Chapter 1 – Infrastructure (INFR)

COMMITMENT: Bay Area transportation and utility facilities and networks are vital lifelines during and following disasters, as well as in the functioning of our region and its economy.

Damage to infrastructure in a disaster can lead to damage to other systems and delayed recovery.

The August 2005 Hurricane Katrina Disaster on the Gulf Coast has reinforced existing knowledge on the role of infrastructure before and after disasters.
(1) Infrastructure systems, including roads and highways, ports and airports, pipelines carrying water, sewage, and natural gas, as well as power and communications systems are all interconnected.
(2) Infrastructure is critical to a safe and resilient economy.
(3) The impacts of major catastrophes are not simply linearly related to the size of the impacted area, but rather can explode exponentially if infrastructure is impacted.
(4) People who are impacted if infrastructure is damaged are disproportionately the young, the elderly, and those with special needs.

These impacts are seen in most large earthquakes, as well storms. Emergency and utility repair vehicles were caught in the gridlock following the earthquake in Kobe, Japan.

The owners of infrastructure systems need to work together to increase the resiliency of these systems.

One of the main reasons for the interdependencies of infrastructure systems is that they tend to be geographically located in the same areas. For example, water, sewer, and natural gas pipelines tend to be under local roads. Communications and electrical cables are either located under those roads or adjacent to them. All have similar exposures to hazards that are related to serving the developed portions of the region. The responsible agencies and hazard exposures of each infrastructure system are described separately on the following pages.

Roadways flooded in Hurricane

Cities, counties, transit districts, water suppliers, wastewater system operators, and other utilities have worked together to set regional priorities for the mitigation of hazards associated with these systems. Because of the large number of special districts involved in operating utility and lifeline systems, a variety of responsible agencies have been identified following each mitigation strategy.

Bay Area transportation and utility facilities and networks are vital lifelines during and following disasters, as well as in the functioning of our region and its economy.

These agencies understand that it is far easier to try to fix problems before a disaster than to deal with the numerous interdependent problems afterwards.

The Existing Transportation System

The Bay Area's transportation system is a complex network of federal and state highways, local roads, light and heavy rail, bus transit, airports, ports, and ferries.

- The system contains over 20,800 miles of highways and roads, with 9,000 miles of bus routes, and 470 miles of rail transit, and 750 miles of bikeways.
- As a region located on San Francisco Bay, the system includes eight toll bridges – seven owned by the state, and one, the Golden Gate Bridge, owned by the Golden Gate Bridge and Highway Transportation District. It also includes approximately 2,000 state-owned and an additional 2,000 locally-owned road structures, including overpasses, interchanges, and smaller bridges.
- There are three international airports, a federal airfield, an air force airport, and 36 public general aviation airports and private airstrips.
- Finally, the region has five public ports, several private ports, and five commuter ferry lines.

Golden Gate Bridge

The entire system is planned and coordinated by the Metropolitan Transportation Commission (MTC), an organization whose job is to ensure that this system functions smoothly and effectively, as well as to plan responsibly to meet the future mobility needs of the region's growing population.

Dozens of other organizations work together to build and maintain this system, including the federal Department of Transportation (DOT), the Federal Highway Administration (FHWA), the Federal Aviation Administration (FAA), the state agencies of Caltrans and the California Transportation Commission (CTC), city and county governments, and special transit districts.

Participating Agencies

Local government agencies actively participating in this transportation portion of the MJ- LHMP include the transportation agencies participating in the original 2005 MJ-LHMP:

- MTC
- BART
- Tri-Delta Transit (ECCTA)

City and county representation has been essential, for many have extensive transportation systems, including:

- City and County of San Francisco (port, SFO airport, and SF MTA or MUNI)
- City of Oakland (port and OAK airport)
- City of San Jose (SJC airport)
- City of Vallejo (Transportation)

Additional transit agencies actively participating in this updated plan include:

- AC Transit
- Contra Costa County Transit (County Connection)
- Golden Gate Bridge, Highway and Transportation District
- Livermore-Amador Valley Transit
- San Mateo County Transit (SamTrans/ Caltrain)
- Santa Clara Valley Transportation Authority (VTA)
- San Francisco Water Emergency Transportation Authority (WETA)

As a multi-jurisdictional plan, this effort makes use of the hazard maps contained in the overall plan, with the additional hazard exposure data documented in this paper.

The various agencies participating in this plan coordinated their efforts through the TRP Steering Committee of MTC. This group, in turn, participated in the overall lifeline effort of the MJ-LHMP through two representatives to the ABAG Lifeline Infrastructure and Hazards Advisory Committee.

Earthquake Hazards and the Bay Area Transportation System

The largest hazard to which the transportation system is exposed is earthquake-generated **ground shaking**. The western U.S. is one of the most seismically active areas of the country, and the Bay Area is one of the West's most active seismic areas.

For transportation systems, **94.3%** of local and state bridges and interchanges are exposed to high shaking levels (peak accelerations of greater than 40% of gravity [g] with a 10% chance of being exceeded in the next 50 years), and **65.2%** exposed to extremely high shaking levels (60% g). In addition, **92.2%** of roads and highways are exposed to high shaking levels (peak accelerations of greater than 40% g with a 10% chance of being exceeded in the next 50 years), and **58%** are exposed to extremely high shaking levels (60% g).

The percentage of rail and fixed transit systems in these hazard levels is similar, with **92.6%** of rail, **85.5%** of ACE, **84.8%** of Amtrak, **97%** of BART, **100%** of Caltrain, **100%** of SF MTA (MUNI), and **100%** of the VTA lines in the high or extremely high shaking areas. The most vulnerable portions of these networks to shaking are bridges, interchanges, and the elevated portions of rail and fixed transit lines. Facilities at the three international airports and the major ports are also in vulnerable locations. **The functioning of all of these systems is critical during emergency response to and recovery from an earthquake.** Thus, most of the hazard mitigation strategies that follow deal with this earthquake shaking hazard.

When **faults** rupture and generate earthquakes, the rupture can extend to the surface, offsetting roads, highways, and rail lines. Existing state law prohibits the construction of structures intended for human occupancy across the trace of an active fault. Although no existing buildings owned by transportation agencies are astride an active fault, freeways, roads, rail, and BART lines do cross these faults.

Hayward fault trace

For example, if the Hayward fault ruptures from San Pablo Bay to its southern end near the Santa Clara County border, fault surface rupture could close approximately 520 roads, including I-80, I-680, Hwy. 4, Hwy. 13, and Hwy. 24. In some cases, local roads have been intentionally placed astride faults as a land-use decision to avoid the placement of buildings astride the fault.

Liquefaction occurs when loose, water-saturated, sand and silt behave like liquid quicksand when shaken in an earthquake. The exposure to liquefaction is far less than shaking. In addition, not all areas of very high susceptibility to liquefaction will actually behave like quicksand in any individual earthquake. The percentage of roads in these areas is **5.5%,** along with **16%** of rail, **1.8%** of ACE, **20.2%** of Amtrak, **7.9%** of BART, **10.4%** of Caltrain, **24.3%** of SF MTA (MUNI), and **2.4%** of the VTA lines. Because liquefaction can result in the buckling and bending of road surfaces, as well as at-grade rail and fixed transit lines, the damage to at-grade routes is likely to be more significant than from shaking.


Damage to road in Northridge earthquake

Landslides can be generated as a result of earthquakes. This hazard is discussed with rainfall-induced landslides later in this document.

Tsunamis can be generated as a result of earthquake fault rupture or underground landslides triggered by earthquakes. After extensive modeling by a number of organizations, maps of the potential inundation areas impacted by tsunamis near the Bay or Pacific Ocean were released in December 2009 for purposes evaluation planning. The most at-risk transportation routes are those bordering the Pacific Ocean and next to San Francisco Bay.

Current Earthquake Hazard Transportation Mitigation Highlights

The amount of effort and money currently being spent on the mitigation of earthquake impacts is higher than any of the other natural hazards.

State and federal agencies, local governments, and all transit agencies routinely take into account predicted earthquake forces in the design of new structures, including office and operations buildings, bridges, and interchanges. BART and Caltrans have even helped to fund the development of innovative new technologies to make transportation networks and structures even more resistant to shaking and liquefaction.

MTC, as the Bay Area Toll Authority, is directing the $8.5 billion program to make the region's state-owned toll bridges more resistant to earthquake shaking and potential problems of liquefaction.

Bay Bridge deck replacement

BART, with $980 million in bonds authorized by voters in its core three-county service area, and an additional $240 million from other sources, is seismically strengthening older portions of its system, including elevated track, 20 passenger stations - and the Transbay Tube. A $3 million grant from the Federal Emergency Management Agency (FEMA) Pre-Disaster Mitigation (PDM) program is helping to fund the dismantling of the Lake Merritt Administration facility as part of the strengthening of the Operations Control Center at that location. The total budget for the BART Earthquake Safety Program is $1.22 billion (in 2004 dollars).

MetroCenter (the administrative office building for ABAG and MTC, as well as the location of the Emergency Operations Center (EOC) for BART and MTC), was retrofitted in 2008. Funding for the **$5** million seismic retrofit was completed, in part, using a **$3** million grant from FEMA.

Regional Priorities for Future Earthquake Hazard Mitigation

In spite of the effort currently spent on earthquake hazard mitigation, more needs to occur. MTC is currently focusing on creating a plan for disaster recovery of the Bay Area transportation system. Through this effort, it has become clear that mitigation efforts targeted at speeding up post-disaster recovery are particularly critical.

Emergency Operations Centers (EOCs) and communications centers for some of the bus and light rail systems operators are of an age and type of construction that makes them susceptible to damage in future earthquakes. The transit operators who own these facilities are examining the potential for structural retrofit or replacement of these key facilities. This task is a high priority for the mitigation of the earthquake hazard. Meanwhile, as retrofit options are examined, another task is focusing on speeding up the post-disaster inspection and re-occupancy of those buildings that are safe.

At **BART**, construction is underway and is scheduled to be completed in 2014. Among the most important tasks in that effort are strengthening of the 1,981 supports for the elevated portions of track, the Transbay tube, and core-system stations.

