100	1907
Canal Ranch Tract	500	1958, 1986
Clifton Court Tract	3,100	1901, 1907
Coney Island	900	1907
Dead Horse Island	200	1950, 1955, 1958, 1980, 1986, 1997
Donlon Island	3,000	1937
Edgerly Island	150	1983
Empire Tract	3,500	1950, 1955
Fabian Tract	6,200	1901, 1906
Fay Island	100	1983
Franks Tract	3,300	1907, 1936, 1938
Glanville Tract	--	1986, 1997
Grand Island	--	1955
Grizzly Island	8,000	1983
Holland Tract	4,100	1980
Ida Island	100	1950, 1955
Jersey Island	3,400	1900, 1904, 1907, 1909, 1981, 1983
Little Franks Tract	350	1981, 1982, 1983
Little Mandeville Island	22	1980
Lower Jones Tract	5,700	1907, 1980
Lower Roberts Island	10,300	1906
Lower Sherman Island	3,200	1907, 1925
Mandeville Island	5,000	1938
McCormack Williamson Tract	1,500	1938, 1950, 1955, 1958, 1986, 1997, 2017
McDonald Island	5,800	1982
Medford Island	1,100	1936, 1983
Middle Roberts Island	500	1938
Mildred Island	900	1965, 1969, 1983
New Hope Tract	2,000	1900, 1904, 1907, 1928, 1950, 1986
Palm Tract	2,300	1907
Pescadero	3,000	1938, 1950
Prospect Island	1,100	1980, 1981, 1982, 1983, 1986
Quimby Island	700	1936, 1938, 1950, 1955, 1986
RD 1007	3,000	1925
RD 17	4,500	1901, 1911, 1950
Rhode Island	100	1938
Ryer Island	11,600	1904, 1907
Sargent Barnhart Tract	1,100	1904, 1907
Sherman Island	10,000	1904, 1906, 1909, 1937, 1969

Delta Island/Tract	Total Acres Flooded	Year Flooded
Shima	2,394	1983
Shin Kee Tract	700	1938, 1958, 1965, 1986
Staten Island	8,700	1904, 1907
Stewart Tract	3,900	1938, 1950, 1997
Terminous Tract	5,000	1907, 1958
Twitchell Island	3,400	1906, 1907, 1909
Tyler Island	8,700	1904, 1907, 1986
Union Island	2,400	1906
Upper Jones Tract	5,700	1906, 1980, 2004
Upper Roberts Island	500	1938
Van Sickle	--	1983, 2017
Venice Island	3,000	1904, 1906, 1907, 1909, 1932, 1938, 1950, 1982
Victoria Island	7,000	1901, 1907
Webb Tract	5,200	1950, 1980

Source: California Department of Water Resources (DWR), 2006 and 2017; DWR Public Affairs Chief Ted Thomas, personal communication, 2006; U.S. Army Corps of Engineers (USACE), 2006

Additionally, there have been other levee failures along the Sacramento and San Joaquin rivers during flood events. Some notable floods include 1950, 1955, 1983, 1986, and 1997 events. During these events Yuba City, Marysville, Linda/Olivehurst, Nicolaus, Manteca, and other areas were flooded.

Climate Change and Levees

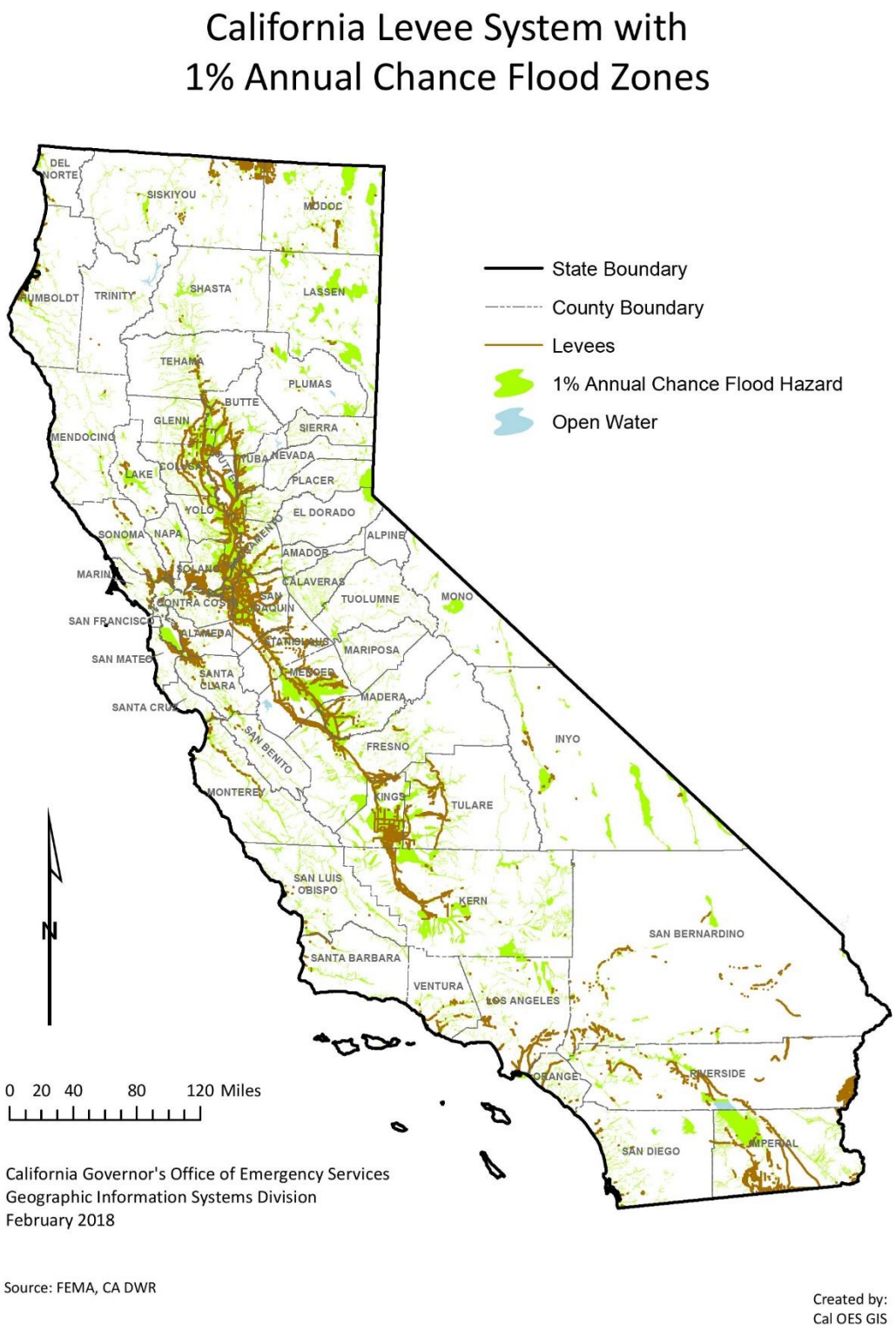
Climate change in California is expected to increase the risk of flooding significantly. Increased flood frequency and magnitude are predicted consequences of climate change.

