Transmission Gully and Existing State Highway 1 Coastal Route
Route Security in Earthquake Events
June 2009

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Summary

The existing transportation routes within the Wellington Region will be affected by a large earthquake either on the Wellington Fault or on one of the other major faults in the region (Ohariu Fault, Wairarapa Fault). All existing roads in and out of the region, including the main State Highways 1 and 2 are expected to be closed for long periods of time (Opus International Consultants, 2009), see Appendix C.

The major vulnerabilities on State Highway 1 running north from Wellington along the western side of the region, are the expected liquefaction and lateral spreading north of Porirua, and landslides along the Pukerua Bay to Paekakariki section.

The Transmission Gully route will bypass these two sections of vulnerability. While some damage along the Transmission Gully route is expected, the route is expected to remain open in small to moderate events, and can be opened for at least limited access quickly after large earthquake events.

Given that both the Existing Route and Transmission Gully are in the same regional hazard setting, both are expected to be vulnerable (but to significantly different extents) to natural hazard events such as large earthquakes. However, in the more frequent operational incidents such as storm induced slips, traffic accidents or hazardous spills, the provision of two routes will provide a much greater level of security and availability of access in and out of the greater Wellington area.
1 Introduction

The Transmission Gully (TG) project is an approximately 27 km long proposed route north of Wellington, between MacKay’s Crossing and Linden, east of State Highway 1, see Illustration 1. The New Zealand Transport Agency, as the road controlling authority for New Zealand’s state highways, is managing the development of the project.

Opus International Consultants (Opus) developed a preferred alignment for the TG project for NZTA (then Transit NZ) in 2007-2008, through scheme assessment, preliminary geotechnical appraisal and cost, risk and value engineering.

NZTA has requested Opus to advise on the security of the Transmission Gully route compared to the Existing State Highway 1 (SH 1) “Coastal” route between Linden and MacKays Crossing. Opus has prepared this report based on previous studies, in association with sub-consultant, GNS Science (GNS).

Illustration 1 - Location of Transmission Gully Route

This report has been based on existing studies of the performance of the Transmission Gully route and of the existing state highways in large earthquake events.
2 Location of Route

2.1 Location of Transmission Gully Route

The Transmission Gully (TG) route runs generally from northeast to southwest, between MacKay’s Crossing (42 km north of Wellington City) and Linden (15 km north of Wellington City).

Travelling towards Wellington City, the TG route, see Figure 1:

- diverges from SH 1 between MacKay’s Crossing and Paekakariki township,
- runs through the “Transmission Gully” valley to the east of Paekakariki Hill Road, over the Wainui Saddle and through the Battle Hill Farm Forest Park,
- crosses State Highway 58 to the east of the Pauatahanui Inlet,
- runs to the east of Whitby and Porirua East, and then
- turns west to rejoin SH 1 near Linden, south of Porirua City.

The NZMS 260 Map Grid Reference for the route is R26 755 231 at the SH 1 crossing near Paekakariki, R27 711 088 at the SH 58 crossing, and R27 645 045 at the SH 1 merge near Linden.

2.2 The Existing State Highway 1 “Coastal” Route

The existing SH 1 “Coastal Route” (CR) between MacKay’s Crossing and Linden, see Figure 1:

- runs southwest from MacKay’s Crossing between the Paekakariki township and the hills on the east,
- runs southwest along the coast at the foot of the coastal cliffs to Pukerua Bay (coastal section),
- runs south through the Pukerua Bay township,
- runs south through the rural area and the townships of Plimmerton and Mana,
- crosses the mouth of the Pauatahanui Inlet at Paremata,
- runs southwest along the eastern bank of Porirua Harbour, and then
- runs south between Porirua City / Kenepuru and Ranui Heights in Porirua East to Linden.
3 Regional Context

3.1 Seismicity

The Wellington Region is located in an area of high seismicity, with a number of major active faults and a subduction zone capable of producing large earthquakes of Richter Magnitude 7.5 to 8.

3.2 Active Faults

The major active faults in the region, which are listed by GNS Science (2008), include the faults identified in Table 1.

