Insurance Institute for Business & Home Safety

After the Shaking Stops: A Communitywide Approach to Managing Post-Quake Fires

By Rem Brown, P.E., IBHS Senior Engineering Manager, and Brent Henzi, IBHS Communications Associate

Earthquakes are a destructive and unpredictable force of nature that can be catastrophic for the lives that are forced to experience one. The power that an earthquake can have and the damaging aftermath, as seen during the recent horrific quake and resulting tsunami in Japan, has put a spotlight on earthquake preparedness. However, fire following an earthquake is a risk to many communities that gets buried in the shadows of other quake issues, such as ground shaking, landslides, surface faults, and tsunami.

While this article looks at specific cases of fire following earthquake in California, a state that experiences 130,000 earthquakes of magnitude 3.9 of less annually, much of the United States is under a constant threat from the risk of an earthquake striking. Many East Coast residents were reminded of this threat when a 5.8 magnitude earthquake centered in Virginia in September 2011. The shaking was felt as far south as South Carolina and north to the Canadian Border, according to the U.S. Geological Survey (USGS).

Also examined in this article are some of the factors that influence the amount of damage from fire following earthquakes. These factors vary among cities because of the widespread variations in the types of earthquake risks and the quakes themselves. Despite these variations, one clear theme has emerged – the risks posed by fire following an earthquake are best examined in light of specific community vulnerabilities.

WHAT'S AT RISK: DEATHS AND DAMAGES

Earthquakes cost thousands of lives and billions of dollars in losses each year. In March 2011, an estimated 15,500 people were killed as a result of a 9.0 magnitude Japanese earthquake and tsunami that followed. Estimates of insured losses from those events ranged from $21 billion to $39 billion, and total losses were estimated to exceed $200 billion. In February 2011, a 6.3 magnitude earthquake struck Christchurch, New Zealand, resulting in 181 deaths and an estimated $20 billion in total losses, of those $10 billion were insured loss [1].

Several major earthquakes also occurred in 2010: a devastating 7.0 magnitude earthquake in Haiti, which caused an estimated 222,500 deaths, $200 million in insured losses and $8 billion in total losses; an 8.0 magnitude earthquake in Chile, which was responsible for 520 deaths, an estimated $30 billion in total damages, and $8 billion in insured losses, and a 7.1 magnitude earthquake in New Zealand that caused an estimated $3.3 billion in insured losses [1].

An aerial view of damage in the Tōhoku region with black smoke coming from the Nippon Oil Sendai oil refinery after the 2011 Tōhoku earthquake

FIRE FOLLOWING EARTHQUAKE CASE STUDIES

THE 1906 SAN FRANCISCO AND 1923 TOKYO EARTHQUAKES

Ground shaking is present in all earthquakes and is the primary cause of damage in most earthquakes [2]. However, history has shown that often fires that follow the shaking are a major cause of damage. Large fires following earthquakes are rare, but when they do occur they often are of catastrophic proportions. Fires that resulted from the 1906 San Francisco Earthquake (estimated at 7.8-8.3 magnitude) and the 1923 Tokyo Earthquake (7.9 magnitude) remain the largest peacetime urban fires in history, where damage caused by fires was far greater than the damage caused by ground shaking. In the 1906 San Francisco Earthquake, fires burned for three days following the initial shaking because of a lack of water. The earthquake and fires caused an estimated 3,000 deaths and destroyed 28,000 buildings. The damage was estimated at $524 million (in 1906 dollars); the fire caused at least 80 percent of the damage. The 1923 Tokyo Earthquake and following fires caused an estimated 140,000 deaths and of the estimated 575,000 houses destroyed, 447,000 homes were lost due to fire [2].

RETROSPECTIVE ON THE 1906 SAN FRANCISCO EARTHQUAKE

The losses and threat from a fire following earthquake in San Francisco are smaller today than in 1906, but still pose a major risk, according to a retrospective study conducted in 2006 by Risk Management Solutions (RMS) [3]. Based on the scenario of a 7.9 magnitude earthquake on the northern section of the San Andreas Fault, similar in location and magnitude to the 1906 San Francisco Earthquake, the study concluded that $260 billion in damages to residential and commercial property and insured losses from $50-$80 billion could occur. Fortunately, improvements to the reliability of the water supply, advancements in firefighting technology and emergency response, improvements in building codes and construction related to earthquakes, and improved communications make a three-day conflagration, like that seen in the 1906 earthquake, unlikely [4]. The RMS study estimated that insured property losses from fire following earthquake would be around 15 percent of the total insured loss or $6 billion. Still, that loss estimate came with the caveat that losses could escalate if fires spread unimpeded because of high winds or lack of water.

