



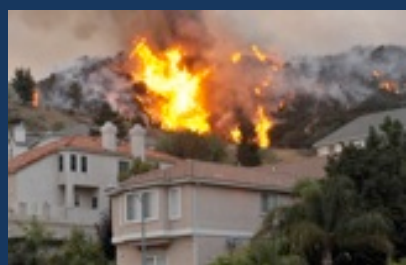
## Integrated view of earthquake hazards and lifeline infrastructures

Anne Wein and Jamie Jones, WGSC, USGS

Jim Wollbrinck, SJWC and EBMUD

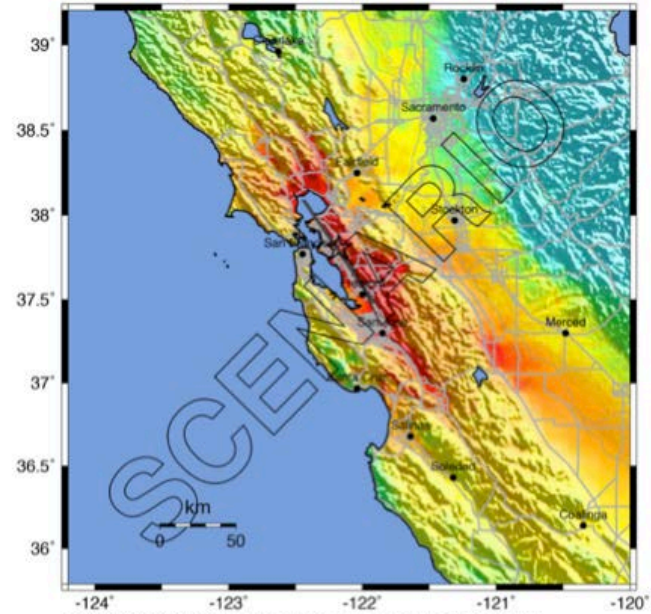
Dale A. Cox, SAFRR, USGS

66+ developers and 60+ communication partners





-- Earthquake Planning Scenario --  
 ShakeMap for HayWiredM7.1 Scenario  
 Scenario Date: Apr 18, 2018 23:18:00 UTC M 7.1 N37.80 W122.18 Depth: 8.0km



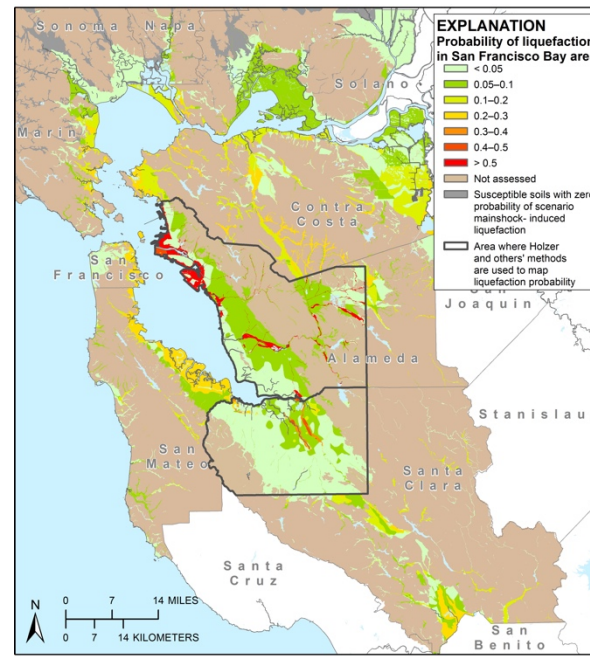
PLANNING SCENARIO ONLY -- Map Version 28 Processed 2015-05-13 22:46:39 UTC

PERCEIVED (SHAKING)	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC. (g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL. (cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

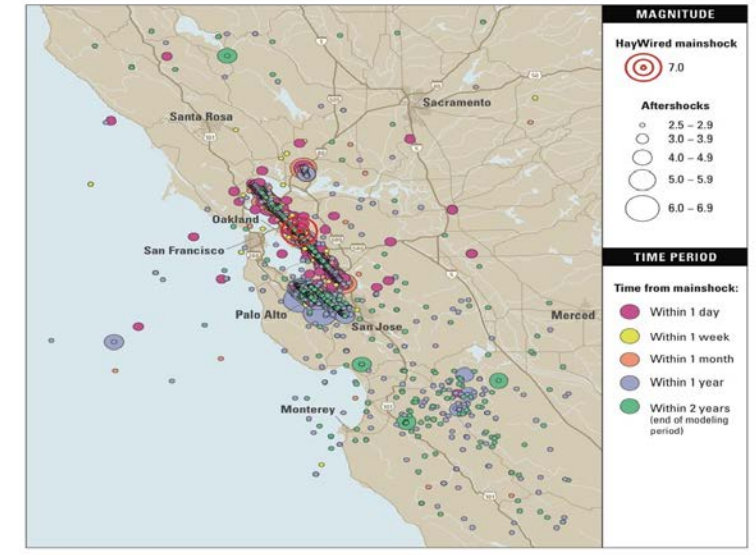
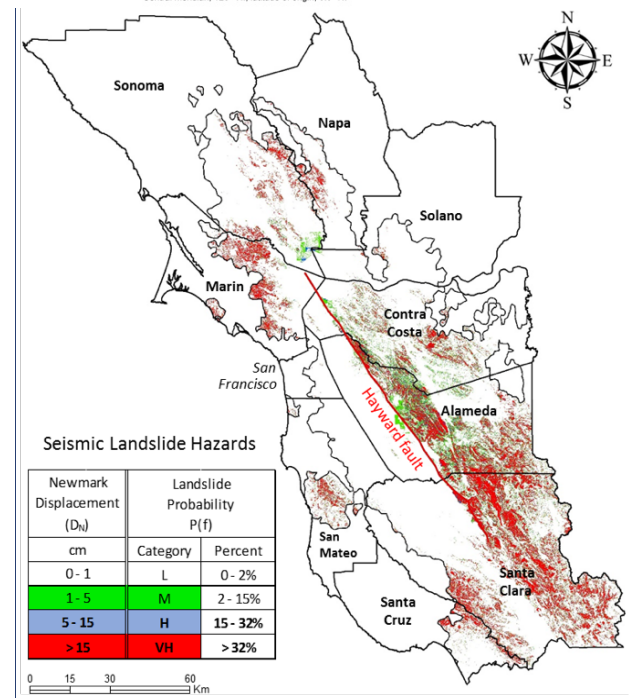
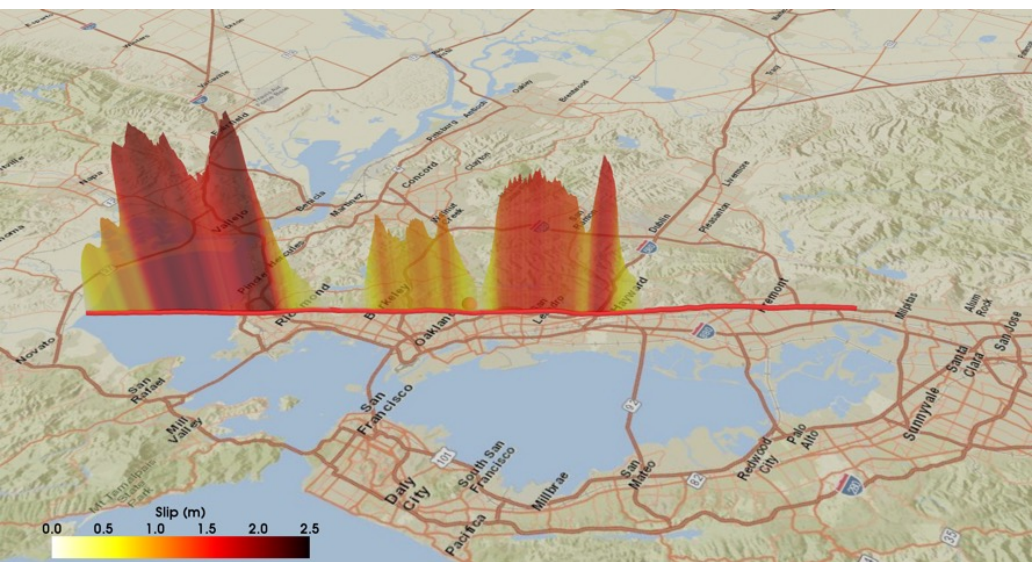
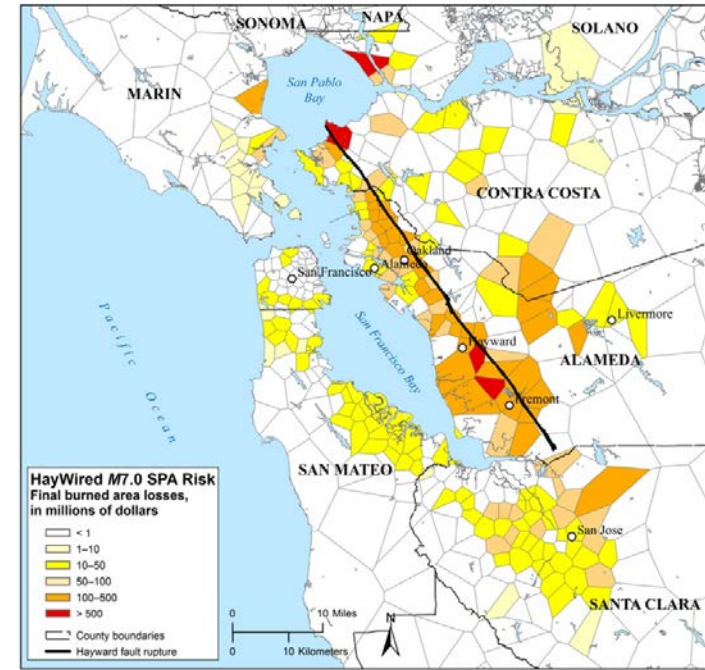
Scale based upon Worden and others (2012)

