Summary Report on

7th US Technical Council for Lifeline Earthquake Engineering Conference

Oakland, California, July 2009

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7th Conference of the US Technical Council on Lifeline Earthquake Engineering

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Summary of Key Observations and Impressions

1. The many risk reduction issues highlighted by Hurricane Katrina appear to have people thinking more about multi-hazards
2. The concept of core Lifeline Utilities as 'Enabling Infrastructure' that underpins other infrastructure categories
    - ie. the core infrastructure services of power, gas and liquid fuels, water, telecommunications and transportation underpin and enable the other infrastructures to operate, therefore should be deemed 'critical', along with financial services.
3. No significant new work or breakthroughs around interdependency analysis
4. Several papers highlighted that the restoration of water supplies to public hospitals is critical to community recovery
    - this was under-estimated in Katrina, as it is in NZ (particularly in Wellington and Auckland).
5. A greater willingness to indicate to the public the likely duration of water system outages
    - eg. San Francisco Public Utilities Commission and the California Seismic Safety Commission acknowledging <u>60 day outages</u> currently anticipated with a rupture of the San Andreas fault, hence the need for a US$4.6billion upgrade of that network
6. A corresponding increase in effort to articulate post-earthquake service levels for restoration. For example, the bulk water outcome objective is:
    - winter demand within 24 hours at 70% of bulk network turnout points equally across the three service regions, and
    - average demand restored across the network within 30 days
7. Encouragement to:
    - keep thinking and acting at a <u>systems</u> level (incl. system of systems) rather than just at an <u>elemental</u> level
    - focus on understanding and addressing the primary dependencies – the 'de-stabilisers' that would cause significant disruptions, rather than seeking to understand and quantify all dependencies
    - act on the weaknesses that we already know exist

1. Conference Overview

This conference is held at approximately four-yearly intervals, and is one of the few international conferences that focus on Lifelines Engineering matters. New Zealand has been represented at TCLEE conferences since 1991, and the information and ideas brought back to have assisted in creating and maintaining the momentum behind Lifelines Engineering in this country.

The US Technical Council for Lifelines Earthquake Engineering (TCLEE) was established in 1974 as a committee of the American Society of Civil Engineers (ASCE). The principal objective of TCLEE is to enable academic and professional lifeline engineers to meet regularly to discuss and share lifeline seismic issues and research, including earthquake investigations and reconnaissance.

TCLEE acts as a focal point for the production of high quality technical guidelines, reconnaissance reports and monographs. They hold this major national conference approximately every four years.

The conference was attended by approximately 250 people. Most were from North America, with some from other countries. A number had registered from China but did not attend due to H1N1 concerns.

Attendees reflected a mix of utility representatives, researchers, consultants, emergency managers (incl. FEMA and national funding agency representatives).

New Zealand was represented by Dave Brunsdon (National Engineering Lifelines Co-ordinator), Brian Park (Watercare Services Ltd, Auckland), David Johnston (GNS Science) and Tom Wilson (University of Canterbury). Funding for Dave Brunsdon and Brian Park's attendance was provided by EQC.

The paper presented by the report authors was *Lifeline Vulnerability to Volcanic Eruption: Learnings from a National Simulation Exercise*, which summarised the key lifeline utility impacts of the Auckland Volcanic Field eruption scenario in Exercise Ruaumoko, with an emphasis on water networks.

The conference had an associated workshop on post-earthquake building safety evaluation processes which was attended by Dave Brunsdon (refer notes in Appendix A). A post-conference meeting was also held with Zan Turner (formerly San Francisco City Council) on post-earthquake building safety evaluation processes, and with David Hammond (US Army Corps of Engineers) on Urban Search and Rescue Engineering matters. Brian Park undertook post-conference visits (funded by Watercare) to the San Francisco Public Utilities Commission (San Francisco Water) and CH2MHill & Mountain Cascade (re Auckland's Hunua No 4 watermain project) in Sacramento.

Conference papers were supplied on a CD; a sample list of papers of interest is included in Appendix B. Copies of papers can be obtained from the report authors.

