HayWired Scenario Exercise Toolkit Development and Trainings:

A Model for End-User Engagement with Scenario Results and Data

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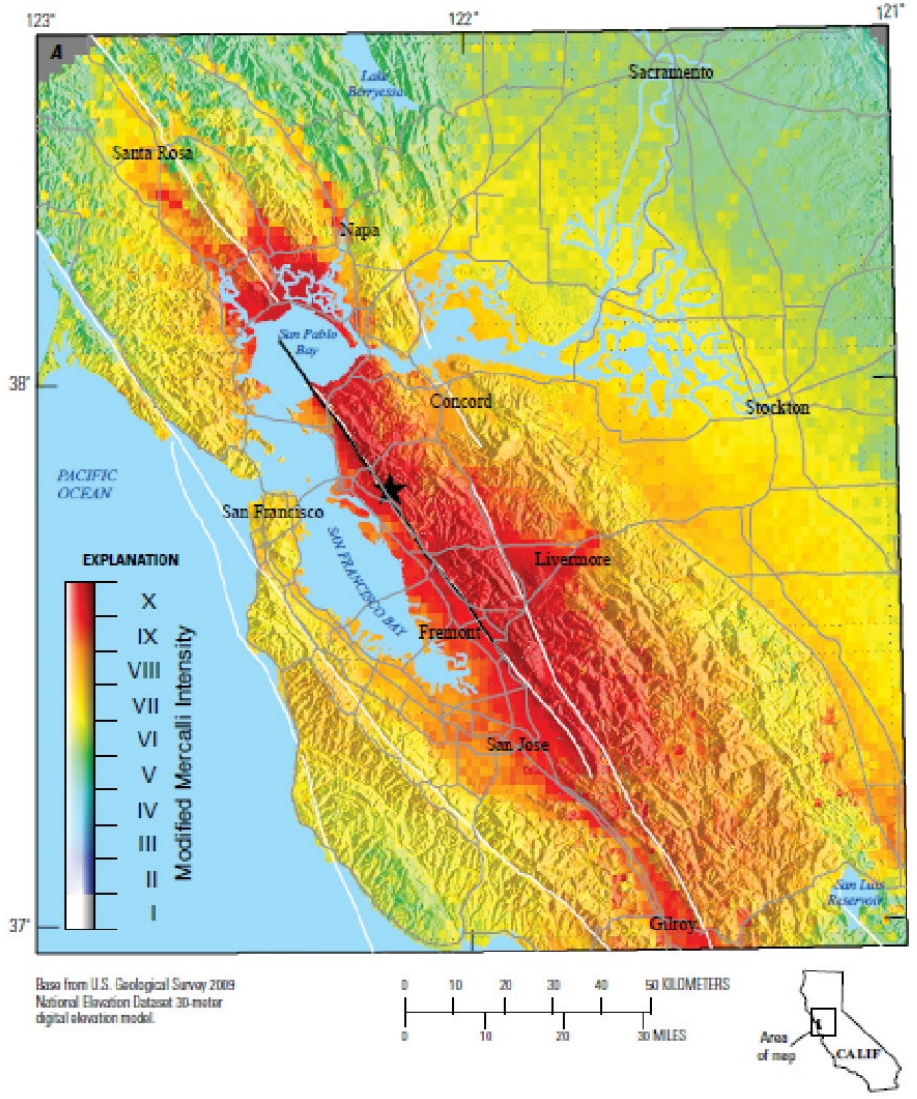
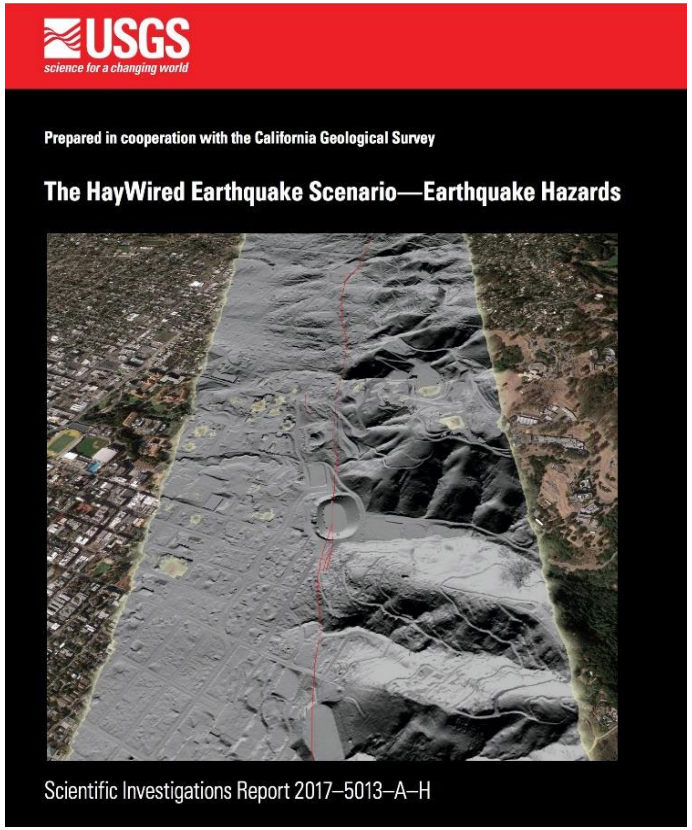
What is the HayWired Scenario?

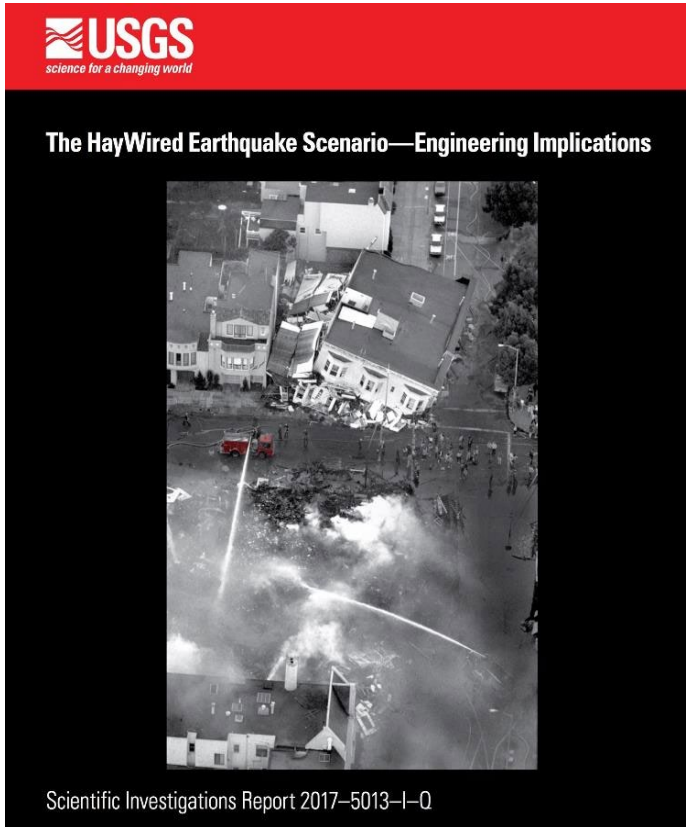
- Multi-year study led by the U.S. Geological Survey (USGS) and many partners
- Explores many impacts of a magnitude 7.0 earthquake on the Hayward Fault, centered near Oakland, and its aftershocks
- Importantly, the fault runs through a densely urbanized and interconnected region
- A resource for science communication and risk reduction, response, and recovery planning.

