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Fire Following Earthquake
– Analysis and Mitigation in North America

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ABSTRACT: Fire following earthquake has the potential for catastrophic loss in Japan and western North America (WNA). In WNA, analysis of the problem over the last several decades has led to a number of measures to reduce this risk. This paper first reviews the development and current status of fire following earthquake analysis in the US, including the current methods employed in HAZUS and by the insurance industry. A number of mitigation measures have been employed or are under development in WNA and include:

- High pressure auxiliary water supply systems in San Francisco and Vancouver, B.C.
- Cisterns
- Portable Water Supply Systems, in San Francisco, Oakland, Berkeley and Vallejo
- Mandated gas shut-off valves, in Los Angeles

However, these measures are in some cases still inadequate, so that the paper concludes with mitigation measures that are currently under development.

Key Words: fire following earthquake, seismic, ignitions, emergency response, suppression, fire spread, conflagration, loss estimation, risk

INTRODUCTION

Fire following earthquake (FFE) is a significant problem in countries with large wood building inventories and high seismicity, such as the US, Canada, New Zealand and Japan. In 2011 both New Zealand and Japan suffered devastating earthquakes, the latter event also being accompanied by several hundred fires. This paper focuses on the problem, and more specifically efforts to mitigate this problem, in North America particularly the US and California.

Historically, every significant earthquake in California has resulted in multiple simultaneous fires that have strained, and at least in 1906 overwhelmed, the fire service. In both the 1971 San Fernando and the 1994 Northridge earthquake, there were over 100 ignitions. Other disasters clearly demonstrate that massive fires are a problem in California under even non-earthquake ignitions, when only one or a few ignitions are involved – the numerous wildland urban interface fires that occur in California almost every year are only the most telling example of this, particularly the 1991 East Bay Hills fire, in which over 3,500 houses were destroyed in several hours, in the cities of Oakland and Berkeley, California. Another example is the 1988 First Interstate Bank Fire, which totally destroyed 4 floors of the state's tallest building (at that time) and severely damaged the rest of the building through water and smoke damage.

MODELING

"*What gets measured, gets managed*" is a well-known adage that applies to the problem of fire following earthquake – in order to manage this problem, we must be able to assess the current risk it poses, and the beneficial impacts of various mitigation alternatives. This section discusses modeling of fire following earthquake, as practiced in North America, including recent improvements in estimation of ignitions, and several studies for major urban areas.

Overview of Modeling in North America

The basic methodology employed to model fire following earthquake in North America was developed in the late 1970s (Scawthorn et al., 1981), and can be seen in Figure 1, the Fire Following Earthquake process, which depicts the main aspects of the fire following earthquake problem. Fire following earthquake is a process, which begins with the occurrence of the earthquake. In summary, the steps in the process are: ■ **Occurrence** of the earthquake – this will presumably cause damage to buildings and contents, even if the damage is as simple as knockings things (such as candles or lamps) over. ■ **Ignition** – whether a structure has been damaged or not, ignitions will occur due to earthquakes. The sources of ignitions are numerous, ranging from overturned heat sources, to abraded and shorted electrical wiring, to spilled chemicals having exothermic reactions, to friction of things rubbing together. ■ **Discovery** – at some point, the fire resulting from the ignition will be discovered, if it has not self-extinguished (this aspect is discussed further, below). In the confusion following an earthquake, the discovery may take longer than it might otherwise. ■ **Report** – if it is not possible for the person or persons discovering the fire the immediately extinguish it, fire department response will be required. For the fire department to respond, a Report to the fire department has to be made. ■ **Response** – the fire department then has to respond. ■ **Suppression** – the fire department then has to suppress the fire. If the fire department is successful, they move on to the next incident. If the fire department is not successful, they continue to attempt to control the fire, but it spreads, and becomes a conflagration. The process ends when the fuel is exhausted – that is, when the fire comes to a firebreak.

