From:	"Mochrie, Paul" <Paul.Mochrie@vancouver.ca>
To:	"Direct to Mayor and Council - DL"
CC:	"City Manager's Correspondence Group - DL" "Reid, Darrell" <Darrell.Reid@vancouver.ca>
Date:	6/4/2018 10:57:09 AM
Subject:	Memo - Fire risks following an earthquake
Attachments:	Memo - Fire Following EQ - Response to Council Inquiry - June 4 2018.pdf

Good morning Mayor and Council,

Please find attached a comprehensive memo prepared by our Office of Emergency Management regarding the risk of explosions and fires following an earthquake, as well as measures to increase seismic resiliency in high-density neighbourhoods. The memo responds to an inquiry from Council regarding the foregoing matters.

In summary, the memo confirms the following:

- Evidence from past events indicates that the number of fires resulting from ruptured gas mains is low relative to the total number of ruptures following a major earthquake.
- There is no evidence that the interaction between downed power lines and ruptured gas mains represents a materially increased risk of fire, as compared to the independent risks associated with those two ignition sources.
- The City of Vancouver has implemented a number of measures to mitigate the risk of fire following a seismic event. The memo also sets out a number of additional considerations in this regard.

Please do not hesitate to contact Chief Reid with any additional questions concerning this matter.

Best,
Paul

Paul Mochrie | Deputy City Manager
City of Vancouver | 453 W 12th Avenue
Vancouver | BC V5Y 1V4
604.873.7666 | paul.mochrie@vancouver.ca

CITY OF VANCOUVER

CITY OF VANCOUVER

OFFICE OF THE CITY MANAGER
Paul Mochrie, Deputy City Manager

MEMORANDUM

June 4, 2018

TO: Mayor and Council

CC: Sadhu Johnston, City Manager
Katrina Leckovic, City Clerk
Lynda Graves, Administration Services Manager, City Manager's Office
Rena Kendall-Craden, Communications Director
Kevin Quinlan, Chief of Staff, Mayor's Office
Naveen Girn, Community Relations Director, Mayor's Office
Darrell Reid, General Manager, VFRS and OEM
Daniel Stevens, Director of Emergency Management

FROM: Paul Mochrie
Deputy City Manager

SUBJECT: Fire Following EQ - Response to Council Inquiry

Reducing Fire & Explosion Risk & Increasing Resiliency in High Density Neighbourhoods after an Earthquake

This memo was written by the Office of Emergency Management in response to an information request from Council on reducing fire and explosion risk and increasing resiliency in high density neighbourhoods after an earthquake. The request for information was made at the October 17, 2017 council meeting (report 012264). The memo incorporates input from Vancouver Fire and Rescue Services (Fire Prevention); Engineering (Water Design); Real Estate and Facilities Management (Facilities Planning); Development, Buildings, and Licensing (Chief Building Official); and the Chief Resilience Officer.

Summary

The Office of Emergency Management conducted a preliminary literature review and received input from a range of City of Vancouver departments on the requested topic. A summary of the findings is below:

- The risk of fire following earthquake is directly related to the number of post-earthquake ignitions and the ability of the fire to spread. Fire ignitions are caused when an ignition source comes into contact with fuel. Some examples include overturned items on heating elements, short circuits and arcing from damaged electrical appliances or wiring, fallen candles, and leaking natural gas coming into contact with an electrical arc from a downed power line or damaged appliance. A fire's ability to spread can be impacted by building material, presence of sprinklers, likelihood of people present to identify and

suppress the fire or report it to the fire department, and the ability of the fire department to respond (which may be hampered by damaged to fire halls, communications systems, the water network, and roads; the number of simultaneous fires they are dealing with; ability of off-duty fire fighters to report to work; and other fire department responsibilities such as rescuing people from collapsed buildings.

- While the risk of fire and explosion resulting from the interaction of damaged gas lines and downed power lines exists, we were unable to find literature dedicated to examining the interaction explicitly. The literature reviewed treats fires from downed power lines distinctly from those resulting from broken gas mains even though both types are discussed in single papers. The lack of readily accessible research leads us to believe that the interaction between downed power lines and broken gas mains does not present as high a risk when compared to other types of post-earthquake fire ignition sources and fuel combinations. Additional research is required to confirm this.