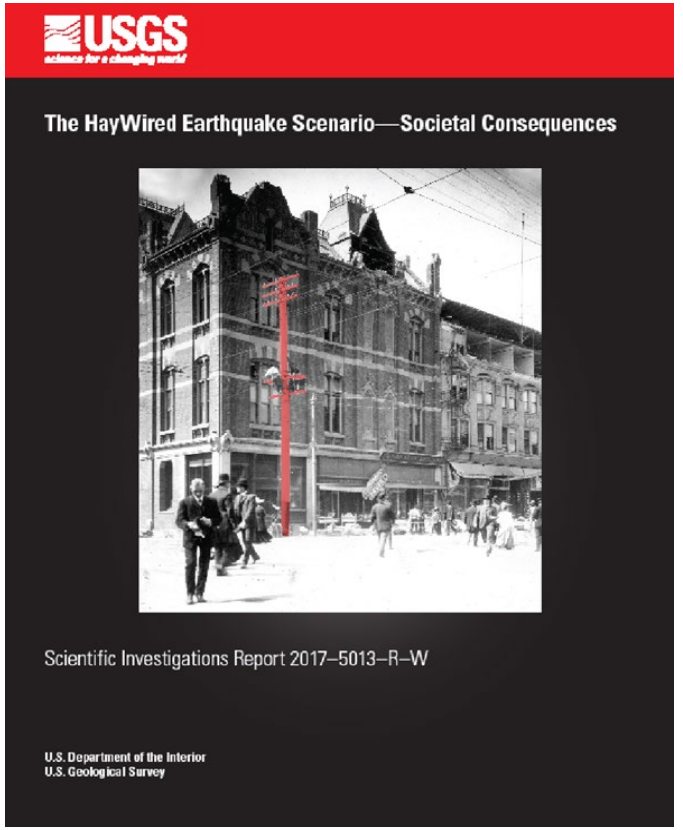
www.USGS.gov/HayWired



Scenario Information – Three volumes





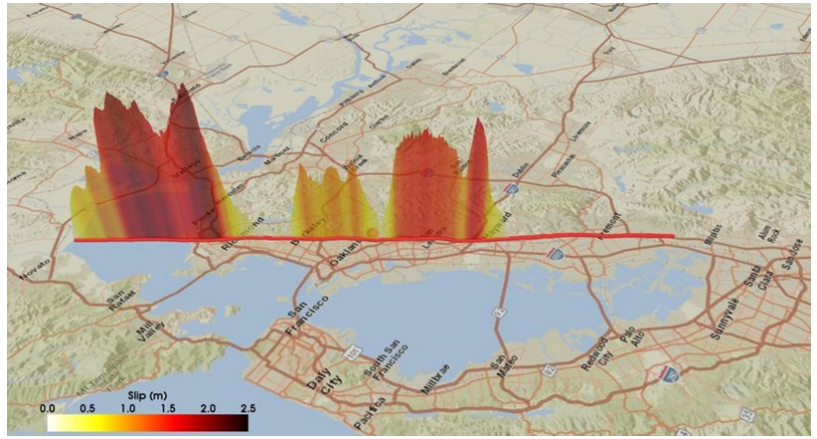


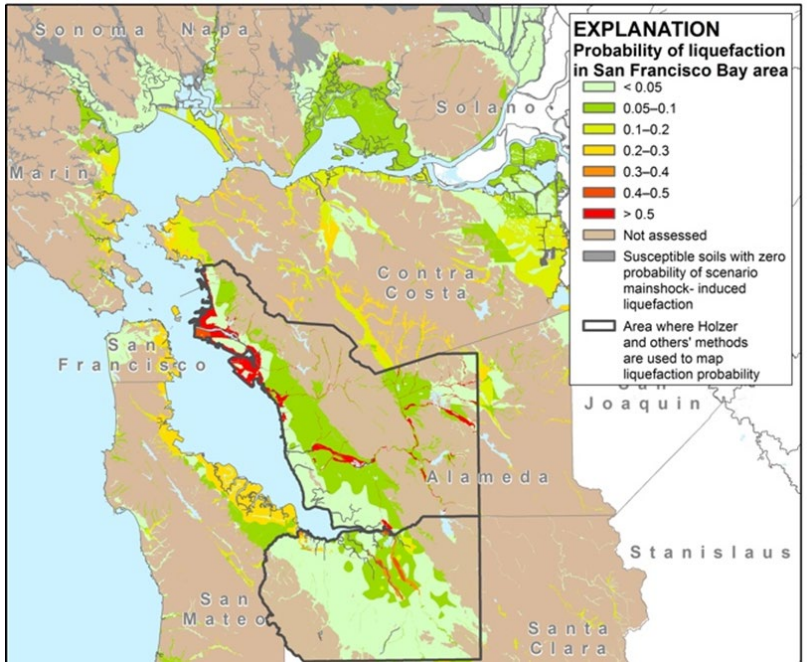
1. Earthquake Hazards
2. Engineering Implications
3. Societal Consequences

www.USGS.gov/HayWired

Earthquake Hazards – Ground Movement

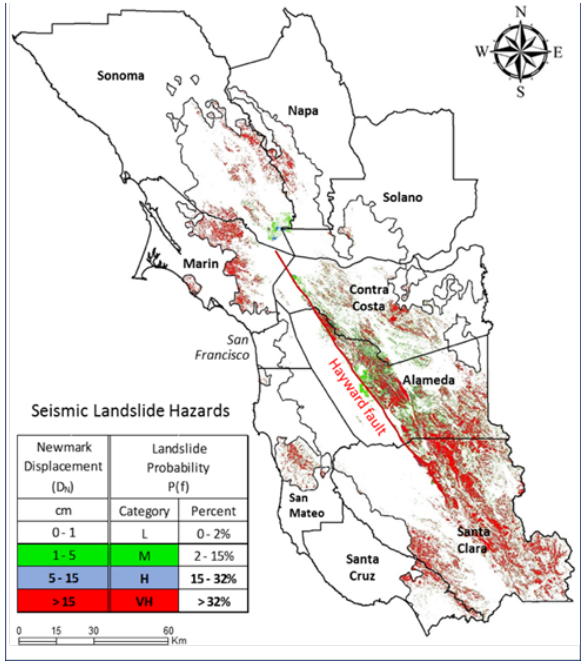
- Surface offset of up to 6 feet along the fault disturbs structures and infrastructures crossing it -- 100s of buildings, roads, fiber optic lines, fuel pipelines, water canals, water pipes, and power lines -- for days, weeks, months, and years following the earthquake.





