Progress Report: CCSF Lifelines Council Interdependency Study

Lifelines Council Meeting #8
April 25, 2012
Lifelines Council’s Objectives

- Develop and improve collaboration in the City and across the region by regularly convening a group of Executive Officers and Senior-level operational deputies of local and regional lifelines providers.

- Understand inter-system dependencies to enhance planning, restoration and reconstruction.

- Share information about recovery plans, projects and priorities.

- Establish coordination processes for lifeline restoration and recovery following a major disaster event.
Interdependency Study Goals (Near-term 2 – 5 years)

- Build a workable understanding of system interdependencies, and consequences of existing conditions, to help expedite response and restoration planning among agencies.
- Identify key assets and restoration priorities/schemes to prioritize post-disaster restoration and reconstruction activities for the city, and ultimately the region.
- Develop a collective set of lifelines performance expectations under current conditions.
Interdependency Study
Desired Outcomes

- Development of a more detailed and comprehensive scenario of lifeline system impacts and restoration assumptions, for agencies to use in emergency response planning, table-top exercises
- Development of an economic loss model that reflects lifeline system impacts and restoration assumptions
- Identify key critical nodes and chokepoints in system interdependencies for continued work on inter-agency coordination and reducing lifeline interdependencies between sectors and systems
Interdependency Study
Desired Outcomes

- Identify priorities for public funding (e.g. city bonds, infrastructure financing districts) necessary to underwrite or encourage correcting choke points that affect multiple systems
- Identify priorities for legislative and regulatory changes, and barriers that need to be overcoming for utilities to improve lifeline post-disaster performance and restoration
- Obtain credentialing for personnel to work on system restoration and recovery
- Launch a regional lifelines interdependency study
- Publish updated expectations so business and community partners know results of gap analysis and understand how their dependencies will be affected.
Lifelines Council
Interdependency Study Approach
(modeled after Chang et al (Vancouver) and Porter et al (Southern California))

**Earthquake Scenario**

Infrastructure Panel(s) by Sector
- Present scenario and lifeline damage inputs
- Summarize findings of prior panels or relevant studies
- Describe system construction
- Describe past seismic performance
- Describe expected performance for scenario
- Complete damage and restoration grid (by county)
- Discuss situational awareness
- Make mitigation recommendations

**Additional Rounds of Panel(s) or Group Workshop**
- Review scenario and infrastructure panel results
- Revise damage and restoration assumptions
- Prioritize interdependencies

**Comprehensive Earthquake Scenario for CCSF**

**Develop Action Agenda and Council’s Year 3 Work Program**
Interdependency Study Progress to Date and Next Steps

- √ Launch study with presentation on interdependency issues and study approaches (April 2011)
- √ Council member working group and other partners/advisors to design and advise on the study (May – July 2011)
- √ Develop system strawman methodology approach (vetted in discussion groups on August 11)
- √ Scenario selection and discussion guide development (Sept – Oct)
- √ Pilot testing of scenario and finalize discussion guide (Nov 2011 – Jan 2012)

- ❏ Infrastructure operator and panel discussions (January – August 2012)
- ❏ Synthesize discussions into integrated scenario and interdependency insights; operator review and approval (September – October 2012)
M7.9 San Andreas Earthquake Scenario affecting 19-counties in Northern California

(EERI, Charles A. Kircher et al. 2006)
## Study Region

<table>
<thead>
<tr>
<th>County</th>
<th>Population</th>
<th>Exposure ($ in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alameda</td>
<td>1,443,741</td>
<td>$155,700</td>
</tr>
<tr>
<td>Contra Costa</td>
<td>948,816</td>
<td>$102,807</td>
</tr>
<tr>
<td>Lake</td>
<td>58,309</td>
<td>$4,796</td>
</tr>
<tr>
<td>Marin</td>
<td>247,289</td>
<td>$36,050</td>
</tr>
<tr>
<td>Mendocino</td>
<td>86,265</td>
<td>$7,285</td>
</tr>
<tr>
<td>Merced</td>
<td>210,554</td>
<td>$12,901</td>
</tr>
<tr>
<td>Monterey</td>
<td>401,762</td>
<td>$33,773</td>
</tr>
<tr>
<td>Napa</td>
<td>124,279</td>
<td>$14,579</td>
</tr>
<tr>
<td>Sacramento</td>
<td>1,223,499</td>
<td>$110,562</td>
</tr>
<tr>
<td>San Benito</td>
<td>53,234</td>
<td>$4,136</td>
</tr>
<tr>
<td>San Francisco</td>
<td>776,733</td>
<td>$100,179</td>
</tr>
<tr>
<td>San Joaquin</td>
<td>563,598</td>
<td>$42,756</td>
</tr>
<tr>
<td>San Mateo</td>
<td>707,161</td>
<td>$84,301</td>
</tr>
<tr>
<td>Santa Clara</td>
<td>1,682,585</td>
<td>$183,312</td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>255,602</td>
<td>$28,383</td>
</tr>
<tr>
<td>Solano</td>
<td>394,542</td>
<td>$34,820</td>
</tr>
<tr>
<td>Sonoma</td>
<td>458,614</td>
<td>$50,858</td>
</tr>
<tr>
<td>Stanislaus</td>
<td>446,997</td>
<td>$33,828</td>
</tr>
<tr>
<td>Yolo</td>
<td>168,660</td>
<td>$14,479</td>
</tr>
</tbody>
</table>