THE NEW NORMAL: POST-QUAKE FIREFIGHTING CAPABILITIES

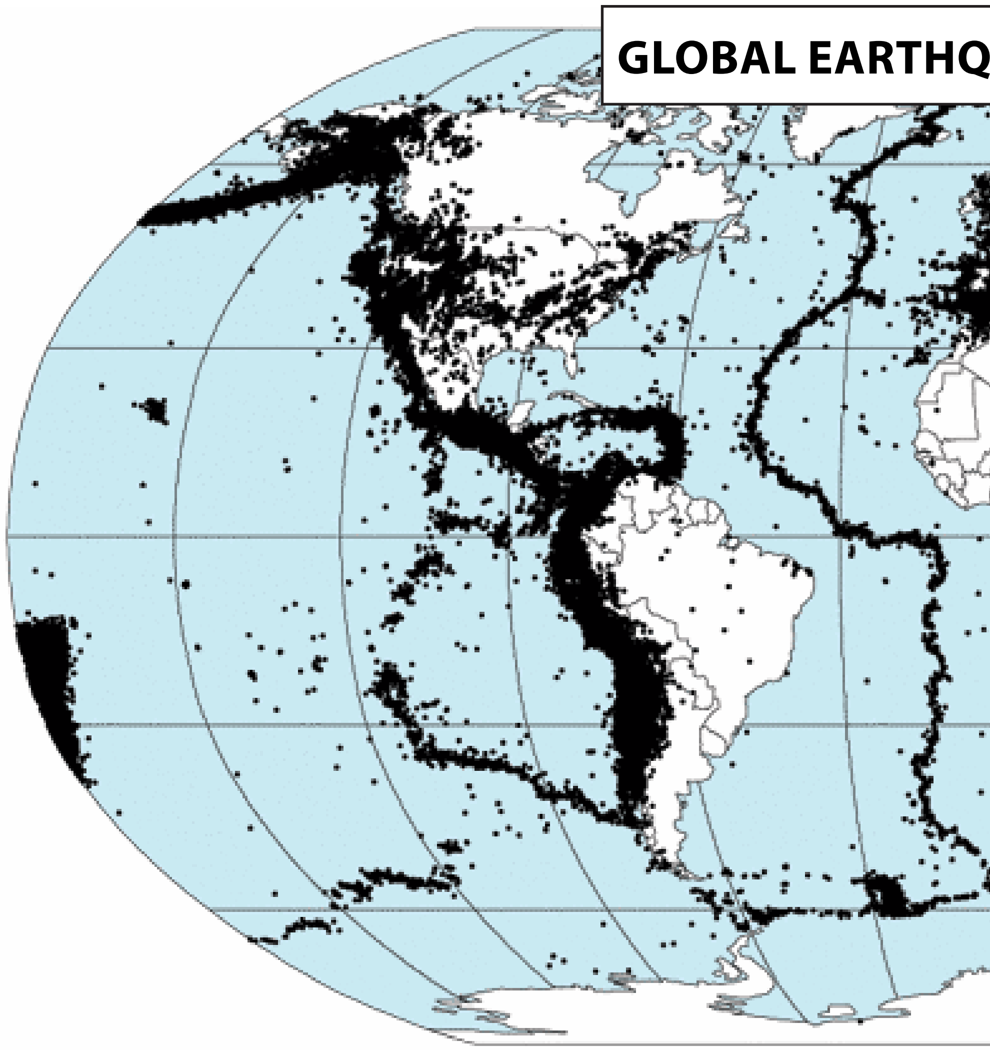
Under normal conditions, fire departments are well equipped to respond to emergencies. Well trained and professional fire services, improved water supplies, and better building practices have significantly reduced large non-earthquake related urban conflagrations in the U.S. The situation changes greatly during the chaos following an earthquake. Response times and resources are stretched thin, which can allow fire to pose a serious potential urban threat. These circumstances can quickly become the "new normal" for a fire department and therefore warrant careful examination.

After an earthquake, fire departments are called upon to respond to structural collapses, hazardous material spills, and medical emergencies. When multiple ignitions occur after the earthquake, already stressed fire departments still must respond quickly. However, these efforts often are hindered by impaired communications, blocked transportation routes, and restricted or reduced water supplies. The potential exists for significant fire-related losses when multiple ignitions occur in vulnerable locations, like neighborhoods with densely spaced combustible wood-framed buildings.