The Sierra Nevada mountain range is the largest reservoir in the state and a key part of California's flood control system. The Sierra Nevada holds water through the winter months in the form of snow, which is then released to the Central Valley as snow melt during the warm months of the year. As annual temperature increase more of the precipitation that would have fallen into the mountains as snow may fall instead as rain, increasing winter flows in the rivers downstream into the Delta system.

As sea-levels rise, flood stages in the Sacramento-San Joaquin Delta of the San Francisco Bay estuary may also rise, putting increasing pressure on Delta levees. This threat may be particularly significant because recent estimates indicate that the additional force exerted upon the levees is equivalent to the square of the water level rise. Estimates using historical observations and climate model projections suggest that extreme high water levels in the Bay and Delta will increase markedly if sea-level rises above its historical rate. These extremes are most likely to occur during storm events, leading to more severe damage from waves and floods. As water levels in the Delta increase, water levels upstream in the Sacramento and San Joaquin Rivers will also increase, putting additional pressure on levees located there.[188]

[188] DWR, 2006; California Climate Change Center, 2006

Map 7.V: California Levee System with 1 Percent Annual Chance Flood Zones



Map 7.V shows the pattern of levees in relation to National Flood Insurance Program (NFIP) 1 percent annual chance flood hazard floodplains in California illustrating the potential for flooding resulting from levee failure. The greatest concentration of levees is in the Central Valley area. Lesser concentrations are found in the San Francisco Bay Area and Southern California.

7.4.3 ASSESSMENT OF LEVEE FAILURE VULNERABILITY AND POTENTIAL LOSSES

The list of levee failures in Table 7.J also documents the consequences of the levee failures in terms of area of land flooded per failure. The consequences of failure are critical for profiling the hazard and developing a rational risk-based assessment. Ultimately, the consequences are in terms of dollar figures associated with crop loss, building destruction, life loss, or saltwater intrusion that brings to a halt the pumping of fresh water to Central and Southern California as well as potential for environmental losses.

The Delta is subject to high water conditions during storm events but also to near-field seismic events. The California Water Policy Council and Federal Ecosystem Directorate (CALFED's "Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees" report of April 2000 concluded that 3 to 10 failures are likely to occur on critical Delta levees during an earthquake with a 1 percent chance of occurring in any year (100-year level of protection). These failures would likely stop the export of Delta water until water quality is restored. Approximately 60 percent of the water supply of the San Francisco Bay Area is extracted from or passes through the Delta. The intrusion of saltwater would force the State of California and Bureau of Reclamation to stop pumping and would endanger the water supply for 3 million acres of irrigated land and over 23 million people. A levee failure would result in an encroachment of brackish or seawater into the Delta. The presence of the saltwater would also have a significant impact on local agriculture and salt-sensitive native species.

The Delta also has many fuel storage facilities and oil and gas pipelines as well as electrical transmission lines and transportation infrastructure across the region. During a seismic event, these lines may fail and cause large-scale spills that would also inhibit the export of Delta water and severely affect one of the nation's largest natural salt water habitats. Levee failure resulting in flooding of a Delta island with infrastructure risks could introduce hazardous material into the water ad impede evacuation routes, and could also affect energy supplies in regions beyond the Delta.

In San Francisco and San Pablo Bays levees protect infrastructure as well as urban areas. The Oakland International Airport is an example of infrastructure protected by levees.

Progress Summary 7.N: Earthquake, High Water, and Levee Failure: Cascading Hazards

Progress as of 2018:
Draft Workshop Report – Earthquakes and High Water as Levee Hazards in the Sacramento-San Joaquin Delta
In July 2016, the Delta Independent Science Board organized a workshop at the University of California (UC) Davis to review and evaluate earthquakes and high water as hazards to Delta levees. The results of this workshop were published in a 24-page workshop report. The workshop highlighted findings that mostly postdated hazard assessments in the Delta Risk Management Strategy.

The workshop participants discussed earthquakes and high water as two of the greatest risks to levees. Specifically:

- The levee failure mechanism resulting from earthquake deemed most likely was liquefaction of sand within levee fills, if ground motions are sufficient.
- Present-day Delta water levels were shown to rise over time with riverine floods, winds surge, and tides, along with sea levels within the estuary. As a result of climate change, floods and winds in the Delta are projected to become more severe. Combinations of higher tides, wind-driven surges, and high river discharge create a significant high-water threat to levees.

The Draft Workshop Report – Earthquakes and High Water as Levee Hazards in the Sacramento-San Joaquin Delta can be downloaded from the Delta Council website at:
http://deltacouncil.ca.gov/sites/default/files/2016/08/2016-07-31-levee-workshop-full-report.pdf.

7.4.4 CURRENT LEVEE FAILURE HAZARD MITIGATION EFFORTS

State Flood Management Initiatives

California voters have approved billions of dollars in bonds over the years to finance various critical infrastructure improvements and retrofit projects. A November 2006 bond election resulted in provision of $4.9 billion of levee repair and improvement funding. The 2006 levee bond election led to formation of the California Department of Water Resources (DWR) Delta Risk Management Strategy (DRMS) program and to initiation of a comprehensive flood mitigation program in the Central Valley. In June 2011 the final Phase 2 Risk Reduction report was issued building on the knowledge gained from the DRMS Phase 1 assessment evaluating scenarios to reduce risk to the state economy. For more information on the DRMS program and to review the Phase 2 report visit: https://www.water.ca.gov/Programs/Flood-Management/Delta-Conveyance-And-Flood-Protection.

Levee Evaluation and Repair

Overview

DWR is undertaking unprecedented efforts to evaluate and upgrade aging and deteriorating levees along the Sacramento River and San Joaquin River valleys and the Delta. Funding for the levee evaluation efforts was provided through the two large flood control bonds, Propositions 84, and 1E, approved by California voters in November 2006. To expedite efforts to protect these communities, levee evaluations were conducted in a fast-track manner over an eight-year period.

To date, nearly 250 levee repair sites have been identified, with more than 100 of the most critical sites having already been repaired. Repairs to others are either in progress or scheduled to be completed in the near future, and still more repair sites are in the process of being identified, planned, and ranked.