The **Golden Gate Bridge** and **Doyle Drive** are undergoing retrofits. The Doyle Drive project, estimated to be completed by 2014, is led by Caltrans, with an estimated cost of $1.045 billion, of which $405 is a local contributions, including $80 million from MTC, $75 million from Golden Gate HBTD, and $245 million from several sources in San Francisco, including SF MTA (MUNI). Work completed to date on the Golden Gate Bridge approaches and anchorages has cost $245 million. Work on the Marin Anchorage ($119 million) will be completed in 2011. The suspension bridge should be completed by 2015.

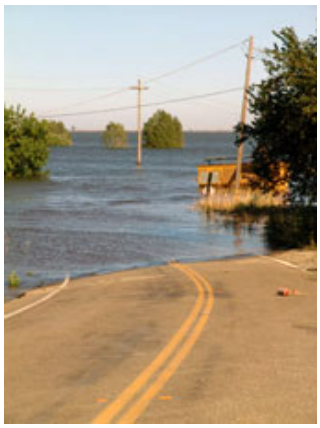
While Caltrans has almost completed the seismic retrofit of bridges and interchanges on state and federal highways, little progress has been made on the retrofit of locally owned bridges. Of the 2,214 locally-owned bridges in the Bay Area, it identified 355 that needed to be have seismic retrofit work as of 2006. Few bridges have been retrofitted in the past 5 years due to lack of funding.

Weather-Related Hazards and the Bay Area Transportation System

The Bay Area has historically had a mild Mediterranean climate characterized by mild rainy winters and dry summers. Flooding and landsliding occurred during the wet season, while wildfires and drought occurred in the dry season.

Climate change has been shown to exacerbate all of these hazards. Thus, the region can expect more flooding and landsliding due to a more abrupt runoff in the spring, as well as increased potential for wildfires any time of year and multi-year drought conditions. The various port facilities, as well as both the Oakland and San Francisco International Airports, are subject to the threat of sea level rise.

Flooding can occur when occasional intense winter storms result in local stream flooding, as well as when particularly warm rains in the Sierras can also result in sudden snow melting. Occasionally strong winter storms can close roads in the Bay Area. However, flooding is a lesser hazard than earthquakes to the region's transportation system. Only **5.2%** of the roads (versus **58%** in extremely high ground shaking areas) are in 100-year flood zones. The percentage of rail in these hazard areas is **15.9%,** along with **14.5%** of ACE, **21%** of Amtrak, **2%** of BART, **6.5%** of Caltrain, **none** of SF MTA (MUNI), and **4.8%** of the VTA lines.



Flooding of road due to Jones Tract levee failure just east of Bay Area

In addition to these traditionally flood-prone areas, some portions of the region, particularly in the Bay-Delta, are actually below sea level.

Of particular concern, much of the Oakland International Airport is below sea level and is protected by a levee that may be vulnerable to earthquake damage and sea level rise.

Road damage due to landslides in 1997-98 El Nino winter in Santa Cruz Mountains –

Landslides can be generated as a result of earthquakes or severe winter storms. While **23.1%** of the region's land is located in areas that are mostly active or ancient landslides, a much smaller percentage of the urban land (**8.3%**) and roads (**7.2%**) are located in these hazardous areas. **None** of the MUNI or VTA light rail lines are located in these areas, and only **1.6%** of rail, **7.3%** of ACE, **1.7%** of Amtrak, **4%** of BART, and **1.3%** of Caltrain lines are in these areas. Landslides have not ever been a significant hazard to these transit systems.

Wildfire hazards are shown in two separate hazard maps – wildland-urban-interface fire threat (WUI) maps and wildfire threat maps. The WUI maps show the wildfire threat in urban areas, while the wildfire threat maps focus on more rural areas.

Oakland Hills firestorm in 1991

Based on the WUI maps, **44.8%** of the roads and **28.1%** of the rail lines, along with **25.5%** of ACE, **21%** of Amtrak, **38.6%** of BART, **32.5%** of Caltrain, **32.4%** of SF MTA (MUNI), and **19%** of the VTA lines, are in wildland-urban-interface fire threat areas. However, only **4.5%** of these areas have burned in the past 130 years. In addition, in much of these hazard areas, the BART system is in a freeway median or underground.

The wildfire threat maps indicate that **7.1%** of the roads and **4.9%** of the rail lines, along with **12.7%** of ACE, **0.8%** of Amtrak, **3%** of BART, **none** of Caltrain, **none** of SF MTA (MUNI), and **none** of the VTA lines, are in areas of very high or extreme wildfire threat.

Drought in the Sierras, as well as the region itself, can cause water shortages. However, this hazard does not directly impact the region's transportation system.

Current Weather-Related Hazard Mitigation Highlights

The amount of effort and money currently being spent on the mitigation of weather-related hazards is far lower than for earthquake-related hazards. Reasons for this difference include (1) infrastructure facilities, roads, and rail systems have a much lower exposure to these hazards and (2) potential weather-related disasters are less regional in scope, making the functioning of transportation systems less critical.

VTA's headquarters buildings are in a flood plain. Due to the efforts of the Santa Clara Valley Flood Control and Water District, the drainage and flooding problems at this facility have been reasonably mitigated.

Landslides are not a major concern to the regional transit systems, rail lines, port, or airport systems. Roads built in landslide hazard areas are currently designed to minimize the likelihood of damage and tend to be less exposed to this hazard than the overall urban areas that they serve. One exception is Highway 1 along the San Mateo and Marin County coastlines. Caltrans worked with local governments to better design roadway alignments. For example, in San Mateo County, bridges and a tunnel are being built to bypass Devil's Slide between Pacifica and Half Moon Bay. The project will be completed in 2011.

Wildfire is a concern in the areas served by the transportation system. However, there is no well-established way to mitigate any hazards associated with the transportation system itself.

Local governments can adapt to climate change by mitigation of sea level rise, flooding, drought, and wildfire hazards. However, climate change itself can be mitigated through efforts at direct control of greenhouse gases and carbon emissions. Fully one half of the Bay Area's greenhouse gas emissions are the result of transportation sources, particularly on-road private vehicles. Efforts to develop greener transportation have been initiated by various transit and transportation agencies in the region.

In particular, MTC is emphasizing transit investments and maintenance of existing infrastructure seeking to moderate growth of private vehicle usage. Other programs encourage increased transit ridership and more walking and biking for short trips. MTC's congestion management and intelligent transportation system programs seek to reduce emissions through smoother, more efficient traffic flow.

Regional Priorities for Future Weather-Related Hazard Mitigation

Additional ways are available to mitigate the impacts of weather-related hazards.

The bus yards of AC Transit and, to a lesser extent, SamTrans that are located near the Bay have experienced flooding and may need redesigned drainage systems to better mitigate the problem. (Flooding has not impacted the buildings.)

MTC, ABAG, the Bay Area Air Quality Management District (BAAQMD), and the Bay Conservation and Development Commission (BCDC) have initiated a **Joint Policy Committee** that has mitigation and adaptation to climate change as a principal focus. One of the main goals of this regional group is reduce carbon emissions through a variety of innovative programs, including encouraging smart growth, initiation of congestion pricing schemes, and other pilot projects.

VTA and SamTrans have been participating in a California Air Resources Board (CARB) pilot program in which a portion of their bus fleet is fueled by **hydrogen cell technology**. AC Transit has been using hydrogen-hybrid busses in its fleet on an experimental basis. These efforts are viewed as the beginning of a process of making transit a cleaner solution to reducing carbon emissions and associated global warming.

The side effect of this effort is that planning for fuel interruption as a result of a disaster has become more critical, and more complex.

Hydrogen fueled bus

Bay Area Commercial and General Aviation Airports

The Bay Area airports are managed independently by the individual cities that own and operate them. However, the Regional Airport Planning Committee (RAPC) is an organization set up by, and operated by, the staff of three regional agencies: the Metropolitan Transportation Commission (MTC), the Association of Bay Area Governments (ABAG) and the Bay Conservation and Development Commission (BCDC).

For purposes of this multi-jurisdictional plan, the discussion of the hazards, risks, and applicable mitigation efforts has been overseen by these three regional agencies on behalf of RAPC, and in turn by the various airports themselves (as owned and operated by the cities).

The Bay Area is home to three international commercial airports:
San Francisco International (SFO);
San Jose International (SJC); and
Oakland International (OAK).

In addition, there are over 30 general aviation airports serving the Bay Area.

RAPC has representatives from all of these key constituencies.

While the following discussion focuses on the three international airports, it also describes related issues at general aviation airports and other airports.

Hazard and Risk Assessment

Earthquake: In 2000, with a grant from FAA through MTC, ABAG performed a hazard and risk assessment of the three major international airports, and a preliminary evaluation of the general aviation airports. Based on past experience in California and other recent earthquakes, the threats to Bay Area airport operations following future earthquakes fall into four general categories:

- liquefaction damage to airport runways, particularly at Oakland, San Francisco, and, perhaps, Moffett Federal Airfield (given that liquefaction mitigation occurred to the runways at SJC);
- shaking damage to air control and terminal facilities, particularly older facilities that may be present at Oakland, Moffett, Hayward, San Francisco, Half Moon Bay, Buchanan, and Livermore airports;
- power and communications disruptions; and
- disruptions to the transportation systems serving the airports.

Flooding: **None** of the three **international** airports are in the 100-year floodplain. However, SJC is surrounded by this floodplain, which may hamper access to and use of the facility in a flood-related disaster. In addition, large portions of the runways of OAK are below sea level, protected only by levees that do not meet current engineering design levels. However, overall, 15% of the land used for general aviation airports are in the 100-year floodplain, including, for example, Buchanan and Palo Alto.

Tsunamis: The tsunami evacuation planning maps released in December 2009 indicate that, within the Bay, OAK would be impacted, but not SFO, SJC, or Moffett Field. A portion of the Half Moon Bay airport also is expected to be impacted.

Landsliding: **None** of these international OR general aviation facilities are in an area of existing landslides.

Wildfire: **None** of these facilities are in an area subject to high wildfire threat, but **27%** of airport land is in a wildland-urban interface (WUI) threat area.

Hazard Conclusion and Risk Assessment: The two significant threats to the international airports are flooding (particularly levee failure and sea level rise) and earthquakes (shaking and liquefaction). WUI threat is **not** significant due to proximity to the Bay.