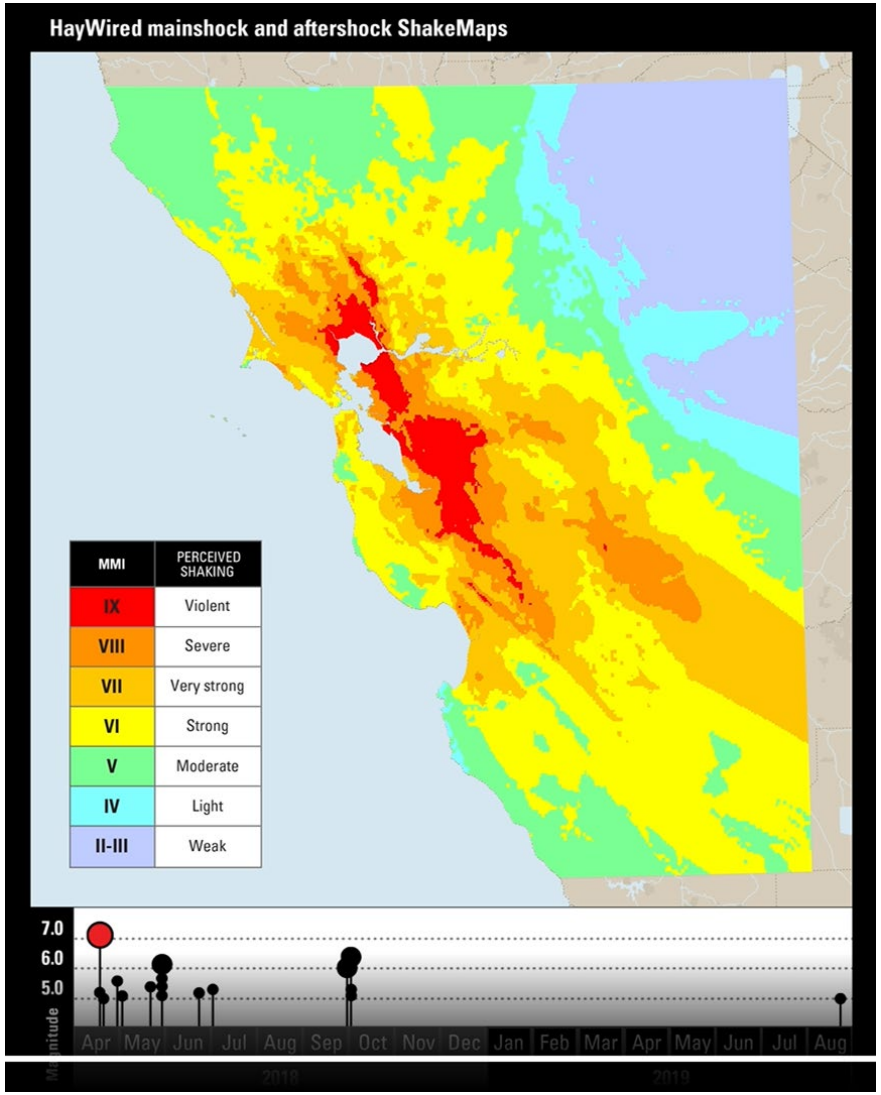
- Liquefaction damages residential & commercial areas in and around the margins of the Bay Area & along rivers.

- Landslides in the East Bay affect telecommunications, utility, and road infrastructures as well as residential areas.



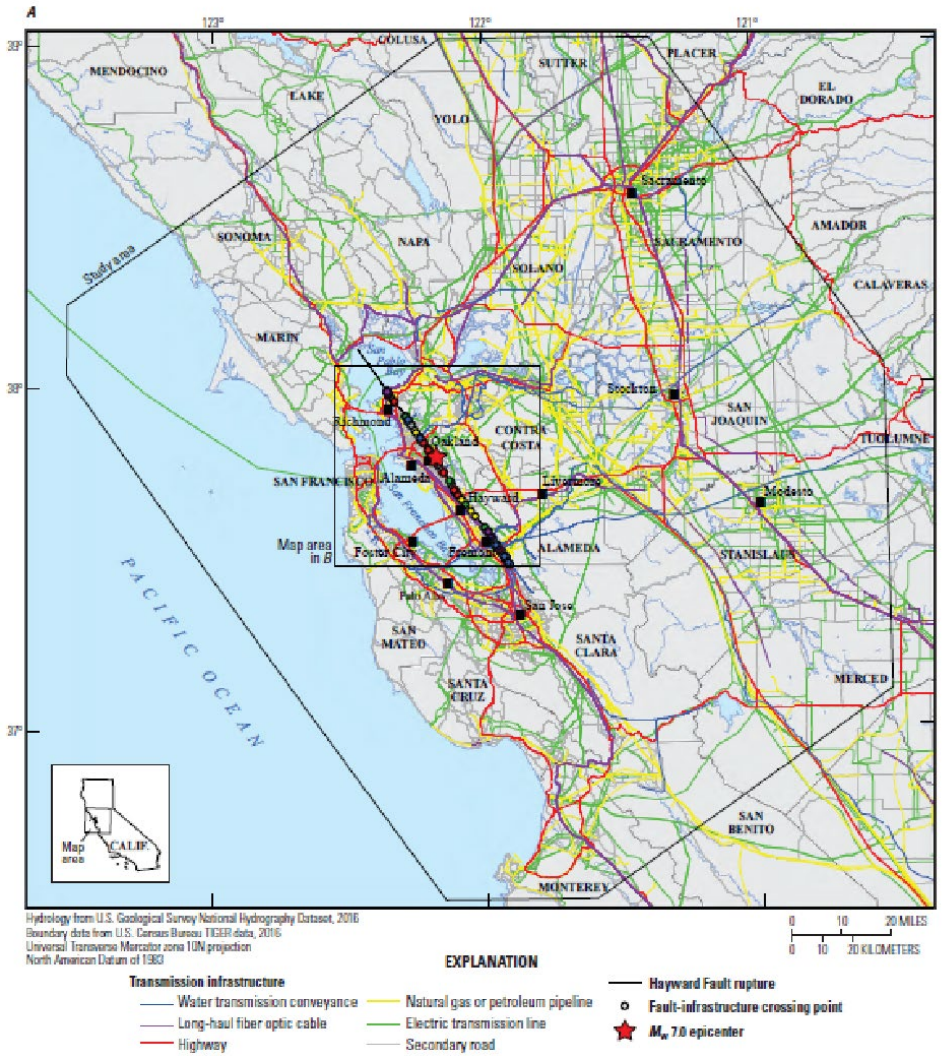
Earthquake Hazards - Shaking

- The strongest ground shaking is along the ruptured fault, to the north and south where shaking is directed, and in sedimentary basins in Livermore and east of San Jose.
    - The strongest ground shaking of the mainshock could damage well-designed structures.
- Some cities and towns in the south Bay experience greater ground shaking from aftershocks than from the mainshock.
    - The strongest aftershock shaking could damage poorly designed structures and those already weakened by the mainshock.