# HayWired

Shaking  
 Surface rupture  
 Liquefaction  
 Landslide  
 Fire following  
 Aftershocks

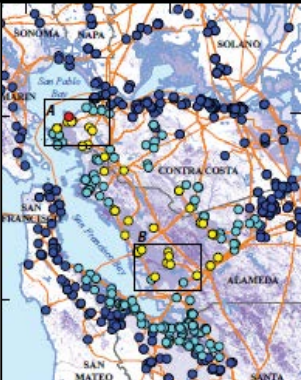

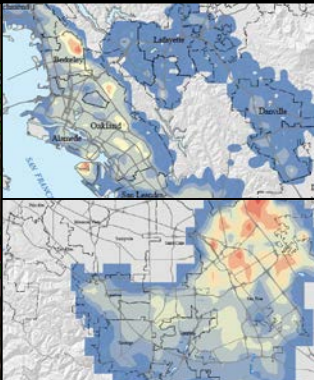
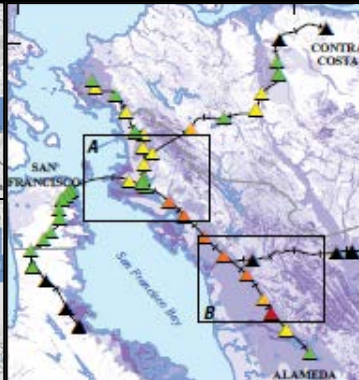


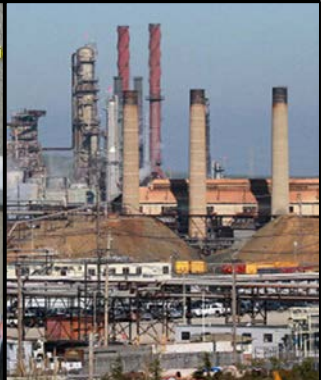


Hydrology from U.S. Geological Survey National Hydrography Dataset, 2016.  
 Boundary data from U.S. Census Bureau TIGER data, 2016, and Federal Emergency Management Agency Hazus-MH 2.1, 2014.  
 North American Datum of 1983 UTM 10N projection.  
 Central meridian, 123° W, latitude of origin, 0.0° N.