### 19-County Study Region
- **Population**: 10,252,240
- **Houdeholds**: 3,655,086
- **Building Cost ($ billions)**
  - Residential: $782
  - Commercial: $204
  - All Buildings: $1,055

Kircher & Associates Consulting Engineers
Scenario Earthquake Ground Motions

1906 MMI Ground Motions

- Best available estimate of how the ground shook in 1906
- MMI ShakeMaps (USGS)
Scenario Earthquake Ground Motions

**M7.9 Ground Motions**

- Best estimate of how the ground will shake next time
- Same methods as those of Seismic Codes (USGS)
  - Frankel et al., 2002, “Documentation for the 2002 Update of the national Seismic Hazards Maps, (USGS OFR 02-420)
- High-Resolution Soil (Site Class) Map
  - California Geological Survey
# Summary of Building Damage and Loss Results Due to Ground Shaking and Ground Failure – Total Study Region

<table>
<thead>
<tr>
<th>Damage or Loss Parameter</th>
<th>Population or Exposure</th>
<th>Scenario Earthquake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1906 MMI</td>
</tr>
<tr>
<td><strong>Number of Severely Damaged Buildings</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential Buildings</td>
<td>2,800,000</td>
<td>80,000</td>
</tr>
<tr>
<td>Commercial Buildings</td>
<td>70,000</td>
<td>7,000</td>
</tr>
<tr>
<td><strong>Social Losses due to Building Damage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Displaced Households</td>
<td>3,700,000</td>
<td>170,000</td>
</tr>
<tr>
<td>Serious Injuries - Nighttime</td>
<td>10,300,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Serious Injuries - Daytime</td>
<td>10,300,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Immediate Deaths - Nighttime</td>
<td>10,300,000</td>
<td>800</td>
</tr>
<tr>
<td>Immediate Deaths - Daytime</td>
<td>10,300,000</td>
<td>1,600</td>
</tr>
<tr>
<td><strong>Direct Economic Losses due to Building Damage (Dollars in Billions)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural System</td>
<td>$300</td>
<td>$15</td>
</tr>
<tr>
<td>Nonstructural Systems</td>
<td>$800</td>
<td>$57</td>
</tr>
<tr>
<td>Contents and Inventory</td>
<td>$500</td>
<td>$14</td>
</tr>
<tr>
<td>Business Interruption (BI)</td>
<td>NA</td>
<td>$8</td>
</tr>
<tr>
<td>Total Building and Contents</td>
<td>$1,500</td>
<td>&gt; $90</td>
</tr>
</tbody>
</table>

Kircher & Associates Consulting Engineers
Commercial Building Damage (M7.9 Scenario)

- Over 10,000 commercial buildings likely to be closed or to have restricted use until repairs are made due to structural damage

<table>
<thead>
<tr>
<th>County</th>
<th>Number</th>
<th>Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alameda</td>
<td>1,307</td>
<td>12%</td>
</tr>
<tr>
<td>San Francisco</td>
<td>3,560</td>
<td>37%</td>
</tr>
<tr>
<td>San Mateo</td>
<td>2,054</td>
<td>41%</td>
</tr>
<tr>
<td>Santa Clara</td>
<td>2,059</td>
<td>19%</td>
</tr>
<tr>
<td>Other Counties</td>
<td>1,271</td>
<td>7%</td>
</tr>
<tr>
<td>All Counties</td>
<td>10,251</td>
<td>15%</td>
</tr>
</tbody>
</table>

Commercial Building Damage [ # / sq.mi.]