Table 1 - Active Fault Earthquake Sources

<table>
<thead>
<tr>
<th>Fault Source</th>
<th>Segment</th>
<th>Likely Magnitude (Richter)</th>
<th>Recurrence Interval (Return Period) (years)</th>
<th>Distance from Transmission Gully (km)</th>
<th>Distance from Existing SH 1 “Coastal Route” (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subduction Zone</td>
<td></td>
<td>7.8 – 8.4</td>
<td>420 – 1,200</td>
<td>22 - 31</td>
<td>22 - 31</td>
</tr>
<tr>
<td>Wellington Fault</td>
<td>Wellington- Hutt Valley</td>
<td>7.6</td>
<td>700</td>
<td>6 - 16</td>
<td>7.5 - 18</td>
</tr>
<tr>
<td></td>
<td>Tararua east</td>
<td>7.3</td>
<td>650</td>
<td>20 - 32</td>
<td>25 - 32</td>
</tr>
<tr>
<td>Wairarapa</td>
<td></td>
<td>8.1</td>
<td>1,000</td>
<td>21 - 27</td>
<td>24 - 33</td>
</tr>
<tr>
<td>Ohariu Fault</td>
<td>Central</td>
<td>7.4</td>
<td>2,200</td>
<td>0 – 4.4</td>
<td>0 – 4</td>
</tr>
<tr>
<td></td>
<td>South</td>
<td>7.4</td>
<td>2,300</td>
<td>1.5 - 19</td>
<td>0.1 - 2</td>
</tr>
<tr>
<td>Wairau Fault</td>
<td>Offshore</td>
<td>7.5</td>
<td>1,900</td>
<td>14 - 21</td>
<td>19 - 25</td>
</tr>
<tr>
<td>Pukerua – Shepherds Gully Fault</td>
<td></td>
<td>7.4</td>
<td>3,450</td>
<td>4.9 - 8</td>
<td>0.1 - 5</td>
</tr>
<tr>
<td>Akatarawa Fault</td>
<td>Moonshine - Otaki</td>
<td>7.4</td>
<td>5,150</td>
<td>10 - 17</td>
<td>10 - 17</td>
</tr>
<tr>
<td>Moonshine Fault</td>
<td></td>
<td>7.1</td>
<td>11,150</td>
<td>0 - 11</td>
<td>2 - 12</td>
</tr>
</tbody>
</table>

Note: After GNS (2008).

The characteristics of these faults and their distances from the TG and the existing SH 1 Coastal routes are summarised in Table 1. The TG route crosses the active Ohariu Fault (Central Segment) near Wainui Saddle, whereas the existing SH 1 Coastal route crosses it through the Paremata Bridges, see Figure 1.
The TG route also crosses the Moonshine Fault zone in the Duck Creek area. However, this fault zone is of far less significance as the recurrence interval of this fault is greater than 10,000 years, and the probability of an earthquake on it is therefore very low.

### 3.3 1855 Wairarapa Earthquake

The last large earthquake in the Wellington Region was the 1855 Wairarapa Earthquake. This Richter Magnitude 8 earthquake was associated with the rupture of the Wairarapa Fault near the western foothills of the Wairarapa area. This caused major damage to the limited infrastructure in the Wellington and Wairarapa areas that existed at that time (Hancox, 2005).

Earthquake-induced landslides were also reported in the Porirua to Paekakariki area in the 1855 Wairarapa earthquake (Brabhaharan et al, 1994; Hancox, 2005), by which time small cuts had been made for roads. The large landslide reported at Paekakariki after the earthquake is inferred to have been the cause of the prominent scar high on the cliff above the old quarry near the Paekakariki railway station (Illustration 2). The estimated intensity in this area was MM VIII-IX (Hancox et al. 1997; Hancox, 2005). It is unlikely that was the only large landslide on coastal slopes in the area – just the only one that was reported.

![Illustration 2 - Aerial view of the possible site of 1855 landslide](Image)

View shows the possible 1855 landslide at the former quarry at Paekakariki and possible large future earthquake induced landslide failure areas (pfa) and debris runout areas (dra) near the Railway Station (RS).

Slope failures caused by the 1855 earthquake were reported to be common along the Paekakariki Hill Road, which was constructed in 1849 utilising many cuts and fills and served as the main route north until the present SH 1 opened in 1939. There were no
reports of landslides on the coast south of Paekakariki as there were no roads in that area (Hancox, 2005; Hancox et al., 1997, 2002). However, there are old rockfall deposits on the coast south of Pukerua Bay which may date from the 1855 earthquake, suggesting that similar landslides probably occurred north of Pukerua Bay as well. Proof of these failures is likely to have been obliterated by road construction in the 1930s.

Large landslides in the 1855 earthquake also severely disrupted access through the Rimutaka Hill road. Landslides along the Hutt Road between Wellington and the Hutt Valley and between the Hutt Valley and the Rimutakas also disrupted access.

3.4 Earthquake Induced Slope Hazard Study

Illustration 3 - Map showing earthquake-induced landslide susceptibility

Shows earthquake-induced slope instability in the area of the Coastal Highway and proposed Transmission Gully route from Porirua Harbour to Paekakariki area (after Brabaharan et al. 1994; Wellington Regional Council, 1995).
Earthquake-induced slope failure hazard studies (Brabhaharan et al, 1994; Wellington Regional Council, 1995) for Wellington Regional Council included the area between Porirua Harbour and MacKays Crossing, and an extract from the map produced in that study is presented in Illustration 3, with the preferred Transmission Gully route superimposed.

The map shows that the existing SH 1 “Coastal Route” between Pukerua Bay and Paekakariki (Coastal Section as well as adjacent to the Paekakariki township and railway station) has a high to very high susceptibility to slope failures in earthquakes. This is due to the presence very steep and high slopes, and the presence of several geomorphic features on the coastal slope which appear to be the scars of large prehistoric landslides which may have been caused by large earthquakes, see Illustration 4.

Illustration 4 - Aerial view of coastal cliff south of Tunnel 7
Shows old failure scars and incipient slumping at the top of the 200 m high slope.

