Regional Resilience Initiative

Infrastructure Policy Paper

March 2013

Photo source: www.earthquake.usgs.gov

earthquake and hazards program
Association of Bay Area Governments

Credits

Principal Authors

Danielle Hutchings Mieler
Earthquake and Hazards Program Coordinator
Dana Brechwald
Earthquake and Hazards Specialist

Design and Production

Dana Brechwald
Earthquake and Hazards Specialist

ABAG Executive Staff

Ezra Rapport
Executive Director
Patricia M. Jones
Assistant Executive Director
Kenneth Moy
Legal Council
Miriam Chion
Planning and Research Director

ABAG Executive Board Leadership

Mark Luce
President
Supervisor, City of Napa
Julie Pierce
Vice President
Mayor, City of Clayton
Mark Green
Immediate Past President
Mayor, City of Union City

ABAG Regional Planning Council

Erin Hannigan
Supervisor, County of Solano
John Holtzclaw
Sierra Club
Tim Sbranti
Mayor, City of Dublin
Jeremy Masden
Executive Director, Greenbelt Alliance
Allen Fernandez Smith
Executive Director, Urban Habitat
Nate Miley
Supervisor, County of Alameda
Desley Brooks
Councilmember, City of Oakland
Julie Pierce
Mayor, City of Clayton
Harry Price
Mayor, City of Fairfield
Mark Ross
Vice Mayor, City of Martinez
Kristina Lawson
Councilmember, City of Walnut Creek
Pixie Hayward Schickele
California Teachers Association
Carol Severin
East Bay Regional Parks District Board of Directors
James P. Spering
Supervisor, County of Solano
Egon Terplan
Planning Director, SPUR
Karen Mitchoff
Supervisor, Contra Costa County

ABAG Publication Staff

Kathleen Cha
Senior Communications Officer, Editorial Assistance
Leah Zippert
Communications Officer, Editorial Assistance
Halimah Anderson
Communications Officer, Editorial Assistance

Project Consultants

Arrietta Chakos
Urban Resilience Strategies
Paula Schulz
Natural Hazards Mitigation

A special thanks to all participants in our workshop series, who provided the basis for our Policy Papers.

Thanks also to our interviewees, who provided detailed input essential to the development of these papers:

Doug Ahlers
Adjunct Lecturer in Public Policy, Harvard Kennedy School
Renee Domingo
Director of Emergency Services and Homeland Security, City of Oakland
Rich Eisner
Regional Administrator, Director of Earthquake and Tsunami Programs, Governor's Office of Emergency Service (retired)
Peter Ohtaki
Executive Director, California Resiliency Alliance
Julie Pierce
Mayor, City of Clayton
Sue Piper
Communications Director, City of Oakland (retired)
Chris Poland
Chairman and Senior Principal, Degenkolb Engineers
Laurel Prevetti,
Assistant Planning Director, City of San Jose
Bruce Riordan
Staff Consultant, Joint Policy Committee
Julie Sinai
Director, Local Government and Community Relations, University of California, Berkeley
Tom Tobin
President, Earthquake Engineering Research Institute
Will Travis
Staff Consultant, Joint Policy Committee (retired)

This project was generously funded by the Bay Area Urban Area Security Initiative (UASI)

ASSOCIATION OF BAY AREA GOVERNMENTS
Mailing Address: P.O. Box 2050, Oakland CA 94604-2050
Location: Joseph P. Bort MetroCenter, 101 8th Street, Oakland CA
(P) (510) 464-7900 (F) (510) 464-7979

ABAG Publication # P13001EQK

Background

In the wake of a major disaster, the recovery of major infrastructure systems will play a large role in our ability to recover quickly and effectively. Many recovery activities are highly dependent upon these systems. For example, goods movement - including supplies for rebuilding and daily goods and food for resuming daily lives - depends on a workable transportation system. People will not be able to stay in their homes if water and wastewater services are not available, and businesses will not be able to reopen. Repairing failed infrastructure systems and restoring their services are vital to the recovery of the Bay Area after a disaster, and failure to do so quickly and efficiently will result in widespread and long ranging, potentially devastating impacts.