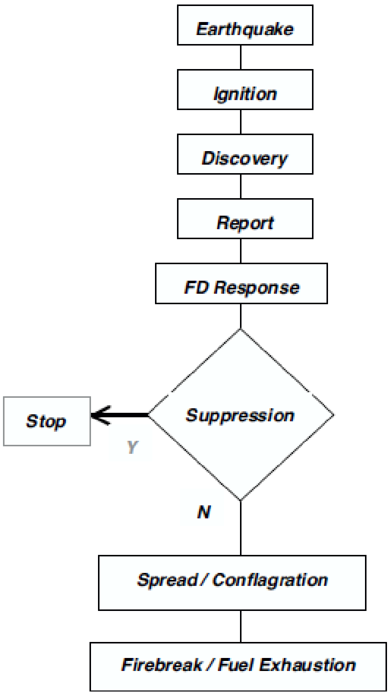

Figure 1 - Fire Following Earthquake Process

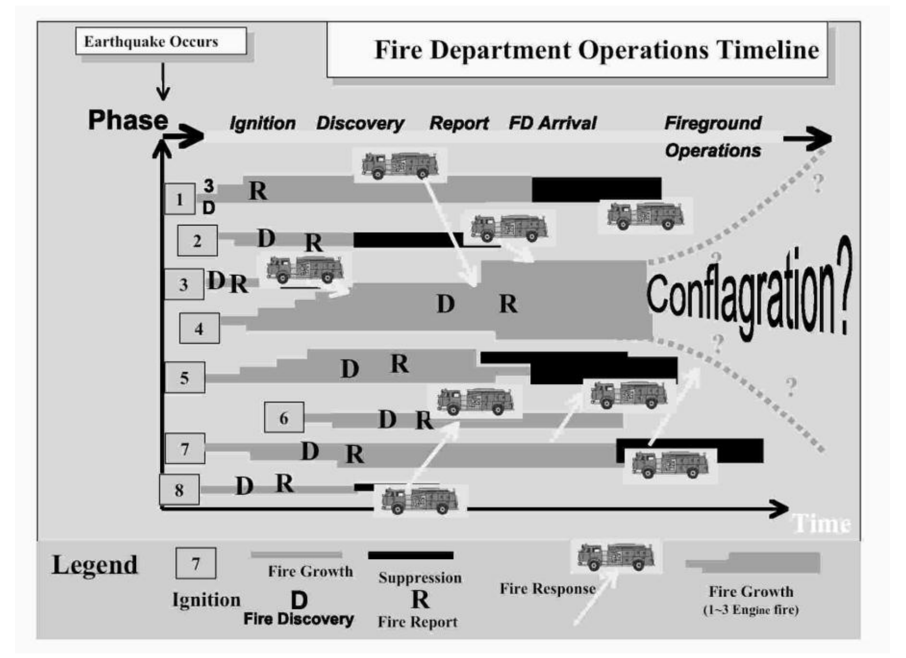

Figure 2 - Fire Department Operations Timeline

This process is also shown in Figure 2, which is a Fire Department Operations Time Line (TCLEE, 2005). Time is of the essence for the fire following earthquake problem. In this figure, the horizontal axis is Time, beginning at the time of the earthquake, while the vertical axis presents a series of horizontal bars of varying width. Each of these bars depicts the development of one fire, from ignition through growth or increasing size (size is indicated by the width or number of bars).

Beginning at the left of Figure 2 (that is, at the time of the earthquake), is the occurrence of various fires or ignitions (denoted by the number of the fire in a square box, see the legend at the bottom of the figure). Some of these fires occur very soon after the earthquake, while others occur sometime later (due for example to restoration of utilities). The mechanism of these ignitions is no different following an earthquake than at other times, although the earthquake can create unusual circumstances for ignition to take place. The primary difference due to the earthquake is the large number of simultaneous ignitions.

Following this ignition, or Fire Initiation, phase there is a period during which the fire is undiscovered but grows. A typical rule of thumb in the fire service is that the rate of growth of an uncombated fire in this phase will double each seven seconds. In Figure 2, the size of the fire is denoted by its number of bars. That is, each bar for a particular fire represents one engine required for control and/or suppression. Thus if, with time, a fire in Figure 2, proceeds from one bar to two and then three, this denotes that the fire is growing and now requires three Class A fire engines to control the fire (Class A fire engines have approximately 1200 gpm of pumping capacity).

The letter “D” denotes discovery of the fire. Discovery under the post-earthquake environment is often no different than at other times, although discovery may be impeded due to damaged detectors, or distracted observers. Upon discovery, citizens may themselves attempt to combat the fire, and will sometimes be successful. We are concerned herein only with ignitions that citizens cannot/do not successfully combat, and which require fire department response. The letter “R” denotes receipt of the Fire Report by the fire department. Under normal circumstances, fires are reported to the fire department by one of four methods: Telephone, Fire department street boxes (voice or telegraph), Direct travel to a fire station by a citizen (so-called “citizen alarms”), or Automatic detection and reporting equipment, usually maintained by private companies.

Under normal circumstances, with the exception of citizen alarms, these methods all communicate the occurrence of a fire within seconds, which is critical in the timely response and suppression of structural fires, and in the size and 'design' of modern fire departments. In the critical minutes following an earthquake, review of earthquake experience has indicated that at present citizen alarms are likely to be the only feasible method for reporting fires, in areas of strong ground shaking. The telephone system may or may not sustain damage, but almost definitely will be incapacitated due to overload. Fire department street boxes are generally no longer in use (in California, only San Francisco maintains street boxes). Automatic detection and reporting equipment account for only a fraction of commercial property. Such equipment may be damaged in an earthquake, and will likely produce many false alarms, leading to lack of response to real fires, due to the inability to discriminate the real from the false alarms. Several other, unconventional, reporting methods may be employed. These include: Amateur short-wave radio operators; Helicopter observation and Ground reconnaissance by police or fire personnel

With regard to the last of these other methods, present post-earthquake damage reconnaissance planning on the part of several larger California fire departments has been reviewed and, in general, found to be unrealistic and inadequate for identifying fires at a sufficiently early stage to prevent conflagration. A fundamental flaw in most of these plans is the performance of the post-earthquake damage reconnaissance by the fire personnel themselves, employing fire apparatus (i.e., engines and trucks).The flaw lies in the fact that following an earthquake, these personnel and apparatus will almost immediately be redirected from the reconnaissance to actual fire or other emergency response.