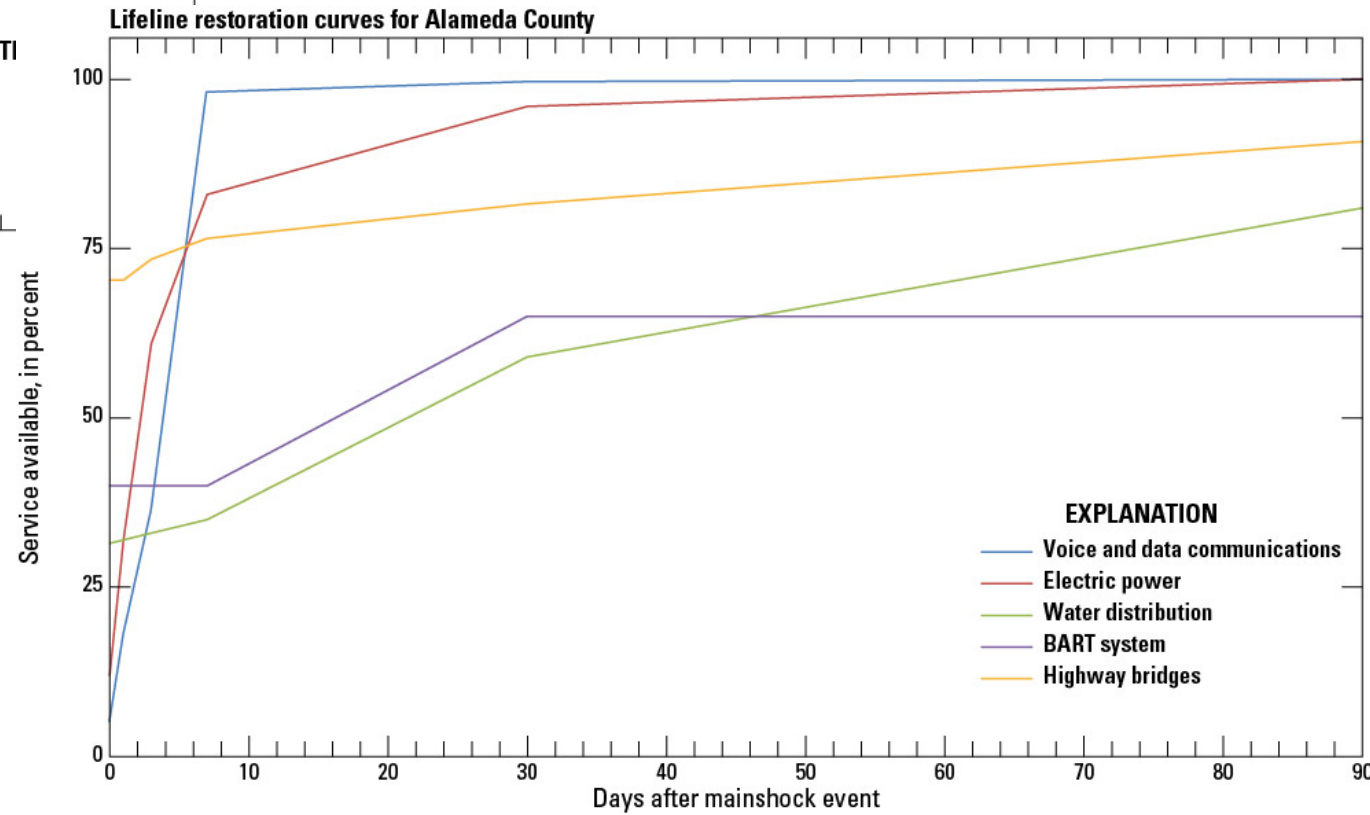
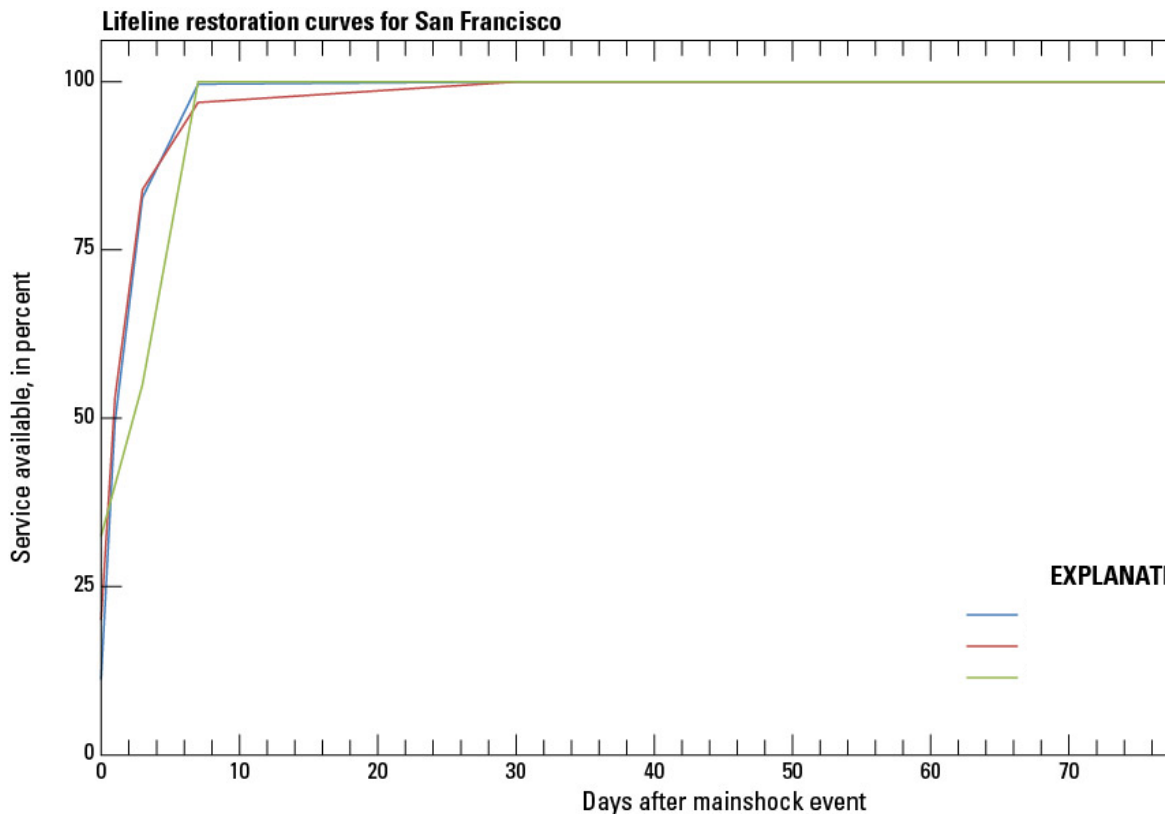


Detweiler and Wein 2017:  
 HayWired Volume 1



							
System	Electric power	Telecomm.	Water	BART	Highway	Gas	Fuel
Hazards	HayWired shaking, ground failure	HayWired shaking, ground failure, fire	HayWired sequence shaking, fault crossing, liquefaction, landslides	HayWired shaking, considered lines crossing fault. in liquefaction, landslides areas	HayWired shaking	HayWired shaking, ground failure	Bay Area earthquake
Damage and service restoration	Hazes + PG&E consultation	Simple model + industry consultation	New model + EBMUD, SJWC	BART station and facility ShakeCast	Caltrans highway bridge ShakeCast + repair estimation	PG&E consultation	California Energy Commission
Interactions	<i>Restoration uncertainties</i>	Functional–power; Restoration–access	Restoration–power, telecom, roads, labor, materials	<i>Power–pump; water–tunnel fire; fuel–generators, buses, comms</i>	<i>Collocated water pipes, fiber optic lines</i>	<i>Restoration uncertainties</i>	<i>Water, natural gas; crude oil, pipelines, rails, roads; power</i>
Results of service disruption	Weeks to month by county	Days to weeks by county; loss predominantly from power outage	Up to 7 months by county; 25% loss from interactions (SJWC)	Up to a few years by station	Up to 10 months by bridge	Months for the region	At least 1 week to 10 days for region

# County lifeline service restorations



- Economic Impacts

1. Property damage
2. Transportation disruption (less impacted)
3. Water disruption (length)
4. Telecomms disruption (reach)
5. Electric power disruption

- Population Displacement

# HayWired and lifeline infrastructure organizations

- Earthquake hazards
  - PG&E: shaking extent, aftershocks
  - BART: shaking hot-spots, fire following the earthquake
- Restoration
  - EBMUD: confirmed length and phases of water supply restoration
- Interactions
  - SJWC: potential outages to hospitals and airport, power outage delays restoration, needs for fuel plan and spare part inventories
- Barriers to coordination
  - Varied capabilities to estimate damage from multiple hazards and restoration
  - Limited interagency sharing
  - Assumptions they make about each other