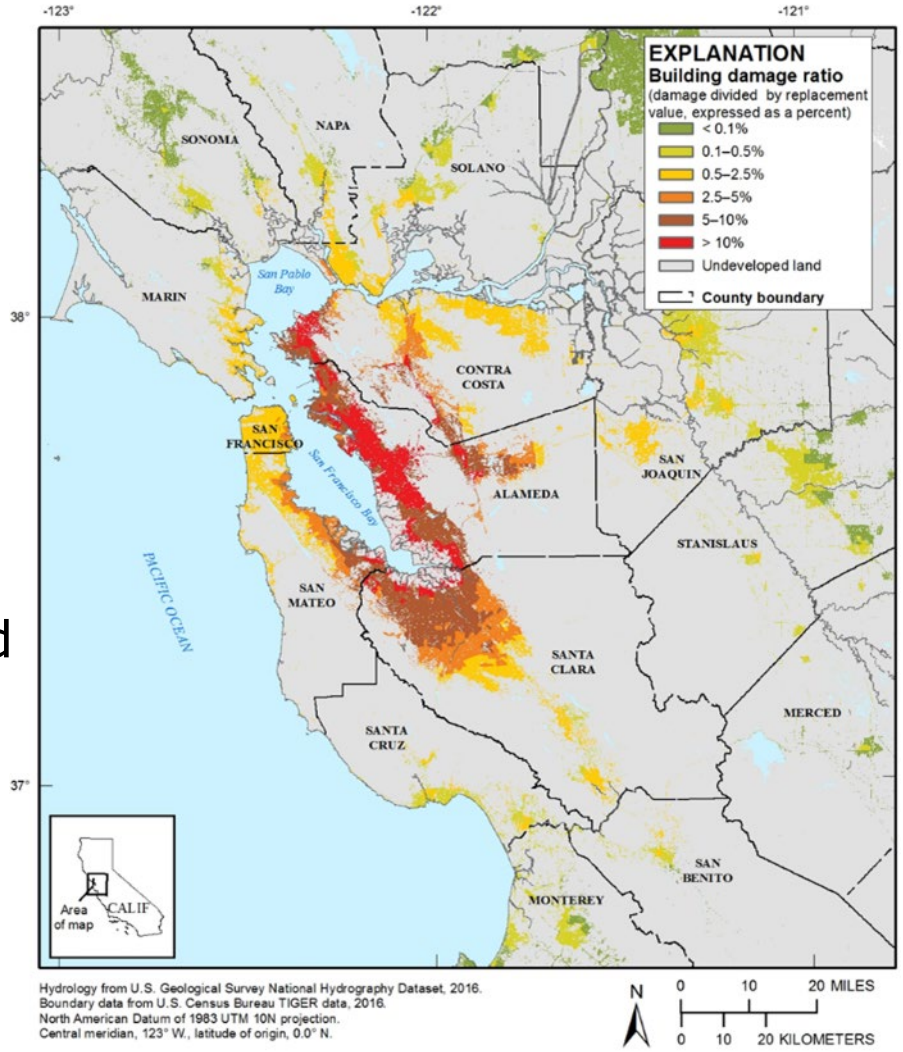
Engineering Implications – Lifeline Infrastructure

- Repair of 1000s of water distribution pipeline breaks and leaks to restore services take up to seven months.
- The percent of phone calls that get through and data transmission rates are reduced by power outages, telecommunications equipment failures, and network congestion.
- Co-located infrastructures may be prone to collateral damage and repair/restoration interdependencies.
- Service restoration times:
  - days to weeks for telecommunications
  - at least 10 days for fuel
  - weeks for electric power
  - months for gas, water, and highway systems
  - years for Bay Area Rapid Transit (BART) stations between Oakland & Fremont



Engineering Implications - Buildings

- 20,000 people trapped in elevators (stalled by widespread power outages) and 2,500 people trapped in collapsed buildings need rescue operations.
- Building repair costs, content, and inventory losses, and business relocation costs exceed $82 billion (2016)
- Costs increase above $100 billion (2016) when fires spread in dense wood-frame building neighborhoods.
- Pre-1970s steel-frame office buildings and newer reinforced concrete residential high-rise buildings (in downtown Oakland and San Francisco) suffer non-structural damage; uninhabitable for up to 10 months.
- Current building code = 0.4% collapse, 5% unsafe to occupy, 19% restricted use. More stringent codes could allow 95% of population to remain in homes & workplaces.

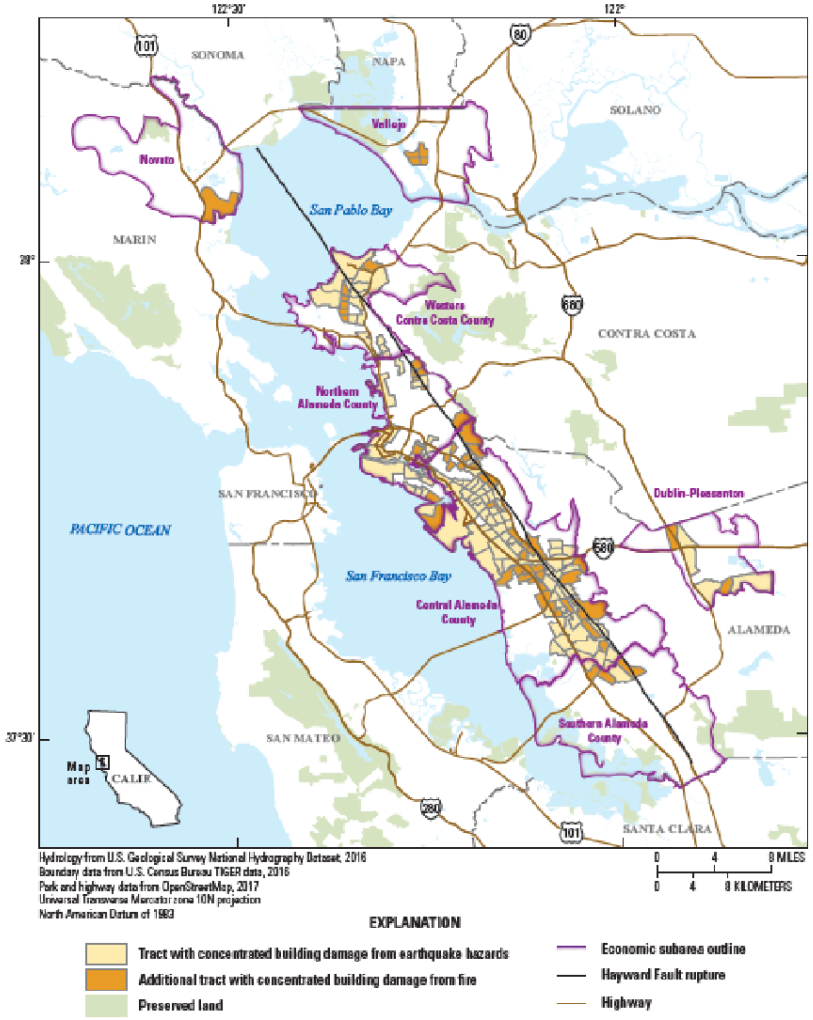


Societal Consequences - Communities

- Neighborhoods with concentrated building damage (see map), longer utility restoration, and extended transportation system recovery are most at risk for population displacement.

- Hundreds of thousands of people are displaced including a disproportionate number of socially vulnerable populations.

- Community recovery -- re-housing displaced populations & financing the rebuild -- is challenged in areas of concentrated building damage, liquefaction, landslides, and surface fault rupture.



Societal Consequences - Economic

- Property damages and commute disruptions cause most of the economic losses that ripple through supply chains.
- Business interruption from building damage peaks in central Alameda County and disproportionately affects industrial and warehouse sectors.
- 100s of 1000s of employees are affected by damage to their workplace, business district, home, neighborhood, and/or commute disruption.
- Implementation of business continuity practices reduces gross regional product losses in the first six months by 40% from $43 billion to $25 billion (2016).
- Recovery from a recession is boosted by reconstruction, but sensitive to cost increases and business relocations.