Existing Mitigation Programs

Earthquake: SJC has had an extensive program to effectively "bridge" ancient stream channels that lie under its runways and are the source of the liquefaction hazard for that airport. OAK and SFO are currently investigating the options for decreasing the liquefaction risk to their runways. The planned program to tackle this issue as part of runway expansion efforts is on indefinite hold.

Flooding: OAK is upgrading its runway levee as it adds facilities to account for sea level rise and levee failure. It has not been successful in getting the necessary funds to improve the entire levee system at this time.

Bay Area Commercial and General Aviation Airports (continued)

Priorities for Future Mitigation Programs

1. Focus on better understanding and mitigation of the liquefaction hazard to runways. We need to expand on the liquefaction analysis conducted for the runways at the three major airports (OAK, SFO, and SJC) to (a) gain further information on the vulnerability of other major airports, particularly Moffett Federal Airfield on the Peninsula and Travis Air Force Base in Solano County, and, if feasible, Buchanan, Hayward, and Livermore in the East Bay; and (b) incorporate more recent geotechnical information becoming available for OAK, SJC and SFO.

2. Ensure that the design of new runways also mitigates liquefaction hazards associated with the connections to the existing runway system. Any runway expansions at SFO and OAK that tie into sections of existing runways which are vulnerable to liquefaction will make the expansions vulnerable as well. Runway work at SJC has been designed to minimize the liquefaction hazard.

3. Improve emergency planning at individual airports and to better coordinate emergency planning among airports and with other forms of transportation. Airport participation in coordinated emergency planning is essential. MTC is starting this planning as part of the integrated Trans Response Plan (TRP) for earthquakes. The Regional Airport Planning Committee has also discussed this issue, particularly as it relates to potential funding.

4. Identify alternate locations capable of handling large commercial and cargo jets after an earthquake should Bay Area commercial airports lose capacity due to road transportation system disruptions, runway damage, or structural damage. Travis AFB will have increased air and vehicle traffic during the post-earthquake emergency response phase because the federal government plans on using Travis AFB as the primary mobilization center for their response to the disaster. With the normal operations that Travis has in addition to this major role, emergency planners should not believe that Travis has additional capacity for other commercial or cargo needs. Options include neighboring commercial airports (Sacramento, Stockton, Monterey, etc.), as well as larger general aviation airports.

5. Identify funding mechanisms for the retrofit or replacement of critical levee systems protecting the runway at OAK. The levee system at this airport is currently vulnerable to both earthquake damage and damage due to sea level rise.

Other mitigation activities related to the airports and their facilities are covered in the individual mitigation strategies of the various cities which own and manage the airports in the Bay Area.

Further airport information: Perkins, J., with William Lettis and Associates (WLA) (Bachhuber, J., Baldwin, J., and Knudsen, K.), 2000. ***Don't Wing It: Airports and Bay Area Earthquakes:*** Association of Bay Area Governments, Oakland, CA. Excerpts are available online at *http://quake.abag.ca.gov/eqtrans/eqtrans.html*.

The Existing Water and Wastewater System

The regional water and wastewater systems are managed by a network of public special districts, city and county departments, and private companies. There are over 100 water retailers and wholesalers in the Bay Area. While most wastewater collection and treatment is handled by cities and counties, some special districts treat wastewater. ABAG estimates that there are 21,851 miles **each** of water and sewer pipes.

Some communities within the Bay region derive their urban, suburban and rural water supplies from groundwater and surface waters within the nine-county region (Napa River, Russian River, Guadalupe River, numerous creeks and springs). Others rely on groundwater and surface waters that are imported from watersheds and basins outside the region (including the Tuolumne, Mokelumne, Sacramento, San Joaquin and Eel River watersheds). The State of California Water Project and the U.S. Bureau of Reclamation Central Valley Project are large suppliers of water to the Bay region.

The Bay Area contains over 400 watersheds, including a portion of the Sacramento/San Joaquin watershed system. Water is distributed from these watersheds via a series of open and closed conveyances within the region, and inter-regionally. A significant amount of annual supply is impounded in 260 major reservoirs and behind numerous small check dams scattered throughout the region. **75%** of the water supplies for the Bay Area are from water agencies that obtain all or part of their water either (1) from aqueducts or canals passing through the Sacramento-San Joaquin Delta or (2) by extracting water from that Delta.

The Bay Area also contains a series of dedicated groundwater recharge areas where groundwater can accumulate for current and future use. Some groundwater recharge areas are employed to begin arresting the decline of groundwater levels in some basins, or to cope with salt water intrusion. These declines can, and do, lead to land subsidence, cones of depression, damaged infrastructure, and altered soil chemistry, which in turn can affect the region's groundwater carrying capacity. Groundwater basins outside the region act as significant storage sites for some Bay Area water needs during dry years.

Conserved and recycled water is another source of water and estimates of its potential are provided in the State of California Water Plan and in a range of Urban Water Management Plans in the Bay Region. The State's Recycled Water Task Force recently estimated that building additional water recycling plants could meet 30 percent of the region's water needs by 2030. Recycled water in the region is used in a wide range of applications, including landscape irrigation, industrial cooling, and agricultural needs, as well as an environmental water source for wetlands restoration. The Department of Water Resources estimates that close to 50 million gallons per day (GPD) of recycled water is produced here, and planned projects have the potential to double this amount in ten years.

Participating Agencies

Special-purpose agencies directly participating in this water supply and wastewater portion of the MJ-LHMP include several special districts:

- Alameda County Water District
- Contra Costa Water District
- Dublin-San Ramon Services District
- East Bay Municipal Utility Dist.
- Mid-Peninsula Water District
- Montara Water & Sanitary Dist.
- Purissima Hills Water Dist.
- Santa Clara Valley Water Dist.
- Sewer Authority Mid-Coastside
- Solano Co. Water Agency
- Solano Irrigation District
- Vallejo Sanitation & Flood Control District
- Zone 7 Water Agency

City and county water departments are represented on the committee overseeing this process by the San Francisco Public Utility District which operates the Hetch-Hetchy system.

Private companies partnering in this updated plan include:

- San Jose Water Company
- Cal Water

As a multi-jurisdictional plan, this effort makes use of the hazard maps contained in the overall plan, with the additional hazard exposure data documented in this chapter.

The various agencies participating in this plan coordinated their efforts through the overall lifeline effort of the MJ-LHMP through representatives to the ABAG Lifeline Infrastructure and Hazards Advisory Committee.

Earthquake Hazards and the Bay Area Water and Wastewater Systems

Examining the locations of dams, water and wastewater treatment facilities, and pipeline networks that make up the water supply and wastewater collection system, shows earthquakes to be the greatest hazard. Because these systems have to be located in urban areas to serve those communities, their general hazard exposure is similar to that of the areas they serve.

While **93.4%** of critical water system facilities and **88.8%** of critical wastewater system facilities are exposed to high **ground shaking** levels (peak accelerations of greater than 40% of gravity [g] with a 10% chance of being exceeded in the next 50 years), **68.1%** of critical water system facilities and **67.5%** of critical wastewater system facilities are exposed to extremely high shaking levels (60% g). In addition, **95.2%** of pipelines are estimated to be exposed to high shaking levels (peak accelerations of greater than 40% g with a 10% chance of being exceeded in the next 50 years), and **62.8%** are exposed to extremely high shaking levels (60% g). Thus, most of the mitigation strategies that follow deal with this hazard. While shaking will not damage pipelines in the same manner as buildings, the ground waves associated with shaking will damage those pipelines.

The ability of the levees in the **Sacramento-San Joaquin Delta** to withstand strong shaking is being studied, as discussed in the box on the following page. The hazards associated with failure of these levees, both directly and indirectly, on the region's water supply could be catastrophic.

When **faults** rupture and generate earthquakes, that rupture can extend to the surface, rupturing aqueducts and pipelines. Existing state law prohibits the construction of structures intended for human occupancy across the trace of an active fault. However, water aqueducts and pipelines cross these faults. For example, if the Hayward fault ruptures from San Pablo Bay to its southern end near the Santa Clara County border, fault surface rupture could severely damage the Hetch-Hetchy aqueducts, the EBMUD aqueducts, the South Bay aqueduct, and numerous local pipelines. Some dams are also on or near faults. In some cases, local roads have been intentionally placed astride faults as a land-use decision to avoid the placement of buildings astride the fault. When this occurs, the water and sewer pipelines are placed in this same alignment.

Liquefaction occurs when loose, water-saturated, sand and silt behave like liquid quicksand when shaken in an earthquake. The exposure to liquefaction is far less than shaking. In addition, not all areas of very high susceptibility to liquefaction will actually behave like quicksand in any individual earthquake. A much higher percentage of wastewater (**35.8%)** than water (**5.4%)** facilities are located in the highest hazard categories for this hazard. As liquefaction results in buckling and bending of the ground, pipelines can be damaged. While the percentage of pipe distribution lines in these areas is only **5.9%**, they tend to serve the largest population centers.

An ABAG analysis of damaged pipelines following the 1989 Loma Prieta earthquake indicated that pipelines in areas subject to liquefaction AND exposed to violent ground shaking were the most likely to have broken or leaked as a result of that earthquake. ABAG has estimated that there could be, for example, **6,000 - 10,000** water pipeline breaks or major leaks in an earthquake on the Hayward fault (compared to 507 in the Loma Prieta earthquake). Rapid repair and replacement of these pipelines is essential to recovery from an earthquake.

San Pablo Dam and Reservoir Upgrade

Landslides can be generated as a result of earthquakes. This hazard is discussed with rainfall-induced landslides later in this document.

Tsunamis can be generated as a result of earthquake fault rupture or underground landslides triggered by earthquakes. After extensive modeling by a number of organizations, maps of the potential inundation areas impacted by tsunamis near the Bay or Pacific Ocean were released in December 2009 for evaluation planning. The most at-risk areas are those bordering the Pacific Ocean and next to San Francisco Bay. An estimated **1.7%** of critical water facilities and **16%** of critical wastewater facilities are in these areas.

Current Earthquake Hazard Water-Wastewater Mitigation Highlights

The amount of effort and money currently being spent on the mitigation of earthquake impacts is higher than any of the other natural hazards.

