Post-earthquake response plans for State Highways in the Wellington Region

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ABSTRACT: Participation in a civil defence exercise (Phoenix V) helped identify that there would be benefit in having more up to date information and a greater understanding of the vulnerability of roads in the region and the time likely to be taken for recovery. In addition, prior planning of the response after earthquakes at locations of key vulnerabilities (where road closure is likely) will significantly help post-earthquake response and recovery.

Earthquake response plans were developed for State Highways 1, 2 and 58 and were discussed with other stakeholders. These included identification of the key critical areas, assessment of the consequences in particular earthquake scenarios and development of a staged approach, where appropriate, to restore access. The resources necessary to restore access was identified, so that prior planning can be carried out. This paper illustrates the response planning through examples of plans developed.

A particular section of the highway between Paekakariki and Pukerua Bay was identified as requiring further assessment, and a more detailed assessment of the extent and volume of landslides was estimated, and plans prepared for access along this section of the highway. This included a staged reopening of temporary access and provisions to manage the risk from aftershocks.

1 INTRODUCTION

Transportation networks are key lifelines for the social and economic well-being of communities, and are essential lifelines for the community. Our country's tectonic, geological, topographical and climatic setting makes these road networks vulnerable to natural hazard events.

The Civil Defence Emergency Management Act 2002 identifies roads as one of the key lifeline utilities, and requires its operators to be able to demonstrate that they have assessed the risks to its networks, and taken proactive measures to ensure that the lifelines (roads) are able to function to the fullest extent possible after natural hazard and other events (Ministry of Civil Defence Emergency Management 2002). This requires comprehensive planning and actions to achieve reduction, readiness, response and recovery after events. As part of this preparation, road controlling authorities need to consider their networks, assess the risks and develop risk management approaches that will allow them to plan and implement mitigation, response and post-event recovery.

The 2008 civil defence exercise (Phoenix V) that simulated response to a major earthquake in the Wellington Region, highlighted that post-earthquake response to quickly re-open roads could be enhanced. Such reopening is required to provide vital access for other lifelines and allow transportation of vital goods for the community. We identified that the following initiatives would significantly enhance post-earthquake response to provide road access in the region, based on research into the management of resilience of transportation networks (Brabhaharan 2002):

- Collate and make readily available information on the integrated resilience of the regional road networks (both state highways and priority local roads) to the road controlling authorities and their advisors and contractors, emergency management staff, and other lifeline authorities.

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- Prior planning of post-earthquake response, to facilitate quick re-opening of the critical routes (or alternative routes) that are important for post-earthquake response and recovery, and enable social and economic functionality.

An integrated resilience map for the critical state highway and local authority road network in the Greater Wellington region for the New Zealand Transport Agency and the five local authorities of Wellington, Hutt City, Upper Hutt, Porirua and Kapiti Coast was developed by Opus International Consultants (Opus), and was presented by Brabhaharan (2010).

Post-earthquake response plans for the state highways in the region were also developed for the New Zealand Transport Agency by Opus. This is presented in this paper.

2 RESILIENCE

Research into strategic management of the resilience of road networks (Brabhaharan et al. 2001, 2002 and 2006) was carried out to assess how the management of natural hazards risk to road networks can be improved in New Zealand. The research conceptually defined resilience in this context as illustrated in Figure 1.

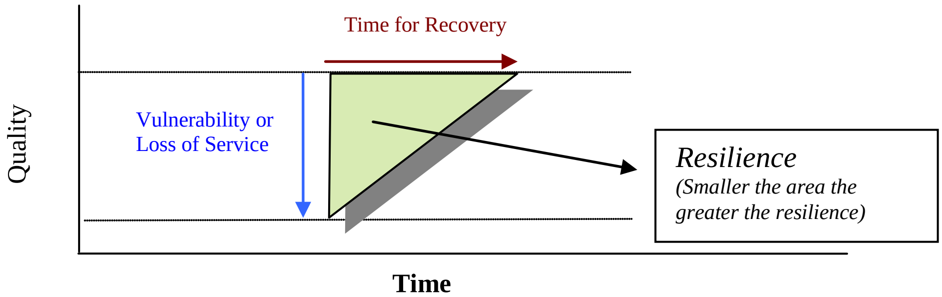

Figure 1. Conceptual Definition of Resilience.