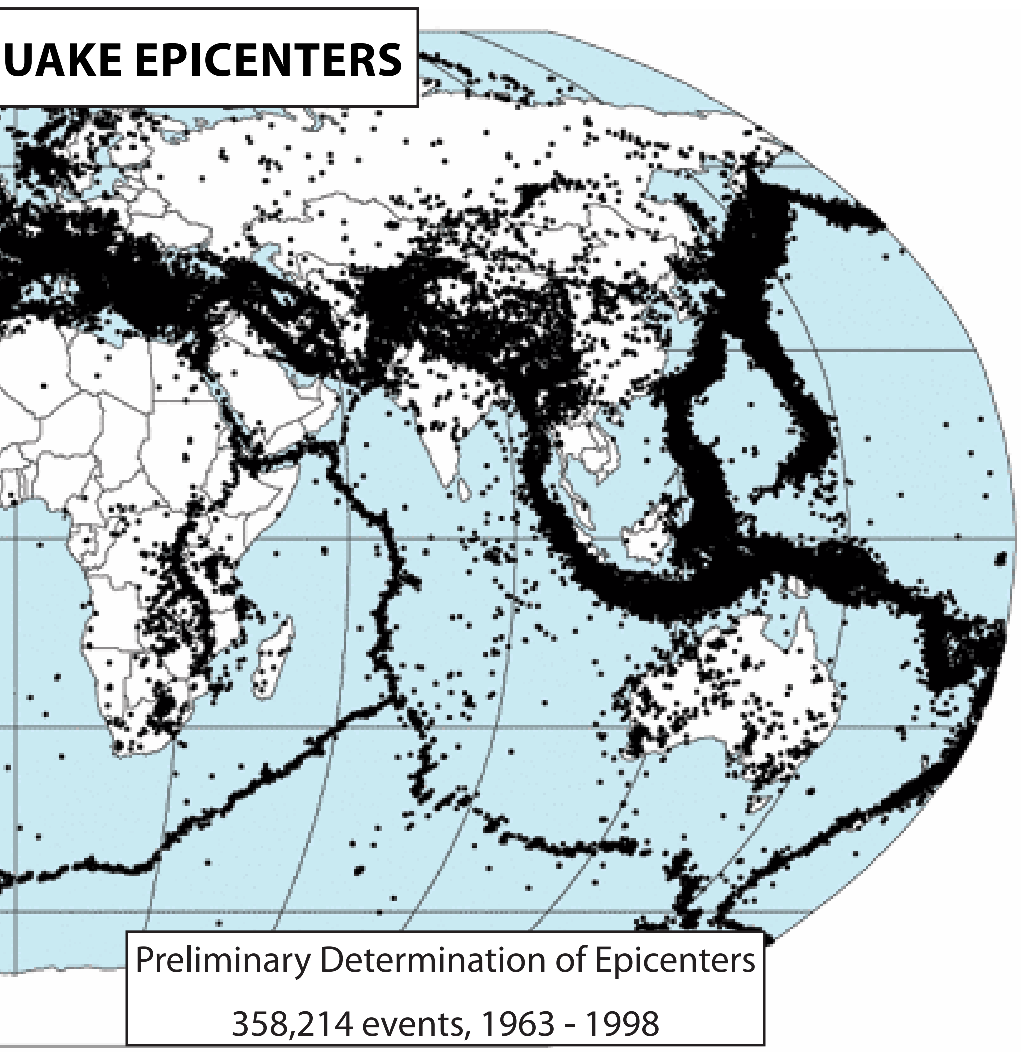
GETTING THE FULL PICTURE: OBSTACLES TO FIRE RESPONSE

On Oct. 17, 1989, just before the start of a World Series game between the San Francisco Giants and the Oakland A's, a 7.1 magnitude earthquake struck within 35 miles of San Francisco [5]. The quake caused an estimated $6 billion in damage, including damaging at least 18,000 homes, killing 62 people and injured another 3,700. A section of the San Francisco-Oakland Bay Bridge and an elevated section of Interstate 880 in Oakland both collapsed.