- Earthquake experience in California has shown that the number of fires resulting from broken gas mains is very low when compared to the number of gas line breaks resulting from an earthquake.

- The fires following the 1906 San Francisco earthquake (M 7.9) are often cited as an extreme example of post-earthquake fire damage in the United States. The fires were devastating and resulted from a perfect alignment of contributing factors, both in the built environment, weather, and human behaviour post-earthquake. Despite the frequency of earthquakes in California, no Californian earthquakes have resulted in a similar level of fire damage since.

- The City of Vancouver has implemented a number of measures to reduce the risk of post-earthquake fire, including both mitigation and response measures. Some of the mitigation and response measures include:
    - construction of the Dedicated Fire Protection System and other methods of utilizing alternate water sources if the primary water distribution system is damaged (e.g. fire boats, portable HydroSub pumps),
    - planning for a seismically resilient network of water mains to service hospitals, critical facilities and Disaster Staging Areas,
    - fire safety provisions in the building by-law and fire code such as mandating of sprinkler systems in all new buildings,
    - an emergency management structure to coordinate response and facilitate reallocation of resources within the City and regionally/provincially,
    - hardened facilities such as the emergency operations centre and E-Comm radio system for first responders, and
    - earthquake response plans.

- Considerations for further risk reduction are included in section 4. However, the suggested measures would require further research and cost/benefit assessment.

1 Introduction

At the October 17, 2017, council meeting (report 012264), a request was made for information on the danger of fire during and after an earthquake, particularly on how the risk of explosion between natural gas leaks & overhead electrical wires can be reduced, and how resiliency in higher-density areas can be increased. This paper is written in response to that request.

Section 2 discusses the risk of fire following earthquake, including natural gas and electrical system damage. Section 3 gives a high-level overview of response and mitigation measures in place at the City of Vancouver, while Section 4 provides some suggestions for additional measures to reduce risk in the densely populated areas of the city.

The information in this paper draws heavily from the experience in California and recent earthquake modelling work[1] for British Columbia conducted by AIR for the Insurance Bureau of Canada. The information from California covers experience in jurisdictions with similar context to Vancouver while the AIR model provides an assessment of the impact of a subduction zone earthquake on British Columbia. However, the AIR model does not model all earthquake types that may impact Vancouver and there are also differences between the California and Vancouver contexts. Given this, the information in this paper should be considered as a high-level overview of the relevant factors but is not exhaustive.

2 Fire Following Earthquake

One impact of earthquakes in dense urban areas is fire, also referred to as *fire following earthquake* in the literature. Fires can result from building and content damage which causes fuels to come into contact with sources of ignition. Fires starting directly following an earthquake can grow unchecked as fire suppression resources are overwhelmed assessing damage, rescuing trapped people, and responding to other fires. Other factors which contribute to the potential for fires to grow unchecked include damage to communications systems and associated delays in reporting of fires (e.g. phone system damaged so fires cannot be reported to 911), the number of simultaneous ignitions, damage to the water system, and damage to the transportation system delaying firefighters from reaching the incident locations and hampering the ability of off-duty fire fighters to report to work and support the post-earthquake response. The extent of fire-following earthquake is difficult to predict due to a number of contributing factors. A number of earthquakes in California have shown a wide range in terms of numbers of ignitions and damage from fire.

Two key components or risk of fire following earthquake are the *number of ignitions* and the *ability for the fire to spread.*

2.1 Ignitions

The recent earthquake risk assessment conducted by AIR for the Insurance Bureau of Canada indicates that fires are most likely to be ignited by overturned items on heating elements, electrical short circuits, and broken gas lines releasing gas that finds an ignition source.