Resilience of the road network depends on:

1. Reduced loss of functionality in the face of natural hazards or other incidents, and
2. Quick recovery to provide service after such events.

Reducing loss of functionality depends on the form and robustness of the road. Quick recovery depends on two aspects:

- The form of the road and the related ability of any damage to be quickly addressed – for example, small slips onto a road can be quickly cleared, whereas reconstruction of a bridge that suffers significant failure will take a long time.
- Preparedness to readily identify and respond to loss or reduction in functionality.

To achieve resilient road networks, Brabhaharan (2006) identified a five-level framework for implementation, as shown in Table 1.

The identification of Emergency Management (Level 4) in Table 1, highlights the importance of effective action when damage occurs in a natural hazard event, such as an earthquake, to enable quick recovery, and thus achieve greater resilience of transportation routes. Quick recovery improves resilience by reducing the time the road network is unable to provide access or the level of service required, and this is illustrated in Figure 1.

Table 1. Levels of Implementation and Responsibility

Level Description		Responsibility	Organisations
Level 1	National road strategy	National strategy, funding/ policy	Ministry for Civil Defence and Emergency Management, with NZ Transport Agency
Level 2	Regional transportation risk management strategy	Regional land transport strategy	Regional local authorities with RCAs
Level 3	Network asset risk management	Asset management	RCAs
Level 4	Emergency management	Emergency response	RCAs
Level 5	Resilience of New development	Project development	RCAs with NZ Transport Agency

Note: RCA - Road Controlling Authorities (Territorial local authorities and New Zealand Transport Agency)

3 PLANNING FOR EMERGENCY RESPONSE

3.1 Understanding the Resilience

Planning post-earthquake response is important to be able to respond quickly after a major natural hazard such as an earthquake. Planning requires an understanding of the resilience of the road network. The resilience of the road network in the Wellington Region was assessed and mapped using a Geographical Information System (GIS) platform for the state highways and the important roads in the district, and this was made available through the NZ Transport Agency's web portal (Opus 2012 and Brabhaharan 2010). The resilience is mapped as three resilience states – damage state, availability state and outage state. The study also identified the resilience of the bridge structures along the route.

3.2 Identifying Critical Areas with Poor Resilience

The resilience state maps for a local large magnitude 7.5 earthquake in the region were used to identify the critical sections of the state highways, where the road will be closed and will take a significant amount of time to reopen. Given that the resilience state maps gave availability and outage states, this was very useful to quickly identify such critical sections.

The types of critical highway locations identified are:

- Bridge structures that are likely to become damaged or collapse and are closed
- Sections of roads closed by major landslides that would take a long time to clear
- Retaining walls that are likely to fail closing the road
- Tunnel approaches likely to be closed by landslides or failure of portal structures.

It is recognised that the actual impacts of each earthquake will vary significantly depending on a variety of factors and the characteristics of each earthquake. These will be confirmed after an earthquake by reconnaissance inspections. However identifying the critical areas most likely to be affected helps plan responses to these events. These locations were then individually considered to assess the likely extent of damage and restoration of access.

3.3 Assessment of Extent of Damage

For bridge structures on the highway, the extent of damage was assessed based on the detailed seismic assessment of bridge structures or where this was not available, the seismic screening of the bridge structures (Opus, 1998). A panel of engineers assessed each bridge to confirm damage, availability and outage states for the bridges, the type of damage and repairs or replacement required.