Helicopter observation and amateur radio operators similarly will typically only be able to identify and report fires after they have reached greater alarm status (that is, when it is too late). Further, most fire officers have no special training in aerial observation or command.

Following receipt of the Fire Report by the fire department, apparatus will respond, if available (in Figure 2, arrival of apparatus at the fireground is denoted by the engine number within a circle-note that herein we only track fire engines, since only engines can suppress serious fires). Response may be impeded by blocked streets due to collapsed structures, or by traffic jams. Upon arrival, the fire may be combated per normal procedures or, if the general situation is sufficiently serious, minimal tactics may be all that is possible.

Water supply is a critical element, and earthquake damage to the water system may reduce supply, thus altering tactics. Due to the interconnectedness of a water supply system, earthquake damage at some distance from a fireground may still result in reduced supply.

In Figure 2 we denote increasing control of a fire by the reduction in the number of bars (i.e., engines required for control). As suppression progresses and control of the fire becomes near total, engines will be released by the incident commander for more pressing emergencies elsewhere. Movement of these released apparatus is denoted by a diagonal arrow showing travel of an engine from one fire to another. As fires are controlled, engines eventually converge on one or several large fires, or conflagrations. Growth and spread of conflagrations is a function of building materials, density, street width, wind, water supply and firefighting tactics.

In this methodology, the process depicted in Figure 2 can be coded in a computer program. An algorithm determines ignitions, assigns a number to each fire, and tracks fire growth. Algorithms also determine fire reporting time and fire engine arrival. Each fire engine is tracked from location to location. Damage and hydraulic performance to the water supply can be determined using detailed loss models of the water system such that the availability of fire flows at any fire location and any time after the earthquake can be tracked; the effectiveness of fire department apparatus to control a fire at a given location can then be estimated based on the size of the fire, the quantity of fire department apparatus at the fire, and the quantity of water available for fighting the fire. Final burnt area for each ignition is thus calculated as a function of fire growth and applied fire suppression capacity. Each aspect of the problem is next discussed in more detail.

HAZUS

The above method, termed a simulation model, is followed for each fire. Fires need to be tracked and merged where they meet (i.e., areas should not be "burnt twice"). Final burnt areas are summed, to arrive at total final burnt area. The implementation of this simulation model for a large urban area is clearly a data- and computationally intensive matter, so that fires following earthquakes are usually estimated using computer programs, termed a simulation code. Several such codes exist including EQEFIRESC, HAZUSSC, URAMPSC, SERA and RiskLink, which are discussed in some detail in (TCLEE, 2005).

HAZUS is the US national program for estimation of earthquake losses, including fire following earthquake losses, and was developed by the National Institute for Building Sciences, for the Federal Emergency Management Agency (HAZUS, 1999). As noted in the HAZUS Technical Manual (HAZUS, 1999): *HAZUS is designed to produce loss estimates for use by federal, state, regional and local governments in planning for earthquake risk mitigation, emergency preparedness, response and recovery. The methodology deals with nearly all aspects of the built environment, and a wide range of different types of losses. Extensive national databases are embedded within HAZUS, containing information such as demographic aspects of the population in a study region, square footage for different occupancies of buildings, and numbers and locations of bridges. Embedded parameters have been included as needed. Using this information, users can carry out general loss estimates for a region. The HAZUS methodology and software are flexible enough so that locally developed inventories and other data that more accurately reflect the local environment can be substituted, resulting in increased accuracy*. HAZUS is available free of charge – see (Scawthorn et al., 2006) for more details.

Ignition Modeling

While the HAZUS methodology was developed over a decade ago, the ignition module was updated more recently (SPA Risk, 2009). Ignitions "refers to each individual fire that starts (ignites) after an earthquake that ultimately requires fire department response to suppress". The HAZUS equation prior to the revision discussed here, was based on 30 data points derived from U.S. earthquakes from 1906 to 1989. Based on a review of relevant earthquakes and available data, seven U.S. events from 1971 to 1994 were selected and the data on ignitions occurring in those events was collected on a consistent basis. The resulting data set is the most extensive of its kind, with 238 data points. Measures of seismic shaking, such as MMI and PGA, were assigned for each data point. Ignition data was normalized by building total floor area to determine ignition rate and a variety of covariate data were regressed against to develop alternative regressions, the most useful of which is a second order polynomial of ignition rate (i.e., mean number of ignitions per million square feet of total building area) as a function of peak ground acceleration:

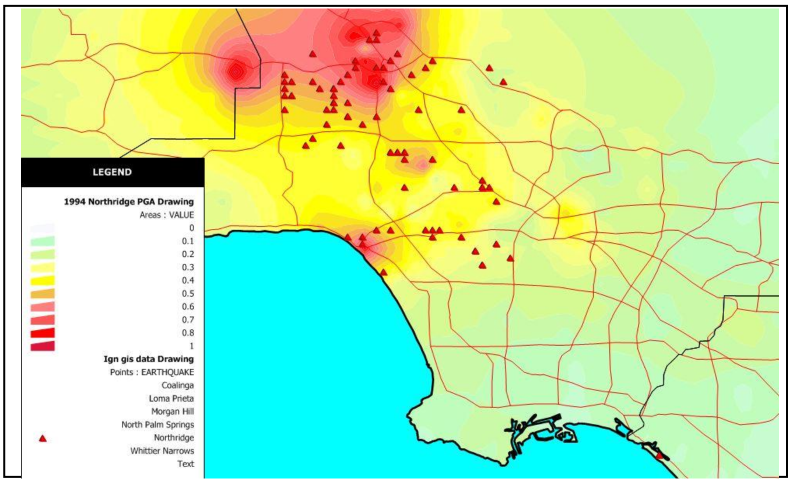

Figure 3 Example Ignition data – 1994 Northridge earthquake

$$\text{Ign./TFA} = 0.581895\,(\text{PGA})^2 - 0.029444\,(\text{PGA}). \qquad (1)$$

This equation is the same format as currently used in HAZUS, so that re-coding effort was minimal. Comparable equations are provided in terms of MMI. The new equations indicated a somewhat lower ignition rate at lower intensities, and a rapidly increasing ignition rate at higher intensities. As an example of the number of ignitions that might be estimated using equation (1), about a hundred ignitions would be estimated for a city of 2 million population shaken to MMI VIII, and over 400 ignitions if shaken to MMI IX. The temporal distribution of ignitions was analyzed and distribution is provided, which indicates that about 20% of ignitions typically occur within the first hour, and 50% within about 6 hours after the earthquake, Figure 4. . Guidance on how to implement these equations in HAZUS was provided, and recommendations for further enhancing the ignition algorithm by inclusion of analytical methods also provided.

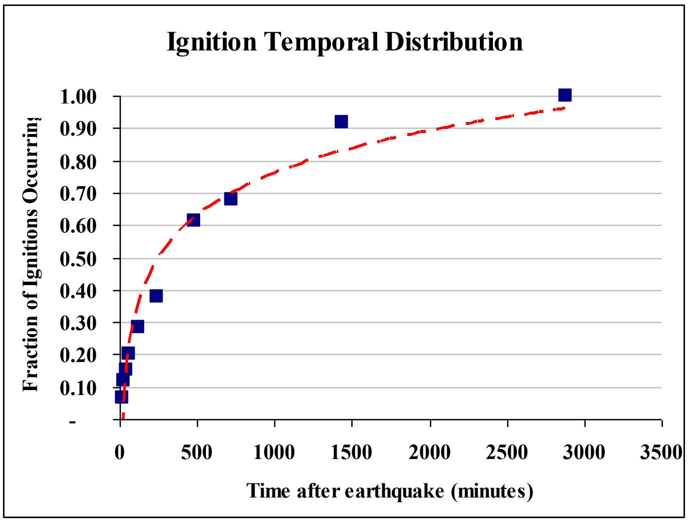

Figure 4 Temporal Distribution of Ignition Report Times, with fitted curve

ShakeOut / Southern California

The 2008 ShakeOut and associated Golden Guardian Exercise examined potential impacts assuming a Mw 7.8 southern San Andreas event affecting Southern California occurring at 10am on 13 November 2008, with breezy, low humidity conditions (Jones et al., 2008). (Scawthorn, 2011b) examined the potential losses arising from fire following earthquake for this event, resulting in MMI VI-VIII in the Los Angeles basin, and found that approximately 1,600 ignitions will occur requiring the response of a fire engine. In about 1,200 of these fires the first responding engine will not be able to adequately contain the fire, such that one or several conflagrations destroying several city blocks will occur in Riverside and San Bernardino counties. Of more concern however, are portions of Orange County and especially the central Los Angeles basin, where the dozens to hundreds of large fires are likely to merge into dozens of conflagrations destroying tens of city blocks, and several of these merge into one or several super conflagrations destroying hundreds of city blocks. Under the assumed scenario conditions, a preliminary estimate is that the approximately 1,200 large fires will result in an ultimate burnt area of approximately 200 million sq. ft. of residential and commercial building floor area, equivalent to 133,000 single