By comparison, the map shows that the northern section of the Transmission Gully route, north of about Battle Hill Farm has moderate to locally high susceptibility to slope failures in earthquakes. This is consistent with the generally lower overall slope height, flatter average slope, and lack of deep seated landslides along the Transmission Gully route (Illustration 5) relative to the SH 1 Coastal route.
3.5 Liquefaction Hazard Study

Earthquake induced liquefaction of the ground and consequent subsidence and lateral spreading has the potential to cause significant damage to transportation facilities, as experienced in the 1931 Napier Earthquake, see Illustration 6.
Earthquake-induced liquefaction hazard studies (Brabhaharan, 1994; Wellington Regional Council, 1993) for Wellington Regional Council included the area traversed by the existing SH1 Coastal Route as well as the TG route. The study presented maps showing the liquefaction hazard and consequent ground damage hazards in the Wellington Region.

Along the existing SH1 Coastal route, the section between Porirua and Plimmerton is prone to significant liquefaction and consequent ground damage hazards as indicated in Illustration 7.

Illustration 7 - Existing Route susceptible to liquefaction between Porirua and Plimmerton

Along the TG route, there is little or no liquefaction potential. The TG route descends around the hillslopes adjacent to Ranui Heights, to rejoin SH1 at Linden, which is outside the liquefaction hazard area.
4 Resilience and Performance States

4.1 Resilience

Knowledge of the performance of the road network in natural hazard events is important to understand the impact on society – the people, emergency services, economic activity, etc. It also enables the expected performance to be compared against desired performance targets, and helps develop risk management measures.

Vulnerability or its corollary, resilience, of infrastructure lifelines such as roads is dependent on the loss of utility or serviceability, and the time taken to bring the road back into its original usage state after the reduction or loss of access. This is shown conceptually in Illustration 6. The smaller the shaded green area, the greater the resilience of the lifeline. The greater the area, the lower the resilience or poorer the performance.

Illustration 8 - Resilience of Network

4.2 Performance States

“Performance States” or “Resilience States” representing performance of the road network have been developed to consider the impact of various natural hazards on road networks on a similar basis (Brabhaharan et al, 2006). These states are summarised in Table 2 and are represented in a 5 or 6 point scale in performance state tables in Appendix A.

Table 2 – Performance States

<table>
<thead>
<tr>
<th>Performance State</th>
<th>Description of State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage State</td>
<td>Damage State represents the expected severity of damage to the road (and cost of damage repairs); see Table A-1 in Appendix A.</td>
</tr>
<tr>
<td>Availability State</td>
<td>Availability State indicates whether the road would be able to be used either at full level, at various reduced levels or not at all, see Table A-2 in Appendix A. This gives an indication of the degree of access expected to be available after an event.</td>
</tr>
<tr>
<td>Outage State</td>
<td>Outage State indicates the duration over which the section of road will be in the expected Availability State, see Table A-3 in Appendix A. This gives an indication of the expected duration of loss or reduced access on sections of the road network.</td>
</tr>
</tbody>
</table>
5 Earthquake Performance

5.1 Earthquake Scenarios

The earthquake performance has been considered for two characteristic earthquake events, a Wellington Fault earthquake and an Ohariu Fault earthquake, the characteristics of which are summarised in Table 3.

Table 3– Earthquake Events

<table>
<thead>
<tr>
<th>Earthquake Event</th>
<th>Richter Magnitude</th>
<th>Rupture Displacement</th>
<th>Recurrence Interval</th>
<th>Probability of Occurrence in 50 years</th>
<th>Existing Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wellington Fault Event</td>
<td>7.5</td>
<td>Horizontal 4 - 6 m Vertical ~ 1 m</td>
<td>600 years</td>
<td>8%</td>
<td>VIII - IX</td>
</tr>
<tr>
<td>Ohariu Fault Event</td>
<td>7.5</td>
<td>Horizontal 3 - 4 m Vertical ~0.7 - 1 m</td>
<td>2,200 years</td>
<td>2.5%</td>
<td>IX - X</td>
</tr>
</tbody>
</table>

Notes:
1. Recent unpublished studies indicate that Wellington Fault recurrence interval may be 800 – 900 years, still considerably lower than Ohariu Fault event (Russ Van Dissen, GNS – pers comm.).
2. Modified Mercalli (MM) Intensity Scale – see Appendix B for description.

These characteristic earthquake events have been used in the previous studies. The Wellington Fault event has a much higher chance of occurring compared to the Ohariu Fault event. The Ohariu Fault rupture would cause severe damage locally where the TG and Coastal routes cross the fault, and will cause a greater intensity of shaking (MM IX to X) given the proximity of the fault to the northern sections of both Transmission Gully and the existing SH 1 Coastal Route.