For non-bridge sections of the highway, the extent of damage was based on the characterisation of the road sections for the road network resilience study, and then an assessment of the extent of damage, such as landslides, at each site by a geotechnical engineer and engineering geologist. We recognised that the Centennial Highway on State highway 1 between Pukerua Bay and Paekakariki would experience very extensive damage and blockage from landslides, and this was assessed in more detail through a specific study of this section.

3.4 Restoration of Access

Measures that could be used to restore access were considered based on the expected damage that is likely to occur in a large earthquake event. The development of preliminary response measures drew from the experience of staff involved from the Transport Agency and Opus, and the learnings from post-earthquake reconnaissance visits by the principal author, such as to the Wenchuan Earthquake in China in 2008, and more recently the Canterbury earthquakes in 2010-2011.

In considering the restoration of access, it became apparent that a staged approach was required, because of the:

- Importance of early access into Wellington, which will be cut-off by a major earthquake.
- Considerable effort and time required to restore permanent restoration of access (e.g. replacement bridge).
- Resources and effort needed to create a more secure temporary access (e.g. bailey bridge).

The alternative methods of providing access were identified, and the time required to implement each alternative access and the duration each alternative may remain in place were assessed. Where necessary the time and resources required were estimated with the help of experienced contractors.

3.5 Resources Required

The resources required to implement each alternative temporary access was assessed and documented, to help with exploration of where such resources could be obtained from.

Resources included construction materials, plant, people and fuel for construction plant.

3.6 Alternative Routes

Alternative access often involved diversion through alternative routes. The suitability of alternative routes was explored through site reconnaissance visits, and any constraints were identified. This included rural four wheel drive tracks though the hinterland, or suburban local authority roads. In some locations the alternative routes had to cross railway lines or use railway corridors.

Alternative tracks were often assessed to be vulnerable to failures from earthquakes, and the quality of access to be weather dependent.

3.7 Property and Consultation

Where the alternatives access involved access through other stakeholders' property or involved their assets, these were identified during the development of the pre-plans. The NZ Transport Agency consulted with these stakeholders to obtain their comments, views and concerns as part of the planning process.

3.8 Identification of Risks

Risks to the implementation of the response plans and to the alternative access arrangements after implementation were identified and documented. This will enable these risks to be considered in implementing and maintaining the temporary access arrangements. These may include the security of piers for a bailey bridge, ongoing rock fall, susceptibility of alternative routes to wet weather, or the uncertainty in the availability of resources due to high demand.

3.9 Implications for other lifelines

Any implications for other lifelines (such as utilities) that share the road corridor or which are affected by alternative routes were also identified.

4 PRELIMINARY RESPONSE PLANS

4.1 Form and Content

Preliminary post-earthquake response plans were produced in a consistent form that could be easily referred to in the aftermath of a large earthquake event.

The plans included the following to make them easy to use in a potentially chaotic post-earthquake environment:

- Simple consistent tabular forms used for each critical area
- Locations and plans of alternative access and routes.
- Photographs of the critical section.
- Background materials, such as critical interchange layouts.
- Asset data including traffic volumes and location references
- Earthquake scenario
- Expected damage, availability and outage states
- Emergency response (primary and alternatives that can be considered depending on actual conditions), details, implementation time and resources.
- Fuel consumption data.
- Adjacent land and ownership
- Results of consultation with stakeholders
- Known implications for other lifelines
- Risks.

The objective is that information on each critical area can be quickly accessed and considered in the aftermath of an event.

4.2 Use

The response plans are live documents to be regularly updated as there are likely to be changes to the state highways, road network and the operating environment.

The plans have been included in the Transport Agency's emergency response plans, and made available to parties involved in emergency response after events.

The plans will be used in civil defence exercises, and any experience from such use can be used to update the response plans.

5 TYPICAL PRELIMINARY RESPONSE PLAN

5.1 Otaki River Bridge

Otaki River Bridge is at a critical location as it provides access to the Wellington Region along State Highway 1 on the north-western corridor. In addition to providing access to Kapiti, it is on an important route that provides access for plant and equipment to be mobilised for reinstatement of other sections of the highway further south; resources to be mobilised for recovery of Wellington; and for transportation of goods for the population.