[1] AIR Worldwide. 2013. "Study of Impact and the Insurance and Economic Cost of a Major Earthquake in British Columbia and Ontario/Québec" http://assets.ibc.ca/Documents/Studies/IBC-EQ-Study-Full.pdf

Overhead power lines in close proximity to buildings also increase the risk as they may be damaged and ignite flammable material on or near the building. Delayed ignitions may also occur when power is restored to areas that initially lost power following the earthquake. Based on the modelling done by AIR for a subduction zone earthquake in BC, it is estimated that ground shaking will cause fires on 55-56 city blocks throughout the Metro Vancouver region in the two days following an earthquake. This is broken down by 6 ignitions within 20 minute of the earthquake, 12 by 1 hour, 24 within 3 hours, and up to 27 after 10 hours (the number of ignitions is cumulative). The extent of damage from these ignitions is directly related to the ability for the fire to spread.

2.2 Ability for the fire to spread

The ability for fires to spread is dependent on a wide range of factors. On average, it is expected that each fire will last about three hours. Some fires will be extinguished locally by people in the vicinity of the fire. However, depending on time of day and type of building, there may not be anyone in the vicinity to report the fire quickly or initiate suppression. Fire department suppression resources will likely be overwhelmed and occupied assessing damage, rescuing trapped people, and responding to other fires, also increasing the likelihood of some fires to spread. Other factors which contribute to the potential for fires to grow unchecked include damage to communications systems and associated delays in reporting of fires (these were both issues reported during the 1995 Kobe, Japan, and 1989 Loma Prieta, California, earthquakes), the number of simultaneous ignitions, damage to the water system, and damage to the transportation system delaying firefighters from reaching the fire locations and hampering the ability of off-duty fire fighters to report to work and support the post-earthquake response. Damage to fire department infrastructure is also a factor.

Vancouver Fire and Rescue Services provides service from 20 Fire halls across Vancouver (including one at UBC), as well as other supporting spaces such as Fire and Rescue Training Centre and Fleet maintenance yard. The oldest fire hall (Fire Hall 6) was built in 1907 with the newest in 2011 (Fire Hall 15). All fire halls have been reviewed as part of the City of Vancouver Seismic Program. Seven out of the 20 halls can expect to receive some level of post-earthquake damage impacting VFRS's ability to respond. Two fire halls are recommended for seismic upgrade and 5 are recommended for redevelopment at this time. Delivery of these projects is conditional of funding and other competing priorities.

Density of buildings and building construction type are also major contributing factors to the spread of fires. Fires are more likely to spread between wood-framed homes (often with combustible-siding) than between mid- and high-rise structures such as those in the downtown core, though high-rise structures are not immune as fire can still spread through windows. Weather is also a major factor in the spread of fires which can be highly variable, with wind and humidity being a significant factor.

Since 1990, the Building By-law has required all newly constructed buildings to be protected by automatic fire sprinklers. Experience has shown that a fire occurring in a building that is sprinklered does not readily spread to adjacent buildings. Over time, the number of buildings that are sprinklered will increase due to development. However, there remain a significant number of older buildings in Vancouver without sprinklers and these are at higher risk of

uncontrolled fire. In addition, sprinkler systems typically get their water from municipal water mains. If the municipal water system is damaged, this could render the sprinkler systems inoperable thereby increasing the likelihood of uncontrolled fire.

The Building By-law also requires minimum setback between buildings. This reduces the risk of fires spreading between buildings. However, older buildings were built to previous regulations where the requirements were not as stringent; therefore protection from setbacks is inconsistent across the city.

2.3 Natural Gas and Electricity

It is estimated that natural gas has played, and will continue to play, a role in between 20 percent and 50 percent of fires following earthquakes in California. It is also estimated that electricity plays a role in as much as 50 percent of fires following earthquake. An assessment of the interaction between electricity and natural gas was not explicitly covered in the literature reviewed.

In the case of electricity, ignitions occur due to damaged wiring or electrical components which act as a source of ignition when they come in contact with combustible material. In the case of gas, ignitions occur when gas is released due to damaged gas systems and an ignition source is found. The ignition source could be electrical arcing in a damaged electrical system or another source, such as a candle or pilot light. It is important to note, however, that natural gas will only burn or explode when the air has a concentration of between 5% and 15% natural gas. Below or above this range the gas will not ignite. Given this, the potential for fire ignition from natural gas is low when compared to the number of leaks, and is most likely to occur in areas where gas can accumulate to the required concentrations.