5.2 Assessment of Performance

The performance of the existing SH 1 Coastal Route has been based on the study carried out in 2008 for NZTA on the vulnerability of the state highway network in NZTA’s Region 9 Wellington (Opus International Consultants, 2008a and 2009). This route vulnerability assessment was carried out using ongoing engineering geological studies in the area dating back to the mid 1970s, by site reconnaissance drive-over by geotechnical specialists, characterisation of the road based on the reconnaissance and terrain / aerial maps, and assessment of the vulnerability with the aid of previous studies such as the Wellington Regional Council (1995) slope failure hazard maps and reports. The evaluation of outage times are based on expert judgement, considering the likely type and size of the slope failures and severity of liquefaction ground damage. Further work is planned to carry out a systematic assessment of outage or restoration times for critical sections, in this case the Pukerua Bay to Paekakariki section of the existing SH 1 Coastal Route.
The performance of the Transmission Gully route has been based on a study of route security as part of the Preliminary Geotechnical Assessment in 2008 (Opus International Consultants, 2008b). This was carried out similarly by characterising the route, based on the proposed scheme earthworks geometry, site reconnaissance of the route and the results from geotechnical investigations and assessment, with some assumptions having to be made on the design and construction, as this highway does not currently exist.

For the purposes of this report, the outcomes from the above studies were adapted to ensure that the performance states presented are for similar events, in this case the characteristic Wellington Fault and Ohariu Fault earthquake events.

5.3 Wellington Fault Event

5.3.1 Existing SH 1 Coastal Route

The Availability State map (Figure 2) shows that the existing SH 1 Coastal Route is likely to be closed along significant sections, including:

- between Porirua and Plimmerton, due to extensive liquefaction and lateral spreading ground damage,
- collapse of the Old Paremata Bridge,
- between Pukerua Bay and Paekakariki Railway Station due extensive large (up to or possibly greater than hundred of thousands to a million cubic metres) landslides in several locations and,
- collapse of the Paekakariki Railway overbridge.

The Outage State map (Figure 3) shows that:

- the Porirua to Paremata section will take up to 3 months to reopen.
- the Pukerua Bay to Paekakariki section is expected to take 3 to 6 months to reopen, given the large volume of landslide materials that may have to be cleared.

5.3.2 Transmission Gully Route

The Availability State map for Transmission Gully route (Figure 2) shows that:

- There will be significant, but smaller volume (up to possibly thousands to ten thousand cubic metres) landslides along some sections, and a few sections north of Battle Hill Farm may be closed,
- Limited access will be available along most of the remaining route.

The Outage state map (Figure 3) shows that:

- Limited access along the route can be restored within 2 weeks.
- The few sections north of Battle Hill that may be closed, are expected to be able to be opened within a period of 2 weeks to 3 months.
5.4 Ohariu Fault Event

5.4.1 Existing SH 1 Coastal Route

The Availability State map (Figure 4) shows that the existing SH 1 Coastal Route is likely to be closed along significant sections, including:

- between Porirua and Plimmerton, due to extensive liquefaction and lateral spreading.
- at Paremata due to collapse of both the old and new bridges due to displacement along the Ohariu Fault trace.
- between Pukerua Bay and Paekakariki Station due to extensive landslides as in Section 5.3.1, but possibly larger (up to millions of cubic metres) and more numerous than those triggered by a Wellington Fault earthquake because of the stronger (MM10) shaking that is likely.
- collapse of the Paekakariki Railway overbridge.

The Outage State map (Figure 5) shows that:

- the Porirua to Plimmerton section will possibly take over 6 months to reopen because of the proximity of the Ohariu Fault and collapse of the Paremata Bridges (unless limited access is restored using a Bailey Bridge, which could still take over 3 months because of closure of access either side of the bridge).
- the Pukerua Bay to Paekakariki section is expected to take more than 6 months to reopen, given the large volume of landslide materials that may have to be cleared.

5.4.2 Transmission Gully Route

The Availability State map for Transmission Gully route (Figure 4) shows that:

- There will be significant landslides (as in Section 5.3.2, but possibly slightly larger and more numerous because of stronger shaking) along several sections north of Battle Hill Farm Forest Park and localised sections at the south end. The landslides and the crossing of the Ohariu Fault rupture (and possibly a splinter fault) near Wainui Saddle are expected close the route along sections north of the Battle Hill Farm Forest Park.
- Limited access will be available along most of the remaining route.

The Outage state map (Figure 5) shows that:

- Limited access along most of the route can be restored within a few weeks.
- The sections north of Battle Hill that may be closed, are expected to be able to be opened within a period of 2 weeks to 3 months.
5.5 Tsunami Effects

5.5.1 Existing SH 1 Coastal Route

Tsunamis can cause significant damage to roads. The impact of medium tsunamis (1 m to 5 m run up) may cause surfaces on coastal roads to be lifted, and collapse or structural damage to bridges. The coastal section of the existing route is prone to significant hazards between Paekakariki and Pukerua Bay, and moderate hazard along the Porirua Harbour (Hancox et al, 2005). Small and medium tsunamis (up to 5 m run up) could inundate and damage both SH 1 and the railway adjacent to the coast, due to debris deposition, and possibly local scouring and pavement damage. A larger tsunami (greater than 5 m run up) would cause major scouring, erosion and deposition of debris on the coastal highway, danger to traffic and probably loss of life. Paleo-tsunami data from the Kapiti area indicate five tsunami events of greater than 5 m run-up in the last 2000 years, with a return period of about 400 years (Kapiti Coast District Council, 2004). Other studies indicate three such events, and suggest a return period for large tsunamis of about 400 – 650 years (Cochran, 2002).