5.2 Damage, availability and outage states

The bridge carries over 17,000 vehicles a day, and was assessed to be vulnerable to extensive damage and likely to be closed for over 3 months.

5.3 Staged provision of access

Given the critical importance of this bridge, a staged preliminary emergency response plan was developed, to provide quick albeit limited access, followed by improved access across this section of the highway.

5.3.1 *Stage 1 – Ford Crossing*

The first stage would be to provide a temporary ford across the river, to be able to mobilise plant and equipment and emergency supplies. The crossing will be located east of the existing bridge from a concrete access road at the north end to the rest area at the south end. Fill from cutting the ramp will be used to form the access road across the river. This will take 2-3 days using multiple earthmoving plant (subject to river flows at that time), with plant available from an adjacent quarry and 1.5 m diameter precast concrete pipes.

5.3.2 *Stage 2 – Construction of Causeway*

The ford may be subsequently upgraded to a causeway to provide more secure access, using additional concrete pipes for river flow, and raising of the access to create a causeway. Gravel from the river and adjacent quarry will be used. This could take 8 to 10 days to implement and may be in place for 3 -4 weeks, until a bailey bridge can be constructed.

5.3.3 *Stage 3 – Bailey Bridge*

Assuming 5 of the 15 spans had collapsed, a 75 m long bailey bridge crossing will be formed. It is assessed that the existing piers are likely to still remain functional and would be adequate as bailey bridge supports. The bailey bridge will take 3 weeks to transport and construct.

5.3.4 *Alternative Rail Bridge*

In the unlikely event that the adjacent rail bridge running parallel with the state highway bridge remains functional after the earthquake, the rail bridge could be used to make it trafficable after providing deck planks.

5.3.5 *Alternative Waihoanga suspension bridge*

An alternative access would be this river crossing off Otaki Gorge Road, supplemented by formation of a road across farmland on predominantly river gravel terrain, connecting the bridge up to Rahui Road on the north side. The suspension bridge has a weight restriction of 20 tonnes (6 tonnes per axle), width restriction of 2.7 m and speed restriction of 5 kph.

5.4 **Risks and Opportunities**

The risks to implementation are that the ford or causeway may be destroyed by floods, the rail bridge may be unavailable for alternative access, the piers cannot support the bailey bridge, or farmland is not available for the Waihoanga suspension bridge route.

On the positive side, the linkage bolts and seat extenders may mitigate deck collapse, and the Peka Peka to Otaki Expressways as part of the Roads if National Significance programme is expected to provide a new resilient bridge across the Otaki River by 2020.

6 CONCLUSIONS

Resilient access requires a combination of reduction of vulnerability to earthquakes and similar hazard events, and enhanced emergency response to quickly restore access after the event. Access is vital after large earthquake events to facilitate response and recovery and provide the necessary essentials for the community. Understanding the resilience of our transportation networks and planning for responding to the expected loss of access would help enormously in being able to quickly respond to road closures and restore access.

Preliminary response plans for critical sections of vulnerability along Wellington Region's state highways have been developed to enable quick response. The development of response plans was facilitated by an understanding of the expected damage, loss of access and outage period, which were provided by the resilience maps developed for the region's state highways and important local roads. Where necessary staged approaches to restoration of access was considered to quickly provide limited temporary access along critical routes or alternative routes, followed by more reliable or better capacity access.

The resources necessary for restoration of access including plant (including operators), materials and fuel were identified so that they could be factored into response planning. Stakeholders were consulted so that the viability of these options could be assessed and also other parties are informed so that they can factor this into their own preparedness planning.

The preliminary response plans will remain a live document, and will be updated regularly to take into consideration the changes in the road network and in the operating environment.

7 ACKNOWLEDGEMENTS

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