2. Overall Trends and Issues

The conference was much more multi-hazard oriented than in the past. The many risk reduction issues highlighted by Hurricane Katrina appear to have many people thinking more about multi-hazards.

- eg. exploring the similarities and differences between earthquake, 911 and Hurricane Katrina hazard contexts
- the increasing threat from larger and more frequent storms
- interdependencies not previously appreciated. For example, oil lines down for 12 to 14 days in Katrina due to lack of power for pumping

This has led to acknowledgement that the future direction is in drawing together the <u>physical</u> environment (natural and built) and <u>social</u> environments (demographic and economic).

There were no new definitions of critical infrastructure. Tom O'Rourke observed that Critical Infrastructure had been an evolving concept in recent years, extending to 17 different sectors in the National Infrastructure Protection Plan in 2006 after 911. This broadening was seen as too complex and unhelpful, causing dilution of focus in terms of where does one sector end and another begin, and allocation of responsibility for risk identification and mitigation.

Keynote speakers questioned whether we are learning enough from infrastructure failures and near misses (nationally and internationally).

- an example in the NZ context is lack of consideration given to how urban fires following earthquake would be fought using water from harbours
- the tyranny of Deja Vu!!

Keynote speakers provided encouragement to

- keep thinking and acting at a <u>systems</u> level (incl. system of systems) rather than just at an <u>elemental</u> level
- focus on understanding and addressing the <u>primary dependencies</u> – the destabilisers, and what would cause significant disruptions - rather than seeking to understand and quantify all dependencies
- act on the weaknesses that we already know exist e.g. SFWater & EBMUD-Haywards; LADWP – San Andreas
- ensure the code compliance of facilities that are in close proximity to risk

While there was no significant new work or breakthroughs around interdependency analysis, there was emphasis on understanding compounding cascade effects (eg the effect of loss of water on telcos in 911, rapid rail; power in Hurricanes Katrina & Rita).

There was also emphasis from the Keynote Speakers that long term economic impact is strongly influenced by the recovery of lifelines.

3. Quantifying Disruption Periods and Service Restoration Levels and Time Frames

There appears to be a greater willingness to indicate to the public the likely duration of water system outages, and a corresponding increase in effort to articulate post-earthquake service levels for restoration.

For example, the San Francisco Public Utilities Commission (SFPUC) and the California Seismic Safety Commission have acknowledged that 60 day outages are currently anticipated with a rupture of the San Andreas fault. This is the justifying basis for a US$4.6billion upgrade of that network.

Officials were being much more guarded about such comments at the last conference six years ago.

The outcome objective (service level target) for this event post-upgrade is winter demand within 24 hours at 70% of bulk network turnout points equally across the three service regions, and average demand restored across the network within 30 days.

Similarly, East Bay Municipal Utility District (EBMUD) are seeking to reduce the post-earthquake water supply loss from (currently) 60% after day 1 and 75% day 2 to 40% loss after day 1, 20% loss after day 10 and 100% recovery within 60 days. This is to be achieved by a combination of emergency connection to SFPUC, shut-off valving and rapid deployment of portable pumping. A similar approach is being adopted by Hayward & Milpitas Cities (customers of EBMUD).

Los Angeles Dept of Water and Power (LADWP) also cited economic loss attributable to failure of water supply as the main motivation to improve system recovery post event. LADWP estimate that a M7.3 San Andreas fault earthquake would cause losses of $213billion (incl. $87b due to fire; $53b business) due to loss of water supply.

Several papers (including by Stephanie Chang) highlighted that the restoration of water supplies to public hospitals is critical to community recovery. This was under-estimated in Katrina, as it is in NZ (particularly in Wellington and Auckland).

A lack of recognition of interdependencies in designing resiliency of networks was however noted (e.g. power and water, EBMUD & Pacific Gas &Electric (PG&E) for Hayward scenario). PG&E have undertaken major facility seismic upgrades post-Loma Prieta with little consultation with EBMUD re critical water facilities (treatment plants, pumping stations etc). EBMUD have addressed the issue with generator connection capability. PG&E acknowledged that they have no priority recovery plan with regard to water.