5.5.2 Transmission Gully Route

Given the inland location, the Transmission Gully route has very low tsunami risk, with little potential for damage.

5.6 Other Events

The focus of this report has been on selected large earthquakes associated with characteristic rupture of the Wellington Fault or the Ohariu Fault. The extent of damage, availability and outage in moderate but more frequent events are also worthy of consideration.

In moderate earthquake or large storm events, the existing SH 1 Coastal Route will be prone to significant closure and outage (of several days to weeks) due to landslides particularly along the coastal cliffs with steep slopes.

In such moderate earthquake or large storm events, the Transmission Gully route is expected to experience only small failures which are unlikely to close the route altogether and it is expected that it will remain open, and at least limited access will continue to be available.

5.7 Discussion of Performance

5.7.1 Existing SH 1 Coastal Route – Porirua to Paremata

Liquefaction and lateral spreading damage are expected to be similar to that observed during the 1931 Napier earthquake which caused severe damage to some roads. The damage will be more severe in an Ohariu Fault event than a Wellington Fault event, given the very close proximity of the Ohariu Fault giving rise to MM IX to X shaking.
Given the severe damage to the pavement, it is likely that this will take several weeks to some months to reconstruct the road embankment and pavement.

5.7.2 Existing SH 1 Coastal Route – Paremata Bridges

The existing old and new Paremata Bridges cross the Ohariu Fault, and in an Ohariu Fault earthquake event, these bridges will collapse due to displacement along the fault. The old bridge is also expected to collapse in a Wellington Fault earthquake event.

5.7.3 Existing SH 1 Coastal Route – Pukerua Bay to Paekakariki

The steep slopes along this section, with scars from past landslides, and the very high coastal cliff makes this section vulnerable to very large landslides (hundreds of thousands to millions of cubic metres). The likely earthquake shaking and associated topographical amplification is expected to lead to amplified ground shaking at the upper sections of slopes, leading to landslides originating from the upper sections of hillsides, with large run out distances beyond the toe of the hillside. The coastal cliffs are some 200 m to 300 m high, and it is expected that the existing highway will be covered by tens of metres of thickness of landslide debris, and it will take months to reinstate access.

The landslides will be more extensive in an Ohariu Fault Event given the very close proximity of the fault and the associated greater earthquake (MM X) shaking.

5.7.4 Transmission Gully – Fault Crossings

The preferred alignment for the Transmission Gully route has been developed (Opus International Consultants, 2008b) to avoid crossing the Ohariu Fault on bridge structures. The alignment has been modified to ensure that the highway will cross the fault in earthworks – embankments, cuts or reinforced soil embankments, and to limit it to a single fault crossing (Brabaharan, 2009). This will enable access to be reinstated quickly by earthmoving machinery.

5.7.5 Transmission Gully – Landslides

The natural hillsides along the Transmission Gully highway are not as steep as the coastal cliffs along the existing SH 1 Coastal route. Hence they are less prone to landslides, and the sizes of landslides will be smaller (up to ten thousand cubic metres only).

The proposed cuttings have been kept to a 45° slope or flatter to minimise the likelihood and size of failures, and where more fault disturbed and weathered rocks are expected, these will be formed to a gentler slope of about 35° (Brabaharan, 2009). The heights of the cuts have been kept to generally less than 60 m. It is envisaged that the rock structure will be further investigated during design and construction, and allowance has been made for some stabilisation measures, such as drainage and rock anchors, or to modify the slopes (Opus International Consultants, 2008b).
Nevertheless some landslides can be expected to occur in large earthquake events, but their sizes are expected to be much smaller than those expected on the existing SH 1 Coastal route, and hence they can be cleared more quickly.

5.7.6 Transmission Gully – Reinforced Soil Embankments

Embankments or reinforced soil embankments with geogrid reinforcements are proposed where the proposed TG highway is close to a splinter fault south of the Wainui Saddle. This would lead to the reinforced embankment displacing as a block during possible rupture of this splinter fault during an Ohariu Fault earthquake event, and access can be quickly reinstated by earthmoving machinery.

5.8 Observations from the 2008 Wenchuan Earthquake, China

A Richter magnitude 8 earthquake (Wenchuan Earthquake) occurred on 12 May 2008 in the Sichuan Province of China. A reconnaissance team of the New Zealand Society for Earthquake Engineering (NZSEE) (including P Brabhaharan), visited the earthquake affected areas in November 2008, and recently made presentations on the observations from that earthquake, and their relevance to New Zealand.