HayWired Scenario
EXERCISE TOOLKIT

A guide for creating discussion-based exercises using the HayWired Earthquake Scenario

USGS science for a changing world

Earthquake Country Alliance

CALIFORNIA RESILIENCY ALLIANCE

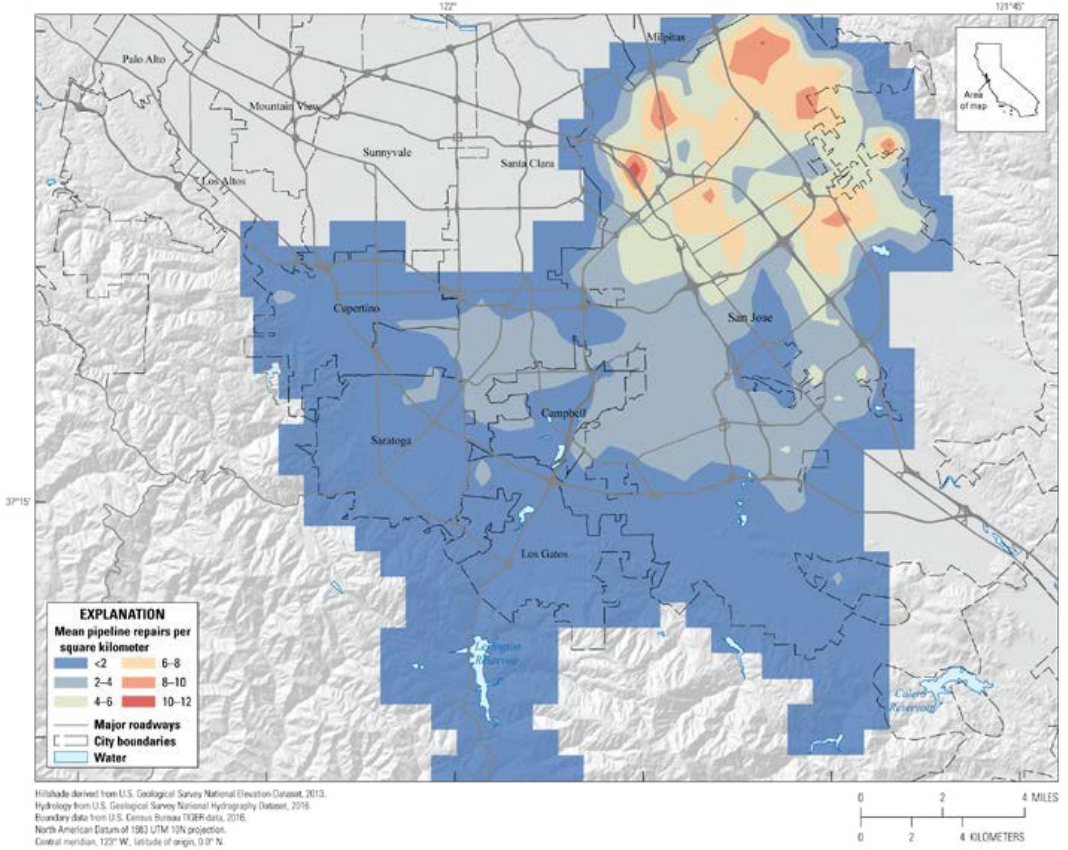
Why the HayWired Scenario is Useful for Exercises

- Emphasizes the variety of physical, technological, and societal impacts associated with the multiple hazards and cascading impacts of such an event.

- Insights gained from exercising for an earthquake can help us to better meet other more frequent challenges.

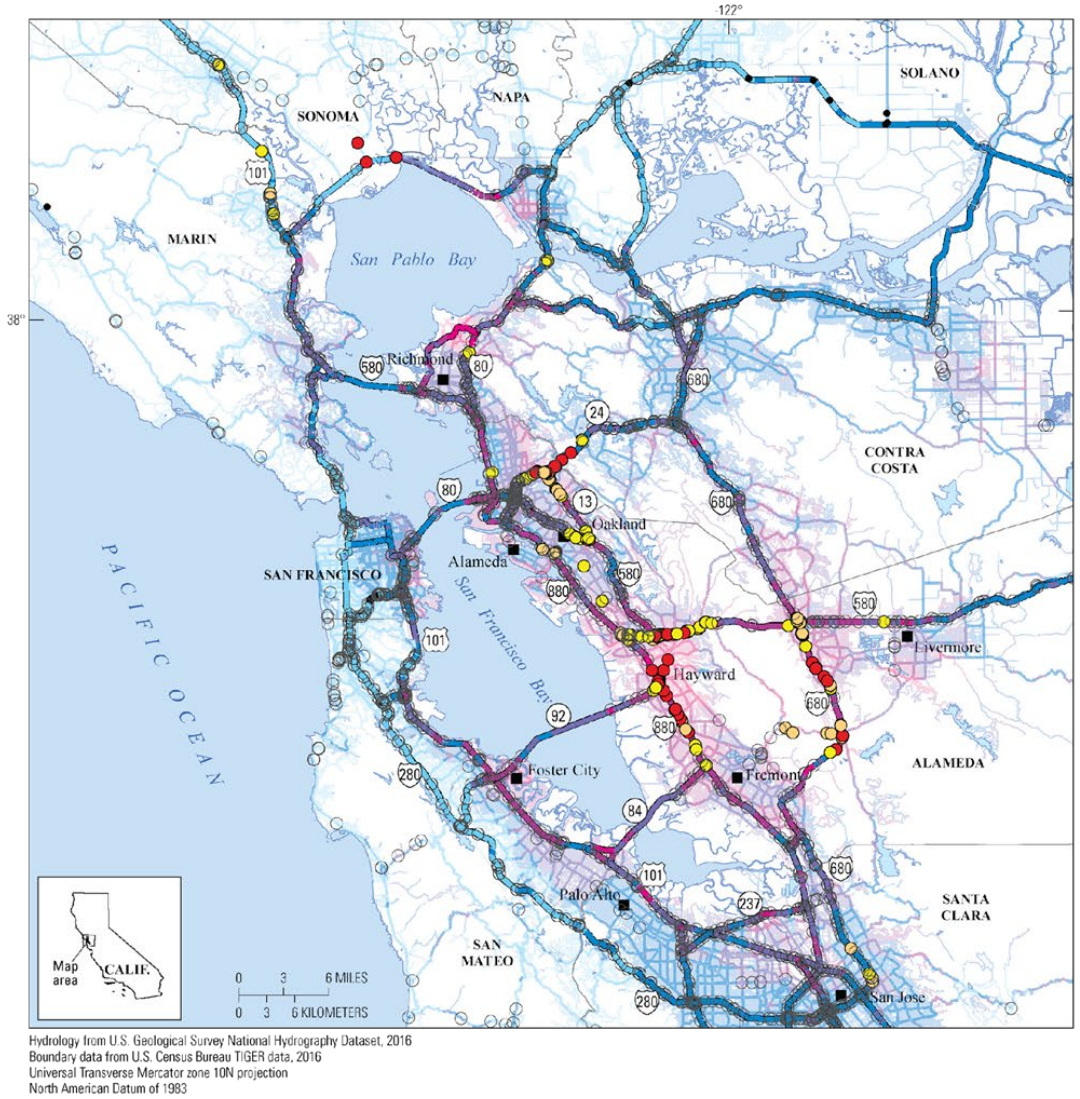
- The Toolkit is designed to help any organization plan, lead, and learn from **discussion-based exercises**.