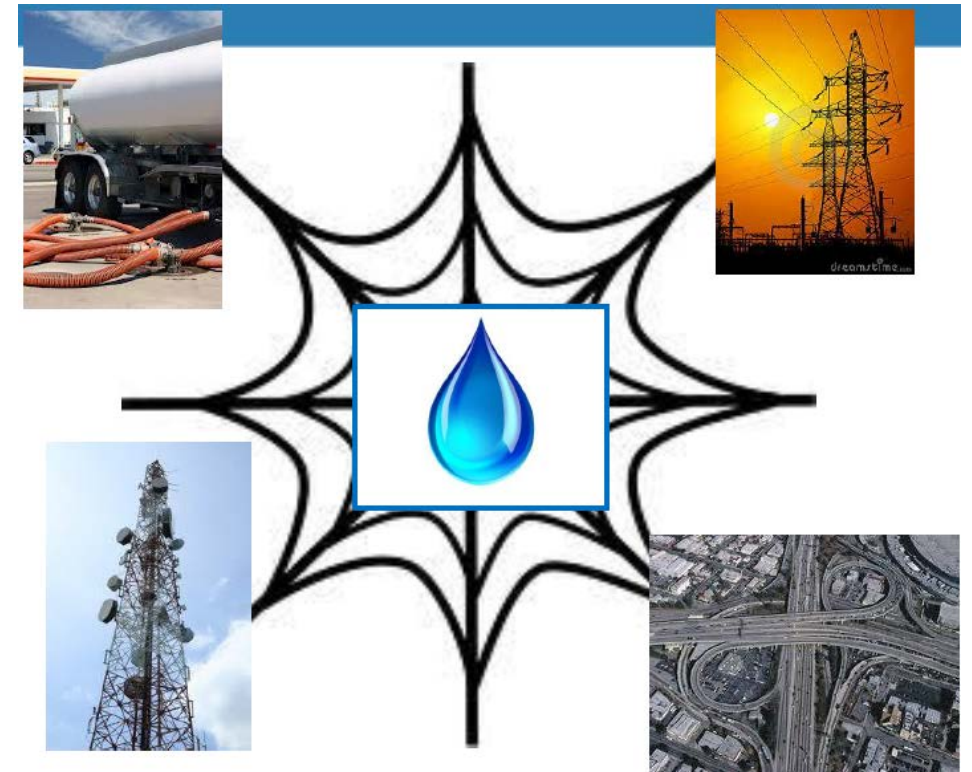
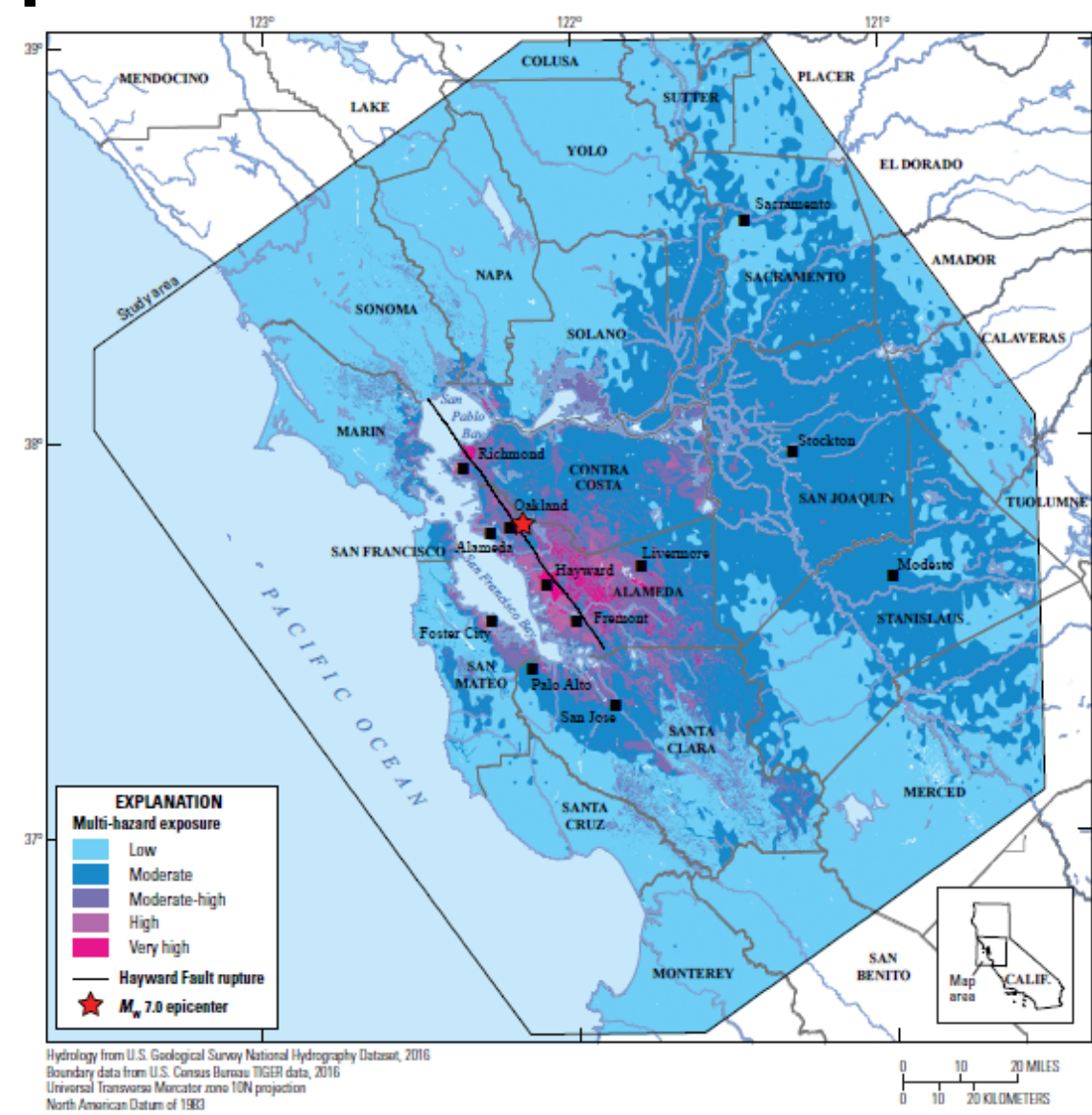
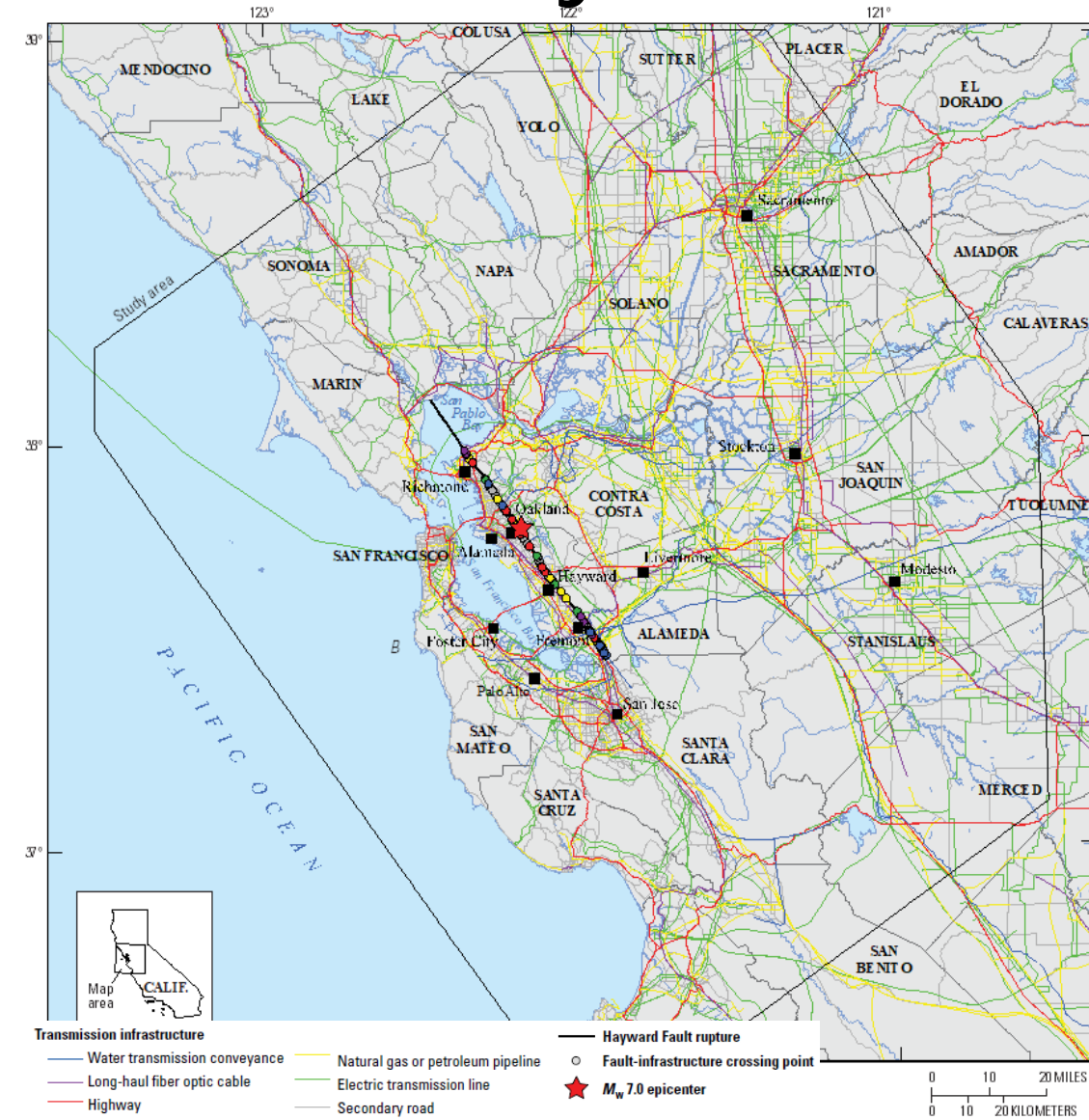