- Over 50
- 20 to 50
- 10 to 20
- 5 to 10
- 2 to 5
- 1 to 2
- Less than 1

Kircher & Associates Consulting Engineers
Residential Impacts (San Francisco)

- 15,000 – 24,000 single family dwellings with extensive or complete damage (12% to 20% of 125,000 total)
- 7,000 – 11,000 other residential buildings with extensive or complete damage (19% to 30% of 37,000 total)
- 60,000 – 88,000 households initially displaced (18% to 27% of ~330K)
- 14,000 – 22,000 people seeking shelter (out of ~800K)
## Fatalities (M7.9 Scenario)

- **3,400 Daytime Fatalities**
  - 1/1,000 Fatality rate
  - (San Francisco County)

<table>
<thead>
<tr>
<th>County</th>
<th>Daytime Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
</tr>
<tr>
<td><strong>By County</strong></td>
<td></td>
</tr>
<tr>
<td>Alameda</td>
<td>378</td>
</tr>
<tr>
<td>San Francisco</td>
<td>823</td>
</tr>
<tr>
<td>San Mateo</td>
<td>1,013</td>
</tr>
<tr>
<td>Santa Clara</td>
<td>802</td>
</tr>
<tr>
<td>All Others</td>
<td>394</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By Building Type</th>
<th>Daytime Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>2,232</td>
</tr>
<tr>
<td>&quot;Bad&quot; Types²</td>
<td>1,179</td>
</tr>
</tbody>
</table>

1. Deaths per 100,000 of population
2. Soft-story wood, un-reinforced masonry and non-ductile concrete

- **1,800 Nighttime Fatalities**
  - One-half due collapse of “bad” building types

<table>
<thead>
<tr>
<th>County</th>
<th>Nighttime Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
</tr>
<tr>
<td><strong>By County</strong></td>
<td></td>
</tr>
<tr>
<td>Alameda</td>
<td>269</td>
</tr>
<tr>
<td>San Francisco</td>
<td>574</td>
</tr>
<tr>
<td>San Mateo</td>
<td>370</td>
</tr>
<tr>
<td>Santa Clara</td>
<td>361</td>
</tr>
<tr>
<td>All Other</td>
<td>271</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>By Building Type</th>
<th>Nighttime Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>892</td>
</tr>
<tr>
<td>&quot;Bad&quot; Types²</td>
<td>954</td>
</tr>
</tbody>
</table>

1. Deaths per 100,000 of population
2. Soft-story wood, un-reinforced masonry and non-ductile concrete
Housing Units Usable and Unusable after a M7.2 San Andreas Earthquake (SPUR/CAPSS)
Fire Following (M7.9 Scenario)

- Fire Following Concepts
  - Ignitions
  - Spread
  - Suppression

- 300 - 600 fire ignitions estimated
  - 30 – 60 San Mateo

- Fire Likelihood Map
  - Areas with older, denser buildings and stronger ground motions

Kircher & Associates Consulting Engineers
### Total Direct Economic Loss

<table>
<thead>
<tr>
<th>County</th>
<th>Loss Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alameda</td>
<td>7.4%</td>
</tr>
<tr>
<td>San Francisco</td>
<td>25.9%</td>
</tr>
<tr>
<td>San Mateo</td>
<td>24.6%</td>
</tr>
<tr>
<td>Santa Clara</td>
<td>11.9%</td>
</tr>
<tr>
<td>Other Counties</td>
<td>2.7%</td>
</tr>
<tr>
<td>All 19 Counties</td>
<td>9.0%</td>
</tr>
</tbody>
</table>

- **Fire** - Plus 5% - 15%
- **Lifelines** - Plus 5% - 15%
- **Total Loss**: **$150 billion**
Redundancy ensures regional functionality, but the level of service will be significantly impacted.

Primary regional access routes from the south – El Camino, 101, and 280.
Roads (Regional)

- N-S: 101-Doyle Drive, 280-Crystal Springs damage. Other damage along 101, 280, El Camino Real, and Highway 1.
- E-W: Bay Bridge damage. Retrofit bridges will not collapse but may not be functional.
- CalTrans and CHP staff will provide damage/functionality reports; 12 – 18 hours to get picture.
- Structures maintenance group does inspections. Shakecast used to prioritize inspections.
Roads (Regional) - Restoration

- System needs will change after disaster, which will affect restoration (i.e. alternate work schedules, relocations)
- Restoration initially will come organically. Start off doing a little bit everywhere. Actions determined by what happens locally.
- Major restoration priorities and communications/decisions will come from State/region EOC.
- Restoration metrics will vary depending upon priorities, resources, and repair process:
  - “Maze” fire – 26 days; 880-Cypress reconstruction – 10 years
  - Have multi-agency regional plans and are working on regional incident mobility plan with MTC.
  - “If we are all working and cooperating, then we will likely get support.”
Roads (Regional) - Interdependencies