Levee Repairs on Tyler Island in February 2017

Source: California Department of Water Resources

Urban Levee Evaluations Geotechnical Evaluation Report

The Geotechnical Evaluation Report is comprised of two volumes that present cumulative geotechnical evaluation results for the studied area. Volume 1, Existing Conditions, reports Urban Levee Evaluations ULE Project analysis results for existing levee conditions and identifies levee reaches and segments that do not meet the design and/or 200-year flood protection criteria (0.5 percent chance of failure in any given year). Volume 2, Remedial Alternatives, reports ULE Project conceptual remedial alternatives and associated costs for those reaches and segments that do not meet criteria based on the results of the Geotechnical Evaluation Report Volume 1. Volume 2 also evaluates the study area levees for seismic vulnerability but does not include conceptual remedial alternatives or associated costs.

Progress Summary 7.O: Levee Hazard Mitigation: Evaluation and Repair

Progress as of 2018: The California Department of Water Resources (DWR) Levee Evaluations Program included the Urban Levee Evaluations (ULE) Project and the Non-Urban Levee Evaluations (NULE) Project. The program evaluated current levels of performance for State Plan of Flood Control (SPFC) levees and associated non-SPFC levees. (If these non-SPFC levees fail, areas protected by the SPFC would flood.)

The ULE Project addressed approximately 470 miles of State-Federal Project Levees and appurtenant non-State-Federal Project levees located in the Central Valley protecting populations of 10,000 people or more. The NULE project addressed the remaining State-Federal Project and non-State-Federal Project levees protecting populations of fewer than 10,000 people. The ULE and NULE Projects were completed in April 2015. Information, analysis, cost estimate tools, and levee performance models developed by the program are being used in local, state, and federal areas of the Central Valley protected by the SPFC. More information on these programs can be found at: http://www.dwr-lep.com.

Urban Levee Evaluations (ULE) Project

The ULE Project evaluated levees that protect areas with more than 10,000 people. The ULE Project evaluated urban State-Federal Project levees, including appurtenant non-project levees, to determine if they meet defined geotechnical criteria and, if appropriate, identify remedial measure(s) to meet those criteria. The goals of the ULE Project included the following:

- Support the Central Valley Flood Protection Plan (CVFPP), federal and local flood management projects, local Federal Emergency Management Agency (FEMA) certification efforts, and the legislative mandate of urban 200-year flood protection by 2025
- Support federal and local flood management programs by providing geotechnical data, analysis, and remedial alternatives to local, state, and federal stakeholders
- Improve geotechnical information exchange methods between state, local, and federal flood management agencies
- Identify critical levee repairs

Non-Urban Levee Evaluation (NULE) Project

The NULE Project is part of DWR's Levee Evaluations program established through FloodSAFE with the primary purpose to evaluate non-urban/State-Federal Project levees and appurtenant non-State-Federal Project levees that protect fewer than 10,000 people. The NULE Project determined whether the non-urban levees meet defined geotechnical criteria and, if appropriate, identified remedial measure(s) to meet those criteria. The goals of the NULE Project include the following:

- Support the CVFPP and Central Valley Flood Evaluation Delineation (CVFED) projects
- Support federal and local flood management programs by providing geotechnical data, analysis, and conceptual remedial alternatives and their costs to local, state, and federal agencies
- Improve geotechnical information exchange methods among state, local, and federal flood management agencies.
- Identify locations where critical levee repairs may be needed.

Two phases have been developed to meet the NULE Project goals:

NULE Phase 1 – Geotechnical Assessment Report (GAR)

The Phase 1 assessments consisted of non-intrusive studies and preparation of the Geotechnical Assessment Report (GAR). Over 1,200 miles of non-urban State-Federal Project levees and over 300 miles of appurtenant non-urban non-State-Federal Project Levees were included in Phase 1 of the Geotechnical Assessment Report. The report contained a compilation of existing data about the levees, levee systems, and historical levee performance. The compiled data were reviewed for levee construction information, subsurface information, and past performance descriptions. Each levee segment was assigned a hazard category. Tools and methodology were developed to consistently assess levee segments based on systematic, consistent, repeatable analysis that correlated geotechnical data with levee performance history. Conceptual remedial alternatives and associated cost estimates were prepared and are presented in a Remedial Alternatives and Cost Estimate Report.

NULE Phase 2 – Geotechnical Overview Report

Phase 2 assessments build on Phase 1 results in DWR selected study areas, which generally consist of levees protecting populations greater than 1000 people. Phase 2 consisted of targeted field explorations, laboratory testing, and analyses to identify levees not meeting criteria established for the NULE Project. The fieldwork and laboratory testing will be summarized in the Geotechnical Data Reports. The analysis of existing conditions and remedial alternatives will be summarized in the Geotechnical Overview Reports. The Geotechnical Overview Report will be divided into two volumes, with Volume 1 describing existing conditions includes the study area overview, methodology, and analysis results. Volume 2 contains remedial alternatives for levees that do not meet criteria, and includes analyses of remedial alternatives and conceptual cost estimates.

All of the above-mentioned reports are completed. The GER and GOR reports were completed on April 30, 2015. DWR has made these reports available electronically. They can be found at http://www.dwr-lep.com.

Urban/Non-Urban Levee Evaluations Cost Analysis Tool

This tool is helping flood managers develop accurate estimates for levee repairs. The tool provides the previously unknown factor in the cost analysis of levee repairs: an analysis of levee conditions for 1,914 miles of levees (1,548 miles of SPFC levees and 366 miles of non-SPFC levees) while also accounting for hard construction costs and soft costs like design. The tool is being used by DWR's Central Valley Flood Management Planning Office, the U.S. Army Corps of Engineers, and local levee maintaining agencies.

Progress Summary 7.P: Delta Levees Program

Progress as of 2018: The Delta Levees Program includes the Special Flood Control Projects Program, the Delta Levees Maintenance Subventions Program, and the Delta Ecosystem Enhancement Section. The Delta Levees Program addresses approximately 1,100 miles of levees. Originally, the program was authorized to address flooding on the eight Western Delta Islands and in the towns of Thornton and Walnut Grove. In 1996, the program was expanded to include the entire Delta and portions of the Suisun Marsh. The Delta levees addressed by the program protect more than 10,000 people.

The Special Flood Control Projects Program provides funding to local agencies in the Sacramento-San Joaquin Delta for levee maintenance and improvement and for habitat mitigation and enhancement. The Delta Levees Maintenance Subventions Program is a cost-share program that provides technical and financial assistance to local levee-maintaining agencies in the Delta for the maintenance and rehabilitation of non-project and eligible project levees. Each year, 70 local agencies enter into agreements for the reimbursement of the eligible incurred costs. The Delta Ecosystem Enhancement Section operates as the environmental arm of the Delta Levees Program and has a primary role in providing environmental oversight for reclamation district projects funded by the program. The primary objective of these projects is to provide habitat and ecosystem benefits for native species. For more information, visit: **https://www.water.ca.gov/Programs/Flood-Management/Delta-Conveyance-And-Flood-Protection**.