One of the key observations was the extent of landslides in mountainous areas affected by the earthquake, and their widespread and devastating effects of transportation infrastructure. Some highways were completely cut off by large landslides (Illustration 9), and some main highways remained closed when the NZSEE team visited the area six months after the earthquake. The observation of landslides in high steep hillside and their impact on roads, generally reinforced the potential for large landslides assessed for the highways in the Wellington Region, in particular for the existing SH 1 between Pukerua Bay and Paekakariki, and the expectation of long duration closure before the roads can be cleared for access. The Wenchuan Earthquake also highlighted the post-earthquake hazards from after-shocks and storms, which further mobilised landslides and debris flows in slopes affected by landslides in the major earthquake event.

Illustration 9 - Highway Completely Buried by Landslides in 2008 Wenchuan Earthquake, China
6 Performance within the Regional Context

The existing transportation routes within the Wellington Region will be affected by a large earthquake either on the Wellington Fault or on one of the other major faults in the region (Ohariu Fault, Wairarapa Fault). All existing roads in and out of the region, including the main state highways 1 and 2, and the Akatarawa Road between Upper Hutt and Waikanae, are expected to be closed for long periods of time (Opus International Consultants, 2009), see Appendix C.

The major vulnerabilities on the State Highway 1 running north from Wellington along the western side of the region, are the expected liquefaction and lateral spreading north of Porirua, the Paremata and Paekakariki Bridges, and the landslides along the Pukerua Bay to Paekakariki section.

The Transmission Gully route will bypass these sections of vulnerability. While some damage along the Transmission Gully route is expected, the route is expected to remain open in small to moderate events, and should be able to be opened for at least limited access quickly after large earthquake events (Brabaharan, 2009).

Given that both the Existing Route and Transmission Gully are in the same regional hazard setting, both are expected to be vulnerable (but to significantly differing extents) to natural hazard events such as large earthquakes. However, in the more frequent operational incidents such as storm induced slips, traffic accidents or hazardous spills, the provision of two routes will provide a greater level of security and reliability of access in and out of the greater Wellington area.
7 References


Hancox, GT, Perrin, ND, and Dellow, GD (2002). *Recent studies of historical earthquake-induced landsliding, ground damage, and MM intensity in New Zealand.* Bulletin of the New Zealand Society for Earthquake Engineering, 35(2)59-95, June 2002


Kapiti Coast District Council (2004). *Kapiti Coast Erosion Draft Management Strategy: Chapter 4- Tsunami Risk* (prepared for KCDC by J Goff, GeoEnvironmental Consultants).


Transmission Gully and Existing SH 1 Coastal Route
Route Security in Earthquake Events

Figures
SH1 Pukerua Bay to Paekakariki closed by major landslides

SH1 severely damaged by liquefaction and lateral spreading.

Availability State, Earthquake
- 6 - Closed and affecting opposite carriageway
- 5 - Closed
- 4 - Difficult
- 3 - Single Lane
- 2 - Poor
- 1 - Full

References:
Availability State for Earthquake Event - 09/05/08 (Date Captured)

Project:
Transmission Gully
Route Security Study

Prepared by:
NZ TRANSPORT AGENCY
June 2009

1:75,000

Wellington Harbour

Wellington Fault

Lower Hutt

Porirua Harbour

Plimmerton

Porirua

Tawa

Linden

Pukerua

Pauatahanui Inlet

SH1

State Highway 1

Paekakariki

Pukerua Bay

Transmission Gully

Mackay's Crossing

Ohariu Fault

Splinter of Ohariu Fault
Outage State, Earthquake

1 - Open (no closure)
2 - Minor (up to 3 days)
3 - Moderate (3 days to 2 weeks)
4 - Severe (2 weeks to 3 months)
5 - Long Term (3 - 6 months)
6 - Very Long Term (> 6 months)

Reference:
Availability State for Earthquake Event - 10/09/09 (Date Captured)
SH1 Pukerua Bay to Paekakariki section closed by major landsliding with debris extending into the sea.

Transmission Gully route affected by fault rupture in Ohariu Fault event.

Paremata bridges collapse due to Ohariu Fault rupture.

SH1 severely damaged by liquefaction and lateral spreading.

References:
Availability State for Earthquake Event - 09/05/08 (Date Captured)
SH1 Pukerua Bay to Paekakariki section closed by major landsliding.

Outage State, Earthquake

1 - Open (no closure)
2 - Minor (up to 3 days)
3 - Moderate (3 days to 2 weeks)
4 - Severe (2 weeks to 3 months)
5 - Long Term (3 - 6 months)
6 - Very Long Term (> 6 months)

References:
Availability State for Earthquake Event - 2008-05-09 (Date Captured)
### Appendix A – Performance States

**Table A-1  Damage State**

<table>
<thead>
<tr>
<th>Damage Level</th>
<th>Damage State</th>
<th>Damage Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Slight</td>
<td>Only slight damage that requires routine maintenance</td>
</tr>
<tr>
<td>2</td>
<td>Light</td>
<td>Minor damage requiring clean up of small slips (few cubic metres) and debris and culverts</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Moderate damage requiring removal of moderate volume of slip debris (tens of cubic metres), small scale repair of underslips (less than 2 m high walls) and minor repair to walls, culverts and other structures</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
<td>Severe damage requiring clearing of large volumes of slip materials (hundreds of cubic metres) and stabilisation, significant structures to repair underslips and major repair to walls, replacement of culverts and other structures</td>
</tr>
<tr>
<td>5</td>
<td>Extensive</td>
<td>Extensive damage requiring clearing of major volumes of landslides and stabilisation, large structures to repair underslips, damages to walls and other structures</td>
</tr>
</tbody>
</table>