4. American Society of Civil Engineers Report Card

- 'D' overall (ranging from D- to C+); largely unchanged over past four years – refer to full copy of report card.
- Promoting resilience is one of the 5 key solutions offered by ASCE.
- A Critical Infrastructure Guidance Task Committee has been formed post-Katrina. Guiding principles are to be published within three months *(NZ followup required).*
- Encouragement was given to ASCE members to get politically active.

5. The American Lifelines Alliance

The American Lifelines Alliance (ALA) is a public-private partnership funded by FEMA and managed by the National Institute of Building Sciences (NIBS). The goal of ALA is to reduce risks to lifelines from *all* hazards, and the output focus is on the production of *best practice guidelines for utilities* (ie post-research, with significant practitioner input). Guidelines produced to date cover piping systems generally, ice storms, seismic fragility formulations for water systems and natural hazards performance objectives for water. See http://www.americanlifelinesalliance.com/ for downloadable versions of these guidelines, and for a matrix which identifies the current status of natural and man-made hazards guidance available in the US (ie. those available and those not yet produced).

Unfortunately ALA is in hiatus, with FEMA funding having been withdrawn. The website is being maintained, but no further work currently underway or being posted.

Discussion panel & keynote speakers noted that while there are building codes, there is a general lack of "Lifelines codes" apart from those previously developed by ALA. For example the common definition of return period earthquake required for Lifelines design, as there are inconsistencies between entities.

US Government stimulus packages allocated $73b of $780b for infrastructure resilience/improvement. However only 49% of the estimated $2.2t required for infrastructure is in the budget.

6. Hazards and Impact Modelling - ShakeCast

- ShakeCast has been developed by US Geological Survey to build upon the successful ShakeMap, which generates mapping representations of the extent and severity of ground shaking following an earthquake.
- ShakeCast (short for ShakeMap Broadcast) uses earthquake shaking data from ShakeMap, compares intensity measures against users' facilities, sends notifications of potential damage to responsible parties, and generates facility damage assessment maps and other Web-based products for emergency managers and responders.
- Operates on an open technology platform, but is able to integrate with more advanced software to estimate damage impacts.

- ShakeCast has been used by CalTrans to estimate the levels of bridge damage to prioritise the bridges to be inspected immediately following an earthquake. This application is seen as being well-suited to state-wide or national networks comprising large numbers of discrete infrastructure, where epicentral information and modeled intensities doesn't provide sufficient information for a rapid, dispersed response.
- Users apply ShakeMap to their own inventory via ShakeCast – it doesn't require submission or sharing of inventory.
- Can be used to generate comprehensive scenarios for modelling response capabilities, and training and exercises.
- Future developments proposed include the ability for users to defines their own metrics

(see http://earthquake.usgs.gov/shakecast or report authors for additional information)

7. Water Sector

General

- Emphasis is on mitigating backbone networks as the first restoration priority to get water to the community
- Importance of redundancy within networks and serviceability/ maintainability as a resilience measure.
- Much work has been undertaken on systems fragility and damage assessment to target mitigation initiatives/priorities
- San Francisco Water (water wholesaler) initiatives cited above are targeted at vulnerable locations along network, and include:
  - Building in network redundancy to enable system maintainability – pipelines, harbour crossings and tunnels duplication
  - Seismic upgrade of Water Treatment Plants
  - Seismically-triggered isolation valve capability at fault crossings (Hayward)
  - Pipeline articulation capability/capacity at fault crossings
  - Redundancy and interconnectedness to enable network reconfiguration
  - Upgrade/reconstruction of impoundment dams to new seismic standards (Calaveras dam)
  - Provision of emergency standby power generation at key facilities
  - EBMUD have a very similar approach but a lesser budget
- LADWP had undertaken assessment of effects (M7.3 San Andreas) on the water supply aqueducts feeding the region and the time required to repair and restore e.g. California Aqueduct 18 to 24 months restoration, with the result being rationing 25 to 75%. Response plan to bring into service local storage that is normally isolated off-line due to water quality issues (Trihalomethanes - THM's) as well as abstraction within consent of underground sources (little flexibility here as over-abstraction will lead to saline contamination). All aqueducts supplying LA are very vulnerable to this scenario.