DWR's Delta Levees Program helps support the work of more than 70 local agencies that maintain, rehabilitate, or improve levees at risk from flooding, tidal stresses, and sea level rise, among other threats, in the Sacramento-San Joaquin Delta. During 2015 and 2016, additional partnerships were established with local agencies that represent individual Delta islands, making it possible to continue reducing flood risk in the Delta. Additionally, 2016 saw the completion of significant levee projects on New Hope Tract, Bouldin Island, Bacon Island, and elsewhere in the Delta. This work contributes toward a major milestone in a $38 million effort that began in 2011 to raise all Delta levees to an interim Hazard Mitigation Plan standard.

Delta Stewardship Council and the Delta Levees Investment Strategy

The Delta Reform Act of 2009 called on the Delta Stewardship Council to lead a multi-agency effort to update priorities for state investments in the Delta levee system to reduce the likelihood and consequences of levee failures and to protect people, property, and state interests, while advancing the coequal goals of improving water supply reliability, restoring the Delta ecosystem, and protecting and enhancing the values of the Delta as an evolving place.

The Delta Stewardship Council was created in legislation to achieve the state-mandated coequal goals for the Delta. In response, the Council has launched the Delta Levees Investment Strategy (DLIS), which will combine risk analysis, economics, engineering, and decision-making techniques to identify funding priorities and assemble a comprehensive investment strategy for the Delta levees.

Beginning in 2014, the development of the DLIS has been underway through collaboration among state agencies, local reclamation districts, Delta landowners and businesses, and other stakeholders. A final draft version (amended by the Council) was released on March 23, 2017. A Memorandum of Understanding for implementation of the DLIS was drafted in June 2017.

Implementation of the DLIS aligns with 2018 SHMP Goal 2*: Minimize damage to structures and property, as well as interruption of essential services and activities* and Goal 3*: Protect the environment.*[189]

More information can be found at http://deltacouncil.ca.gov/delta-levees-investment-strategy.

[189] http://deltacouncil.ca.gov/delta-levees-investment-strategy. (Delta Stewardship Council website, 2017)

Other Levee Programs Addressing Flood Risk:

Delta Levees System Integrity

This program focuses on levee repair, maintenance and improvement, and habitat enhancement within the Sacramento-San Joaquin Delta. The program includes the Delta Levees Special Projects Program and the Delta Levees Maintenance Subventions Program. More information on these programs can be found at: https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Delta-Levees-Special-Flood-Control-Projects and https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Delta-Levees-Maintenance-Subventions.

Delta Special Investigations

This program focuses on levee repair, maintenance, and improvements within the Delta. The program includes the following projects: Delta Knowledge Improvement, North Delta, and West Delta. More information on this program can be found at: https://www.water.ca.gov/LegacyFiles/floodsafe/fessro/docs/special_investigations_update.pdf and http://water.ca.gov/floodsafe/fessro/docs/special_investigations_update.pdf.

Marysville Ring Levee

This project provides a 0.5 percent annual chance level of protection for the people of Marysville, critical infrastructure (California State Highways 20 and 70, railroad) and a 173-bed, Level III regional trauma center. Partners for this project include the USACE, DWR, Central Valley Flood Protection Board, Marysville Levee Commission, and Yuba County Water Agency. More information on this project can be found at: http://www.ycwa.com/the-ycwa/flood-management/marysville-ring-levee/.

Local Levee Assistance

Initiated by Proposition 84, this DWR cost-share program was created to assist flood management throughout the state. The program funds evaluations and critical repairs of flood projects at a cost share of up to 90 percent for multi-benefit projects that protect disadvantaged communities. The funds allocated for these grants are expended through competitive grants to local public agencies responsible for flood control at the project location. More information on this program can be found at: https://www.water.ca.gov/Work-With-Us/Grants-And-Loans/Local-Levee-Assistance-Program.

Progress Summary 7.Q: Lower Elkhorn Basin Levee Setback Project

Progress as of 2018: The California Department of Water Resources (DWR) is working on the Lower Elkhorn Basin Levee Setback project—the first state-led construction project to increase flood protection in the Central Valley. The project is the first step toward implementation of the Yolo Bypass Multi-Benefit Improvements outlined in the 2017 Central Valley Flood Protection Plan update and Sacramento Basin Wide Feasibility Study.

The project will set back the north levee of the Sacramento Bypass and the eastern Yolo Bypass levee between Interstate 5 and the Sacramento Bypass by 1,500 feet. This is the first step to adding capacity to the Sacramento Flood System in the Yolo Bypass. This initial project will lower the water surface elevation adjacent to the urban areas of Sacramento and West Sacramento and is a part of the larger effort that will the elevation as much as 3 feet.

The Lower Elkhorn Basin Levee Setback project and the efforts in the Yolo Bypass involve more than just flood protection. The Yolo Bypass has a history of successfully combining agriculture, flood capacity, and environmental benefits. Portions of the bypass are farmed for rice in the summer and flooded for birds in the winter. They are also a part of the flood bypass system and can relieve pressure from high water on levees adjacent to urban areas. The Lower Elkhorn Basin Levee Setback project and other projects in the area will continue this practice. Land that becomes a part of the bypass area will be farmed in a similar way to other areas within the bypass. There is also an opportunity for an environmental corridor adjacent to the Tule Canal in the bypass, as well as recreational opportunities.

Hamilton City J levee

This project would provide increased flood protection for an agricultural support community and 1,500 acres of restored habitat. Partners for this project include the USACE, Central Valley Flood Protection Board, and Reclamation District 2140. For more information on this project, see Best Practices Highlight 7.G or visit: http://www.sacriver.org/aboutwatershed/roadmap/projects/hamilton-city-levee-setback.

Best Practices Highlight 7.F: Hamilton City Flood Damage Reduction and Ecosystem Restoration Project

Hamilton City is located along the Sacramento River about 85 miles north of Sacramento in Glenn County. Given its proximity to the Sacramento River, the city has an extensive history of flood evacuations and flood fighting to avoid failure of the private "J" levee, which is the only existing protection. The existing levee protects the town's population of approximately 2,070 residents and 758 properties and is substandard. The "J" levee, built in the early 1900s to contain flows in the Sacramento River, failed twice in the 1970s and has required emergency reinforcement five times since 1983. The "J" levee does not meet current construction standards and could fail even with river levels below the top of the levee. See Figure 7.M for an overview map of the project area.

A 2004 feasibility study by the U.S. Army Corps of Engineers (USACE) and the Reclamation Board of the State of California determined that the project could reduce the chance of flooding from once every 10 years to once every 75 years, with an expected $577,000 decrease in annual flood damages.