- Regional service organization helps ensure distributed labor, equipment, and materials (particularly near construction areas). Fuel facilities throughout region (state contract).
- EOC/Caltrans communication center seismic retrofitted. Ensure water and power (UPS, generator) for 72 hours. Worst case: use CHP communications center (Vallejo).
- Upstream dependencies – telecommunications (cell phones and 800MHz radio) and power, fuel, and human needs for crews (water, food, shelter).
- Downstream dependencies – All lifelines needing regional access (labor and supplies)
  - federal staging areas (Travis, Livermore)
  - checkpoints managed by local police or CHP.
350 MGD* systems peak capacity; 265 MGD current delivery; 218 MGD* from Hetch Hetchy, plus local reservoirs

Halfway through $4.6 bn Water Seismic Improvement Program to be completed in 2016; ~$1 bn in San Francisco

High reliability of San Francisco 5-line transmission system already. Performance standards:
  - 3 of 5 major “turnouts” (70%) in San Francisco within 24 hours
  - 100% in 30 days

*MGD – million gallons per day

(Source: SFPUC)
Distribution system (1,200 miles) generally reliability but portions will fail in major seismic event:
  - System largely gravity flow (not heavy power dependence)
  - Ductal iron pipeline replacement program underway
  - Remote distribution monitoring that will be upgraded; rely on valve shutoff

- 3 to 4 days of storage already in SF
- Emergency water program involving spigots at reservoirs, water trucks, and bagging

Sunset Reservoir (SFPUC)

Emergency Drinking Water well, SF Zoo (Istock; SPUR)
Water – Restoration

- SFPUC reports into SF EOC; also have their own DOC
- SF Level of Service will need to be determined at time of disaster
- SF restoration priorities set by Mayor and incident commander
  - Transmission system repairs will have some priority
  - Distribution system repairs will consider critical facilities, largest population areas, and doable repairs. Currently replacing 9 miles of pipeline per year, ramping up to 15 miles by 2014.
- Regional restoration priorities (if choices necessary) would come through State/region EOC
Uncertain reliability of distribution system; portions will be damaged.

Deliver water to 3 of 5 of SF turnouts (70%) within 24 hours of a disaster; 100% in 30 days

High reliability of transmission system.
Water - Interdependencies

- Regional nature of SFPUC provides high level of independence for fuel (across 7 counties), chemicals (3 to 4 days), communications (SCADA, cellular), heavy equipment, and labor
  - Draft MOU with 4 Bay Area utilities; EBMUD --> LA DWP; state water providers
  - Use SCADA system and staff inspections
- Gravity flow of system limits dependence on electricity for pumping
- Key upstream dependencies – fuel, telecommunications
- Key downstream dependencies – fire department (working on MOU), underground utilities that might be flooded by breaks, critical facilities (hospitals already connected to 2 or 3 of the 8 pressure zones), financial services and major industries
Electricity – Transmission and Distribution

- 3 electric transmission lines come up the peninsula, a “DC line” operated by 3rd party crosses SF Bay
- Critical substation could experience significant damage, resulting loss of all 3 transmission lines
- DC line can’t provide independent service
- SF has no electric generation capacity
- Much of SF distribution system is underground, subject to significant damage
- San Mateo and Alameda County will also have significant damage
Electricity – Restoration

- PG&E headquarters expected to suffer only minor damage; relocation plan will move critical businesses out of SF if necessary
- PG&E will have regional (State-directed) and local restoration priorities (SF EOC):
  - Damaged underground distribution system will be challenging to repair
  - Electric load must be balanced during restoration to avoid system damage; unpredictable outages likely until sufficient capacity restored
  - Restoration across city will depend upon damage locations/concentrations, population concentrations (evacuated areas will likely be delayed), seasonality, and ability to expedite services to critical facilities
Much of SF distribution system is underground, subject to significant damage, and more challenging to repair.

SF has no electric generation capacity.

Critical substation could experience significant damage, resulting loss of all 3 transmission lines.