**Table A-2  Availability State**

<table>
<thead>
<tr>
<th>Availability Level</th>
<th>Availability State</th>
<th>Availability Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Full</td>
<td>Full access except condition may require care.</td>
</tr>
<tr>
<td>2</td>
<td>Poor</td>
<td>Available for slow access, but with difficulty by normal vehicles due to partial lane blockage, erosion or deformation.</td>
</tr>
<tr>
<td>3</td>
<td>Single Lane</td>
<td>Single lane access only with difficulty due to poor condition of remaining road.</td>
</tr>
<tr>
<td>4</td>
<td>Difficult</td>
<td>Road accessible single lane by only 4x4 off road vehicles.</td>
</tr>
<tr>
<td>5</td>
<td>Closed</td>
<td>Road closed and unavailable for use.</td>
</tr>
<tr>
<td>6</td>
<td>Closed +</td>
<td>Road closed and unavailable for use and affecting alternate direction carriageway.</td>
</tr>
</tbody>
</table>
Table A-3  Outage State

<table>
<thead>
<tr>
<th>Outage Level</th>
<th>Outage State</th>
<th>Damage Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open</td>
<td>No closure, except for maintenance</td>
</tr>
<tr>
<td>2</td>
<td>Minor</td>
<td>Condition persists for up to 3 days</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Condition persists for 3 days to 2 weeks</td>
</tr>
<tr>
<td>4</td>
<td>Severe</td>
<td>Condition persists for 2 weeks to 3 months</td>
</tr>
<tr>
<td>5</td>
<td>Long term</td>
<td>Condition persists for 3 to 6 months</td>
</tr>
<tr>
<td>6</td>
<td>Very long term</td>
<td>Condition persists for &gt; 6 months.</td>
</tr>
</tbody>
</table>
Appendix B

Landslide & Environmental Criteria for NZ Modified Mercalli Intensity Scale
### MODIFIED MERCALLI (MM) INTENSITY SCALE – Landslide and Environmental Criteria