Image: Jim Wollbrinck, SJWC

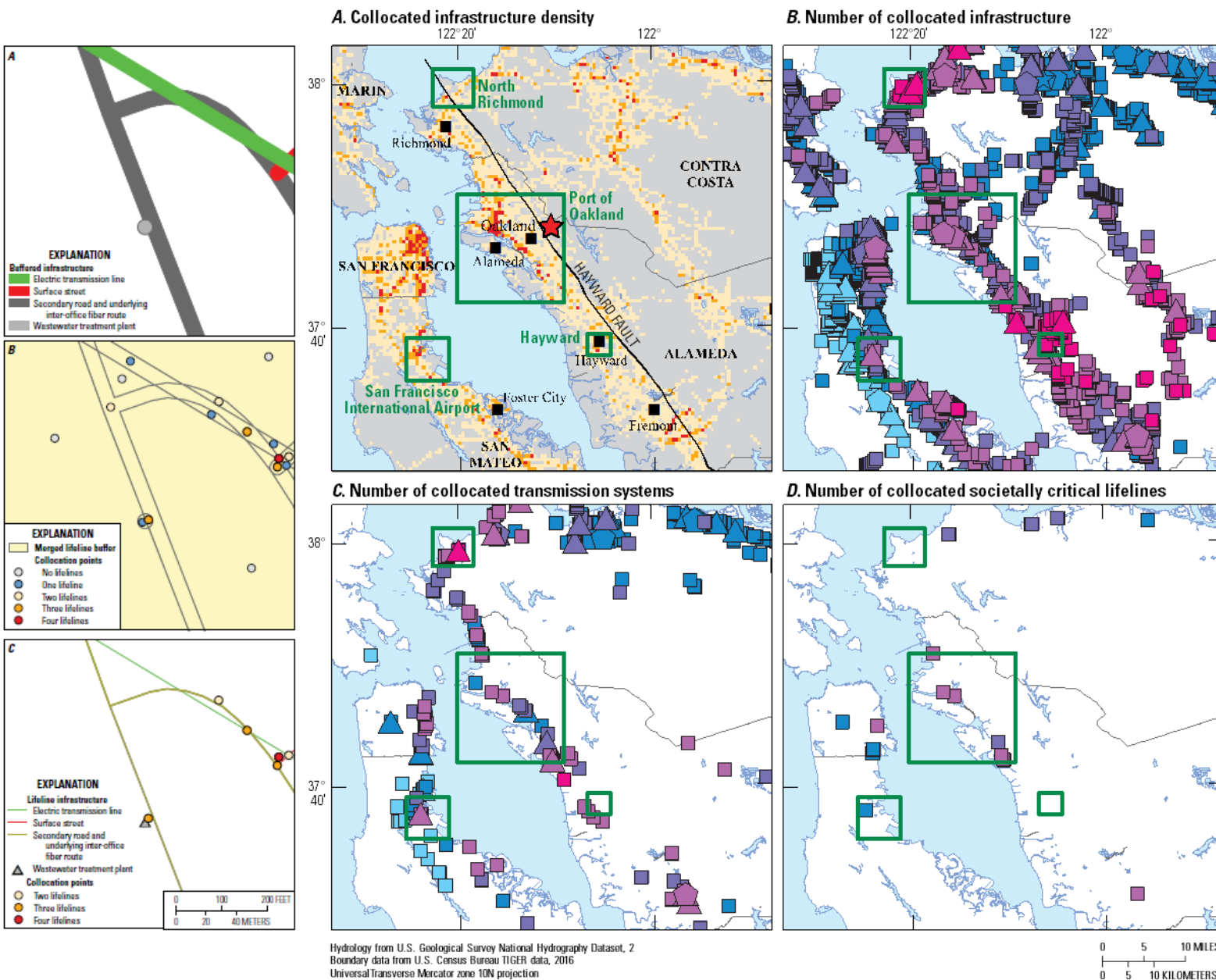


# Standardization of multiple lifeline infrastructure systems and earthquake hazards



	Relatively most intensely exposed systems	Shaking	Shaking + liquefaction	Shaking + landslides	Shaking + liquefaction + fire	All hazards (+ fault rupture + landslides)
Transportation	Bart stations and yards	X (13%)				
	Highway bridges					X
	Roadways					X
	Air and sea ports		X			
Energy	Oil terminals		X (20%)			
	POL terminals, storage facilities, tank farms		X (33%)		X	
	Natural gas compressor stations	X (15%)	X (9%)			
	Oil and gas pipelines					X
	Power transmission lines					X
Telecommunications	Internet exchange points	X (27%)				
	Cellular sites	X (13%)				X
	Data centers				X	
	Fiber optic cables					X
Water	Wastewater treatment		X (13%)			
	Dams	X (10%)		X		
	Water conveyance systems			X		

# Collocation of lifeline infrastructure

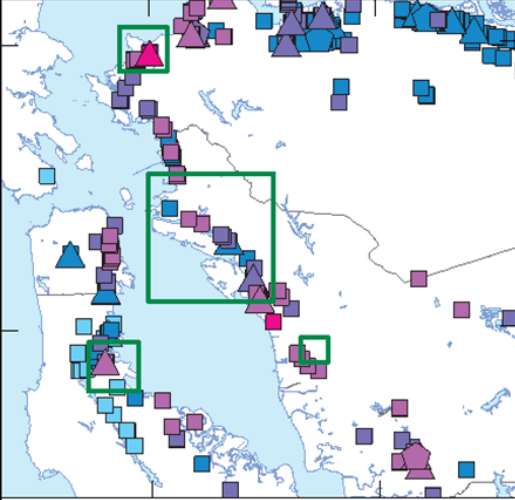


- Density of collocated infrastructure
- Count of collocated infrastructure
- Count of collocated transmission infrastructure
- Count of collocated societally critical (economic impact, service areas, safety) infrastructure