- The emphasis of many of the above initiatives is to protect network for drain down and loss of storage.
- Some very good technical information gathered from research on pipeline connections and pipelines performance at fault crossings. This includes welded steel pipe joints under compression and tensile loads that should be very helpful in design of connections to fixed structures (reservoirs) and pipelines for NZ situation and may resolve on-going technical disagreements.
- Design approach for pipelines (water, gas) is for 475 year return event and compare with 1,000 & 2,000 year event. Design to 2/3rds of max. loading (475 year return period) as full effects are not experienced over entire pipeline. Targeted site specific design at fault crossings – this seems to be a very practical approach, and ties in with interpretation of American Lifelines Association guidelines.

GIRAFFE Software

A new software package has been developed for Los Angeles water supply which enables damaged segments to be excluded and major leaks modelled – ie. not equilibrium-based like typical hydraulic network models.

Graphical Iterative Response Analysis of Flow Following Earthquakes (GIRAFFE) is a software program which estimates the damage and serviceability for the Los Angeles water supply system when it is heavily damaged and standard hydraulic analysis models do not apply. It is leading to a better understanding of the critical role of reservoirs - both within networks operationally and for supply the community in the short-term.

GIRAFFE is used to estimate multiple realisations of the initial post-earthquake damage, and to estimate the serviceability associated with the changing damage states at 12 hour time intervals, as the damage is repaired by the restoration model. Damage is represented explicitly as breaks and leaks on trunk lines and as an increase in demand for the distribution lines, reflecting the extra water that breaks and leaks will draw from the trunk line network.

To estimate serviceability associated with a given damage state, GIRAFFE checks the connectivity of the system and removes components that are isolated from water sources. It then runs a normal hydraulic analysis using the engine from EPANET (Rossman 2000). If any nodes are found to have negative pressure, they are removed from the system and the analysis is rerun. This process is repeated until there are no nodes with negative pressures. The output from GIRAFFE includes the flow and/or pressure at each system component (e.g., pipe, junction, reservoir). For each demand node, it indicates whether it is satisfied or not (i.e., whether the trunk network can get water to that node). It also produces the system serviceability.

The main types of output provided by the restoration model are: (a) restoration curves showing serviceability versus time, with uncertainty bounds; (b) maps showing the spatial distribution of restoration at 12 hour intervals; (c) the total time crews spend working, traveling, and idle for each type of crew, by reporting location; and (d) the number of materials used during each 12-hour period, by district yard at which they are stored and material type.

There is also interaction between this model and GIS plots of urban density.

More information about GIRAFFE and possible adaptation for NZ is being sought.

8. The 2008 Wenchuan Earthquake

Feedback of the China situation following the 2008 Wenchuan event focused on the lack of seismic codes, lack of enforcement of existing codes and in reconstruction following - ie. failure to learn.

Cellular telephony was relatively effective in communication after the event. The lack of underground cable systems due to late development of telecommunications was a positive. However, many basic structural issues with facilities (towers, switchyards, buildings).

Emergency water supplies of 8 gallons (~36 litres) per person per day were provided to those people in tent cities from portable purification units (some donated). This allocation was set to replicate normal consumption levels. Water supplies in towns were temporarily reinstated via above-ground PE piping. A two month systems restoration period of normal service was typically achieved.

9. Other Observations

Crisis planning and development of organisational structures for response was referred to as 'virtual' resilience, as opposed to the more traditional physical aspects of resilience.

The principal value of simulation exercises is seen in building the culture of improvisation.

A keynote presentation by Massoud Amin (Toward Smart and Self-healing Interdependent Infrastructures) commented that large blackouts are growing in frequency and extent in North America. The main thesis was that transmission investment and capacity margin has progressively reduced since 1975. He quoted from a 2006 study which showed the following:

Country	Investment in HV Transmission	No. of Transmission Owning Entities
New Zealand	$22m/GW/yr	1
Denmark	12.5	1
United States	4.6	450

The importance of "Champions" – Tom O'Rourke cited the example of the San Francisco Fire Chief who developed a response plan for earthquake in the 1980s learning from their 1906 event that significantly reduced loss due to fire following Loma Prieta in 1989.