EarthquakeCountry.org/haywired

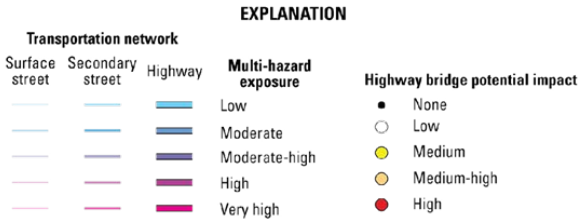


Number of water pipeline repairs needed per square kilometer after the earthquake, in San Jose and nearby areas.

The Wealth of Information in the Scenario



Multi-hazard exposure of roadways and potential impacts to California Department of Transportation highway bridges



Data Spanning Many Themes and Topics

Exposure of telecommunications infrastructure to HayWired earthquake scenario hazards in the San Francisco Bay region, California.

Total in study area	Fiber routes, long-haul (km)	Fiber routes, interoffice (km)	Cellular sites	Fiber-lit buildings, data centers	Fiber-lit buildings, central offices	Fiber-lit buildings, point of presence	Wireless switch offices	Internet exchange points	Microwave towers	AM radio antennas	FM radio antennas	NTSC television transmitters	Digital television transmitters
Fire following earthquake													
Percentage developed[1]	63%	60%	73%	98%	95%	95%	96%	100%	66%	22%	18%	11%	27%
Low exposure	1,029	7,882	2,054	287	158	14,650	11	8	905	9	7	0	0
Percentage exposed	17%	17%	25%	67%	23%	36%	21%	73%	24%	12%	2%	0%	0%
Moderate exposure	287	1,284	251	3	38	2,264	1	0	111	0	2	0	0
Percentage exposed	5%	2%	3%	1%	6%	6%	2%	0%	3%	0%	1%	0%	0%
High exposure	254	409	119	0	9	540	0	0	40	0	2	0	0
Percentage exposed	4%	1%	1%	0%	1%	1%	0%	0%	1%	0%	1%	0%	0%
Total exposure	1,570	9,575	2,424	290	205	17,454	12	8	1,056	9	11	0	0
Percentage exposed	26%	20%	29%	68%	30%	43%	23%	73%	28%	12%	3%	0%	0%

Toolkit Development Partners

As with the HayWired reports, partners from many organizations have helped to develop the Toolkit or provide feedback:

- United States Geological Survey (USGS)
- Statewide California Earthquake Center (SCEC)
- Earthquake Country Alliance (ECA)
- California Resiliency Alliance (CRA)
- Federal Emergency Management Agency (FEMA)
- California Governor's Office of Emergency Services (CalOES)
- California Geological Survey (CGS)
- Association of Bay Area Governments (ABAG)
- Bay Area Council Economic Institute
- Joint Venture Silicon Valley
- Bay Area Center for Regional Disaster Resilience
- Pacific Earthquake Engineering Research Institute (PEER)
- State of California Seismic Safety Commission (CSSC)

HayWired Toolkit & Facilitator Tools

- The Toolkit provides guidance for how to use the Scenario for Discussion Based Exercises
- Each set of *Facilitator Tools* includes:
  - *Discussion Guide*
    - Suggested exercise objectives
    - Recommended participants
    - Discussion questions to select from
    - Locations of relevant data in the Reports
  - *Imagery Slideset*
    - Relevant maps, charts, and tables from the Scenario reports
- Facilitators can follow closely, or use as inspiration for their exercises

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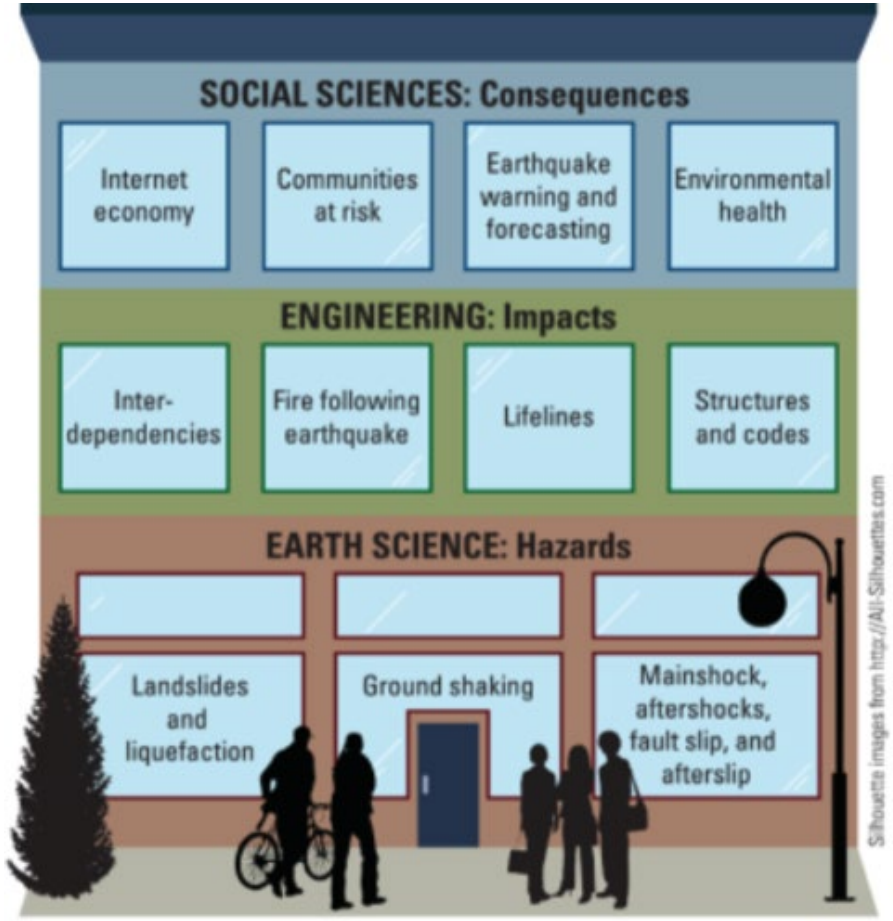
Section 2: Scenario Information



- Begins with an overview of key Scenario findings:
  - Earthquake Hazards
  - Engineering Implications
  - Societal Consequences
- Includes an annotated index connecting chapters of the HayWired Scenario Reports to the themes and topics suggested for exercises within the Toolkit.