All water and wastewater special districts, as well as cities and counties, routinely take account of predicted earthquake forces in the **design of new structures,** including office and operations buildings, as well as wastewater and water treatment plants and conveyance networks.

Bay Area residents have **funded major improvements to the San Francisco PUC Hetch-Hetchy, EBMUD, and Contra Costa Water District (CCWD)** systems, particularly related to storage tanks, treatment plants, and fault crossings. However, with these major systems, as well as with smaller agencies, the capital improvements budgets are limited. These financial issues are have been exacerbated by the 2008-09 recession.

Dam owners and operators, under the regulation of the State Division of **Safety of Dams**, routinely inspect their facilities and reevaluate their safety in light of current engineering and seismology. Based on these assessments, EBMUD is retrofitting San Pablo Dam and Reservoir at a cost of $75 million dollars. The San Francisco PUC Calaveras Dam Replacement Project has an estimated total cost of $409 million dollars.

EBMUD, CCWD, and Santa Clara Valley Water District have installed, and SFPUC and Alameda County Water District are in the process of installing, shut-off valves in pipelines that cross active faults. These valves, installed on each side of the fault, enable above-ground potable water bypass lines to be rapidly installed.

Water and wastewater agencies have started to plan for speeding the repair and functional restoration of water and wastewater systems through joining the Water/Wastewater Agency Response Network (WARN). The plan is to stockpile shoring materials, temporary pumps, surface pipelines, portable hydrants, and other supplies. Some water suppliers have also purchased equipment to bag emergency drinking water for customers.

ABAG's Sewer Smart Program, with water and wastewater districts, has developed innovative materials to help the public cope with disrupted storm drains, sewer lines, and wastewater treatment. This program grew out of the exposure of the wastewater system to earthquake hazards and the information gap identified as part of this project.

Future Regional Mitigation Priorities Related to the Delta

The levee failures resulting from Hurricane Katrina, combined with the Jones Tract levee failures in the **Sacramento-San Joaquin Delta**, have led to an evaluation of the potential impact of a major earthquake or flood on that Delta system. As previously stated, **75%** of the water supplies for the region are from water agencies that obtain all or part of their water from the Delta or have conveyances that pass through it.

The State of California has conducted a Delta Risk Management Study (DRMS) that has explained the problem and associated risks. The State, the water agencies, and other organizations are currently working to identify mitigation options that would protect the water supply and environmental quality of the Delta. At this point, various strategies are being reviewed. While the Governor's administration favors a canal bypass, this option would partially protect Southern California water interests, but, as currently envisioned, would not protect the water supply of the Bay Area. The cities, counties, and special districts in the Bay Area are, and will continue to be, involved in this multi-billion dollar discussion.

From the standpoint of risk, damage to the Delta levees from a major earthquake that would also cripple portions of the urban Bay Area (such as one on the Hayward fault) is more problematic than damage from a Delta-area fault because the region's resources would be more heavily impacted. ***Thus, a disaster mitigation effort for the Delta that incorporates recovery goals is essential.***

Future Regional Mitigation Priorities Related to Pipelines

The **pipeline distribution systems** for water and sewer lines typically have not been replaced since they were originally installed, in some cases almost 100 years ago. These pipelines will break and leak. Ways to mitigate this damage through repair and replacement of the most susceptible lines has started, but will not be completed for several years.

Weather-Related Hazards and the Bay Area Water and Wastewater Systems

The Bay Area has historically had a mild Mediterranean climate characterized by mild rainy winters and dry summers. Flooding and landsliding occurred during the wet season, while wildfires and drought occurred in the dry season.

Climate change has been shown to exacerbate all of these hazards. Thus, the region can expect more flooding and landsliding due to a more abrupt runoff in the spring, as well as increased potential for wildfires any time of year and multi-year drought conditions. Some wastewater treatment facilities may be subject to the threat of sea level rise.

Flooding can occur when occasional intense winter storms result in local stream flooding, as well as when particularly warm rains in the Sierras result in sudden snow melting. Flooding is a lesser hazard than earthquakes to the region's water and wastewater systems. A significant **11.5%** of the wastewater and **3.8%** water critical facilities in the region are in the 100-year flood plain. While an estimated **3.7%** of pipelines are in these areas, flooding of areas above pipelines is not a significant hazard because areas are not expected to be flooded for weeks at a time.

Occasionally strong winter storms can close roads in the Bay Area.

Finally, warm storms in the Sierras can cause rapid snow melt, which can lead to high water levels that can damage levees in the Sacramento-San Joaquin Delta. Delta islands can also be flooded due to damage **not** associated with storms because of the poor quality of some Delta levees. In addition to these traditionally flood-prone areas, some portions of the region, particularly in the Bay-Delta, are actually below sea level and other areas are subject to sea level rise.

Landslides can be generated as a result of earthquakes or severe winter storms. While **23.1%** of the region's land is located in areas that are mostly active or ancient landslides, a much smaller percentage of the urban land (**8.3%**) and water and wastewater system pipelines (**3.9%**) are located in these hazardous areas. While **0.6%** of the major wastewater facilities are located in these areas, **11%** of the water facilities are located in these areas. However, erosion and siltation can also impact the storage capacity of critical reservoirs.

Wildfire hazards are shown in two separate hazard maps – the wildland-urban-interface fire threat (WUI) maps and the wildfire threat maps. The WUI maps show the wildfire threat in urban areas, while the wildfire threat maps focus on more rural areas.

Based on the WUI maps, an estimated **51.1%** of the water and wastewater pipelines are in fire hazard areas, as well as **66.8%** of the critical water facilities and **44.4%** of the critical wastewater facilities. While only **4.5%** of these areas have actually burned in the past 130 years, this indicates a build-up in fuel loads.

The wildfire threat maps indicate that **14.7%** of the critical water facilities and only **1.5%** of the critical wastewater facilities are in areas of high, very high, and extremely high wildfire threat, as well as **6%** of the pipelines.

Drought in the Sierras, as well as the region itself, can cause water shortages because of the large dependency of the Bay Area on imported water.

Current Weather-Related Hazard Mitigation Highlights for Water and Wastewater Systems

The amount of effort and money currently being spent on the mitigation of the impacts of weather-related hazards is far less than for earthquake-related hazards due to the much lower exposure of water and wastewater facilities, storage tanks, aqueducts, and pipelines to these hazards. In addition, the potential disasters have tended to be less regional in scope, making the functioning of these systems less critical.

However, climate changes may greatly increase the potential need for additional funding. For example, because wastewater treatment plants tend to be located in the lowest areas of the region, planning has started to include adaptation to sea level rise on the part of these facility operators. In addition, water agencies have begun planning for water quality degradation.

The principal exception to this assessment is the potential for catastrophic flooding of islands in the Sacramento-San Joaquin Delta. The State Department of Water Resources has taken the lead in working with reclamation districts to strengthen those levees for flooding damage.

Landslides are not a major concern, in general, for water and wastewater systems. Damage tends to be localized. The exposure of these systems is similar to that of the transportation network. One solution is to install flexible pipelines in areas of past landslides as part of the capital improvements budget, a practice being implemented by water agencies and now being discussed by wastewater agencies.

Regional Priorities for Future Weather-Related Hazard Mitigation

Additional ways to mitigate these weather-related hazards are available, particularly the following.

Wildfire is a concern in the areas served by the water and wastewater systems. This hazard is particularly of concern in areas that would be exposed to fire caused by an earthquake because the water supply could be temporarily crippled by the earthquake. Thus, the water supply agencies need to develop a coordinated approach with fire jurisdictions to identify needed improvements to the water distribution system, initially focusing on areas of highest wildfire hazard (including wildfire threat areas and in wildland-urban-interface areas).

Pipe elbow being installed to avoid a landslide area

Interrelationships with electrical, natural gas, and telecommunications systems

The San Francisco Bay Area is serviced by the Pacific Gas and Electric Company (PG&E), a private utility. PG&E, as a private utility, is not directly covered by this MJ-LHMP. However, this company has been actively involved in hazard mitigation both before and after the 1989 Loma Prieta earthquake. Such mitigation efforts are crucial to the operations of water and wastewater systems due to requirements for power for systems operations. For example, the water requires power for pumping and the wastewater system requires power at the treatment plants.

PG&E has completed structural mitigation on 73% of its buildings, an effort scheduled for completion in 2014. The Gas Pipeline Replacement Program has the objective of replacing 10% of the most at-risk steel pipeline system by 2014. As of 2009, 89% of the effort was complete.

PG&E electrical system substation buildings are being retrofitted; mitigation has been completed on 83% of the buildings and the remainder of the work is scheduled for completion by 2010. Equipment in those buildings is being anchored and seismically qualified equipment is being installed.

Telecommunications facilities and equipment are the most resilient of the infrastructure systems and are expected to return to service most rapidly.

In the case of all of infrastructure systems, however, operators should plan for interruptions in service during the response and recovery phases of a disaster and pre-plan to mitigate those risks.

Lifeline System Interdependencies and Disaster Recovery

As mentioned earlier, one of the main reasons for the interdependencies of infrastructure systems is that they tend to be geographically located in the same areas. For example, water, sewer, and natural gas pipelines tend to be under local roads. Communications and electrical cables are either located under those roads or adjacent to them. All have similar exposures to hazards that are related to serving the developed portions of the region.