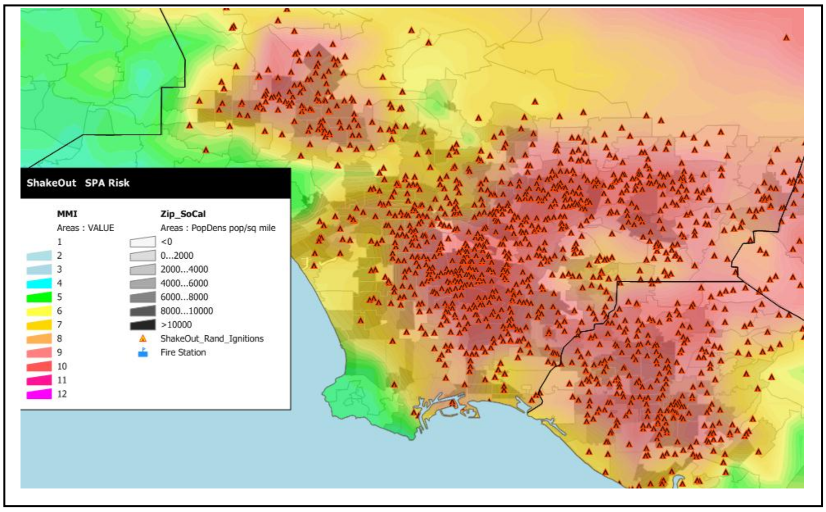

Figure 5 Ignitions (one trial) overlaid on MMI for M7.8 ShakeOut Scenario and Population Density by zip code, Central LA Basin

family dwellings. Directly attributable to these fires following the earthquake will be the loss of hundreds to perhaps a thousand lives, and an economic loss of forty to perhaps as much as one hundred billion dollars, This loss is virtually fully insured and could result in distortions in the US and global insurance industry. Other economic impacts included the loss of perhaps a billion dollars in local tax revenues. A number of opportunities were identified for mitigating this problem, including construction of a seismically reliable basin-wide saltwater pumping system, and the mandatory use of automated gas shut-off valves, or seismic shut-off meters, in densely built areas.

CAPSS / San Francisco

CAPSS (Community Action Plan for Seismic Safety) is a major study undertaken by the San Francisco Department of Building Inspection to understand earthquake risk in San Francisco and develop appropriate mitigation projects (see www.sfcapss.org). (Scawthorn, 2010) analysed fire following earthquake as part of the CAPSS project, with the support and assistance of the San Francisco Fire Department (SFFD). A stochastic model for analyzing fire following earthquake for San Francisco was developed, utilizing data received from CAPSS, SFFD and others, to assess fire following earthquake impacts due to four earthquake scenarios: magnitude 7.9, 7.2 and 6.5 events on the San Andreas fault near San Francisco, and a magnitude 6.9 event on the Hayward fault. These events cause high ground motions in San Francisco that result in ground failure in many parts of the City – ground motions are particularly high in the western part of San Francisco, which was not yet built up in 1906 and therefore is not protected by the special high pressure SFFD Auxiliary Water Supply System (AWSS, discussed further below).

Depending on the specific earthquake scenario, these ground motions and ground failures are estimated to cause over 1,000 breaks in the potable water system, so that SFFD's AWSS and cisterns will be the only source of firefighting water in many parts of the City. The AWSS itself will sustain some damage, forcing SFFD to fall back to cisterns only in some places. At the same time, SFFD's 42 fire engines will almost certainly not be able to respond to all the post-earthquake fires, which are estimated to be about 100 on average (with a 10% chance of as many as 140) for the magnitude 7.9 San Andreas event. As a result, the methodology employed here estimated ignitions, building burnt areas and dollar losses for the four scenario events. These results are presented in Table 1 as ranges within which losses will fall half (i.e., 50%) of the time (correspondingly, half the time the losses will be outside – that is, either more or less) than the indicated ranges:

Table 1 Bounds for Losses to Buildings due to Fire Following Earthquake

	25% ~ 75% Confidence Range		
	Ignitions	**Loss** $ billions	**Total Burnt Building Floor Area** mill. Sq. ft.
San Andreas Mw 7.9	68 ~ 120	$ 4.1 ~ $ 10.3	11.2 ~ 28.2
San Andreas Mw 7.2	52 ~ 89	$ 2.8 ~ $ 6.8	7.7 ~ 18.6
San Andreas Mw 6.5	48 ~ 70	$ 1.7 ~ $ 5.1	4.7 ~ 14.0
Hayward Mw 6.9	27 ~ 46	$ 1.3 ~ $ 4.0	3.6 ~ 11.0

For example, for the Mw 7.9 event, essentially a repeat of the 1906 earthquake, losses will on average be about $7.6 billion, and half the time will be more than $4.1 billion and less than $10.3 billion. More detailed results are presented in the report, but the significance of these results is not in their precision, but rather in their overall magnitude. The model producing these results was validated by application to the 1989 Loma Prieta event, and examined for methodological and parametric sensitivity, with satisfactory results.