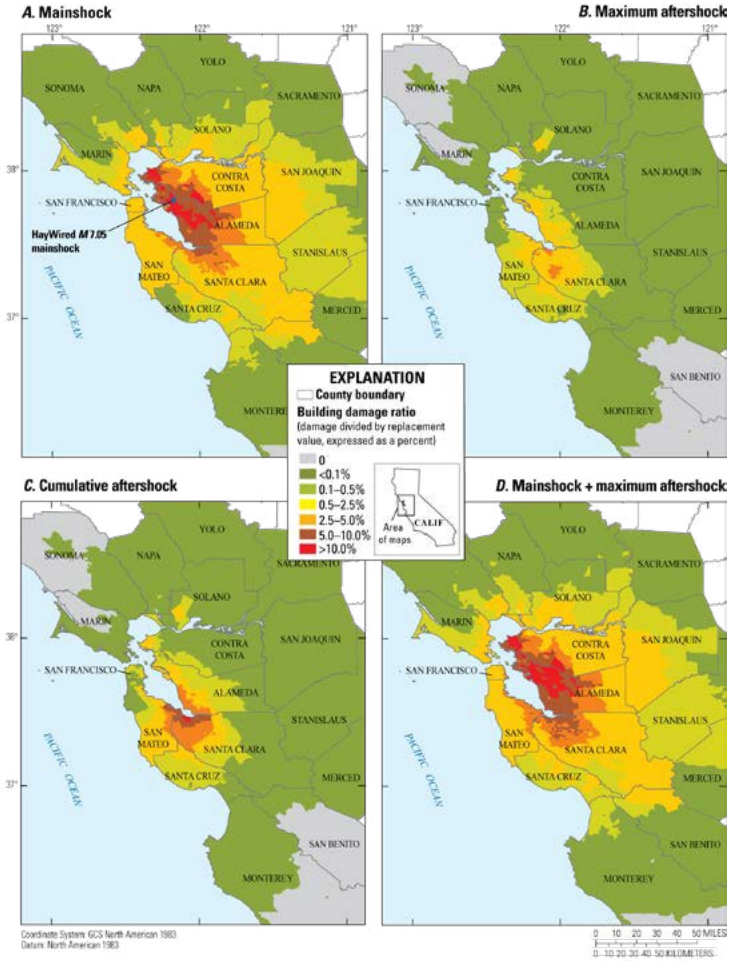
Volume 2: Engineering Implications

Chapter/ Pages	Chapter Title	Topics	Themes
J (p. 13-56)	HayWired Scenario—Hazus Analyses of the Mainshock and Aftershocks	Building Inventory Data; Hazus Results—HayWired Mainshock; HayWired Liquefaction and Landslide Implementation in Hazus; HayWired Landslide implementation in Hazus; Liquefaction	Aftershocks & Fault Afterslip; Alternate Locations; Building Contents; Clean-up; Structural & Non-Structural Building Damages

Section 3: Developing Your Exercise

- Guidance for developing a discussion-based exercise, with a corresponding planning worksheet
  - Basic questions to consider
  - How to select a theme/idea to exercise (with consideration for the different phases of emergency management)
  - Description of components needed:
    - Discussion objective
    - Key participants
    - Base scenario (specific for *your* exercise)
    - Discussion questions
    - Relevant data and visuals

Section 4: Facilitating Your Exercise



- Now that you have developed (or selected) the components needed for your exercise, this section provides best practices for how to:
  - Prepare your participants
  - Get started, including ground rules
  - Manage discussion dynamics - to involve all participants, manage the pace, etc.
  - Use visuals and data
  - Take notes to capture key results

Section 5: Implementing Lessons

- The goal of your exercise should be to enable continuous improvement by applying the lessons and insights learned.
- This section has suggestions for how to:
  - Capture lessons, insights, ideas, and actions
    - What gaps and vulnerabilities were identified?
    - What tasks and actions were identified?
    - What were the team's strengths?
  - Leverage results to improve everyday operations
  - Find answers to questions that remain unanswered
  - Follow through on actions and tasks

Appendix I: Exercise Themes

Exercise Ideas cover all four phases of the emergency management cycle:

Planning & Preparedness ⇨ Response ⇨ Recovery ⇨ Mitigation

Exercise Ideas span these themes:

Access to Data & Information
Accounting for Employees
Aftershocks & Fault Afterslip
Alternate Locations
Building Content
Clean-up
Communications & Internet
Customer Base
Elevators
Employee Commutes & Residences
Employee Retention & Staffing Shortages
Fire After the Earthquake
Fuel & Generators
Insurance
Utilities, Telecommunications, and Transportation in Fault Zones
Mail / Package Delivery
Mental Well-being
Natural Gas & Power
ShakeAlert
Structural & Non-Structural Damages
Supply Chains / Movement of Goods
Utility Shutoffs
Wastewater / Sewer
Water
Working Remotely

Ideas can be layered and combined to build more complex exercises.

Appendix I: Exercise Themes & Ideas

- The Toolkit identifies **30 Themes** addressed in the scenario, spanning **45 ideas** for discussion-based exercises; these are organized within each emergency management phase.
- Document symbols indicate the **20 *Facilitator Tools*** created based on suggested ideas

Mitigation: Reducing vulnerabilities and the impacts of hazards

Theme	Exercise Ideas
Access to Data & Information	**Issue:** This Scenario disrupts electric power and connectivity to data services, with restoration timelines varying by infrastructure types and location. The earthquake may impact your ability to access records. **Idea:** Identify options to reduce the risk of losing access to important data and information you will need post-earthquake. **HayWired Scenario Report References:** Volume 3 (Chapter S and T)
Building Contents	**Issue:** This Scenario upsets building contents and overturns unanchored equipment. **Idea:** In each of your work and storage areas, identify supplies and equipment that have the potential for moving, falling, or tipping. For items posing safety risks and/or higher monetary loss, identify how you can secure them or otherwise minimize the risk. **HayWired Scenario Report References:** Volume 2 (Chapters J and Q); Volume 3 (Chapter S)

Facilitator Tools

TOPICS	EMERGENCY MANAGEMENT PHASE
Access to Data & Information	Mitigation
Aftershocks & Fault Afterslips	Recovery
Building Content	Mitigation
Communications & Internet	Planning & Preparedness
Communications & Internet	Response
Economic Impact	Recovery
Employee Commutes & Residences	Planning & Preparedness
Employee Retention & Staffing Shortage	Recovery
Fire After the Earthquake	Mitigation
Food Access & Insecurity	Planning & Preparedness
Fuel	Planning & Preparedness
Mail & Package Delivery	Response
Mental Wellbeing	Recovery
Natural Gas	Response
Payroll	Planning & Preparedness
Power	Recovery
Supply Chain & Movement of Goods	Mitigation
Supply Chain & Movement of Goods	Planning & Preparedness
Wastewater & Sewers	Response
Water	Planning & Preparedness

Facilitator Tools

- Each set of *Facilitator Tools* includes:
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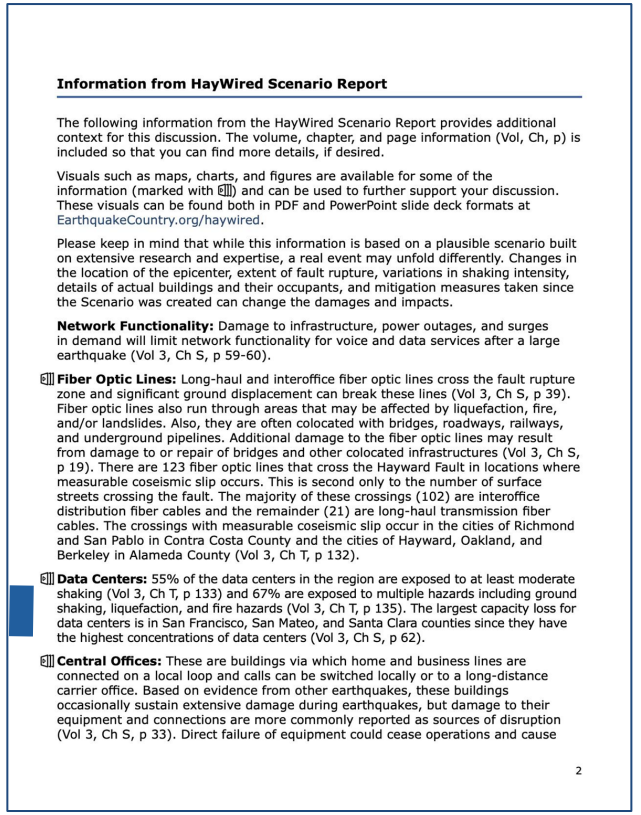
Data from HayWired Scenario Report

Data Centers:

55% of the data centers in the region are exposed to at least moderate shaking (Vol 3, Ch T, p 133) and 67% are exposed to multiple hazards including ground shaking, liquefaction, and fire hazards (Vol 3, Ch T, p 135).