The community's flood damage reduction and ecosystem restoration project is an example of successful collaborative partnerships in which stakeholders have come together to help coordinate the project and secure funding, land, and other resources in an effort to construct the new levee. The project aims to reduce flood risk and damage, to repair the river ecosystem through restoration of river function and improved habitat, and to form successful partnerships between stakeholders in the process. The project, which includes a 6.8-mile setback levee, 1,450 acres of floodplain, and 1,361 acres of habitat restoration, is expected to cost $72.9 million.

The project, which began in 2015, is the first in the nation to be authorized for construction under the USACE guidelines to develop multi-purpose projects that include both flood risk reduction and ecosystem restoration. Reclamation District 2140 was formed to be the non-federal sponsor of the project and will own, operate, and maintain the levee once construction has been completed. State funding (about $5 million) was provided through the Flood Corridor Program.

For more information regarding the Hamilton City project, visit the following websites:
http://www.spk.usace.army.mil/Missions/Civil-Works/Hamilton-City/,
http://rd2140.org/hamilton-city-levee-update/ and
http://bondaccountability.resources.ca.gov/Project.aspx?ProjectPK=8589&PropositionPK=5.

Figure 7.M: Hamilton City Flood Damage Reduction and Ecosystem Restoration Project Overview

Source: Reclamation District 2140, http://rd2140.org/hamilton-city-levee-update/

Best Practices Highlight 7.G: Local Levee Assistance: Mission Beach Seawall, San Diego

The Local Levee Assistance Program was established by the California Department of Water Resources to provide financial assistance to local public agencies responsible for flood management outside the Sacramento-San Joaquin Delta. The Local Levee Assistance Program helped fund the design of improvements to repair and replace portions of an existing seawall and adjacent walkway at Mission Beach in San Diego, a major tourism and business area. This $1.2 million project demonstrates collaboration between state and local governments and the program's ability to fund flood management projects beyond traditional levee repair projects.

Mission Beach Seawall, San Diego

Source: California Department of Water Resources, 2014 Flood Management Activity Highlights: Managing Risk and Protecting the Environment.

7.5 DAM FAILURE AND SAFETY HAZARDS, VULNERABILITY, AND RISK ASSESSMENT

7.5.1 IDENTIFYING DAM HAZARDS – FAILURES AND OVERTOPPING

Dam failure is the uncontrolled release of impounded water from behind a dam. Flooding, earthquakes, blockages, landslides, adverse geological conditions, lack of maintenance, aging infrastructure, improper operation, poor construction, vandalism, and terrorism can all cause dam failure. Dam failure from overtopping is a specific failure mechanism resulting from inadequate spillway capacity or other spillway issues and seiches. Dam failure can result in catastrophic downstream flooding that may affect life and property.

Dam failure from overtopping can occur when the inflow volume into a reservoir (primarily caused by stormwater runoff) exceeds the volume of water that can be stored and evacuated from a reservoir via its spillway. With a changing climate that includes an expectation of increased extreme weather events in California, including prolonged periods of severe drought and intense wet periods with less snowpack and degraded conditions in source watersheds, dam operation becomes more difficult and the risk of spillway activation and dam failure from overtopping may increase.

7.5.2 PROFILING DAM HAZARDS – FAILURES AND OVERTOPPING

Dams and reservoirs of jurisdictional size are defined in the California Water Code Sections 6000 through 6008. A jurisdictional dam in California has a height greater than 6six feet while impounding 50 acre-feet or more or a height greater than 25 feet with storage capacity of 15 acre-feet or more. As of early 2018, there are more than 1,537 dams of jurisdictional size in California. Approximately 1,250 of these dams are under jurisdiction of the California Department of Water Resources (DWR), Division of Safety of Dams (DSOD). Dams and reservoirs owned by the federal government are not subject to state jurisdiction except as otherwise provided by federal law. In California, there are approximately 287 dams owned by federal government agencies such as the United States Forest Service (USFS), United States Bureau of Reclamation (USBR), United States Army Corps of Engineers (USACE), and the United States military.

Los Angeles County leads the state with 91 jurisdictional dams, followed by Sonoma County with 64 dams. Del Norte County is the only county in the state that has no dams of jurisdictional size.

The term “dam failure” encompasses a wide variety of circumstances characterized by damage to a component of the dam or an appurtenant structure leading to an uncontrolled release of impounded water. Situations that would constitute a dam failure vary widely, from small problems to a partial or catastrophic collapse of the entire dam or appurtenant structure. Potential causes of a dam failure are numerous and can be attributed to adverse geologic conditions, deficiencies in the original design of the dam, the quality of its construction, the maintenance of the dam and operation of the appurtenances of the functioning dam, and acts of nature including flooding from precipitation and damage from earthquakes. Most of these causes and deficiencies are related to the dam having been constructed in an era a dam was constructed that, which pre-dates our current engineering knowledge. Water overtopping the dam crest is a cause of failure in earthen dams. Overtopping can cause erosion of the dam crest and potentially a dam breach. Piping of dam fill material within earthen dams is another failure mechanism. Piping is a form of erosion that occurs internal to an embankment or its foundation, caused by internal flaws such as fracturing within rock or soil, rodent burrowing, and/or the presence of extensive root systems from vegetation growing on and around the dam.

In the past 50 years, there have been only a small number of dam failures in California. The most catastrophic dam failure in California’s history is that of the infamous St. Francis Dam in Los Angeles County, which failed in March 1928, shortly after construction of the dam was completed. This failure resulted in the deaths of more than 450 people and the destruction of nearly 1,000 homes and buildings. Numerous roads and bridges were also destroyed or damaged beyond repair. The Division of Safety of Dams (DOSD) was established as a direct result of this catastrophe. Other significant dam incidents in California’s history include the Baldwin Hills Dam failure in 1963, the near-failure of the Lower San Fernando Dam in 1971, and the failure of the spillway system at Oroville Dam in 2017.

Construction at the Oroville Dam Spillway in January 2018

Source: California Department of Water Resources

In February 2017, the gated spillway at Oroville Dam, the tallest dam in the United States, suffered a failure within its concrete chute. A 60-foot-deep hole developed in the lower third of the chute as a result of normal spillway operations undertaken to lower the reservoir in advance of a moderately large storm. The subsequent occurrence of the storm in the days after the initial incident and the inability to fully use the primary spillway led to the filling of the reservoir and the use of its unlined emergency spillway for the first time ever. After two days of usage and erosion of the unlined hillside and head cutting, concerns regarding the stability of the emergency spillway weir developed, and nearly 200,000 people downstream were evacuated.