Although an estimated 26 ignitions occurred in the city of San Francisco following the earthquake, fire losses were considered minor in comparison to the structural damage from the earthquake. However, one of the fires occurred in the Marina District, a neighborhood of closely spaced wood-framed buildings. The fire, which was fueled by a broken gas line, threatened to become a major conflagration. Ground failure and broken pipes caused a loss of pressure in the main and backup water supply systems in the Marina District. The fire was finally extinguished by the third water supply system in San Francisco. This "backup to the backup" water supply has only been fully implemented in the early 1980's [6].



This fire serves as a reminder that other factors impeding fire response following earthquakes can significantly impact the extent of the damage and determine whether a single ignition destroys a city block or is quickly extinguished. In addition to the reliability of the water supply as mentioned in the example above, impeding factors can include the time of day, wind speed and humidity, building density and construction features, impairment of communication and transportation systems. Communities should carefully examine their post-earthquake fire risk in light of these complex factors and others specific to the individual community, and implement strategies to reduce that risk to acceptable levels.



Causes of fires following earthquake include electricity (electrical shorts, frayed wires, and tipped appliances); gas leaks ignited by sparks or open flames; reactions from spilled chemicals; open flames from stoves, candles, fireplaces, and grills; and arson. For example, fires caused by the Northridge Earthquake that occurred near Los Angeles, California in 1994, just more than half the ignitions were due to electrical systems and about a quarter were due to gas systems. Based on a review of the causes of fire ignitions in recent earthquakes, it's estimated that natural gas has played a role in 20 percent to 50 percent of ignitions, while it is estimated that electrical systems could be a factor in as many if not more ignitions. In some cases, both could be a factor [7].

Individually or in combination, the source and number of ignitions, weather conditions, water supply, firefighting resources and emergency response, density and construction of buildings, communication and transportation systems, soil conditions, and intensity of shaking all can play a role in determining the extent of damage from fires following earthquake.

FIRE FOLLOWING EARTHQUAKE SCENARIOS

2008 USGS SHAKEOUT

Preparing to manage the consequences of a major earthquake begins with a realistic evaluation of the potential for damage from local seismic events. This process would include an accurate assessment of local seismic hazards; an estimate of the level of destruction to buildings and infrastructure (water supply, gas and electric utilities, transportation and communication systems) that may be expected from earthquakes; the potential for secondary events, such as major landslides, tsunamis, dam failures, and fire following earthquake; and an estimate of any other events that might have an impact on emergency operations.

Perhaps one of the best ways to present this type of technical analysis in a way that makes sense to most people is to create a "scenario". One of the first occasions when this was the approach taken was in the 2008 United States Geological Survey (USGS) ShakeOut Scenario. The "what if?" earthquake modeled in the ShakeOut Scenario is a 7.8 magnitude quake on the southern San Andreas Fault. The ShakeOut Scenario was created to show how hazards science can increase a community's resiliency to natural disasters through improved planning, mitigation, and response [8].

The scenario was used in the first Great Southern California ShakeOut drill held in October 2008 in which millions of people participated. The next drill will take place in October 2011 and will involve millions of people in British Columbia, California, Guam, Idaho, Nevada and Oregon, Utah.

The ShakeOut has since been expanded to other western states, and the first Central U.S. ShakeOut was held in February 2011 in recognition of the Bicentennial of the New Madrid Earthquakes of 1811-1812. Another drill is planned for the seven states with New Madrid quake risks on Feb. 7, 2012.

SAN FRANCISCO CAPSS SCENARIOS

Four other possible earthquake scenarios and their impact were recently examined by the Applied Technology Council for the San Francisco Department of Building Inspection under the Community Action Plan for Seismic Safety (CAPSS) Project. The CAPSS report, "Here Today — Here Tomorrow: The Road to Earthquake Resilience in San Francisco–Potential Earthquake Impacts (ATC 52-1)," documented this information [9].

Although no one knows when the next "big one" will strike San Francisco, scientists estimate that a magnitude 6.7 or larger earthquake will occur in the Bay area within the next 30 years. Based on one of four scenarios, a magnitude-7.2 earthquake occurring on the peninsula segment of the San Andreas Fault closest to San Francisco could potentially result in 5,600 injuries and as many as 300 deaths, not including casualties from fire.

An estimated 73 fires requiring fire department response could break out within hours of the earthquake, according to the model. These fires could burn the equivalent of 4,900 single-family homes that were not heavily damaged by the earthquake. While damage from shaking alone is estimated at $30 billion, $4.3 billion is estimated from just fire (in 2009 dollars). Total property damage is estimated at $34 billion. When additional losses are included the total loss is estimated at $44 billion.