Initiatives that improve efficiency e.g. road safety; traffic congestion; road, bridge maintenance improve resilience in post-event situation i.e. good value for money

SPUR

SPUR has served as San Francisco's major civic planning organisation bringing together active citizens, public servants, business leaders and elected officials to plan collaboratively for the future of San Francisco. One of the SPUR programs is Disaster Planning, which includes establishing goals for disaster recovery, and taking steps toward a "Resilient City" – see www.spur.org/disasterplanning .

SPUR defines different levels of earthquake event, based around the Expected event - M7.2 (10% chance in 50 year period) – with also a Routine event - M5 and Extreme event - M7.9, for setting performance targets.

Conceptual target restoration times for lifelines are indicated in the following table:

EXAMPLES OF LIFELINE RESTORATION TIMES

	LIFELINE SYSTEM	TARGET STATE FOR RECOVERY
Category I (4 hours)	Municipal water supply system	Water service or temporary supplies available to 100% of facilities critical to response
	Auxiliary water supply system	Water available for firefighting in 100% of city neighborhoods
	Electric power	Power restored, or temporary power available to, 100% of facilities critical to response
	Natural gas	Establish immediate control of the system and shut off service to quadrants in which damage is likely to be significant and result in hazardous conditions
	Port of San Francisco	Critical ferry facilities available for transportation of first responders and evacuations
Category II (30 days)	Municipal water supply system	Water service restored to 90% of customers
	Natural gas	Service restored to 95% of customers in non-liquefaction areas
	Transit	90% of MUNI capacity restored
	San Francisco International Airport	Open for emergency traffic and evacuation flights
Category III (30 days)	Water, wastewater, electric power, and telecommunications	Service restored to 95% of customers
	Natural gas	Service restored to 95% of customers, including those in liquefaction zones
	Transit	Service restored for 90% of Muni customers
	San Francisco International Airport	Airport open for commercial traffic

Source: SPUR analysis

Field Trip - Bay Bridges

The final afternoon of the conference was taken up with an on the water field trip viewing a number of bridges around the San Francisco Bay, with commentary from people associated with the each structure discussing the various aspects of the seismic upgrade of each bridge. Of note was the complete reconstruction of the Bay Bridge (Oakland section) that suffered a span collapse in the Loma Prieta earthquake. A spectacular engineering undertaking, culminating in the major upcoming challenge is the cut-over of traffic from old to a temporary bridge to enable completion of the new structures. This is planned for a 48 hour period over a weekend - see http://baybridge360.org/# .

It is evident that many $millions are being spent on building resilience into transportation infrastructure.

Acknowledgements

Funding for attending the US TCLEE conference and associated workshops was provided by the Earthquake Commission, whose encouragement and support is gratefully acknowledged.

Dave Brunsdon and Brian Park

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Appendix A:

California Post-Disaster Building Safety Assessment Program

Building Safety Evaluation Training Workshop 28 June 2009

- This all-day training workshop was the standard Californian Safety Assessment Program (SAP) training session for post-disaster building safety evaluators.
- It was attended by ~24 engineers from structural, geotechnical, civil and electrical disciplines. The course is open to architects and building control officials, but none attended.
- The state emergency management agency (CalEMA) administers the scheme, including a comprehensive database of >6,000 trained engineers and architects. Official photo identity/ authorization cards are issued to those undertaking this course. These cards have a validity period of 5 years, with a half-day refresher course required to stay valid for a further 5 years.
- The course was similar in content and structure to the pilot modules recently delivered in NZ. Modules dealing with the assessment of lifeline structures were also included, but these didn't link in well with actual utility needs and processes, and would probably be considered too specialist for general NZ usage.
- The two recently developed NZ pilot training modules for (i) managers and (ii) evaluators appear to be appropriate.