Many of our significant infrastructure systems are vulnerable to damage in earthquakes.[1] The majority of the Bay Area population resides along two transportation corridors along major fault lines. Highway 101, connecting the South Bay to the Peninsula and the North Bay, parallels the San Andreas Fault and Highways 580 and 880, linking the South Bay to the East Bay and Solano County, are situated on and adjacent to the Hayward fault.

Nearly every major east-west connection that the Bay Area depends on upon for water, power, gas and transportation crosses several major faults. Hundreds of streets underlain with transmission lines also cross faults. In an earthquake, these major lifelines transmission systems will be damaged by significant lateral movement caused by crossing fault lines. East Bay Municipal Utility District (EBMUD) estimates that 40 percent of its customers will be without water, and that it could take as many as 50 days to restore full service.[2] Similarly San Francisco Public Utilities Commission estimates that until its Hetch-Hetchy pipeline retrofit is complete in 2014, a major earthquake could cause catastrophic failure of the pipeline, which could take as long as 60 days for full repair.[3] The liquefaction prone margins of the Bay will cause additional infrastructure damage, particularly for sewer treatment plants, the Port of Oakland and the San Francisco and Oakland airports.

Many issues will impact our ability to quickly repair damaged infrastructure. These warrant further understanding and study now, before a disaster, so stakeholders are better prepared to face the complex task of restoring infrastructure systems when disaster hits.

The major infrastructure systems included in the recommendations set forth in this paper are:

- Power systems
  - Electricity generation and transmission
  - Oil and natural gas pipelines
- Water and wastewater
  - Treatment
  - Transmission systems
- Transportation systems
  - Local roads
  - Highways
  - Public transportation systems – buses, rail and ferries;
- Telecommunications systems
  - Phone and data lines

Other significant infrastructure systems in the Bay Area not included in this initial study include gas refineries, airports and ports. Each system depends on physically or virtually linked elements to stay operational. These elements range from the people who operate and control the systems; mechanical and electrical equipment; transmission lines; buildings that house operations and equipment; and information systems that process large amounts of data. In a disaster, all these elements are vulnerable to damage from ground shaking, liquefaction, landslides, fire, or flooding, and damage to just one portion of the system may cause complete failure in all or part of the system, cutting off services to customers. Cascading systems' failure is a norm in metropolitan disruptive events due to tightly coupled infrastructure mechanics.

1 This section is largely adapted from 1868 Hayward Earthquake: 140-Year Retrospective, RMS November 2010. Modeled loss estimates consider post-event loss amplification.

2 "EBMUD: A Decade of Seismic Mitigation Progress – More Work to Do." Presented at ABAG's Regional Planning Committee, December 3 2008 by Bill Cain.

3 City and County of San Francisco Emergency Response Plan, Earthquake Annex. (April 2008).

Infrastructure systems are interdependent and will not be able to be fully restored without the repair of corresponding, upstream structures. For example, treating wastewater is dependent upon power systems to operate pumps and other equipment. Because of such dependencies and links, it can be very difficult to make assumptions about how disasters will impact a particular system or how recovery will take place if the impacts to lateral or upstream system are unknown. Interdependencies also create new or exacerbate existing failures over time if not promptly resolved. The implications of delayed recovery due to interdependencies are largely unknown. Salient lessons in social restoration and recovery can be found from recent regional disasters such as the 2011 Tohoku earthquake and 2012 Superstorm Sandy and can be applied in other disaster-prone regions.