The incident emphasized the importance of re-evaluations of appurtenant structures, including understanding the original design and construction; inspections alone were not likely to have predicted the incident but, in conjunction with a re-evaluation, the underlying causes may have been discovered. It is of note that the storms that occurred were below historical maximums, but the 2016-2017 water year was the wettest ever for that region of California. The event emphasized the importance of dam appurtenances, and especially the importance of having adequate outflow capacity and spillway design features.

Continued Repairs on the Oroville Dam Spillway in February 2018

Source: California Department of Water Resources

7.5.3 ASSESSMENT OF DAM FAILURE VULNERABILITY AND POTENTIAL LOSSES

State's Role in Vulnerability Assessment

The State of California has not made local vulnerability assessments quantitatively. The major role that California, and specifically DOSD, has traditionally had is to assess the safety of dams, including the dam's vulnerability to hazards such as floods and earthquakes, but not necessarily to assess downstream consequences. In order for the state to look at the vulnerabilities of downstream communities, regularly updated inundation maps are needed. Prior to 2017, California did not have these maps. The state took a major step forward in having the capability to determine downstream vulnerabilities in 2017, with the passage of Senate Bill 92 requiring dam owners with certain hazard classifications to develop inundation maps and emergency action plans for their dams.

As a result of Senate Bill 92 and the subsequent updated inundation maps, the state will assess potential vulnerability and losses to dam failure for most dams in the state. These efforts will be possible once the inundation mapping program and emergency action plan development is completed in California by 2021.

Assessment of Local Vulnerability and Potential Losses

Information related to community vulnerability and loss assessments may be found in Local Hazard Mitigation Plans (LHMPs). Local planning departments have access to the state's inventory of inundation maps, which are kept on a server and published annually as DVDs. These DVDs are provided without cost to both governmental agencies and non-governmental parties upon request.

7.5.4 CURRENT DAM FAILURE HAZARD MITIGATION EFFORTS

Dam Safety Legislation and Programs

Since 1929, the state has supervised all non-federal dams in California to prevent failure for the purpose of safeguarding life and protecting property. Supervision is carried out through the state's Dam Safety Program under the jurisdiction of DWR. The legislation requiring state supervision was passed in response to the St. Francis Dam failure and concerns about the potential risks to the general populace from a number of water storage dams. The law requires:

- Examination and approval or repair of dams completed prior to August 14, 1929 (the effective date of the statute)
- Approval of plans and specifications for and supervision of construction of new dams and the enlargement, alteration, repair, or removal of existing dams
- Supervision of maintenance and operation of all dams under the state's jurisdiction

The 1963 failure of the Baldwin Hills Dam in Southern California led the legislature to amend the California Water Code to include within state jurisdiction both new and existing off-stream storage facilities. Dams and reservoirs subject to state supervision are defined in California Water Code Sections 6002 through 6009. In administering the Dam Safety Program, DWR must comply with the provisions of the California Environmental Quality Act (CEQA). As such, all formal dam approval and revocation actions must be preceded by appropriate environmental documentation.

In 1972, Congress moved to reduce the hazards from the 28,000 non-federal dams in the country by passing Public Law 92-367, the National Dam Inspection Act. With the passage of this law, Congress authorized the USACE to inventory dams located in the United States. The action was spurred by two disastrous earthen dam failures during the year in West Virginia and South Dakota that caused a total of 300 deaths.

The Water Resources Development Act of 1986 (Public Law 99-662) authorized the USACE to maintain and periodically publish an updated National Inventory of Dams (NID). The Water Resources Development Act of 1996 (Public Law 104-303), Section 215, re-authorized periodic updates of the NID by the USACE. Section 215 further established the National Dam Safety Program and named the Administrator of FEMA as its coordinator. The National Dam Safety and Security Act of 2002 (Public Law 107-310) added security to the list of critical dam safety issues. The Dam Safety Act of 2006 (Public Law 109-460) added condition assessment ratings of dams to the NID and reauthorized the National Dam Safety Program. The Water Resource Reform and Development Act of 2014 reauthorized the National Dam Safety Program most recently.

On the heels of the Oroville Dam incident in February 2017, the Governor announced a four-point plan to bolster dam safety and flood protection in California. In the spring of 2017, the state legislature passed Senate Bill 92, which was signed by the Governor on June 27, 2017. Along with the Governor's Executive Order action, this law bolsters dam safety provisions in the California Water Code and Government Code. It tasked DWR/DSOD with additional dam safety items and required that DWR/DSOD review and approve dam inundation maps for Emergency Action Plans (EAPs). The new language also required that the California Governor's Office of Emergency Services (Cal OES) review and approve EAPs, provide that the EAP included the required/approved inundation maps.

Consistent with Senate Bill 92, the new Water Code resulted in the following:

- DWR has updated the classification of the public safety risk of all state jurisdictional dams based on downstream hazard potential and reviews of critical appurtenant structures. (California Water Code Section 6160)
- For state jurisdictional dams identified as significant, high, or extremely high hazard classifications, DWR is required to review, provide comments, and when complete, approve inundation maps (incorporating enhanced mapping technology) prepared by dam owners for the failure of their dam and identified critical appurtenant structures under various failure scenarios unique to the dam. (California Water Code Sections 6060 and 6161)
- DWR will make approved dam failure inundation maps publicly available. (California Water Code Section 6161)
- All state jurisdictional dams excluding low hazard dams will be required to submit an Emergency Action Plan (EAP) using these approved inundation maps. Cal OES shall review and approve the EAP upon DWR/DSOD approval of the dam inundation map(s) prepared by the dam owner. (California Water Code Section 6161)
- All state jurisdictional dams excluding low hazard dams will be required to do a notification exercise once a year. (California Government Code Section 8586.9)
- Cal OES will assist local public safety agencies in integrating EAPs within their all hazards plans. (California Government Code Section 8586.9)
- All state jurisdictional dams shall update their inundation map and EAP every 10 years or sooner if the dam system changes significantly or local development patterns change. (California Water Code Sections 6060 and 6161)
- New regulatory tools for enforcement to support the above requirements will range from monetary fines to operational restrictions for failure to comply. (California Water Code Section 6060 and 6161)
- DSOD will receive $3 million in budget allocations (funded by fees paid for by dam owners) to conduct more extensive evaluations of appurtenance structures, such as spillways, gates, and outlets, than the previous visual inspections. This includes geologic assessment and hydrological modeling, which is being expedited for dams that have spillways and structures similar to the Oroville Dam before the 2018-2019 flood season.

Additional information about inundation mapping and EAPs, as amended by Senate Bill 92, is found in the Government Code Section 8589.5.