The purpose of the CAPSS project is to recommend specific actions that will reduce death, injury, and damage in San Francisco from future earthquakes. The Potential Earthquake Impacts (ATC 52-1) document examined the impact of a future earthquake, but another CAPSS document, "Here Today — Here Tomorrow: The Road to Earthquake Resilience in San Francisco A Community Action Plan for Seismic Safety (ATC 52-2)," is the call to action to reduce the impacts of future earthquakes [10].

ATC 52-2 identifies 17 important actions for the San Francisco city government to take in order to reduce the impact of future earthquakes in San Francisco, six of which are related to mitigating fire following earthquake in San Francisco:

- Mandatory retrofit of large wood frame soft story structures. These buildings are susceptible to collapse and vulnerable to fire.
- Require all buildings to be evaluated for seismic risk upon sale. The evaluation would include fire ignition and spread risk.
- Require retrofits of vulnerable buildings over a period of time. This would ensure that owners of vulnerable buildings that threaten the broader community ultimately improve those buildings.
- Require automatic gas shut-off valves on select buildings in specific areas. Require owners of certain vulnerable buildings and buildings in fire department-designated post-earthquake high fire hazard areas to install automatic gas shut-off valves.
- Evaluate measures to reduce post-earthquake fires. Multiple city departments would work together to evaluate and implement measures to reduce fire ignitions and spread, and improve fire suppression capacity following earthquakes.
- Address the hazards from damage to building systems, appliances, equipment and non-structural building elements. Damage to building systems, such as fallen ceilings and fixtures, broken pipes, and overturned equipment and appliances, increase the potential for fire ignitions and spread.

The CAPSS recommendations and implementation plan, along with the political will of San Francisco city leaders, serve as a real life example of the type of community planning and action required for improving earthquake safety and community resilience.

COMMUNITYWIDE ACTION: RISK REDUCTION STRATEGIES

Some opportunities for mitigation of fire following earthquake do exist. Fire following earthquake is a process, and there are opportunities for intervention in that process. The process begins with:

1. The earthquake and ground shaking;
2. followed by ignition;
3. discovery of the fire;
4. reporting the fire;
5. fire department response, and
6. fire suppression

Reducing the damage from shaking reduces the potential for ignitions. There are also a number of mechanisms that may reduce fire ignitions in earthquakes. These include:

- Using modern arc fault circuit interrupters to avoid electrical fires
- Using flexible connections for gas-fired appliances
- Addressing the high pressure gas lines inside buildings

Other steps to prepare the interior of a building, such as securing heat sources, including appliances, lamps, and water heaters that could fall over and spark a fire also help reduce the risk of damage. Installing automatic gas shut-off valves is another potential opportunity to control ignitions in densely built-up areas, along with using seismically designed automatic fire sprinkler systems in these areas.

Structural preparations include addressing known building vulnerabilities, such as anchoring a home to its foundation and strengthening cripple walls to helps reduce the potential for ignitions. Further guidance on structural and non-structural retrofits that reduce earthquake damage can be found in the IBHS publication, "HYPERLINK "http://www.disastersafety.org/content/data/file/earthquakeguide.pdf"Earthquake Risks around the U.S.– How to Protect Your Property".

Following are other factors that will determine the severity of fire following earthquake and which should be evaluated through a community examination. These include:

- Local and regional fire fighting resources
- Vulnerabilities of communication and transportation infrastructure
- Vulnerabilities of water supplies and potential for alternate sources
- Vulnerabilities of gas and electric utilities
- Building stock and building density
- Areas with potential for ground failure
- Areas of high risk for fire following earthquake (areas of high density, flammable buildings on soils with potential for ground failure)
- Effect of weather conditions on fire spread
- Damage assessment from ground shaking

By evaluating each factor and considering the potential mitigation of some factors to limit losses from fire following earthquake, seismic upgrades can be considered objectively and the benefits and costs of mitigation can be analyzed.

To become better prepared to deal with this risk, each community with seismic exposure must examine their own unique vulnerabilities to these types of fires, evaluate that risk, and decide on the best plan for mitigation. Although much of the information presented in this article is based on studies done in California, the potential problem of fire following earthquake exists wherever there is major earthquake risk. The areas at risk include the central U.S., Pacific Northwest, South Carolina and along parts of the East Coast, and these risks should be evaluated.