Technical Process Issues

- Typically 95% of evaluations undertaken following an event are Rapid (equates to *Rapid Level 1* in NZ terms)
- Detailed Evaluations (*Rapid Level 2* in NZ terms) typically involve specially composed teams
- There is a similar uncertainty as in NZ regarding the level/ scale of building that a Rapid (Level 1) assessment should be limited to. It can be inferred that it shouldn't be applied to more than 4 storeys in height
- Red (Unsafe) placards now have 'This is not a demolition order' added in response to perceptions and experiences from previous earthquakes.
- There has been debate between Los Angeles officials and engineers about the merits of having the estimated damage levels on the Rapid (Level 1) Evaluation forms, as this isn't really the focus of these initial assessments.
- There is still considerable debate and lack of clarity around criteria for short-term habitability
    - Agreed that buildings can be occupied without water and sanitation
    - But there needs to be a clear briefing on this by Local Authority at the operational briefing

Scheme Administration

- Administered by key official within CalEMA, supported by a Steering Committee comprising reps from the 5 professional groups (Engineers (3), Architects, Building Control officials) and three state agencies.
- This Steering Committee meets quarterly. The focus is on preparedness and promoting awareness, but also on response mechanisms.
- The rep from each of the professional groups is also a SAP Response Co-ordinator, who rings around on a call tree basis to activate resources from unaffected parts of the state when an event occurs (the NZ concept of engineering co-ordinators in Wellington, Auckland and Christchurch, using the IPENZ *List of Engineers for Emergency Response,* has been based on this).
- It is expected that each local authority has a designated and trained Building Safety Evaluation leader for preparation and response purposes. The state also has a mutual aid agreement between all local authorities that each can provide up to 3 days 'free' assistance to affected authorities.
- The current capacity is ~6,200 trained and registered evaluators (incl. 300 from other states), and 200 trainers. Their target capacity is between 7,000 and 10,000 evaluators (from a base of 71,000 professional engineers and a population of 40 million. This could imply that NZ should have 700 trained and registered evaluators).

<u>Administration: Overview Observations</u>

- The Californian approach is a very structured and administration-intensive set of arrangements that is probably not warranted in NZ. But these arrangements highlight the following for NZ:
  - The DBH Reference Group should include reps from IPENZ and NZIA
  - The professional groups need to have designated co-ordinators in at least the main centres

San Francisco Building Occupancy Resumption Program

- The San Francisco Building Occupancy Resumption Program (BORP) is a system of post-earthquake inspection arrangements that are initiated by building owners or tenants and pre-approved by Council. For a description of the programme, refer to www.ci.sf.ca.us/site/dbi_page.asp?id=11515
- BORP is considered important by the City (provides comfort that the inspection of larger and more complex structures are covered)
- 104 building owners are registered on the San Francisco BORP scheme, with approximately 25 engineering firms participating
- About a dozen other Californian cities have a version of BORP, plus UC Berkeley and Stanford University
- The concept has merit for NZ. The complex administrative framework would however require a simpler approach for it to work in NZ

Appendix B:

List of Papers of Interest

Principal Author	Title	Comments
Stephanie Chang et al	Social Impacts of Lifeline Losses: Modeling Displaced Populations and Health Care Functionality	Plus Powerpoint presentation
Stephanie Chang et al	Societal Impacts of Infrastructure Failure Interdependencies: Building an Empirical Knowledge Base	Plus Powerpoint presentation
Rachel Davidson et al	Post-earthquake Water Supply Restoration in Los Angeles	Plus Powerpoint presentation
Craig Davis	Scenario Response and Restoration of Los Angeles Water System to a Magnitude 7.8 San Andreas Fault Earthquake	
N. Romero, Tom O'Rourke et al	Los Angeles Water Supply Response to 7.8Mw Earthquake	
Dorothy Reed	Multi-Hazard Analysis of Electric Power Delivery Systems	
Dorothy Reed & N. Nojima	Interdependence Between Power Delivery and Other Lifelines	
Yumei Wang	Lifeline Resiliency: A Look at Earthquake Risk in Portland, Oregon	
Kuo-Wan Lin & David Wald	Using ShakeCast and ShakeMap for Lifeline Post-Earthquake Response and Earthquake Scenario Planning	