Green boxes denote areas examined in more detail





	North Richmond area, Contra Costa County	San Francisco International Airport area, San Mateo County
Hazards	Strong shaking, high fire density, up to 2m surface rupture and fault afterslip	High liquefaction probability, moderate shaking intensity
Infrastructure	Petroleum and natural gas pipelines, railways, transmission lines, fiber optic cables, surface streets	Roadways, fiber optic cables, transmission lines, natural gas pipelines
<p data-bbox="30 439 254 471">Interactions</p> 	<p data-bbox="542 439 1544 571">Collocation (parallel): (1) railway corridor with petroleum pipeline; (2) railway corridor with fiber optic cable and transmission line.</p> <p data-bbox="542 582 1544 671">Collocation (intersection): transmission line crossing a natural gas pipeline.</p> <p data-bbox="542 682 1544 771">Collocation (hub): multiple (4–5) fiber optic cables, 5 petroleum pipelines, and 2 natural gas pipelines.</p> <p data-bbox="542 782 1544 871">Collocation (hub on fault): surface street crosses parallel fiber optic cable and railway.</p> <p data-bbox="542 882 1544 1021">Collocation (parallel across fault): (1) 3 petroleum pipelines and 2 natural gas pipelines; (2) railway and fiber optic cable.</p> <p data-bbox="542 1032 1544 1328">Restoration: response/restoration complicated and delayed by fire; telecommunications dependencies on electric power service possible if substation is affected by fire and backup power discharges; repair of collocated (parallel and intersecting) lifeline infrastructure would require coordination.</p>	<p data-bbox="1544 439 2504 521">Collocation (parallel): Fiber optic cable running on a bridge.</p> <p data-bbox="1544 635 2504 821">Collocation (parallel and hub): parallel highway and fiber optic cables crossed by natural gas and petroleum pipelines; transmission lines running parallel to and crossing natural gas pipelines.</p> <p data-bbox="1544 1035 2504 1128">Substitution: less impacted surface streets could substitute for impacted highway.</p> <p data-bbox="1544 1139 2504 1278">Restoration: repairs of collocated lifeline infrastructure requires coordination between systems.</p>

# Thank you for your attention

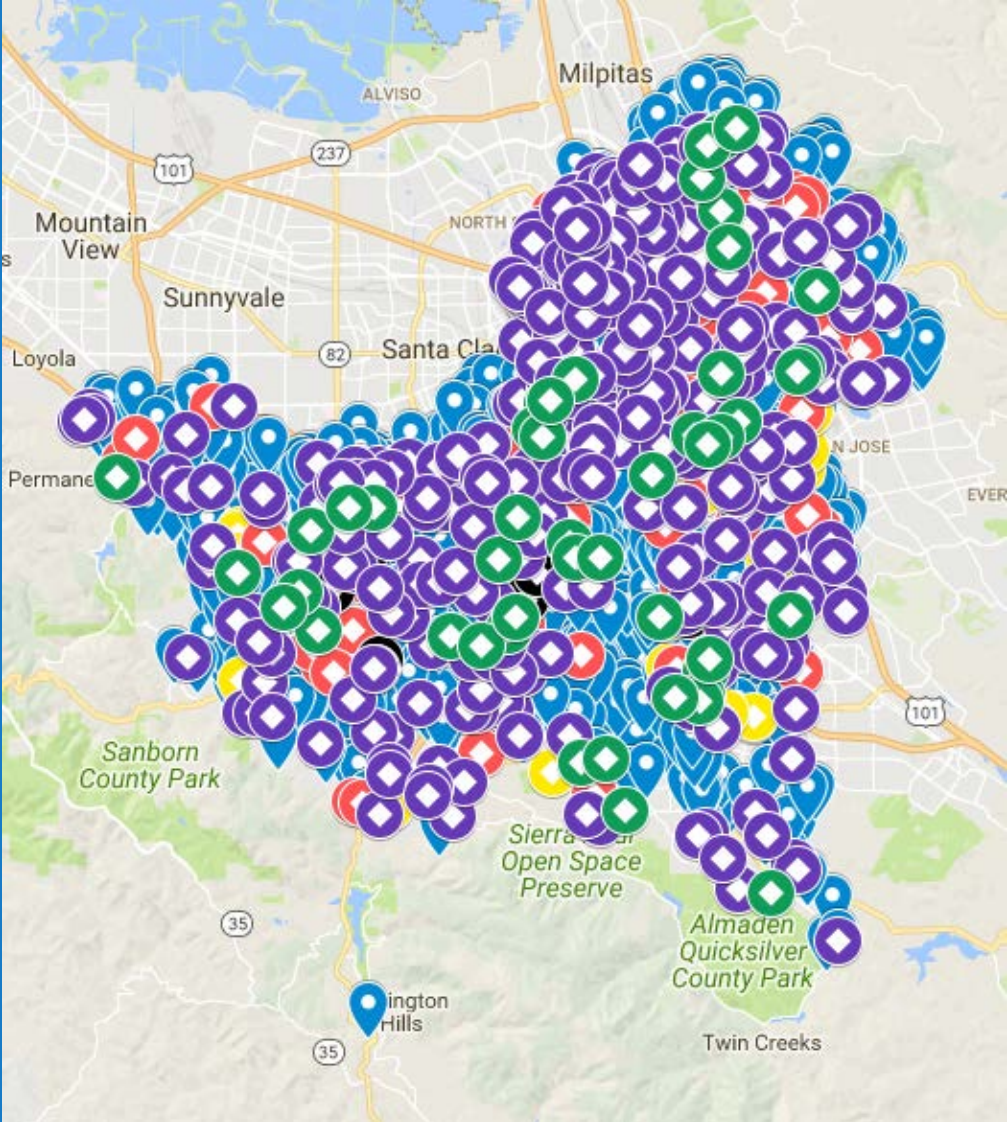
The relevant HayWired chapters are:

- Water supply: <https://pubs.er.usgs.gov/publication/sir20175013v2>
- Lifelines: <https://pubs.usgs.gov/sir/2017/5013/vol3/t/sir20175013t.pdf>
- Economic impacts: <https://pubs.usgs.gov/sir/2017/5013/vol3/v/sir20175013v3.pdf>  
and in publication queue