However, in addition to geographic interdependencies, lifeline systems also have system interdependencies. Examples include the relatively flexible use of the transportation system to deliver water treatment chemicals to a water treatment facility and the short-term relatively inflexible use of the electric power system to run pumps at that water treatment facility. Such interdependent analyses therefore need to address the length of time required to restore various services or interdependences to a level adequate for recovery. The length of time of a disruption increases the impacts. However, typically, doubling the time of disruption more than doubles the impacts. In addition, the disruption of one infrastructure system delays the recovery of other systems because the infrastructure systems are not available. Thus, speeding recovery of infrastructure systems and focusing on interdependencies of those systems is critical.[1]

The following linkages between the water supply systems and other infrastructure lifeline systems are critical:

Water ◄-► Transportation –
(◄ = needed by water from transportation; ►= needed from water by transportation)
◄-► Co-location hazard exposure of distribution pipelines beneath roads
◄ Transport of repair and maintenance vehicles to locations for repairing pipelines
◄ Transport of repair, customer service, and operations facility crews to-and-from their homes
◄ Delivery of chemicals to water treatment facilities
◄ Delivery of fuel to run critical facilities
◄ Delivery of emergency drinking water in bags to customers at emergency distribution points
► Water for concrete construction and dust control

Water ◄-► Telecommunications –
(◄ = needed by water from telecommunications; ►= needed from water by telecom)
◄-► Co-location hazard exposure of distribution pipelines beneath roads with cable and underground wiring; above ground networks also aligned with roads (and thus pipeline corridors)
◄ Automated systems and process control equipment for treatment and operations
◄ Communication with repair and maintenance crews
◄ Communication with customers for repair and maintenance requests
◄ Emergency communications with emergency operations centers
► Water for communication equipment cooling systems

Water ◄-► Petroleum, natural gas, and electrical systems –
(◄ = needed by water from energy systems; ►= needed from water by energy systems)
◄-► Co-location hazard exposure of natural gas and some other fuel lines beneath roads, as well as electric power lines both beneath and adjacent to road corridors
◄ Gasoline and lubricants for use in repair and maintenance vehicles repairing pipelines
◄ Gasoline and lubricants for vehicles of repair, customer service, and operations facility crews to-and-from their homes
◄ Electric power for pump and lift stations, treatment plant operations, and control systems

[1] See, for example, Peerenboom, J., Fisher, R., and Whitfield, R., 2001. "Recovering from Disruptions of Interdependent Critical Infrastructures" presented at the ***CRIS/DRM/IIIT/NSF Workshop on Mitigating the Vulnerability of Critical Infrastructures to Catastrophic Failures***" Lyceum, Alexandria, Virginia.

◄ Fuel to run back-up generators at some critical facilities
► Water for refinery production, pumps, compressors, cooling, emissions reduction, and fire suppression
► Water for electric power plant operations, including cooling and emissions reduction

The following figure shows these linkages.

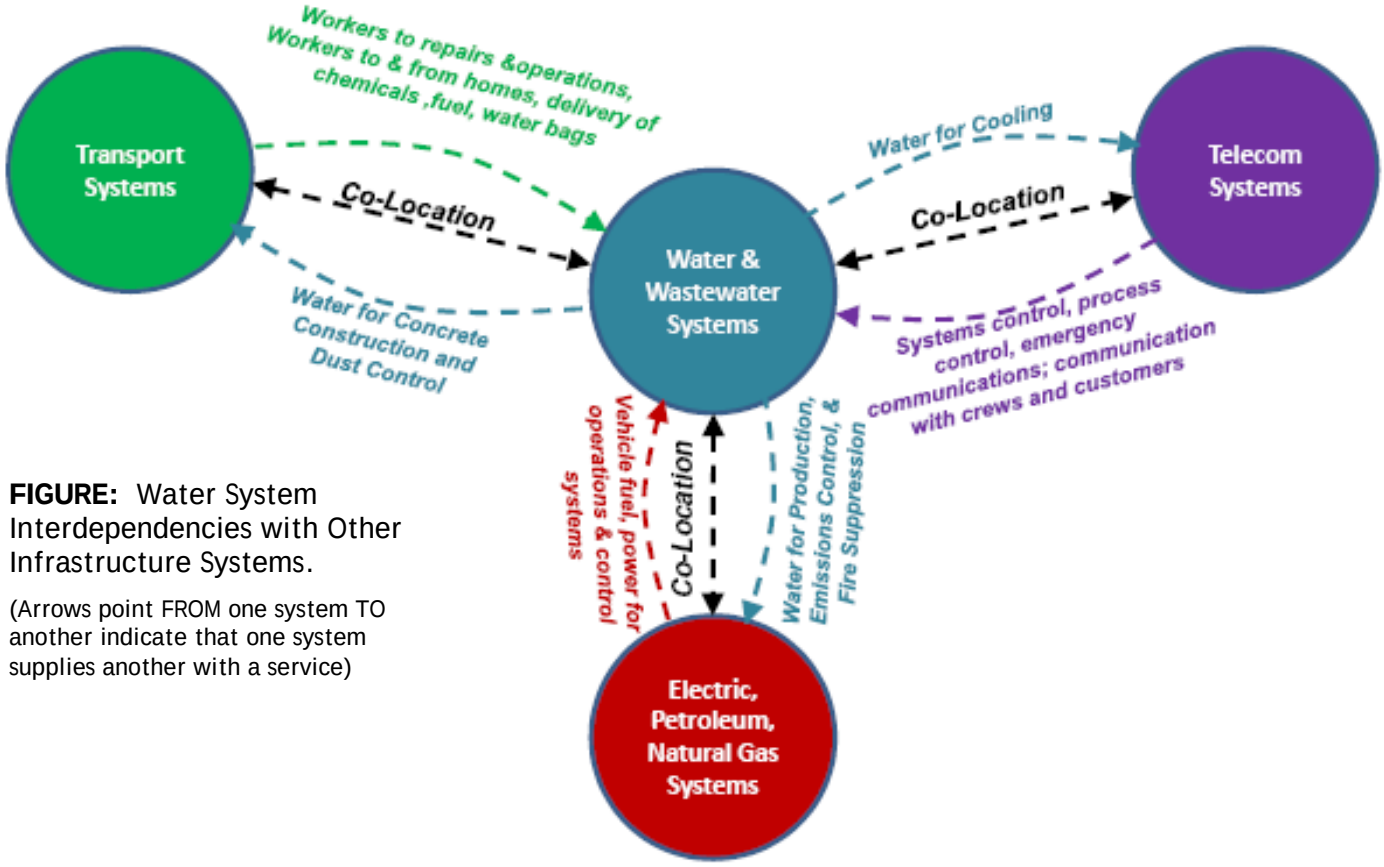


FIGURE: Water System Interdependencies with Other Infrastructure Systems.

(Arrows point FROM one system TO another indicate that one system supplies another with a service)

The following linkages between transportation systems (including airports) and other lifeline systems also are critical:

Transportation ◄-► Water – (repeated for completeness)

◄-► Co-location hazard exposure of distribution pipelines beneath roads
(◄ = needed by transportation from water; ►= needed from transportation by water)
◄ Water for concrete construction and dust control
► Transport of repair and maintenance vehicles to locations for repairing pipelines
► Transport of repair, customer service, and operations facility crews to-and-from their homes
► Delivery of chemicals to water treatment facilities
► Delivery of fuel to run critical facilities

Transportation ◄-► Telecommunications –
(◄ = needed by transportation from telecommunications; ►= needed from transportation by telecom)
◄-► Co-location hazard exposure of cables and underground wiring beneath roads or along roads
◄ Automated systems and process control equipment for trains
◄ Communication between transit operators and bus/train drivers
◄ Communication with repair and maintenance crews of roads, ports, and airports
◄ Communication with people needing to travel to and from work (or using airports and ports)
◄ Emergency communications with emergency operations centers

► Transport of repair and maintenance vehicles to locations for repairing cables, wires, and equipment
► Transport of repair, customer service, and operations facility crews to-and-from their homes
► Delivery of replacement specialized equipment to critical facilities

Transportation ◄-► Petroleum, natural gas, and electrical systems –
(◄ = needed by transportation from energy systems; ►= needed from transportation by energy systems)
◄-► Co-location hazard exposure of natural gas and some other fuel lines beneath roads, as well as electric power lines both beneath and adjacent to road corridors
◄ Gasoline and lubricants for use in road and highway repair and maintenance vehicles
◄ Gasoline & lubricants for buses & vehicles of repair & operations facility crews to-and-from their homes
◄ Electric power for train operations, some buses, street lights, gas station pumps, credit card machines, and control systems
◄ Fuel to run back-up generators at some critical operations facilities
► Transport of repair and maintenance vehicles to locations for repairing pipelines, power lines, & equipment
► Transport of repair, customer service, and operations facility crews to-and-from their homes
► Delivery of fuel to gas stations and delivery of replacement equipment to refineries and critical facilities