The largest capacity loss for data centers is in San Francisco, San Mateo, and Santa Clara counties since they have the highest concentrations of data centers (Vol 3, Ch S, p 62).



Information from HayWired Scenario Report

The following information from the HayWired Scenario Report provides additional context for this discussion. The volume, chapter, and page information (Vol, Ch, p) is included so that you can find more details, if desired.

Visuals such as maps, charts, and figures are available for some of the information (marked with ▥) and can be used to further support your discussion. These visuals can be found both in PDF and PowerPoint slide deck formats at EarthquakeCountry.org/haywired.

Please keep in mind that while this information is based on a plausible scenario built on extensive research and expertise, a real event may unfold differently. Changes in the location of the epicenter, extent of fault rupture, variations in shaking intensity, details of actual buildings and their occupants, and mitigation measures taken since the Scenario was created can change the damages and impacts.

Network Functionality: Damage to infrastructure, power outages, and surges in demand will limit network functionality for voice and data services after a large earthquake (Vol 3, Ch S, p 59-60).

▥ **Fiber Optic Lines:** Long-haul and interoffice fiber optic lines cross the fault rupture zone and significant ground displacement can break these lines (Vol 3, Ch S, p 39). Fiber optic lines also run through areas that may be affected by liquefaction, fire, and/or landslides. Also, they are often colocated with bridges, roadways, railways, and underground pipelines. Additional damage to the fiber optic lines may result from damage to or repair of bridges and other colocated infrastructures (Vol 3, Ch S, p 19). There are 123 fiber optic lines that cross the Hayward Fault in locations where measurable coseismic slip occurs. This is second only to the number of surface streets crossing the fault. The majority of these crossings (102) are interoffice distribution fiber cables and the remainder (21) are long-haul transmission fiber cables. The crossings with measurable coseismic slip occur in the cities of Richmond and San Pablo in Contra Costa County and the cities of Hayward, Oakland, and Berkeley in Alameda County (Vol 3, Ch T, p 132).

▥ **Data Centers:** 55% of the data centers in the region are exposed to at least moderate shaking (Vol 3, Ch T, p 133) and 67% are exposed to multiple hazards including ground shaking, liquefaction, and fire hazards (Vol 3, Ch T, p 135). The largest capacity loss for data centers is in San Francisco, San Mateo, and Santa Clara counties since they have the highest concentrations of data centers (Vol 3, Ch S, p 62).

▥ **Central Offices:** These are buildings via which home and business lines are connected on a local loop and calls can be switched locally or to a long-distance carrier office. Based on evidence from other earthquakes, these buildings occasionally sustain extensive damage during earthquakes, but damage to their equipment and connections are more commonly reported as sources of disruption (Vol 3, Ch S, p 33). Direct failure of equipment could cease operations and cause

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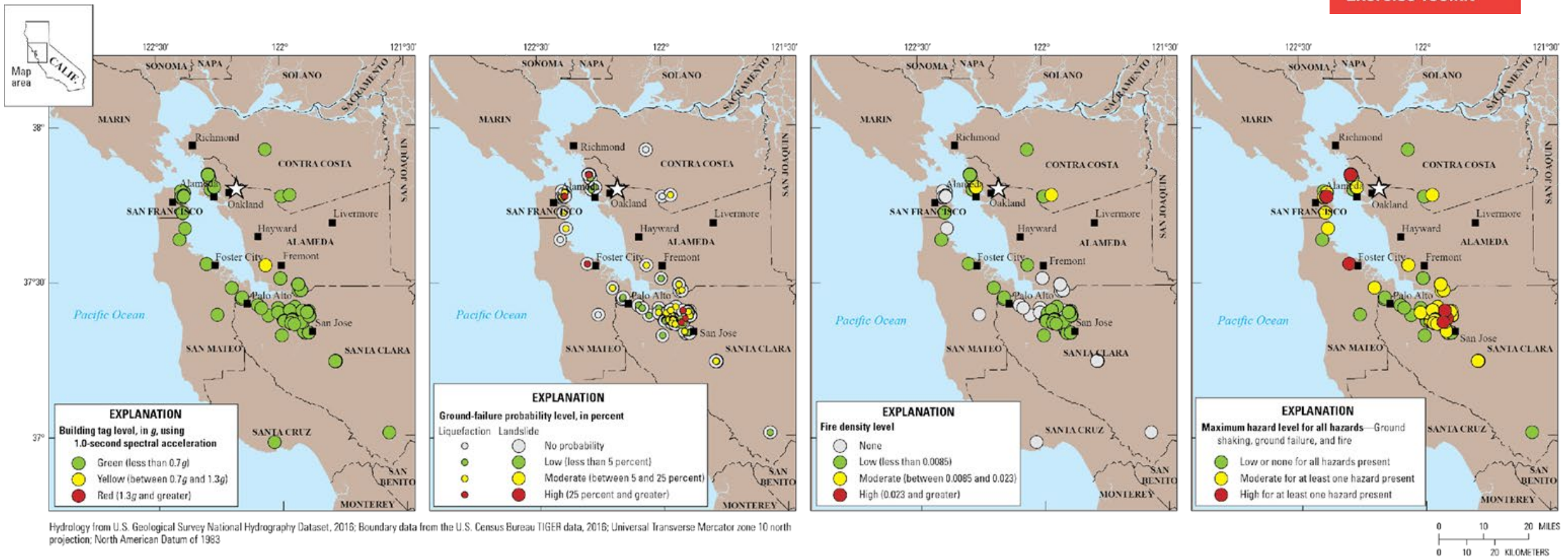
HayWired Exercise Toolkit
Facilitator Tool Discussion Guide
Access to Data and Information



Maps showing damage and exposure to HayWired Earthquake Scenario mainshock hazards for data centers. White star shows the mainshock epicenter. Descriptions of the 4 maps: *A*, Map of potential building tagging from shaking for data centers assuming moderate code (overturning of unanchored equipment also possible in yellow-tagged and red-tagged buildings). *g* is acceleration due to gravity. *B*, Map of data center exposure to ground-failure hazards (liquefaction and landslide). *C*, Map of data center exposure to fire following earthquake hazards (represented by fire density level—burned-building square footage relative to the developed area containing the fires). *D*, Map of data centers affected by maximum level of hazard from shaking, ground failure, and fire.

Training Workshops

- 12 USGS-funded workshops have been held around the Bay Area (and 1 in Los Angeles) to introduce the Toolkit and provide trainings for discussion-based exercises.
- Each workshop included an exercise using one of the Facilitator Tools, developed by Monika Stoeffl (CRA)
  - Attendees were provided roles within mock organizations to discuss the issues presented and develop strategies
  - More than 200 representatives of large and small businesses, non-profit organizations, government agencies, and community groups have participated.