awein@usgs.gov

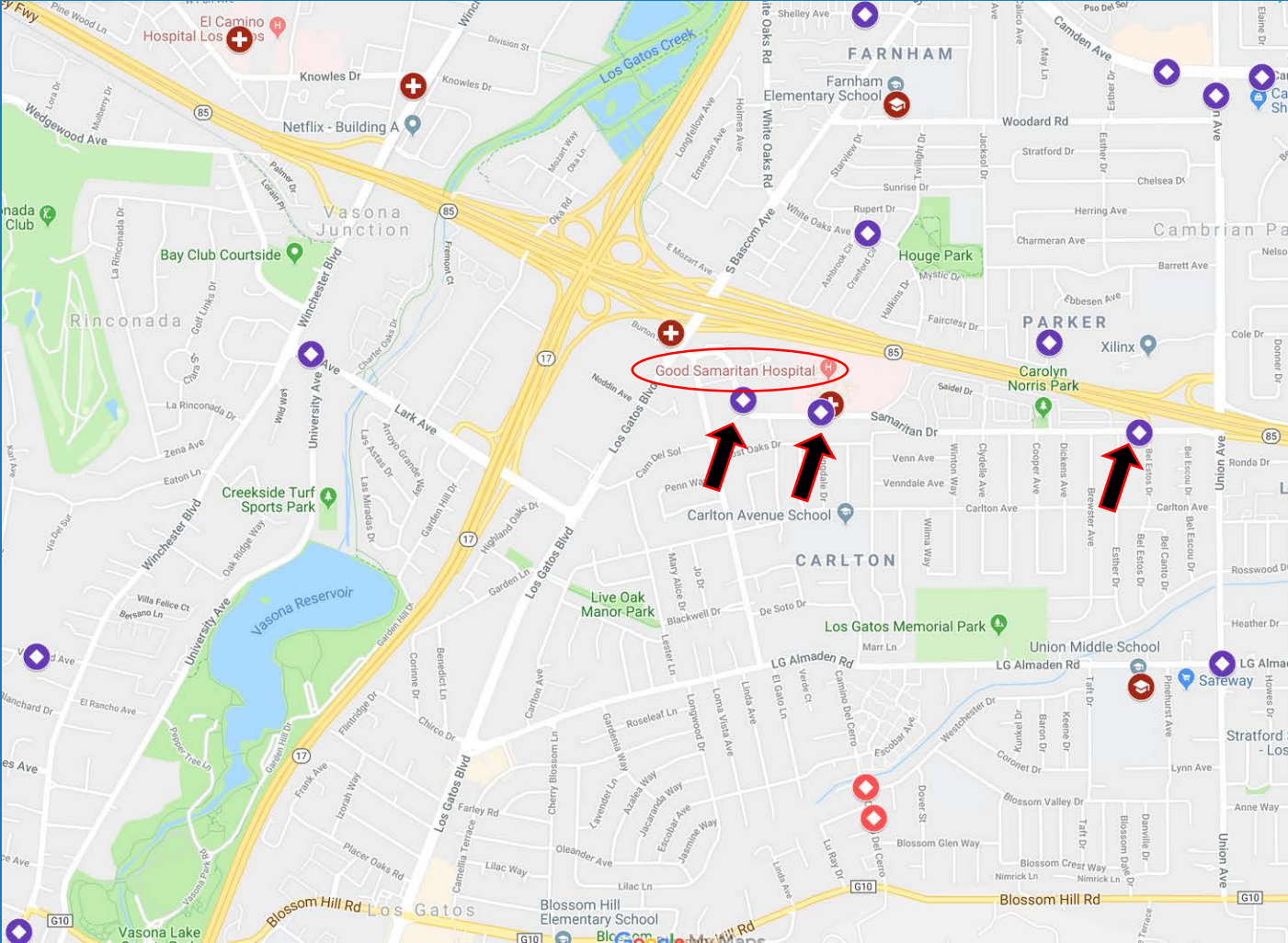


# Haywired and SJWC

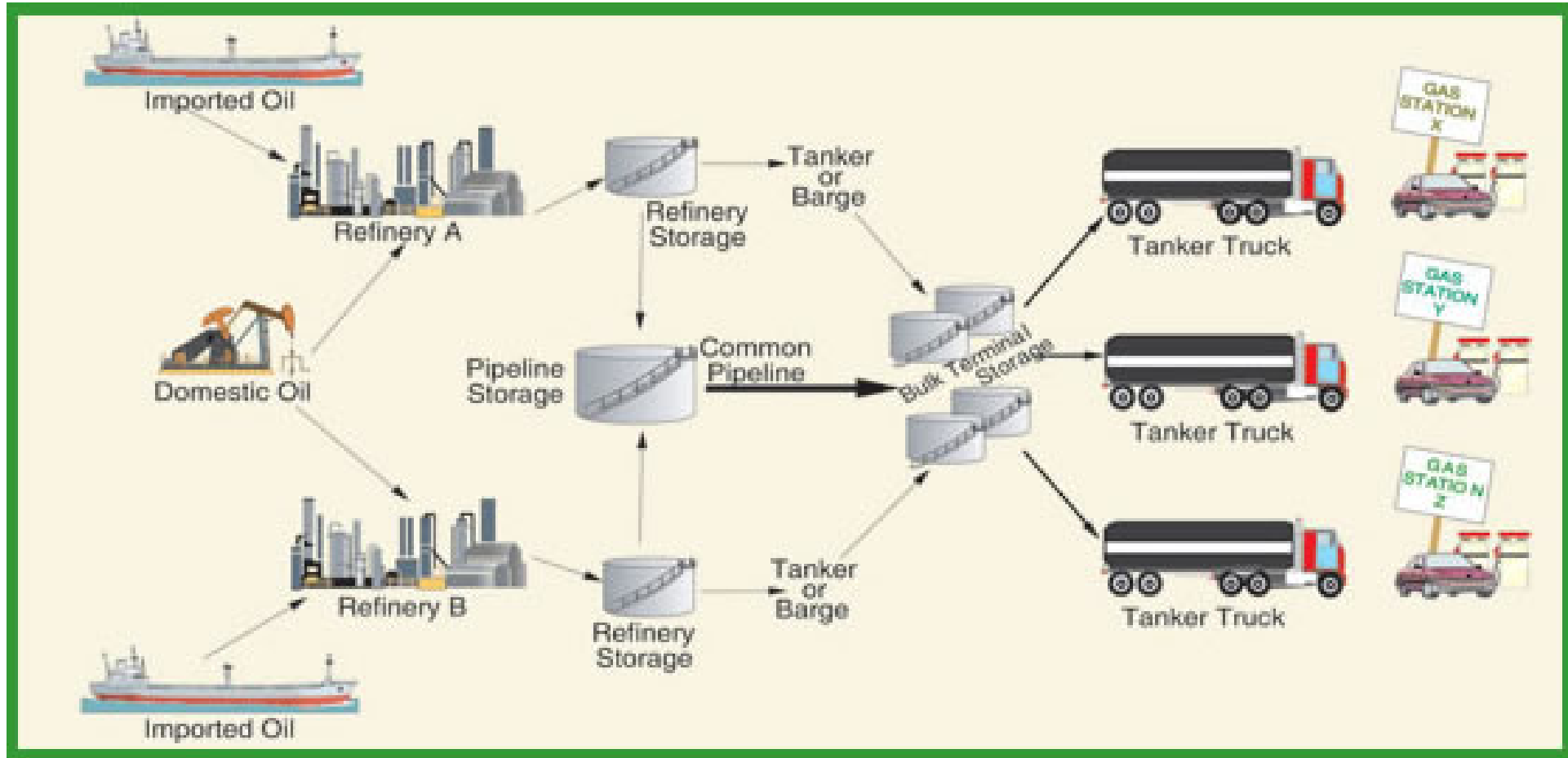




# Haywired and SJWC



# Transportation Fuel Infrastructure



Source: Energy Information Administration



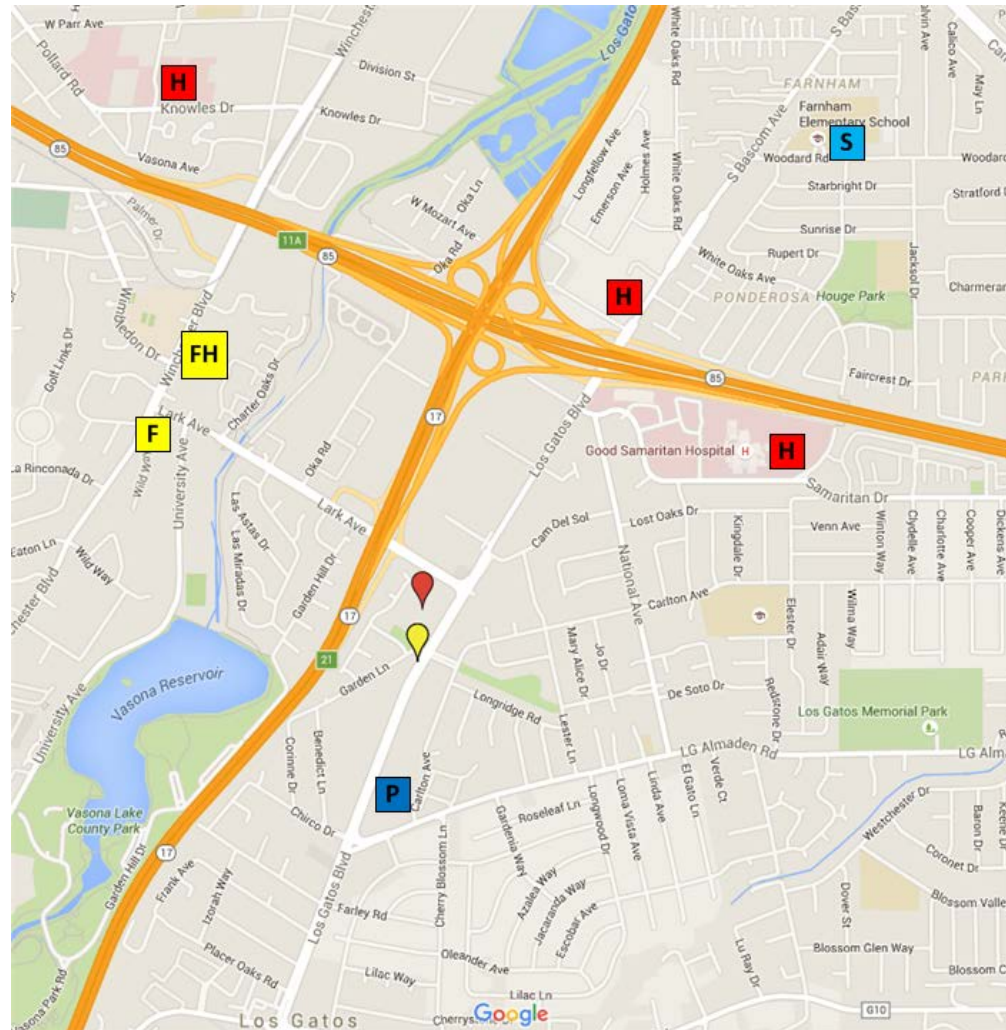
# SJWC Fuel Plan - County

- Kinder Morgan's Southern California system is not connected to its Northern California system.