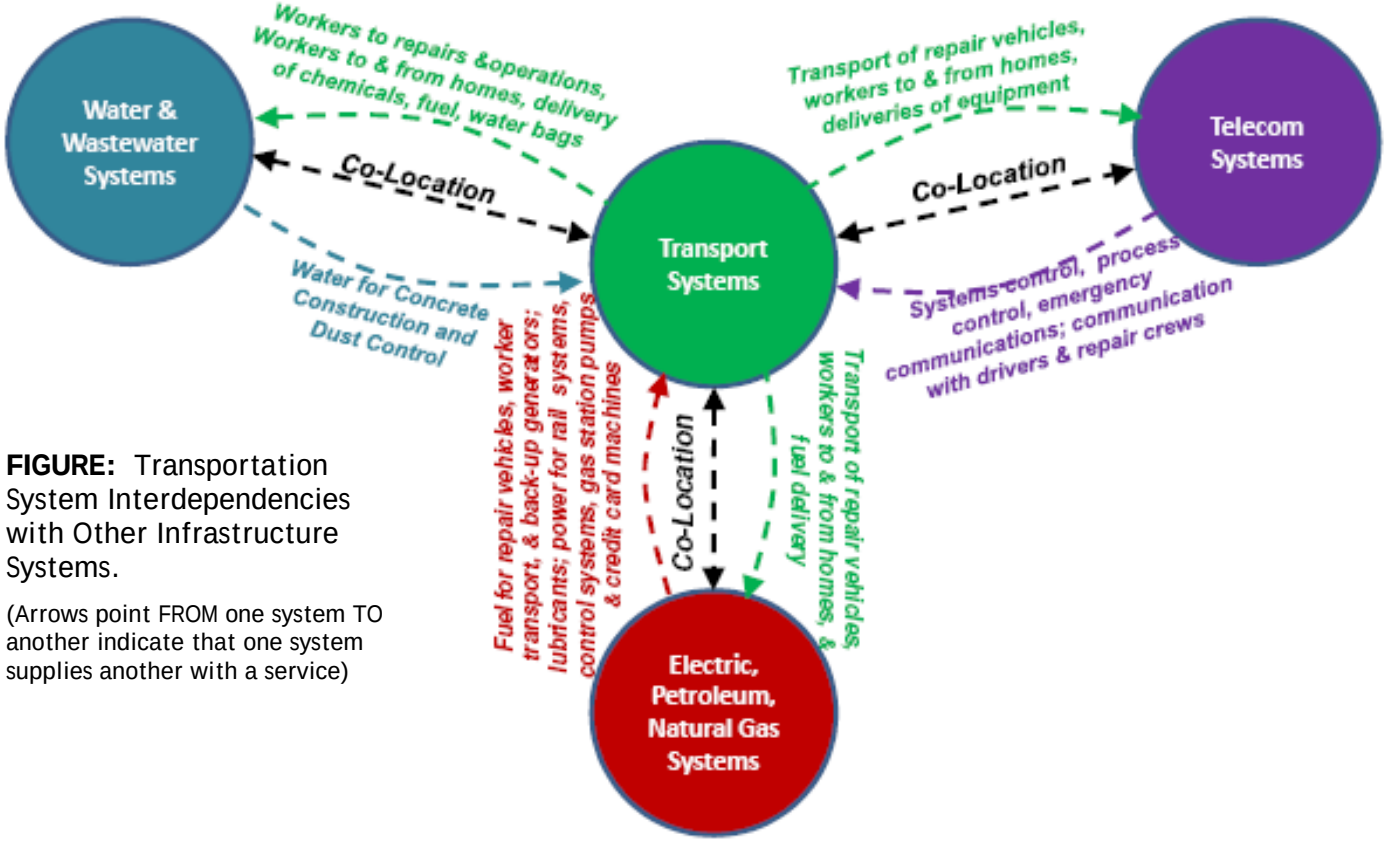


FIGURE: Transportation System Interdependencies with Other Infrastructure Systems.

(Arrows point FROM one system TO another indicate that one system supplies another with a service)

Combining these two figures creates a more complete picture of the interdependencies of water and transportation systems (typically managed by local governments) than the original Peerenboom and others (2001) figure, even though the distinctions among natural gas, electric power, and oil are not highlighted. This combined figure is shown below.

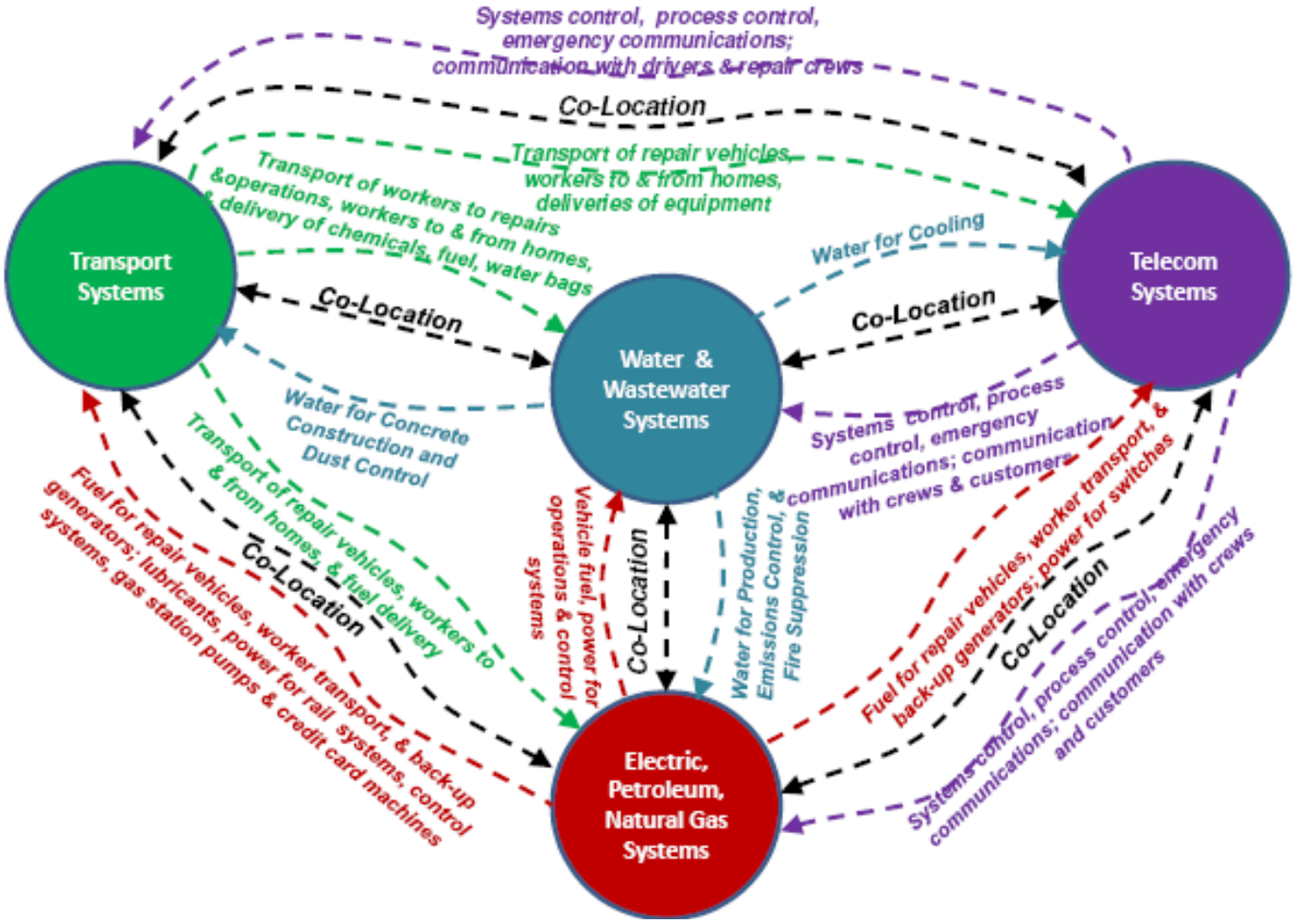


FIGURE: Transportation System Interdependencies with Other Infrastructure Systems.

(Arrows point FROM one system TO another indicate that one system supplies another with a service)

Certain Mitigation Practices Apply to All Hazards.

There are various steps that cities, counties, and infrastructure providers take to mitigate the hazards posed by multiple disasters. For example, all large-scale disasters can cause problems due to interdependencies and common issues of reoccupancy and recovery. Other actions may specifically relate to one type of infrastructure, but can mitigate multiple hazards. Finally, infrastructure providers, cities, and counties all need to communicate with the public.

ACTIONS APPLYING TO MULTIPLE HAZARDS AND INTERDEPENDENCIES OF INFRASTRUCTURE

In the event of a large-scale disaster, multiple infrastructure and utility system operators will all be scrambling to repair damage to return those systems to functioning. To the extent that roads are damaged or closed, pipeline and other repair crews will have difficulties in accessing their damaged systems. These and other interdependencies of infrastructure systems are addressed in the following coordinated strategies for systems mitigation.

Strategy	*Regional Priority*	*Responsible Agency*
1–(Strategy INFR a-1): Assess the vulnerability of critical facilities owned by infrastructure operators subject to damage in natural disasters or security threats, including fuel tanks and facilities owned outside of the Bay Area that can impact service delivery within the region. Note - Infrastructure agencies, departments, and districts are those that operate transportation and utility facilities and networks.	Existing program, underfunded	All infrastructure providers, including cities and counties
2–(a-4): Retrofit or replace critical lifeline infrastructure facilities and/or their backup facilities that are shown to be vulnerable to damage in natural disasters.	Existing program, underfunded	All infrastructure providers, including cities and counties
3–(a-3): Encourage the cooperation of utility system providers and cities, counties, and special districts, and PG&E to develop strong and effective mitigation strategies for infrastructure systems and facilities.	Existing program	Cities, counties, regional agencies, and infrastructure providers
4–(a-5): Support and encourage efforts of other (lifeline infrastructure) agencies as they plan for and arrange financing for seismic retrofits and other disaster mitigation strategies. (For example, a city might pass a resolution in support of a transit agency's retrofit program.)	Existing program	Cities, counties, regional agencies, and infrastructure providers
5–(a-7): Engage in, support, and/or encourage research by others (such as USGS, universities, or Pacific Earthquake Engineering Research Center-PEER) on measures to further strengthen transportation, water, sewer, and power systems so that they are less vulnerable to damage in disasters.	Existing program	Cities, counties, regional agencies, and infrastructure providers
6–(a-14): Encourage communication between State Emergency Management Agency (CalEMA), FEMA, and utilities related to emergencies occurring outside of the Bay Area that can affect service delivery in the region.	Existing program	Cities, counties, regional agencies, and infrastructure providers
7–(f-1): Ensure that critical buildings owned or leased by special districts or private utility companies participate in a program similar to San Francisco's Building Occupancy Resumption Program (BORP). The BORP program permits owners of buildings to hire qualified engineers to create facility-specific post-disaster inspection plans and allows these engineers to become automatically deputized as City/County inspectors for these buildings in the event of an earthquake or other disaster. This program allows rapid reoccupancy of the buildings. Note - A qualified engineer is a California licensed engineer with relevant experience.	Existing program	Cities, counties, regional agencies, and infrastructure providers

ACTIONS APPLYING TO MULTIPLE HAZARDS BUT FOCUSED ON A SINGLE TYPE OF SYSTEM —

Some mitigation policies may apply to multiple hazards, but may be focused on a single type of infrastructure system, such as water and wastewater, power and communications, or transportation. The following strategies are organized in this manner.

Water and Wastewater: These systems require mitigation of hazards to critical facilities, including dams, water and wastewater treatment facilities, pumps, and pipelines. Projects can often be developed that mitigate problems associated with multiple hazards.