The fragmented nature of infrastructure system ownership and regulations exacerbate barriers to recovery planning and impact the ability to address the vulnerability of the interdependency of physical systems. Many utility systems are privately or jointly owned and vary widely in size, control, access to resources, accountability, age, seismic standards, guidelines, and code requirements. In total, there are over 500 special districts with overlapping jurisdictions that provide services within the Bay Area. The California Utilities Emergency Association represents California utilities on emergency related issues, but currently there is no forum for utility leaders to coordinate with other owners within the Bay Area and plan for recovery and restoration, so providers may not have a comprehensive understanding of how their systems fit in with other systems. Multiple owners or service providers can lead to a wide variety of practices, technologies, and mitigation standards within any given sector. This diversity creates problems with understanding, anticipating, and coordinating disaster recovery activities.

Goal #1: Increase technical understanding of region-wide infrastructure system vulnerabilities

Currently, few understand the ways in which systems are interdependent. The information that is available is largely based on speculation, not rigorous analysis. The region needs peer-reviewed technical studies to better understand system vulnerabilities and what consequences may result from cascading failures. Some of this information is considered confidential for security reasons; however, information should be shared at levels of detail sufficient to understand how to resolve issues post-earthquake.

New technologies can assist with gathering technical data for analysis, but may increase vulnerability as operators of interdependent infrastructure systems become more reliant on virtual systems to monitor and control infrastructure. While technology has the potential to provide greater and more sophisticated information on system performance, it also introduces new interdependencies on power and IT systems because of reliance on computer servers. For example, Pacific Gas and Electric (PG&E)'s Smart Grid system provides better, more accurate information about the power system if it is operational. But reliance on specialized technology can make systems more difficult to restore and requires improved human expertise and intervention in crises, which can impede restoration and recovery.

We need a detailed understanding of how interdependencies interact and what impacts might occur in disruptions due to disasters. The following actions suggest how this might be done.

I-1: Establish regional baseline assessment and system performance standards to identify vulnerabilities and define interdependencies

Current methods for evaluating system performance in a disaster typically involve the use of an earthquake scenario to anticipate ground shaking and what damage and loss may occur. This loss estimate is then reviewed together with interviews of staff with technical expertise in different system components and operations. Performance findings for multiple system components and their links then

need to be aggregated to comprehensively understand the workings of the complete system. This approach leads to a qualitative and holistic understanding of vulnerabilities, but is limited by incomplete human understanding and interpretation. [4]

Other analytic tools include computer modeling of systems using software programs that generate disaster loss estimates based on specific disaster scenarios, including HAZUS or systems' visualization applications developed for the defense industry. These methods provide a vulnerability snapshot of systems and system components. Elements of these assessments include information on component fragility, system fragility, and critical data on functionality, repair time, and repair cost.

It is crucial to note that smaller service providers may lack resources to use existing tools effectively, or may not have accurate results due to lack of technical expertise in failure studies. Both qualitative and quantitative analyses offer data on typical systems' failures operators may encounter in disasters, which can support improved crisis response and provide powerful motivation to implement pre-disaster recovery planning.

The region needs to establish common tools for evaluation and assessment, and build consensus around the type of analysis and how to present findings. One way to begin this is to establish common earthquake scenarios for evaluating systems so consequences can be compared and interdependencies are defined across the region. San Francisco's Lifelines Council utilizes a repeat of the 1906 earthquake as its assessment scenario; this 7.9 San Andreas Fault earthquake falls within San Francisco Planning and Urban Research (SPUR)'s definition of an "Extreme" earthquake scenario.

SPUR's *Resilient City* reports typically base recommendations on an "Expected" earthquake, defined as a 7.2 San Andreas quake, the same used for San Francisco's Community Action Plan for Seismic Safety program. Both of these scenarios are appropriate for San Francisco, but other scenarios such as a Hayward Fault event, may be more useful for planning in other Bay Area locations. Therefore, utilizing multiple planning scenarios may be productive for regional planning purposes. The common earthquake scenarios should be severe enough and present a wide enough scope of damage to be realistic and useful, but should not be so extreme that mitigation strategies would be seen as too costly.