Furthermore, the Governor has requested that the federal government adopt the state's new detailed evaluations of dam appurtenant structures at federal dams; update rule curves for reservoir regulation and flood control through the U.S. Army Corps of Engineers (USACE), allowing non-federal authorities to help fund the necessary reviews; and appropriate federal funding for the newly created federal program to rehabilitate high-hazard dams through the FEMA National Dam Safety Program.[190]

DWR adopted emergency regulations under the Administrative Procedure Act that establish criteria for dam owners to prepare and submit inundation maps for review and approval by DWR. Specifically, these emergency regulations specify definitions, failure scenarios, and submittal requirements for inundation maps for dams and critical appurtenant structures that could affect downstream life or property. DWR proposes these emergency regulations for adoption into the California Code of Regulations, Title 23, Division 2, Chapter 1, Article 6. Further information regarding these regulations can be found at: https://www.water.ca.gov/Programs/All-Programs/Division-of-Safety-of-Dams.

Following Office of Administrative Law's approval of the emergency regulations, DWR will initiate the permanent regulation rulemaking process for inundation maps.

Additionally, under Proposition 1, $2.7 billion of state funds are being invested in water storage projects, the largest single investment in new dams and reservoirs in decades. Potential projects to be funded under Proposition 1 include new dam construction and reservoir expansions.

[190] https://www.gov.ca.gov/2017/02/24/news19696/;
https://www.gov.ca.gov/wp-content/uploads/2017/09/Fact_Sheet_Governor_Brown_Four_Point_Plan_to_Bolster_Dam_Safety_and_Flood_Protection.pdf

Risk MAP

FEMA has recently launched an effort under its Risk MAP program to communicate risk of dam failure and to coordinate state and private mitigation and preparedness efforts. According to FEMA, most people living downstream of a dam are unaware of the potential hazards associated with dam failure, have never seen the respective dam failure inundation map, and are unaware of an evacuation plan or an EAP associated with the failure of that dam. There is a need, therefore, to include dam failure risk awareness as part of a comprehensive flood risk communication strategy and develop a communication strategy that reports on dam failure risk and promotes dam safety. The audience for these strategies includes dam owners/operators, dam regulators, emergency managers, floodplain managers, planners, public and private decision-makers, and the population at risk.[191]

Mitigation of dam failure is constantly occurring at both the federal and state level. For example, the U.S. Bureau of Reclamation is planning to replace the longest earthen section of Folsom Dam to mitigate earthquake damage. In addition, the Folsom Dam Joint Federal Project is a project to construct an auxiliary spillway at Folsom Dam that will work in conjunction with the existing spillways to help the Sacramento region achieve a 200-year level of flood protection. Project construction was completed in October 2017. The purpose of the Folsom Dam Joint Federal Project is to improve the ability to manage large flood events by allowing more water to be safely released earlier in a storm event and leaving more storage capacity in the reservoir to hold back the peak inflow when it arrives. A peak inflow of 450,000 cubic feet per second in a 200-year design storm, releases can be held to 160,000 cubic feet per second or less, which can be safely conveyed with the improved American River levees. The new auxiliary spillway also allows passage of the probable maximum flood without damaging the dam. This is an example of the complex modification of existing dam infrastructure to accommodate larger rain floods that may occur with or without climate change.

At the state level, as of early 2018, the 210-foot-high New Calaveras Dam is under construction to replace the existing upstream dam due to seismic stability issues, and officials are reviewing a similar project south of San Jose, which will mostly remove and replace a 235-foot-high dam to address seismic stability concerns. Finally, also as of 2018, the state is undertaking a massive project to reinforce and reconstruct the spillways at Oroville Dam. These are just a few examples of the numerous dam mitigation projects being undertaken as of 2018.

DWR Division of Safety of Dams

Engineers and engineering geologists at the DSOD review and approve plans and specifications for the design of dams and oversee their construction to ensure compliance with the approved plans and specifications. Reviews include site geology, seismic setting, site investigations, construction material evaluation, dam stability, hydrology, hydraulics, and structural review of appurtenant structures.

In addition, DSOD engineers inspect over 1,200 dams on a yearly schedule to ensure they are performing and being maintained in a safe manner. The DSOD also periodically reviews the stability of dams and their major appurtenances in light of improved design approaches and requirements, as well as new findings regarding earthquake hazards and hydrologic estimates in California.

California's Dam Safety Program has incorporated elements of the FEMA National Dam Safety Program. For example, the DSOD has categorized state-regulated, jurisdictional dams based on FEMA's hazard classifications.

The DSOD continues to work on a national level to effect positive changes to dam safety practices. DSOD staff are participating in the following NDSRB work groups: the Emergency Action Plan (EAP) work group, the research work group, and the National Inventory of Dam (NID) condition assessment work group. The SOD has also been heavily promoting the use of the Decision Support System for Water Infrastructural Security (DSS-WISE) as a tool that state regulators can use to quickly prepare inundation maps for dam break scenarios through the National Dam Safety Review Board.

[191] James E. Demby, Jr., PE, FEMA ,"Dam Failure – the Other Flood Hazard." Presentation, 2009 American Planning Association National Planning Conference, Minneapolis, April 25-29, 2009.

The DSOD reviewed the hazard classification of all its dams and sub-divided the high hazard classification into two classifications: High Hazard and Extremely High Hazard. As of August 2017, there are 1,249 dams under state jurisdiction, of which 474 are High Hazard and 196 are Extremely High Hazard (670 High Hazard per FEMA definitions). Remediation needs at this time have been identified at 97 dams, of which 60 are High or Extremely High Hazard.

More information can be found at: https://www.water.ca.gov/Programs/All-Programs/Division-of-Safety-of-Dams.

California Governor's Office of Emergency Services (Cal OES)

Senate Bill 92 was signed into law in 2017 establishing new rules that include mandated Emergency Action Plans (EAPs) for state-regulated dams that have been identified to have extremely high, high, and significant hazard classifications. Prior to this change, inundation maps, the cornerstone of emergency plans, were only created or updated at the time the dam was built or enlarged and did not take into account a failure of an appurtenant structure or failure of downstream flood facilities, such as a levee breach. A dam inundation map delineates the area that would be flooded by a particular dam breach or failure. It includes downstream effects and shows the probable path followed by water released from a failure of a dam or from extreme flood flows released through a dam's spillway and/or other appurtenant works.

EAPs are a critical component of a strong dam safety program. EAPs outline the action steps that are taken to protect life and property and include dam failure detection measures through inspections and maintenance, determinations of emergency levels based upon the threat of flooding, notification protocols for local government and the public, and other preventive measures dam owners and operators can take. EAPs use dam inundation maps to guide actions and notification protocols since they show the potential area of flooding and its impacts

Prior to Senate Bill 92, California had inadequate inundation maps, as well as insufficient requirements for the development of EAPs. Senate Bill 92 requires Cal OES to review and approve EAPs following DWR DSOD approval of the dam inundation map(s) prepared by the dam owner. In order to implement these state legislative requirements, Cal OES received $1.8 million in state funding to support five new permanent staff positions in the Dam Safety Planning Division, which is charged with reviewing and approving EAPs of all jurisdictional dams in California. The Division will implement Cal OES's program requirements related to dam safety and work closely with DWR DSOD in ensuring that the inundation maps have been approved and then incorporated into the new EAP for approval.