Strategy	*Regional Priority*	*Responsible Agency*
1–(a-2): If a dam owner, comply with State of California and federal requirements to assess the vulnerability of dams to damage from earthquakes, seiches, landslides, liquefaction, or security threats.	Existing program	Dam owners
2–(a-13): If you own a dam, coordinate with the State Division of Safety of Dams to ensure an adequate timeline for the maintenance and inspection of dams, as required of dam owners by State law, and communicate this information to local governments and the public.	Existing program	Dam owners
3–(a-6): Develop a plan for speeding the repair and functional restoration of water and wastewater systems through stockpiling of shoring materials, temporary pumps, surface pipelines, portable hydrants, and other supplies, such as those available through the Water /Wastewater Agency Response Network (WARN). Communicate that plan to local governments and critical facility operators.	Existing program	Water and wastewater agencies

Power and communications: While power is typically supplied by Pacific Gas and Electric Company (PG&E), a private utility, power users can work to mitigate the impacts of power loss, regardless of type of disaster by renting or owning back-up equipment. Communications systems also are private companies, but impacts of damage to those systems also can be mitigated.

Strategy	*Regional Priority*	*Responsible Agency*
1–(a-8): Pre-position emergency power generation capacity (or have rental/lease agreements for these generators) in critical buildings of cities, counties, and special districts to maintain continuity of government and services.	Existing program, underfunded	Cities, counties, regional agencies, and infrastructure providers
2–(a-11): Minimize the likelihood that power interruptions will adversely impact lifeline utility systems or critical facilities by ensuring that they have adequate back-up power.	Existing program, underfunded	Cities, counties, regional agencies, and infrastructure providers
3–(a-12): Encourage replacing above ground electric and phone wires and other structures with underground facilities, and use the planning-approval process to ensure that all new phone and electrical utility lines are installed underground.	Existing program, underfunded	Cities and counties
4–(a-21): As an infrastructure operator, designate a back-up Emergency Operations Center with redundant communications systems.	Existing program, underfunded	All infrastructure providers

Transportation: The regional transportation system is critical to evacuation, medical transport, and delivery of chemicals and fuel to other infrastructure operators, as identified in the following mitigation strategies.

Strategy	*Regional Priority*	*Responsible Agency*
1–(a-9): Ensure that critical intersection traffic lights function following loss of power by installing battery back-ups, emergency generators, or lights powered by alternative energy sources such as solar. Proper functioning of these lights is essential for rapid evacuation, such as with hazmat releases resulting from natural disasters.	Existing program, underfunded	Cities and counties
2–(a-10): Develop unused or new pedestrian rights-of-way as walkways to serve as additional evacuation routes (such as fire roads in park lands).	Existing program, underfunded	Cities, counties, and infrastructure system land owners
3–(a-15): Ensure that transit operators, private ambulance companies, cities, and/or counties have mechanisms in place for medical transport during and after disasters that take into consideration the potential for reduced capabilities of roads following these same disasters.	Existing program	Cities, counties, and transit districts
4–(a-16): Recognize that heat emergencies produce the need for non-medical transport of people to cooling centers by ensuring that (1) transit operators have plans for non-medical transport of people during and after such emergencies including the use of paratransit and (2) cities, counties, and transit agencies have developed ways to communicate the plan to the public.	Existing program, underfunded	Cities, counties, and transit districts
5–(a-17): Effectively utilize the Regional Transportation Management Center (TMC) in Oakland, the staffing of which is provided by Caltrans, the CHP and MTC. The TMC is designed to maximize safety and efficiency throughout the highway system. It includes the Emergency Resource Center (ERC) which was created specifically for primary planning and procedural disaster management.	Existing program	MTC only
6–(a-18): Develop (with the participation of paratransit providers, emergency responders, and public health professionals) plans and procedures for paratransit system response and recovery from disasters.	Existing program, underfunded	Cities, counties, MTC, and transit districts
7–(a-19): Coordinate with other critical infrastructure facilities to establish plans for **delivery** of water and wastewater treatment chemicals.	Existing program	Water and wastewater agencies
8–(a-20): Establish plans for **delivery** of fuel to critical infrastructure providers.	Existing program, underfunded	Infrastructure agencies with transportation agencies

ACTION APPLYING TO MULTIPLE HAZARDS AND FOCUSED ON THE DELTA AREA ----------

The Sacramento-San Joaquin Delta is critical to several infrastructure systems. Yet, as identified in several recent technical documents, the Delta as it is now managed and configured is not sustainable. Specific mitigation actions are premature at this time. However, the following strategy, which focuses on monitoring those efforts, is appropriate, even for those infrastructure agencies that are not located in this area, because the impacts of damage to the Delta would have indirect consequences for the remainder of the region. Delta issues will be reviewed when this Plan is updated in five years.

Strategy	*Regional Priority*	*Responsible Agency*
16–(a-22): Monitor scientific studies of the Sacramento-San Joaquin Delta and policy decisions related to the long-term disaster resistance of that Delta system to ensure that decisions are made based on comprehensive analysis and in a scientifically-defensible manner. Levee failure due to earthquakes, flooding, and climate change (including sea level rise and more frequent and more severe flooding) are all of concern. The long-term health of the Delta area is critical to the Bay Area's water supply, is essential for the San Francisco Bay and estuary's environmental health, provides recreation opportunities for Bay Area residents, and provides the long-term sustainability of Delta communities. While only part of the Delta is within the nine Bay Area counties covered by this multi-jurisdictional LHMP, the Delta is tied to the infrastructure, water supply, and economy of the Bay Area.	Existing program, underfunded	Cities, counties, regional agencies, and all infrastructure providers

ACTIONS APPLYING TO MULTIPLE HAZARDS AND PUBLIC EDUCATION ----------

Bay Area residents should be made aware of the significant threats posed by various natural disasters. As such, jurisdictions should work to make sure that residents are well prepared for the broad spectrum of potential hazards as related to infrastructure system.

Strategy	*Regional Priority*	*Responsible Agency*
1–(g-1): Provide materials to the public related to planning for power outages.	Existing program	Cities, counties, and power suppliers
2–(g-2): Provide materials to the public related to family and personal planning for delays due to traffic or road closures, or due to transit system disruption caused by disasters.	Existing program	Cities, counties, and transportation agencies
3–(g-3): Provide materials to the public related to coping with reductions in water supply or contamination of that supply BEYOND regulatory notification requirements.	Existing program	Cities, counties, and water suppliers
4–(g-4): Provide materials to the public related to coping with disrupted storm drains, sewage lines, and wastewater treatment (such as materials developed by ABAG's Sewer Smart Program).	Existing program	Cities, counties, and sewer agencies
5–(g-5): Facilitate and/or coordinate the distribution of emergency preparedness or mitigation materials that are prepared by others, such as by making the use of the internet or other electronic means, or placing materials on community access channels or in city or utility newsletters, as appropriate.	Existing program	Cities, counties, regional agencies, and all infrastructure providers

6–(g-6): Sponsor the formation and training of Community Emergency Response Teams (CERT) for the employees of your agency. [Note – these programs go by a variety of names in various cities and areas.]	Existing program	Cities, counties, regional agencies, and all infrastructure providers
7–(g-7): Develop and distribute culturally appropriate materials related to disaster mitigation and preparedness, such as those on the http://www.preparenow.org website related to infrastructure issues.	Existing program	Cities, counties, regional agencies, and all infrastructure providers

Hazard-Specific Vulnerabilities of Infrastructure Systems

Damage from earthquakes, flooding, wildfire, and landsliding is sometimes best mitigated through hazard-specific strategies.

The following section will discuss strategies for mitigating the hazards posed by these specific threats to various infrastructure systems.

ACTIONS RELATED TO EARTHQUAKE HAZARDS AND VULNERABILITIES

The most pressing and potentially dangerous hazard facing Bay Area infrastructure is from earthquakes. The probability of a major earthquake is high. Many infrastructure systems remain vulnerable to shaking, faulting, landsliding, and liquefaction resulting from such an earthquake. Finally, the probability of cascading failures of multiple systems creating a mega-catastrophe is higher than for other disasters.

Functional infrastructure systems are the arteries of the Bay Area during the response and recovery process. Thus, it is extremely important that these systems undergo mitigation. Damage from earthquakes is the largest risk facing these systems. Thus, the number of strategies related to earthquake hazard mitigation is large. Some strategies apply to multiple systems, while others are specific to transportation systems, and still others to water and wastewater systems.

Multiple infrastructure systems: The retrofit of critical facilities requires large amounts of money; priorities for mitigation must be set. These priorities should be based on servicing existing development prior to servicing new development, a set of priorities that can result in more compact development. New and existing infrastructure projects also need to comply with applicable codes. If a facility is found to be a hazard, it is important that workers in these facilities be kept informed of the retrofit and mitigation status.

Strategy	*Regional Priority*	*Responsible Agency*
1–(b-2): Establish a higher priority for funding seismic retrofit of existing transportation and infrastructure systems (such as BART) than for expansion of those systems.	Existing program, underfunded	Cities, counties, regional agencies, and all infrastructure providers
2–(b-8): Comply with all applicable building and fire codes, as well as other regulations (such as state requirements for fault, landslide, and liquefaction investigations in particular mapped areas) when constructing or significantly remodeling infrastructure facilities.	Existing program	Cities, counties, regional agencies, and all infrastructure providers

3–(b-9): Clarify to workers in critical facilities and emergency personnel, as well as to elected officials and the public, the extent to which the facilities are expected to perform only at a life safety level (allowing for the safe evacuation of personnel) or are expected to remain functional following an earthquake.	Existing program	Cities, counties, regional agencies, and all infrastructure providers

Transportation systems: Transportation systems have special mitigation strategies related to bridges and road structures. In addition, to the extent that a water-based system is created, this system can serve as a back-up for BART and the toll bridges.

Strategy	*Regional Priority*	*Responsible Agency*
1–(b-1): Expedite the funding and retrofit of seismically-deficient city- and county-owned bridges and road structures by working with Caltrans and other appropriate governmental agencies.	Existing program, underfunded	Cities and counties
9–(b-10): Develop a water-based transportation "system" across the Bay for use in the event of major earthquakes. Implementation of such a system could prove extremely useful in the event of structural failure of either the road-bridge systems or BART and might serve as an adjunct to existing transportation system elements in the movement of large numbers of people and/or goods.	Existing program	San Francisco Water Emergency Transportation Agency (WETA)

Water and wastewater systems: Both water and wastewater systems rely on critical facilities and pipeline networks that are vulnerable to various earthquake-related hazards.