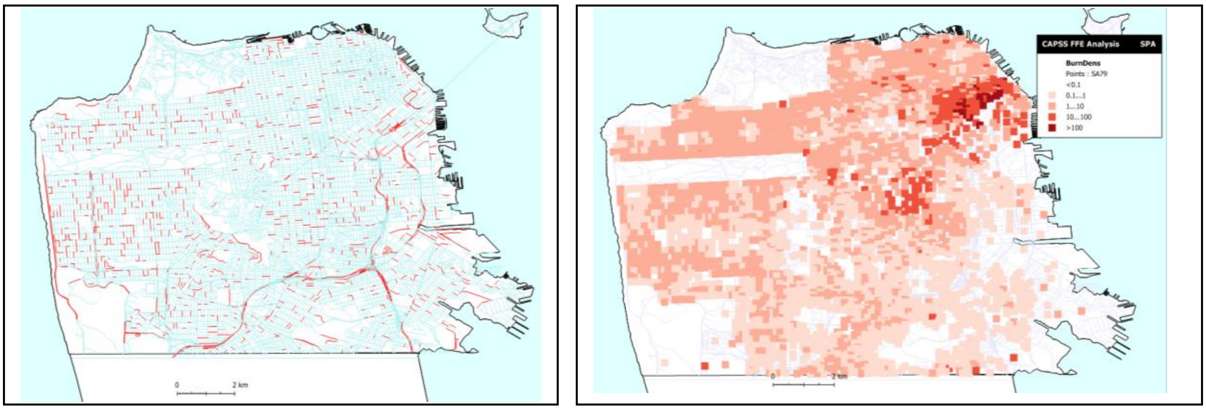

Figure 6 (left) San Francisco proxy Municipal Water Supply System (i.e., potable water system) with estimated pipe sections with breaks shown in red, for San Andreas Mw 7.8 scenario. Note that the estimation of the pipe breaks is a random process, so that only the general distribution, and not specific locations, of breaks are meaningful. (right) Distribution of Burn Density per block (millions $) for San Andreas Mw 7.8 Scenario.

WATER SUPPLY

While the fire service in California since 1906 has professionalized and advanced technologically to the point of being perhaps the best in the world, it has not been tested by a major earthquake since 1906. Water systems in California have failed in virtually all urban earthquakes in California – as a result, water departments have engaged in major reviews of their system's seismic vulnerability, and spent hundreds of millions of dollars seismically upgrading their systems. Exemplary programs include LADWP and MWD in Southern California, and EMBUD and San Francisco's Hetch Hetchy system in Northern California, to name a few of the larger programs.

Nevertheless, the Achilles Heel of these systems, and the entire fire following earthquake problem, remains the distribution system – despite massive seismic retrofit programs, it has not been possible to replace all of the distribution systems, and it is quite possible that numerous distribution breaks will occur in the high intensity areas of a major earthquake, which are also the areas most likely to have fires. Distribution breaks will not neighborhood of the fire – for the firefighter, effectively the same thing. Knowing this, fire departments have identified and developed plans to access alternative water sources – in most cities

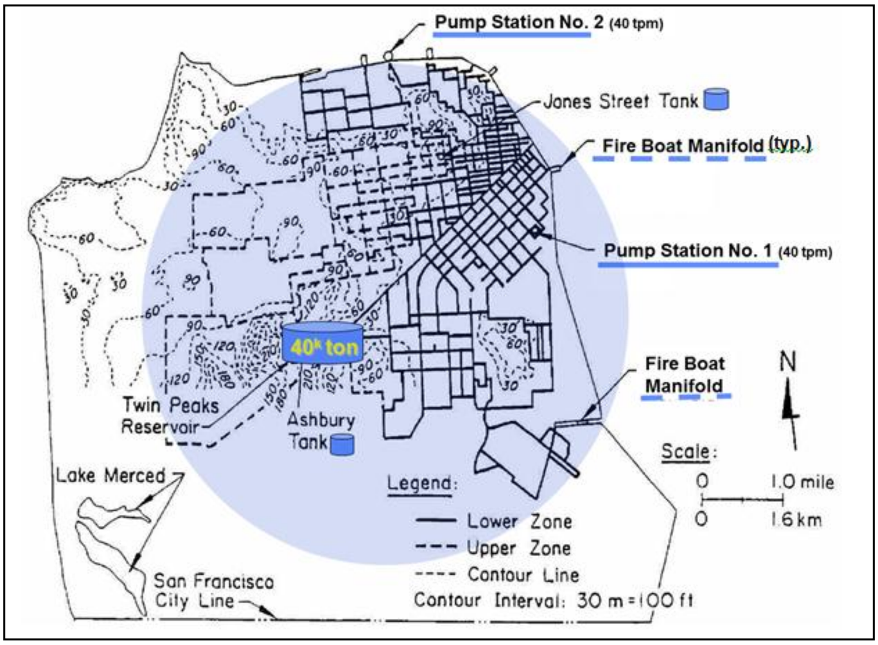

Figure 7 San Francisco AWSS

for example, these include swimming pools, tanks, creeks, ponds and storm water drains. San Francisco, due to its experience in 1906, has gone far beyond this, to develop and maintain the high pressure seawater-supplied Auxiliary Water Supply System (AWSS) and 172 cisterns (underground water tanks spread throughout the city). In fact, San Francisco in June 2010 approved $104.2 million to enhance this system as part of a $412.3 million bond, which also included a new police/fire headquarters and rehabilitation of existing fire stations.. However, most other cities, particularly Los Angeles, San Jose and San Diego, lack such systems and, quite worryingly, the capacity of their water supplies (normal, and alternative) have been little examined vis-à-vis the demands that multiple simultaneous post-earthquake fires will place on those supplies.