We need to, as a region, assess the existing state of infrastructure systems, much of which is aging, deteriorating, and functioning at capacities beyond their original design, which all increase vulnerability. ABAG has helped lead local efforts to assess infrastructure in Priority Development Areas (PDAs), but this effort should be expanded and considered through the lens of seismic vulnerability. Considering that much of our infrastructure is buried or difficult to acquire data on, new methods should be identified and shared for quantifying in-situ conditions. Such assessment techniques include remote sensing technologies, sensors, use of cameras and video cameras, and component testing. Existing assessments done by utilities should also be collected and made publicly available.

Regional infrastructure stakeholders could conduct and share research on evaluations, best practices, and recommendations for effective and uniform analysis of vulnerabilities. This might include common assumptions about what magnitude of earthquake to use as the basis for analysis and mitigation, and improve regional understanding about possible disaster losses.

I-2: Conduct a regional assessment of system interdependencies and the consequences of cascading failures

Similar to San Francisco Lifelines Council's current lifeline qualitative review, the region should conduct a high-level assessment of Bay Area infrastructure systems to identify and assess critical interdependencies. The study could be based on a standardized earthquake scenario or scenarios and identify and assess lifeline systems by performance

4 This approach is similar to the one taken by the San Francisco Lifelines Council for their Lifelines Interdependency Study. For more information on this approach, see http://sfgsa.org/index.aspx?page=4964

Transmission lines carrying power and phone services to the city of San Francisco. Sutro tower is perhaps the city's most well-known antenna tower in the city, transmitting television signals to residents since 1973. Photo source: Window Snyder, www.dec.net

(similar to SPUR's performance categories) along with peer-reviewed approaches. Then communities can prioritize system improvements based on defined performance targets that suggest key mitigation actions.

Understanding vulnerabilities is a first step that must be followed by defining disaster consequences. Infrastructure failures have direct and indirect economic, environmental, and societal consequences, ranging from lost revenue to a store without power to public health issues due to lack of wastewater treatment.

We need better tools to understand the short and long-term consequences to the regional economy from infrastructure failures, including how time and geographical scales impact economic consequences. Attempting to understand the number of people who will be directly affected and the severity of the consequences can also be a significant motivator for developing a better recovery plan.

I-3: Evaluate the usefulness of creating performance targets to establish region-wide performance goals for all infrastructure systems

In addition to better understanding vulnerabilities and risks, providers need to have a more accurate understanding of feasible timelines for recovering their systems, interdependent systems, and the consequences of these timelines. Many providers' anticipated recovery timelines make assumptions about the performance of interdependent systems, and may not be accurate or feasible. Providers need a better understanding of how factors outside of their control may impact their ability to quickly restore service. Providers also need to better understand potential trigger points and cascading effects of delays in recovery. Is there a point when a delay triggers a much larger consequence, either within their system or in an interdependent system?

Interdependencies may also change as time passes. For example, a system that has generator capacity for three days is not dependent upon power for this time, but once the generator fuel runs out, they become dependent on the power grid or short-term fuel supply if power is not yet restored. This type of delayed interdependency or failure is not well understood.

SPUR has created categories of expected performance for lifelines within San Francisco, as well as goals and targets for recovery of infrastructure systems within four hours, three days, 30 days, and four months and beyond after a disaster. ABAG suggests considering developing similar performance categories at a regional level using peer-reviewed evaluation methodology to provide clear expectations and goals for all utility providers, as well as provide a useful tool for evaluating the current state of systems and com-

Collapse of the upper deck of the reinforced-concrete Cypress Street Viaduct in Oakland following the 1989 Loma Prieta Earthquake. The collapse resulted in 42 fatalities. Photo source: www.nasa.gov

municating this information with other providers. SPUR also provides a table for identifying target states of recovery as compared to expected current status, and a similar table using regional performance goals could be widely utilized by regional infrastructure providers.