In the 1987 Whittier Narrows earthquake, approximately 75% of gas leaks occurred at appliances (primarily at water heaters) and similar results were noted in the San Fernando earthquake of 1971. This is important to note when it comes to mitigation measures as these connections are within buildings and not components of gas company distribution systems, such as underground gas mains.

In the case of both natural gas system damage and damage to the electrical system, mitigation measures include strengthening buildings to minimize damage to in-building lines and wiring. California has also seen significant reductions in natural gas supply line failures by preventing gas-fired equipment from moving relative to the building during an earthquake. This can be achieved by securing equipment (such as stoves and water heaters) to the building so the supply lines do not break. Such measures are promoted in the City of Vancouver's public emergency preparedness education and by Fortis BC. Kits are readily available to secure heaters and other gas-powered appliances (approx. cost of $20-$100, depending on kit and type of appliance). In areas with overhead high-voltage power lines, consideration should be given to burying these lines to reduce risk of electrocution and fire should they be damaged.

The combination of natural gas line ruptures and downed power lines needs to be investigated further and was not explicitly covered in the literature reviewed. However, natural gas is lighter than air and dissipates quickly in open space. This means that while downed power lines (which

are generally outdoors) may cause arcing, the chances of the arc coming into contact with natural gas of a combustible concentration may be low when compared to its potential to ignite other material. Nevertheless, damage to components of the natural gas and electrical systems contribute to a significant proportion of fires following earthquake.

3 Response Measures

Vancouver has a number of response measures in place to respond to fire following earthquake. These include the Dedicated Fire Protection System, gradual buildout of a seismically resilient water network, disaster response plans for VFRS and for the rapid assessment and restoration for our water system, and the coordination mechanisms inherent in our emergency management structures (e.g. emergency operations centre, department operations centres, and disaster staging areas) which are designed to function with or without central coordination in place. These response measures contribute to the likelihood of identifying fires, assigning resources to fight them as quickly as possible, and ensuring the water supply is sufficient to support firefighting efforts. An overview of our key response measures is presented below.

3.1 Response Plans and Coordination Structures

The City and its departments have a range of response plans to coordinate rapid response to earthquake. These include the overall City of Vancouver Emergency Response and Recovery Plan which specifies the overall coordination structure comprised of the emergency operations centre to coordinate between and support departments, department operations centres (such as the VFRS Department Operations Centre) to coordinate department operations, and Disaster Staging Areas throughout the City to enable rapid response by on-duty/on-shift field staff while the emergency operations centre and department operations centres are being established.

VFRS also has an earthquake response plan to rapidly assess the City to identify response needs (e.g. fires and collapsed buildings) by driving pre-determined routes from each fire hall. This will aid the identification of fires even if 9-1-1 is overloaded or otherwise impacted. The VFRS drive-by survey complements similar assessments conducted by other staff operating out of our Disaster Staging Areas.

Engineering Services has a water system response plan which includes rapidly assessing the key components of the water network to isolate breaks and maintain and restore supplies of water for firefighting. In addition, the City has a number of emergency wells to draw ground water, although yield volumes are expected only to supply emergency drinking water.

Despite these measures, there are also hindrances to maximizing the effectiveness of a coordinated response. These include differences in equipment standards, including differing hydrant connections and fire apparatus, between municipalities and the potential difficulty in getting off-duty fire fighters and other staff into Vancouver from their homes in neighbouring municipalities (especially those that require crossing major bridges).

3.2 Response Infrastructure

The City of Vancouver has emergency response infrastructure that will be activated following an earthquake. This includes an Emergency Operations Centre (EOC) in a post-disaster building, E-Comm, with redundant systems energy, water, food, and communications systems. In the case that the building is impacted, alternate emergency operations centre equipment has been stationed at other locations so that an EOC can be established in a safe alternate facility.