- Fuel re-supply by pipeline from Northern California not possible
- Tanker trucks quickest, viable option to bring in additional fuel

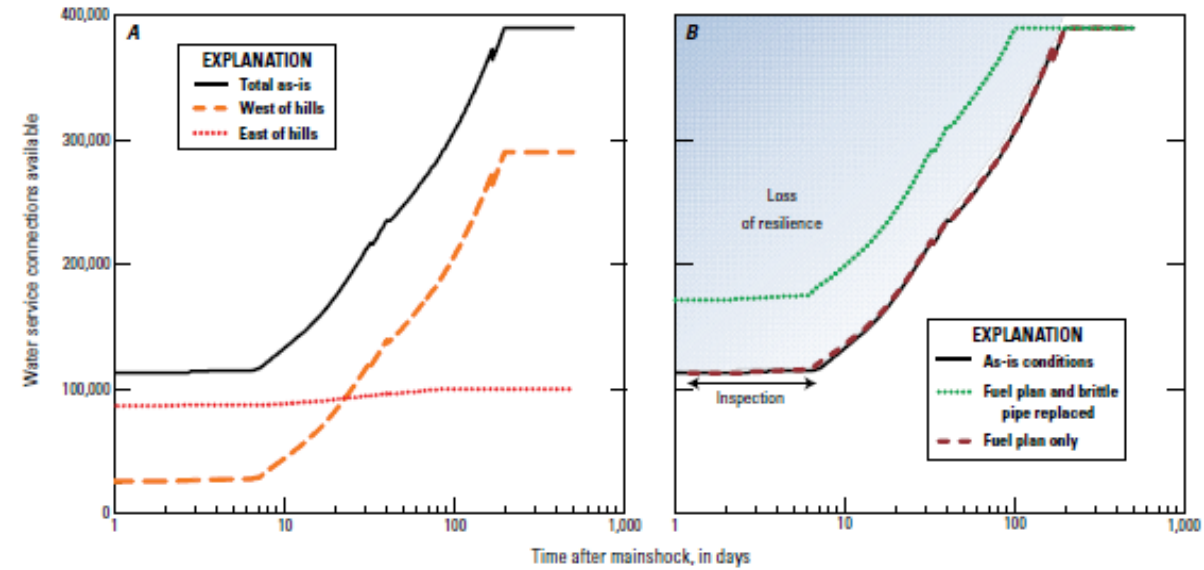
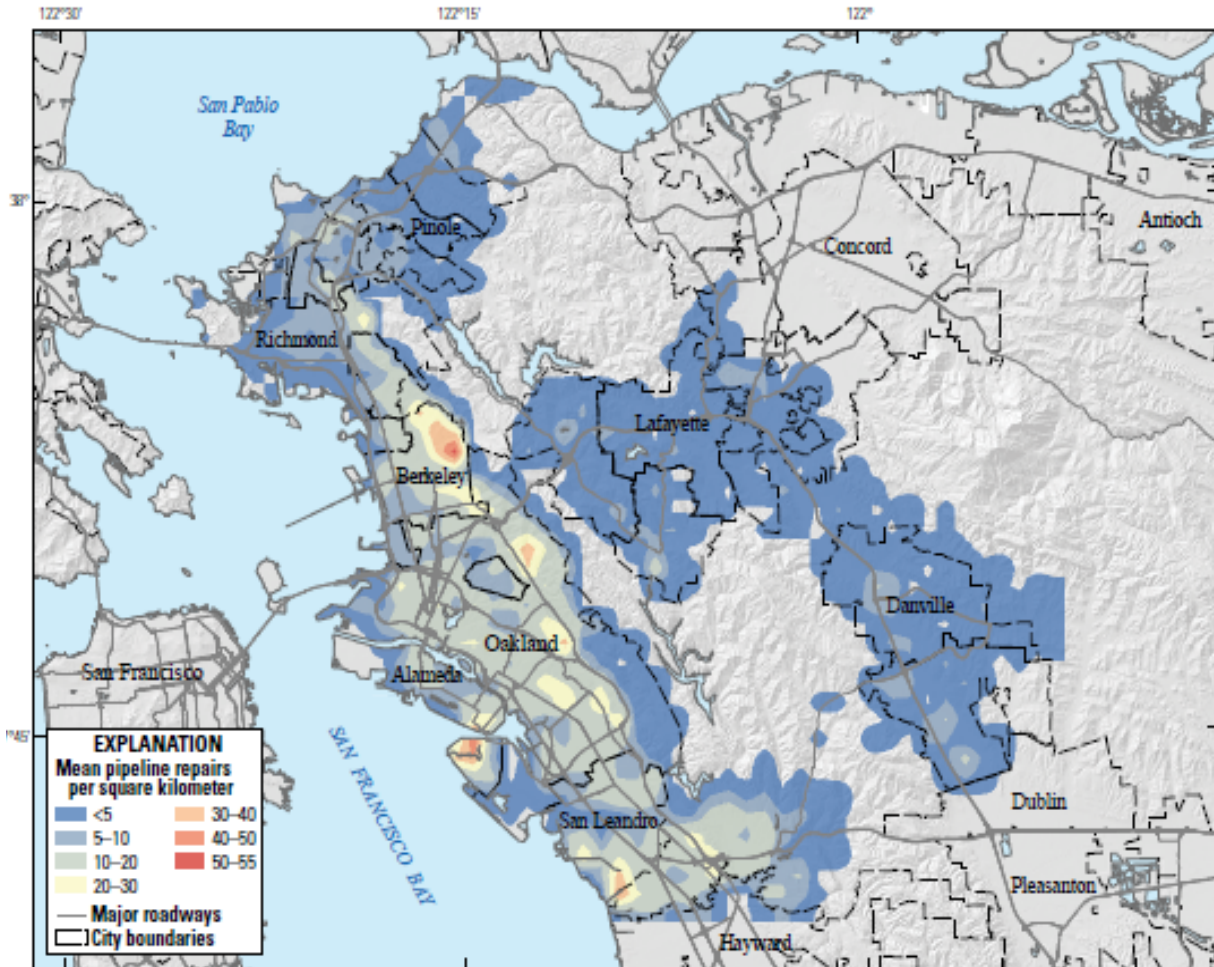




# SJW Fuel Plan - County



# EBMUD



Restoration curves

Repairs for HayWired mainshock and aftershocks