I-4: *Identify strategies to reduce interdependencies and develop plans to assist with implementation*

Concurrent with examining vulnerabilities and impacts, research could be conducted to identify cost-effective, feasible strategies to mitigate interdependencies, including system redundancy or backup, "islanding" vulnerable systems to limit their impacts, or creating smaller, self-contained "districts" of systems rather than one large, vulnerable system. This study should include identifying existing policies and regulations that impede or assist recovery as well as identifying what policies and regulations are need to propel infrastructure recovery.

Critical to reducing interdependencies is breaking down barriers of confidentiality. Currently, many providers have begun their own internal analysis of their systems to understand their own vulnerabilities. While being mindful of security, proprietary and liability issues, summary results of these analyses should be shared with other providers to develop a common operating picture. This can help providers understand how other sectors and providers' assumptions and timelines will impact their own restoration efforts.

Providers and regional coordinating bodies (such as that suggested below in Recommended Action I-5) could also benefit from understanding if their risk and vulnerability assessment tools are powerful and technically accurate enough to gain an adequate understanding of likely consequences from a disaster and be able to plan appropriate mitigation actions.

Goal #2: Increase ways to share risk information to collectively improve regional infrastructure system resilience

As previously identified, to better understand interdependencies the industry must improve risk information sharing among service providers and regional stakeholders before a disaster occurs. We also have to participate in collaborative planning and accelerate mitigation. This sharing and collaboration is vital to an effective recovery.

By understanding interdependent failures that occur and identifying cross-system "hot spots," communities,

facilitated by regional coordinating bodies, can best and most quickly repair all services, not just individual systems. Strategic repairs on a region-wide basis will enhance and expedite Bay Area recovery.

One way to begin to understand this is to seek lessons from past disasters on the process of infrastructure system recoveries and what providers learned after the fact. These lessons may come from Bay Area providers who recall the recovery process after Loma Prieta in 1989, or they may come from the 20 east coast states hit by Sandy. Examining the recovery process in past disasters inevitably reveals interdependencies and impacts and can also uncover missed opportunities for efficiency to implement now before a future disaster.

Communication and information sharing also allows for informed prioritization of infrastructure recovery, allowing key nodes such as hospitals, support centers, emergency housing, and government buildings to recover first. Understanding upstream and downstream interdependencies for repairs as well as which systems key community resources rely upon can to develop an appropriate timeline for streamlined recovery. Understanding priorities and system interdependencies allows providers to identify primary repairs to minimize interdependency and restore certain portions of systems quickly. Regional performance categories, as discussed above, can be utilized as a tool to make prioritizations based on the performance category.

I-5: Establish a senior leadership forum on infrastructure resilience issues to convene providers and stakeholders

Infrastructure providers and the region's jurisdictions need a forum in which to share and gain situational awareness, spark mitigation programs and create new or utilize existing decision-making and prioritization tools. Currently, there are many sources of information available to infrastructure decision-makers - ranging from Caltrans, other providers, news reports, and crews working on the ground. Organized assistance can also help to identify cross-sectoral specific data needs and ways to circulate risk studies among providers. Tapping a third-party, neutral convener can offer impartial perspectives in prioritizing policy and strategic actions as well as providing a central information hub. A committee team can engage other stakeholders for decision-making and program prioritization, including the broader community.

There are already other mechanisms in place that serve this type of function, including the Bay Area Emergency and Security Information Collaborative (BAESIC), California Water Agency Response Network (CalWARN), and the Bay Area Water Multi-Agency Coordination Group, but these are sector-specific. Bringing existing groups together and developing a larger forum based on these smaller existing models can leverage current actions. The committee team could also consider using the California Earthquake Clearinghouse, an existing body that compiles damage information after a disaster for use by government agencies, non-profit organizations, and academia, as a conduit to collect and distribute infrastructure damage information after a disaster. •