Dam owners are responsible for creating EAPs in accordance with FEMA's Federal Guidelines for Dam Safety: Emergency Action Planning for Dams, and based on their new or updated inundation maps. Dam owners are required to update their EAP regularly in accordance with Senate Bill 92. In order to assist dam owners with meeting legislative requirements, Cal OES is developing tools to aid dam owners in preparing EAPs and exercising their plans. Additionally, Cal OES will be working with dam owners and local public safety agencies to help integrate the EAPs into other emergency plans, such as local hazard mitigation plans and emergency operations plans. Cal OES will also coordinate emergency response drills with dam owners and local emergency management agencies.

FEMA Integration

The National Dam Safety Review Board advises FEMA's Administrator in setting national dam priorities and considers the effects of national policy issues affecting dam safety. In an effort to stay abreast of national dam safety efforts, the DSOD along with Cal OES are members on the National Dam Safety Review Board.

Mindful of the new legislative requirements and the importance of the federal guidelines to the program in California, Cal OES is the new advisory emergency management liaison on the National Dam Safety Review Board and sits on the Emergency Action Plan (EAP) Workgroup. As the Emergency Management Liaison, Cal OES will provide outside expertise and perspective to the National Dam Safety Review Board on emergency management and dam safety issues that are not available among the members, most of whom bring an engineering perspective to dam safety. Furthermore, Cal OES will identify and bridge gaps between the dam safety and emergency management communities and assist in developing partnerships among these critical stakeholders. In this role, Cal

OES and the DSOD are in a unique position to influence dam safety at the national level and enhance the integration of dam safety officials and the emergency management community. California has also integrated FEMA's Federal Guidelines for Dam Safety: Emergency Action Planning for Dams within Government Code Section 8589.5 as requirements for the development of EAPs for state jurisdictional dams.

Cal OES and DWR DSOD are also volunteering to host a FEMA pilot program for Dam Safety Collaborative Technical Assistance that kicked off in June 2018. This program, based in Ventura County, will bring together operators from five dam facilities (operated by three different entities) with the county Office of Emergency Services to prepare more resilient emergency action plans for both the dam facilities and downstream communities. In addition to local participation, representatives from FEMA's National Dam Safety Program, the National Integration Center's Technical Assistance team, FEMA Region IX, Argonne National Laboratory, Cal OES, and DWR will attend. This pilot program will serve as a foundation for Cal OES to develop and roll out a similar program to assist local public safety agencies statewide to integrate EAPs into local hazard plans (emergency operations plans and Local Hazard Mitigation Plans) in accordance with Senate Bill 92.

Progress Summary 7.R: Dam Inundation Mapping and MyPlan

Progress as of 2018: As part of the focus on dam safety in California, the California Governor's Office of Emergency Services (Cal OES) redirected Hazard Mitigation Grant Program funding to support the development of inundation maps for 18 high hazard California dams. These include dams that do not otherwise have financial or technical resources to complete the required inundation maps. California State University (CSU) Sacramento, Office of Water Program, assisted Cal OES in simplifying the inundation mapping process, improving the quality of the state's existing inundation maps, and expanding the number of inundation maps within California. CSU Sacramento provided support to continuing efforts by the Division of Safety of Dams (DSOD) and Cal OES to improve the quality and usefulness of the state's inundation mapping process by producing inundation maps using the Federal Emergency Management Agency (FEMA) National Dam Safety Program's Decision Support System for Water Infrastructural Security (DSS-WISE) software application recently developed by the University of Mississippi with FEMA financial support.

An opportunity for enhanced outreach to local governments and the public lies with inclusion of digital dam inundation mapping data on the MyPlan website. Corresponding dam inundation area layers will be created and added to MyPlan approximately 6 months after Cal OES approval of the related EAP for each dam. This will allow local planners to better plan for a dam failure incident within their jurisdictions.

Obstacles and Challenges

Under Senate Bill 92 (2017), inundation maps, along with corresponding Emergency Action Plans (EAPs), are due to Cal OES and the DWR DSOD on January 1, 2018 (for dams with a hazard classification of Extremely High), January 1, 2019 (for dams with a hazard classification of High), and January 1, 2021 (for dams with a hazard classification of Significant). It should be noted that dams classified as low hazard are exempt from the requirements of Senate Bill 92.

California faces some challenges in its efforts to mitigate the effects of dam hazards in California. There are 945 dams whose owners must submit EAPs by 2021. Some dam owners may lack resources to respond to the new state requirements. The financial burden on dam owners to produce the inundation maps is significant. Inundation maps are required to be produced by a qualified, licensed engineer for primary dams, as well as any critical appurtenant structures. With a limited pool of qualified engineers, there may not enough resources to produce the maps, and the expense to the owners may be increased if they need to contract out for mapping services.

With the statutory deadlines, there are an overwhelming number of maps and EAPs to review in a short time period. As of the spring of 2018, the DSOD had received inundation maps for over 150 dams, and will ultimately receive over 1,000 more inundation maps by the end of 2020. The DSOD independently reviews and verifies the accuracy of the maps through modeling by its technical experts. Additionally, as of the spring of 2018, the Cal OES Dam Safety

Planning Division had received 179 EAPs for review and is responsible for completing review of each EAP within 60 days of receipt in accordance with Senate Bill 92.

Many of the 179 EAPs submitted to Cal OES were determined to be incomplete and brought to light the need for updated guidance to support dam owners in developing an EAP. As a result, Cal OES and the DSOD are working to create updated sample EAP and review tools.

The review processes for both the inundation maps and EAPs is time-consuming and staff resources are limited. The aggressive schedule for submission of both inundation maps and EAPs from 2018 to 2021 will stretch both DSOD and Cal OES capability to meet the statutory requirements of the forward-leaning and comprehensive California Dam Safety Program.

7.5.5 ADDITIONAL DAM FAILURE HAZARD MITIGATION OPPORTUNITIES

The DSOD is required by state law to work with other state and federal agencies, dam owners and operators, floodplain managers, planners, and the public to make dam inundation maps available for the benefit of citizens interested in learning their dam failure inundation risk. Dam inundation maps can be useful in the preparation of Local Hazard Mitigation Plans (LHMPs) and general plan safety element updates. Inter-agency coordination to support the transparency of and improved access to inundation mapping is pending.

Oroville Dam during the Oroville Spillway Assessment Visit, February 14, 2017

Source: California Governor's Office of Emergency Services (Cal OES)