To further examine this issue, (Scawthorn, 2011a) surveyed fire and water agencies – responses were received from agencies representing about one third of urban California, and key findings included:

- Most larger urban fire and water agencies are ill informed as to the specifics of their earthquake risk
- Earthquake is recognized as a key issue by fire and water agencies, although many water agencies see provision of potable water as a higher priority in some cases than firefighting.
- Water agency system vulnerabilities are not well understood by fire agencies, although water and fire agencies both generally believe most municipal water supply systems are unreliable in a major earthquake.
- Some fire agencies have vigorously addressed this issue, developing innovative high pressure and/or portable water supply systems. Many have not.
- Some water agencies have alternatives given loss of normal water supply, but many are not well enough equipped to actually move water a significant distance.
- Fire and water agency liaison is not very good, and is often somewhat indirect solely through larger enterprise-wide coordination meetings. Emergency firefighting water supply is not a focus.

In summary, the survey found that the risk of post-earthquake conflagration in urban California is very significant, and that the crucial need for post-earthquake firefighting water supply is falling through a gap. Reasons why this is happening are briefly explained, but the key issue is how to correct the situation. To do so, the following general recommendations were provided:

1. Highlight the problem to the California Fire Service, for example by a meeting of the Metro Fire Chiefs, perhaps in conjunction with the Seismic Safety Commission and CalEMA.
2. Enlist the Water Community via a joint meeting of key senior fire chiefs and water department managers, perhaps held under the auspices of the Seismic Safety Commission and CalEMA.
3. Develop state-wide requirements for earthquake firefighting water reliability target, and that water and fire agencies should develop and submit plans for measures intended to achieve these goals by a given date.

Additionally, three specific measures are suggested for further study:

- Development of a standardized California portable water supply

Figure 8 San Francisco, Oakland and Vallejo FD PWSS units

system (PWSS) that would be deployed in major urban areas. This PWSS system would suffice for the San Francisco Bay Area.

- Development of a saltwater high pressure system for the Los Angeles Metropolitan Area (Los Angeles and Orange counties), to be used in conjunction with the PWSS. The LAM area saltwater system is quite feasible, if existing larger storm drain channels can be used for pipeline rights-of-way.
- Development and deployment of neighborhood equipment container caches, for use by NERT, CERT and other volunteers, to enhance their currently very limited post-disaster firefighting capability.

Figure 9 Berkeley FD 12” (30 cm) Aboveground Water Supply System (BAWSS)

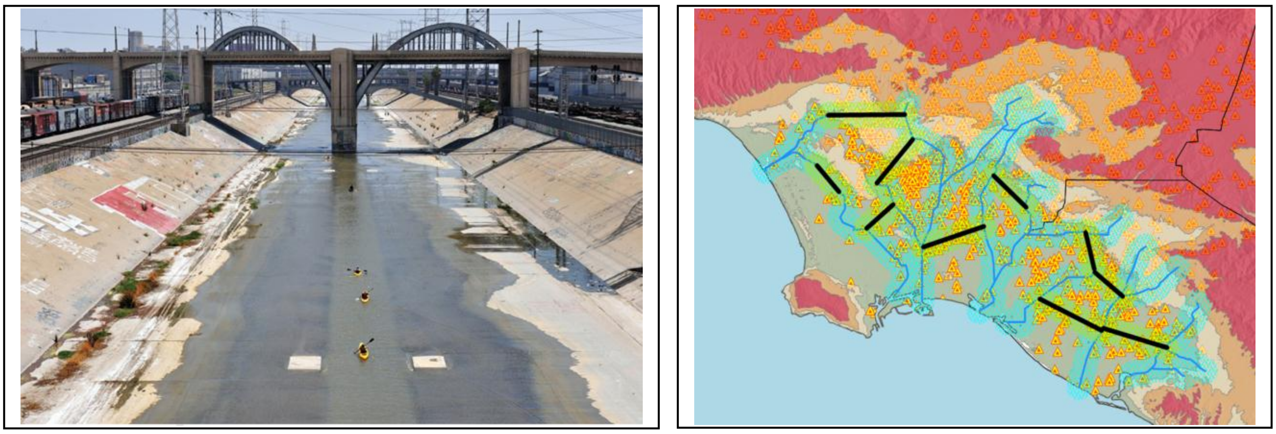

Figure 10 (left) Los Angeles county storm drain channel network (right) selected existing larger Los Angeles and Orange county storm drain channels (blue lines) with connectors to be built (black lines) overlaid on ShakeOut scenario ignitions. Blue buffer zones around lines would be areas reachable by a PWSS.