A major earthquake in the central portion of the United States could result in several thousand fatalities and approximately $300 billion in direct economic losses, making it the costliest natural disaster in U.S. history, according to an HYPERLINK "https://www.ideals.illinois.edu/handle/2142/14810"analysis by the Mid-America Earthquake (MAE) Center at the University of Illinois. Although fire following earthquake was not included in this analysis, the report recognizes the importance of a fire following earthquake analysis by concluding that "Based on the inventory analysis for the 8 states (Illinois, Indiana, Kentucky, Tennessee, Alabama, Mississippi, Arkansas and Missouri), about 80 percent of inventory is comprised of wood buildings, causing the fire damage probability to be high. Therefore, it is essential that in future stages of impact assessment adequate FFE models be implemented."

The intent of this article has been to broaden awareness of the problem and encourage local evaluation within communities at risk. Although a one-size-fits-all solution does not exist, a communitywide approach to identifying vulnerabilities and reducing the risks of damage from the previously mentioned factors will go a long way in limiting the chances and impacts of fire following earthquake.

Mitigation actions to reduce the amount of damage should be evaluated and prioritized once vulnerabilities are known. Effectively communicating the risk and ways to reduce the risk to the public from within the community begins the march toward actions that result in a more resilient community. What gets done before the disaster determines what happens after the disaster.

REFERENCES

[1] Insurance Information Institute. (2011, September). Earthquakes: Risk and Insurance Issues. Retrieved September, 2011. HYPERLINK "http://www.iii.org/issue_updates/eathquakes-risk-and-insuance-issues.html"

[2] Scawthorn, C., Eidinger J. M., & Schiff A. J. (Editors).Technical Council on Lifeline Earthquake Engineering (TCLEE), 2005. Fire Following Earthquake, Technical Council on Lifeline Earthquake Engineering Monograph No. 26, American Society of Civil Engineers, Reston, VA, 345 pp.

[3] Risk Management Solutions. (2011, April). Estimating Insured Losses from the 2011 Tohoku, Japan Earthquake and Tsunami – RMS Special Report. Retrieved September, 2011. HYPERLINK "http://www.rms.com/Publications/2011TohokuReport_041111.pdf"

[4] Grossi, P., & Muir-Wood, R. (2006) Risk Management Solutions The 1906 San Francisco Earthquake and Fire: Perspectives on a Modern Super Cat. Retrieved September, 2011. HYPERLINK "http://www.rms.com/publications/1906_SF_EQ.pdf"

[4] Scawthorn, C. (2011, April 28). Lifeline Aspects: PEER–EERI Preliminary Briefing re 11 March 2011 Tohoku Earthquake and []. Pacific Earthquake Engineering Research Center 28 April 2011 HYPERLINK "http://peer.berkeley.edu/events/wp-content/uploads/2011/04/5_Lifeline-Aspects-Scawthorn-11March2011-Jpn-EQ-Tsunami_to_post-sm.pdf"

[5] Kircher, C., Seligson, H., Bouabid, J., & Morrow, G. When the Big One Strikes – Estimated Losses due to a Repeat of the 1906 San Francisco Earthquake. Retrieved September 2011. HYPERLINK "http://www.1906eqconf./mediadocs/BigonestrikesReport.pdf"

[6] Scawthorn, C., O' Rourke, T.D., & Blackburn, F.T. (2006, April) The 1906 San Francisco Earthquake and Fire – Enduring Lessons for Fire Protection and Water Supply. Earthquake Spectra, Volume 22. HYPERLINK "http://www.sparisk.com/documents/06Spectra1906SFEQandFire-%09EnduringLessonsCRSTDOFTB.pdf"

[7] California Seismic Safety Commission. (2002, July 11). Improving Natural Gas Safety in Earthquakes. Retrieved September 2011. HYPERLINK "http://www.seismic.ca.gov/pub/CSSC_2002-03_Natural percent20Gas percent20Safety.pdf"

[8] Scawthorn, C. The ShakeOut Scenario-Supplemental Study- Fire Following Earthquake [PowerPoint Presentation] U.S. Geological Survey 2008 HYPERLINK "http://www.colorado.edu/hazards/shakeout/fire.pdf"

[9] Applied Technology Council. Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco Potential Earthquake Impacts (ATC 52-1). Retrieved 2011 September. HYPERLINK "http://www.sfcapss.org/PDFs/Impacts521.pdf"

[10] Applied Technology Council. Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco A Community Action Plan for Seismic Safety (ATC 52-2 Retrieved 2011 September. HYPERLINK "http://www.sfcapss.org/PDFs/CAPSS_522.pdf"