Another critical component of the City's response infrastructure is the Disaster Staging Areas. These are facilities which on-duty/on-shift staff will use to coordinate critical operations immediately following an earthquake. They are located in shipping containers in open spaces away from buildings that could be damaged. They consist of communications equipment, damage assessment kits, and coordination tools and equipment as well as associated procedures and information to guide response activities. The Disaster Staging Areas will enable staff to coordinate response efforts within their respective zone and between zones while the emergency operations centre and department operations centres are being established. The initial priorities for each Disaster Staging Area are to assess damage (including identification of fires), clear key transportation routes, and conduct rapid building damage assessment on critical facilities so they can be cleared for use. The Disaster Staging Areas complement and integrated with the activities of VFRS and other first responders and provide a bottom-up coordination method for field staff.

In addition to these key locations, the City also utilizes the E-Comm radio system which is a hardened radio communications system for first responders and emergency management. Most of our key response sites and personnel have E-Comm radios installed or are in the process of having them installed (expected completion end of Q2 2018). These sites also include backup communications in the form of satellite phones, engineering radios, wireless (cell-phone based) internet, and Amateur Radio capabilities.

To enhance the resilience of our existing water system, a plan for a coarse network of hardened, strengthened water mains has been developed. This network has been developed with VFRS and the OEM, and will, upon buildout, provide a resilient and more reliable water service to hospitals, critical facilities, and Disaster Staging Areas. Currently, investment in the seismically resilient network has been through opportunistic upgrades leveraged through growth and redevelopment, as well as through our existing pipe renewal programs. At the current rate, the network will be complete in approximately 80 years. As part of the capital planning process, it is recommended that a focused and targeted investment be made in areas of the city with ground conditions that have a higher susceptibility to movement as these areas are where the water system is at a greater risk of sustaining damage.

The Dedicated Fire Protection System was built to provide redundancy to our primary water system. The system consists of two salt-water pumping stations connected to a resilient network of underground pipes and hydrants in downtown Vancouver, parts of Kitsilano, and reaching east to Vancouver General Hospital. The DFPS also consists of a deployable above-ground hose and hydrant system to extend the reach of the DFPS beyond the fixed network. The DFPS was designed to ensure the high-density areas of Vancouver have ready access to firefighting water should the regular water network be damaged. While the system was designed to cover high density areas of Vancouver, the city has grown and changed since it was built. Resilience

of the water infrastructure in the new high-density areas should be reviewed in conjunction with new infrastructure investments to main water lines by Metro Vancouver, the gradual buildout of a hardened, seismically resilient potable water network, and consideration given to expansion of the DFPS if warranted. Work in this area is underway in Engineering Services.

3.3 Community Response

Response at the community level may come in several forms, including suppressing small fires before they become large or detecting and reporting fires.

VFRS provides fire safety awareness training to the public as well as hands-on courses in how to effectively use a fire extinguisher to quickly suppress small fires. The effectiveness of these programs should be reviewed and consideration given to how these programs can be expanded to reach a greater audience and/or integrated into or cross-promoted by other emergency preparedness training offered by the City (such as the emergency preparedness training through the neighbourhood emergency preparedness program).

Reporting of fires is also a critical role of the community. While 9-1-1 is the normal reporting mechanism for fires, the telephone system may be damaged or overwhelmed following a major earthquake, especially as more and more people rely on mobile communications. The City has established Disaster Support Hubs throughout the City, primarily at community centres, to enable community-led support. In addition to other functions, these Disaster Support Hubs are locations that the public could report fires and other critical incidents if 9-1-1 or the phone system is overloaded or not functioning. These critical incidents could be relayed back to the emergency operations centre by Amateur Radio. It should be noted that these sites rely heavily on community and volunteer efforts, such as those of the Vancouver Volunteer Corps (including the VECTOR amateur radio volunteers) and neighbourhood-based organizations, and the ability for each Disaster Support Hub to be an effective relay of critical information will be linked to the ability for volunteers and community members to mobilize. It is always preferable for fires to be reported directly to 911 when possible.