Figure 11 San Francisco NERT equipment container cache

Regarding insurance, the industry has played a key role in U.S. fire protection for over 100 years, and continues to do so today. This is due in part to the enormous exposure of the industry - about 9.5 million residential and 1 million commercial property insurance policies were in force in California in 2009, with a total value of $ 4.7 trillion, almost all of it exposed to fire following earthquake. The insurance industry through its periodic review of fire departments and their water supplies seeks to assure that fire departments remain well trained and equipped, and adequately supplied with water, for normal firefighting conditions. However, guidance provided by the insurance industry for adequacy of public water supplies does not mention or consider earthquake. The study examined a more densely built-up neighborhood in San Francisco, where it was shown that the water required for post-earthquake conflagration is far in excess of that required by current insurance standards.

PUBLIC AWARENESS

In order to increase public awareness of this issue, a four page brochure has been prepared, that graphically illustratates the risk of fire following earthquake, and offers recommendations for reducing this risk. The brochure will be a key tool in a major effort by the California Seismic Safety Commission to garner support for reducing this risk. The brochure is available at http://www.seismic.ca.gov/pub/CSSC_2011_4_PAGER_Water_Supply_PEER_Report.pdf .

2010 San Bruno Gas Pipeline Explosion; Source: National Geographic Pictures

FIRE FOLLOWING EARTHQUAKE

will water be there for firefighters?

Fire following earthquake (FEE) is a significant problem in California. Fire services in California have not been tested by a major earthquake since 1906. This study shows that a major earthquake in major metropolitan cities in California will result in simultaneous ignitions and water distribution breaks.

PEER

2008 ShakeOut Exercise M_w 7.8 San Andreas earthquake analysis found that

APPROXIMATELY 1,600 IGNITIONS OCCUR IN SOUTHERN CALIFORNIA, WITH THE CENTRAL LA BASIN EXPERIENCING HUNDREDS OF LARGE FIRES.

Los Angeles Basin; Source: johnlund.com

MOST FIRE AND WATER DEPARTMENTS IN CALIFORNIA

could be BETTER INFORMED about the specifics of their earthquake risk

generally believe most municipal water supplies are UNRELIABLE in a major earthquake

do NOT FULLY UNDERSTAND water department system vulnerabilities

Source: Survey of fire and water agencies conducted by PEER, 2011

Tokyo oil refinery following the 2011 Mw 9.0 earthquake; Source: daehanilbo.co.kr

CALIFORNIA IS HIGHLY EXPOSED

there are about 9.5 million residential properties

1 MILLION commercial property insurance policies in CA

$4.7 trillion is the total value of insured property

guidance provided by the insurance industry for adequacy of public water supplies DOES NOT mention or consider EARTHQUAKES

Source: Statistics from the CA Department of Insurance, 2009

there is a crucial need for post-earthquake fire fighting water supply in California.

this problem should be **highlighted** in joint meetings between key figures in the California Fire Service and key water agencies. State-wide plans for post-earthquake fire fighting should be developed and implemented.

Recommendations from PEER

THREE STEPS FOR SUG

1 Develop a standardized C Portable Water Supply Sys (PWSS) to be deployed in urban areas. This PWSS w suffice for the San Francis Area.

3 Develop and deploy neig post-disaster fire-fightin CERT, and other volunte

Portable Water Supply Systen

SALTWATER HIGH PRESSURE SYSTEMS

as alternative sources of water

San Francisco has already developed and maintains a high pressure seawater-supplied Auxiliary Water Supply System (AWSS). SF recently, in June 2010, approved a $412 million bond issue to enhance their system.

Central Los Angeles and Orange County could benefit from building a saltwater high pressure system since they are at great risk due to fire following earthquake.

This map shows Los Angeles and Orange County high pressure salt water system pipe network in storm drain channels (blue lines) with proposed connectors (black lines) overlaid on ShakeOut scenario ignitions. The pipe network is supplied from pump stations (P). Blue and yellow buffer zones around pipelines would be areas reachable by a PWSS.

GIS generated model; Source: Scawthorn

One of the larger drain channels in LA; Source: hcn.org

PEER

Pacific Earthquake Engineering Research Center

for more information, download PEER Report 2011/08

Water Supply in regard to Fire Following Earthquake by Charles Scawthorn

at:

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OR

http://peer.berkeley.edu/publications/peer_reports_complete.html

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Figure 12 Brochure re fire following earthquake

CONCLUDING REMARKS

Fire following earthquake is a significant problem in seismic portions of North America. The problem is being attacked on a broad front, not all aspects of which could be discussed due to space limitations. (Davidson and Lee, 2006, Lee, 2009, Lee et al., 2008, Lee and Davidson, 2006, Lee and Davidson, 2010a, Lee and Davidson, 2010b, Robertson and Mehaffey, 2000, Mickelson and Moore, 1995) are other workers in this field. The California Seismic Safety Commission is currently encouraging major urban fire and water agencies to work together to develop and implement post-earthquake water supply reliability goals for fighting fires.

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