Strategy	*Regional Priority*	*Responsible Agency*
2–(b-3): Include "areas subject to high ground shaking, earthquake-induced ground failure, and surface fault rupture" in the list of criteria used for determining a replacement schedule for pipelines (along with importance, age, type of construction material, size, condition, and maintenance or repair history).	Existing program	Water and wastewater agencies
3–(b-4): Install specially-engineered pipelines in areas subject to faulting, liquefaction, earthquake-induced landsliding, or other earthquake hazard.	Existing program, underfunded	Water and wastewater agencies
4–(b-5): Replace or retrofit water-retention structures that are determined to be structurally deficient, including levees, dams, reservoirs and tanks.	Existing program, underfunded	Water and wastewater agencies and dam owners
5–(b-6): Install portable facilities (such as hoses, pumps, emergency generators, or other equipment) to allow pipelines to bypass failure zones such as fault rupture areas, areas of liquefaction, and other ground failure areas (using a priority scheme if funds are not available for installation at all needed locations).	Existing program, underfunded	Water and wastewater agencies
6–(b-7): Install earthquake-resistant connections when pipes enter and exit bridges and work with bridge owners to encourage retrofit of these structures.	Existing program, underfunded	Water and wastewater agencies

ACTIONS RELATED TO WILDFIRE AND STRUCTURAL FIRE HAZARDS AND VULNERABILITIES

Water supply: Providing a reliable source of water for fire suppression requires the cooperation of cities, counties, fire districts, and water supply agencies.

Strategy	*Regional Priority*	*Responsible Agency*
1–(c-1): Ensure a reliable source of water for fire suppression (meeting acceptable standards for minimum volume and duration of flow) for existing and new development.	Existing program, underfunded	Cities, counties, and water suppliers
2–(c-2): Develop a coordinated approach between fire jurisdictions and water supply agencies to identify needed improvements to the water distribution system, initially focusing on areas of highest wildfire hazard (including wildfire threat areas and in wildland-urban-interface areas).	Existing program, underfunded	Cities, counties, fire agencies, and water suppliers

Vegetation management: One of the simplest, yet most important aspects of a wildfire hazard mitigation strategy is vegetation management. The specific vegetation management program called for in the following strategy is designed to project critical facilities owned by infrastructure operators.

Strategy	*Regional Priority*	*Responsible Agency*
1–(c-3): Develop a defensible space vegetation program that includes the clearing or thinning of (a) non-fire resistive vegetation within 30 feet of access and evacuation roads and routes to critical facilities, or (b) all non-native species (such as eucalyptus and pine, but not necessarily oaks) within 30 feet of access and evacuation roads and routes to critical facilities.	Existing program, under funded	Cities, counties, and infrastructure operators

Access and transportation: Access is critical in ensuring that development is protected from wildfires.

Strategy	*Regional Priority*	*Responsible Agency*
1–(c-4): For new development, ensure all dead-end segments of public roads in high hazard areas have at least a "T" intersection turn-around sufficient for typical wildland fire equipment.	Existing program	Cities and counties
2–(c-5): For new development, enforce minimum road width of 20 feet with an additional 10-foot clearance on each shoulder on all driveways and road segments greater than 50 feet in length in wildfire hazard areas.	Existing program	Cities and counties
3–(c-6): Require that development in high fire hazard areas provide adequate access roads (with width and vertical clearance that meet the minimum standards of the Fire Code or relevant local ordinance), onsite fire protection systems, evacuation signage, and fire breaks.	Existing program	Cities and counties
4–(c-7): Ensure adequate fire equipment road or fire road access to developed and open space areas.	Existing program	Cities and counties
5–(c-8): Maintain fire roads and/or public right-of-way roads and keep them passable at all times.	Existing program, underfunded	Cities and counties

ACTIONS RELATED TO FLOODING HAZARDS AND VULNERABILITIES

Coordination, cooperation, and watershed analysis: Local jurisdictions and flood control agencies can work most effectively if they cooperate. Conducting watershed analyses is a prime example of the need for cooperation.

Strategy	*Regional Priority*	*Responsible Agency*
1–(d-16): Work for better cooperation among the patchwork of agencies managing flood control issues.	Existing program	Cities, counties, & flood control agencies
2–(d-1): Conduct a watershed analysis of runoff and drainage systems to predict areas of insufficient capacity in the storm drain and natural creek system.	Existing program, underfunded	Cities, counties, & flood control agencies
3–(d-2): Develop procedures for performing a watershed analysis to examine the impact of development on flooding potential downstream, including communities outside of the jurisdiction of proposed projects.	Existing program, underfunded	Cities, counties, & flood control agencies
4–(d-3): Conduct a watershed analysis at least once every ten years unless there is a major development in the watershed or a major change in the Land Use Element of the General Plan of the cities or counties within the watershed.	Existing program, underfunded	Cities, counties, & flood control agencies
5–(d-15): Work cooperatively with water agencies, flood control districts, Caltrans, and local transportation agencies to determine appropriate performance criteria for watershed analysis.	Existing program, underfunded	Cities, counties, transportation & flood control agencies

Role for new flood control projects: As the Bay Area grows, sometimes it is essential that new flood control projects are constructed, assuming that they have high benefit-cost ratios and have appropriate environmental mitigation.

Strategy	*Regional Priority*	*Responsible Agency*
1–(d-4): Assist, support, and/or encourage the U.S. Army Corp of Engineers, various Flood Control and Water Conservation Districts, and other responsible agencies to locate and maintain funding for the development of flood control projects that have high cost-benefit ratios (such as through the writing of letters of support and/or passing resolutions in support of these efforts).	Existing program	Cities, counties, regional agencies, and all infrastructure agencies
2–(d-5): Pursue funding for the design and construction of storm drainage projects to protect vulnerable properties, including property acquisitions, upstream storage such as detention basins, and channel widening with the associated right-of-way acquisitions, relocations, and environmental mitigations.	Existing program, underfunded	Cities, counties, & flood control agencies

Role for maintenance of existing flood control projects: Once flood control projects are built, a mechanism needs to be in place to insure that they are maintained. In addition, some of these projects need to be reevaluated on an on-going basis.

Strategy	*Regional Priority*	*Responsible Agency*
1–(d-6): Continue to repair and make structural improvements to storm drains, pipelines, and/or channels to enable them to perform to their design capacity in handling water flows as part of regular maintenance activities. (This strategy has the secondary benefit of addressing fuel, chemical, and cleaning product issues.)	Existing program, underfunded	Cities, counties, & flood control agencies

2–(d-7): Continue maintenance efforts to keep storm drains and creeks free of obstructions, while retaining vegetation in the channel (as appropriate) to allow for the free flow of water.	Existing program, underfunded	Cities, counties, & flood control agencies
3–(d-8): Enforce provisions under creek protection, stormwater management, and discharge control ordinances designed to keep watercourses free of obstructions and to protect drainage facilities to conform with the Regional Water Quality Control Board's Best Management Practices.	Existing program, underfunded	Cities, counties, & flood control agencies
4–(d-9): Develop an approach and locations for various watercourse bank protection strategies, including for example, (1) an assessment of banks to inventory areas that appear prone to failure, (2) bank stabilization, including installation of rip rap, or whatever regulatory agencies allow (3) stream bed depth management using dredging, and (4) removal of out-of-date coffer dams in rivers and tributary streams.	Existing program, underfunded	Cities, counties, & flood control agencies
5–(d-10): Use reservoir sediment or reed removal as one way to increase storage for both flood control and water supply.	Existing program, underfunded	Dam owners & flood control agencies
6–(d-12): Provide or support the mechanism to expedite the repair or replacement of levees that are vulnerable to collapse from earthquake-induced shaking or liquefaction, rodents, and other concerns, particularly those protecting critical infrastructure.	Existing program, underfunded	Levee owners & flood control agencies

Flooding and infrastructure systems: Some assets of infrastructure operators cannot be moved. These facilities need to be protected from flooding, or redesigned to minimize damage caused by flooding.

Strategy	*Regional Priority*	*Responsible Agency*
1–(d-11): Identify critical locally-owned bridges affected by flooding and either elevate them to increase stream flow and maintain critical ingress and egress routes or modify the channel to achieve equivalent objectives.	Existing program, underfunded	Cities, counties, & flood control agencies
2–(d-13): Ensure that utility systems in new developments are constructed in ways that reduce or eliminate flood damage.	Existing program	Cities, counties, & infrastructure providers
3–(d-14): Determine whether or not wastewater treatment plants are protected from floods, and if not, investigate the use of flood-control berms to not only protect from stream or river flooding, but also increase plant security.	Existing program, underfunded	Wastewater agencies

Flood monitoring systems: Flood monitoring can play a key role in some mitigation strategies for infrastructure systems. For example, with appropriate monitoring, key trucks, buses, and other movable equipment can be transported out of areas that are about to be flooded.

Strategy	*Regional Priority*	*Responsible Agency*
1–(d-17): Improve monitoring of creek and watercourse flows to predict potential for flooding downstream by working cooperatively with landowners and the cities and counties in the watershed.	Existing program, underfunded	Flood control agencies with cities and counties
2–(d-18): Using criteria developed by EPA for asset management, inventory existing assets, the condition of those assets, and improvements needed to protect and maintain those assets. Capture this information in a Geographic Information System (GIS) and use it to select locations for creek monitoring gauges.	Existing program, underfunded	Flood control agencies with cities and counties

ACTIONS RELATED TO LANDSLIDE HAZARDS AND VULNERABILITIES

The following two strategies concerning landslides relate specifically to infrastructure systems.

Strategy	*Regional Priority*	*Responsible Agency*
1–(e-1): Include "areas subject to ground failure" in the list of criteria used for determining a replacement schedule (along with importance, age, type of construction material, size, condition, and maintenance or repair history) for pipelines.	Existing program	Water and wastewater agencies
2–(e-2): Establish requirements in zoning ordinances to address hillside development constraints in areas of steep slopes that are likely to lead to excessive road maintenance or where roads will be difficult to maintain during winter storms due to landsliding.	Existing program	Cities and counties

Sources: page 1-2 MTC, page 1-3-USGS and Google Earth, page 1-4 MTC (Noah Berger), page 1-5 Stockton Library, Monterey County Office of Emergency Services, USGS (R. Baum), page 1-6 VTA, pages 10 & 13 EBMUD, page 12 CalFIRE.