Transmission lines up the peninsula are pretty robust. DC line from East Bay can’t provide independent service.
Electricity – Interdependencies

- Mutual aid agreements in place
- Upstream dependencies – road clearance and access for heavy equipment; potential inundation of any underground facilities from ruptured water or sewage lines; fuel for both generators and vehicles; communications; human needs for crews (water, food, shelter)
- Downstream dependencies – most lifelines dependent on electricity; emergency shelters and other critical facilities
Gas – Transmission and Distribution

- 3 gas transmission lines come up the peninsula, and meet at a single point in San Francisco before citywide distribution
- SF gas load can be managed with only 2 of 3 lines; loss of 2 lines would result in pressure loss and potential curtailment of gas service throughout SF
- SF gas distribution lines are underground but more flexible plastic. SF gas leaks controlled through 2,200 valves that can be shut-off manually, where and when needed
- San Mateo County will also have significant damage
Gas – Restoration

- PG&E will have regional (State-directed) and local restoration priorities (SF EOC):
  - 2,200 valves across city will be shut-off, where and when needed, to isolate gas leaks in underground distribution system
  - Restoration will require entry to every property/unit to check for gas leaks and relight gas-fired equipment
  - In addition to city priorities, opportunities to quickly restore service in minimally damaged and safe areas will be taken when possible. Restoration across city will depend upon damage locations/concentrations, population concentrations (evacuated areas will likely be delayed), seasonality, and ability to expedite services to critical facilities
Gas – Interdependencies

- Mutual aid agreements in place
- Upstream dependencies – road clearance and access for heavy equipment; potential inundation of any underground facilities from ruptured water or sewage lines; fuel for both generators and vehicles; communications; human needs for crews (water, food, shelter)
- Downstream dependencies – emergency shelters and other critical facilities heavily dependent upon gas
SF gas distribution system is underground, but in flexible plastic pipe. If transmission lost, system restoration will take months. 3 transmission lines up the peninsula meet at a single point. If 2 lose transmission, then resulting pressure loss could curtail service citywide.
Electricity and Gas Restoration
(Progress Report; April 2012)

- 25% Electricity at 2 days
- 95% Electricity at 1 week; 100% at 1 month
- 100% Gas at 6 months (assuming loss of transmission)
- 10% Gas at 1 month
Issues/Needs
(Progress Report; April 2012)

● Regional (multi-city, multi-operator) exercises:
  – Interdependency between different operators (Roads)
  – Mass evacuation (Roads)
  – Regional restoration policy discussions (Water)
  – Valve shut-off exercise (Water)

● Communications options/testing:
  – No radio and use CalEMA “cloud” (Roads)
  – Minus cell phones and internet (Water)

● Pre-planning of service requirements for essential facilities such as shelters (Electricity/Gas)
Issues/Needs
(Progress Report ; April 2012)

- Creation of new transmission routes that don’t follow existing routes, such as an electric link between Embarcadero to Portrero substations (Electricity/Gas)
- Develop pre-designated lifelines routes for operators (Roads)
- Develop pre-disaster credentialing system for access that includes non-utility contractors/mutual aid providers (Electricity/Gas)
- Develop emergency medical service for lifelines restoration personnel (Electricity/Gas)
- Customer (resident, business) level scenarios of damage, restoration schemes and decision-making (Water)
Lifelines Interdependencies – Vancouver Study
Lifeline Interdependencies in San Francisco
(Progress Report ; April 2012)

Legend
- Color indicates level of service disruption
- Line width indicates level of dependency

- Roads (regional)
- Electric/Power
- Water
- Natural Gas
- Fuel
- Telecom
Potential Interactions among San Francisco Lifelines
(Progress Report; April 2012)
(Yao et al 2005, based on Kameda, Nojima, 1992; Scawthorn 1993; and others)

- **Type A – Functional disaster propagation**, due to failure of interdependence among lifelines
  - Roads (regional) and electricity
- **Type B – Collocation interaction**, physical disaster propagation among lifeline systems
  - Underground water failures impacting underground electricity and gas
- **Type C – Substitute interaction**, influences on alternative systems
  - Electrical and gas
- **Type D – Restoration interaction**, various hindrances in the restoration stage
  - Underground water failures impacting underground electricity and gas
- **Type E – Cascade interaction**, increasing impacts on a lifeline due to initial inadequacies
  - Water impacting fire-fighting
- **Type F – General interaction**, between internal components of a lifeline system
  - Electrical substation failure, Water turnout failures
Details on Next Steps

- Infrastructure operator and panel discussions:
  - PG&E (electric and gas) (Nov 2011)
  - Caltrans (regional roads) (Nov 2011)
  - SFPUC (water) interdependency discussion (April 2012)
    - SFPUC (wastewater) (May/June 2012)
    - SFDPW (city roads and debris (include Recology)) (May/June 2012)
    - BART and MUNI (June 2012)
    - Telecommunications operators panel (July 2012)
    - Port/airport operators (include WRDA) panel (July 2012)
    - Fuel and refineries panel (August 2012)
- Develop integrated scenario and interdependency insights (September 2012)
- Operator review and approval (October 2012)