4 Additional Mitigation Measures to Reduce Risk in High Density Urban Areas

This section outlines a number of additional measures that may be considered as options to further reduce risk in high-density areas of Vancouver. Each measure requires further assessment for cost-benefit, taking into consideration other measures currently in place or underway. Further work in identifying resilience-building measures is also being led by the Chief Resilience Officer as part of the Resilience Strategy development.

Reducing number of fire ignitions

1. **Increase education, incentives, and regulation to increase the number of secured gas appliances and electrical equipment.** While the City of Vancouver and partners have provided information on securing of such equipment, it is up to each individual building owner, manager, or tenant to take necessary steps to secure the equipment. The City and partners (such as the insurance industry) should explore additional ways to continue educating, incentivizing, and/or regulating the securing of such equipment, and

measure the extent of unsecured equipment in the City through a survey.

2. **Explore options for automatic gas shut offs.** Automatic seismic gas shutoffs are not recommended for wide use as most in-building gas systems are not damaged during earthquakes (and most of those that are damaged do not result in fires before they are shut off or repaired). The widespread automatic shutdown of gas results in significant delays to re-connecting gas at buildings as it must be restored by certified technicians who will be in short supply post-earthquake. However, the literature discusses options for automatic gas shutoff devices that shut off gas when leaks are detected as opposed to when a certain level of shaking is experienced. Gas shut-off devices may be suitable in some high-risk buildings and should continue to be explored and encouraged where suitable.

3. **Upgrade high-risk existing buildings and include reducing fire risk in retrofit programs**. While new buildings should meet current seismic requirements in the building code, the majority of buildings in Vancouver were built before seismic requirements were introduced. Many buildings at high-risk of structure failure are also at higher risk of fire. The Building By-law has graduated levels of seismic and fire protection upgrade requirements for any building proposed to be renovated or have a change of use. The City is conducting a comprehensive risk assessment of all buildings with intent to bring recommendations to Council in 2019.

Reducing ability for fire to spread

4. **Continued investment in hardening the network of water mains.** As discussed in Section 3.2, continued investment in the buildout of a seismically hardened water network is strongly recommended to provide hospitals, critical facilities, and Disaster Staging Areas with a reliable source of water.

5. **Assess coverage of DFPS given population growth and expected development patterns and consider expansion.** As discussed in section 3.2, the City of Vancouver built the Dedicated Fire Protection System to provide firefighting water to the densely populated areas of Vancouver if the regular water system was damaged. It is limited in geographic scope, covering mostly the downtown core, parts of Kitsilano, and extending east to Vancouver General Hospital. However, as the City continues to grow and develops new high-density areas, the DFPS coverage should be reviewed alongside the development of the seismically hardened water network.

6. **Install power lines underground.** Some developments have high voltage power lines buried underground which removes the risk of downed overhead lines. The City should work with BC Hydro to continue efforts to bury overhead power lines where possible, as this will greatly reduce the risk of fire from downed power lines. This has the co-benefits to reducing power outages from windstorms and reduces risk to the public from electrocution from downed power lines.

Improving response coordination and mutual aid

7. **Exercise post-earthquake fire response coordination mechanisms.** The City has a multi-year emergency exercise program which includes a City of Vancouver earthquake exercise in 2019 and participation in the upcoming regional/provincial exercise.

8. **Explore standardization of fire equipment and hydrant connections regionally.** To facilitate mutual aid between fire departments, standardization of some fire equipment should be considered, including hydrant connections and portable pumps.

5 Conclusion

Fire following earthquake remains a significant risk to life and property, and damage to gas and power systems contribute to a significant proportion of post-earthquake fires. The literature does not explicitly examine the interaction between damage to electrical wires and damage to the gas system, however, in some situations damage to both systems can result in fires. The risk of fire from the combination of damaged power and electrical systems is likely low compared to fires resulting from damage to the two systems independently, and the overall instances of fire resulting from damage to these systems is low compared to the overall damage to these systems (i.e. most damage to gas and electrical systems in an earthquake does not result in fire).

Paul Mochrie
Deputy City Manager