<table>
<thead>
<tr>
<th>MM 6</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Notes:</strong></td>
<td>* Some or ‘a few’ indicates that threshold for an effect or response has just been reached at that intensity. Effects below MM 6 generally insignificant in NZ.</td>
</tr>
<tr>
<td><strong>Intensity:</strong></td>
<td>Moderate to large rockfalls and disrupted soil conditions.</td>
</tr>
<tr>
<td><strong>Falls:</strong></td>
<td>Small (&lt;10^2 m^3) landslides from steep slopes.</td>
</tr>
<tr>
<td><strong>Cracks:</strong></td>
<td>Fine cracking on some slopes.</td>
</tr>
<tr>
<td><strong>Surface:</strong></td>
<td>Earth disturbances (including surface movements).</td>
</tr>
<tr>
<td><strong>Landslides:</strong></td>
<td>Small to moderate landslides from coastal cliffs, and possibly large to very large (&gt;10^7 m^3) rock slides and avalanches from steep mountain slopes.</td>
</tr>
<tr>
<td><strong>Sliding:</strong></td>
<td>Small to moderate sliding on steep slopes.</td>
</tr>
<tr>
<td><strong>Settlements:</strong></td>
<td>Temporary landslides and settlements along banks of rivers, lakes, and canals.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MM 7</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Notes:</strong></td>
<td>* Intensity is principally a measure of damage. Environmental damage (response criteria) occurs mainly on susceptible slopes and in certain materials, hence the effects described above may not occur in all places, but can be used to reflect the average or predominant level of damage (or MM intensity) in a given area.</td>
</tr>
<tr>
<td><strong>Intensity:</strong></td>
<td>Weak to moderate rockfalls and disrupted soil conditions.</td>
</tr>
<tr>
<td><strong>Falls:</strong></td>
<td>Small (&lt;10^2 m^3) landslides from steep slopes.</td>
</tr>
<tr>
<td><strong>Cracks:</strong></td>
<td>Fine cracking on some slopes and ridge crests.</td>
</tr>
<tr>
<td><strong>Surface:</strong></td>
<td>Earth disturbances (including surface movements).</td>
</tr>
<tr>
<td><strong>Landslides:</strong></td>
<td>Small to moderate landslides from coastal cliffs, and possibly large to very large (&gt;10^7 m^3) rock slides and avalanches from steep mountain slopes.</td>
</tr>
<tr>
<td><strong>Sliding:</strong></td>
<td>Small to moderate sliding on steep slopes.</td>
</tr>
<tr>
<td><strong>Settlements:</strong></td>
<td>Temporary landslides and settlements along banks of rivers, lakes, and canals.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MM 8</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Notes:</strong></td>
<td>* Environmental response criteria have not been suggested for MM 11 and MM 12, as those levels of shaking have not been reported in New Zealand. However, earlier versions of the MM intensity scale suggest that environmental effects at MM 11 and MM 12 are similar to the new criteria proposed for MM 9 and 10 above, but are possibly more widespread and severe.</td>
</tr>
<tr>
<td><strong>Intensity:</strong></td>
<td>Strong to moderate rockfalls and disrupted soil conditions.</td>
</tr>
<tr>
<td><strong>Falls:</strong></td>
<td>Small to moderate landslides from coastal cliffs, and possibly large to very large (&gt;10^7 m^3) rock slides and avalanches from steep mountain slopes.</td>
</tr>
<tr>
<td><strong>Cracks:</strong></td>
<td>Fine cracking on some slopes.</td>
</tr>
<tr>
<td><strong>Surface:</strong></td>
<td>Earth disturbances (including surface movements).</td>
</tr>
<tr>
<td><strong>Landslides:</strong></td>
<td>Small to moderate landslides from coastal cliffs, and possibly large to very large (&gt;10^7 m^3) rock slides and avalanches from steep mountain slopes.</td>
</tr>
<tr>
<td><strong>Sliding:</strong></td>
<td>Small to moderate sliding on steep slopes.</td>
</tr>
<tr>
<td><strong>Settlements:</strong></td>
<td>Temporary landslides and settlements along banks of rivers, lakes, and canals.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MM 9</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Notes:</strong></td>
<td>* Environmental response criteria have not been suggested for MM 11 and MM 12, as those levels of shaking have not been reported in New Zealand. However, earlier versions of the MM intensity scale suggest that environmental effects at MM 11 and MM 12 are similar to the new criteria proposed for MM 9 and 10 above, but are possibly more widespread and severe.</td>
</tr>
<tr>
<td><strong>Intensity:</strong></td>
<td>Severe rockfalls and disrupted soil conditions.</td>
</tr>
<tr>
<td><strong>Falls:</strong></td>
<td>Large to very large landslides from coastal cliffs, and possibly very large (10^6 m^3 or greater) rock slides and avalanches from steep mountain slopes.</td>
</tr>
<tr>
<td><strong>Cracks:</strong></td>
<td>Fine cracking on some slopes.</td>
</tr>
<tr>
<td><strong>Surface:</strong></td>
<td>Earth disturbances (including surface movements).</td>
</tr>
<tr>
<td><strong>Landslides:</strong></td>
<td>Large landslides from coastal cliffs, and possibly very large (10^6 m^3 or greater) rock slides and avalanches from steep mountain slopes.</td>
</tr>
<tr>
<td><strong>Sliding:</strong></td>
<td>Large to very large sliding on steep slopes.</td>
</tr>
<tr>
<td><strong>Settlements:</strong></td>
<td>Temporary landslides and settlements along banks of rivers, lakes, and canals.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MM 10</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Notes:</strong></td>
<td>* Environmental response criteria have not been suggested for MM 11 and MM 12, as those levels of shaking have not been reported in New Zealand. However, earlier versions of the MM intensity scale suggest that environmental effects at MM 11 and MM 12 are similar to the new criteria proposed for MM 9 and 10 above, but are possibly more widespread and severe.</td>
</tr>
<tr>
<td><strong>Intensity:</strong></td>
<td>Very severe rockfalls and disrupted soil conditions.</td>
</tr>
<tr>
<td><strong>Falls:</strong></td>
<td>Very large landslides from coastal cliffs, and possibly very large (10^6 m^3 or greater) rock slides and avalanches from steep mountain slopes.</td>
</tr>
<tr>
<td><strong>Cracks:</strong></td>
<td>Fine cracking on some slopes.</td>
</tr>
<tr>
<td><strong>Surface:</strong></td>
<td>Earth disturbances (including surface movements).</td>
</tr>
<tr>
<td><strong>Landslides:</strong></td>
<td>Very large landslides from coastal cliffs, and possibly very large (10^6 m^3 or greater) rock slides and avalanches from steep mountain slopes.</td>
</tr>
<tr>
<td><strong>Sliding:</strong></td>
<td>Very large sliding on steep slopes.</td>
</tr>
<tr>
<td><strong>Settlements:</strong></td>
<td>Temporary landslides and settlements along banks of rivers, lakes, and canals.</td>
</tr>
</tbody>
</table>
Appendix C

Vulnerability of Highways in the Greater Wellington Area
Pukerua Bay to Paekakariki section closed by major landslides for many weeks to months.

Rimutaka Hill Road closed for many weeks to months by landslides, underslips and failure of retaining walls.

Reduced to single lane access by slips for many days.

SH1 severely damaged by liquefaction and lateral spreading.

Liquefaction and lateral spreading closing Cobham Drive for many weeks.

SH1 closed to single lane access only by landslides.

Closed by large landslides taking weeks to restore.

Wellington Urban Motorway partially closed by retaining wall failures.

Failures at Mt. Victoria Tunnel portal closing tunnel for weeks.

Underslips close outer lane of SH 58 for many weeks.

SH 58 closed for many days by slope failures above road.

SH 58 closed for many weeks by landslides, underslips and failure of retaining walls.

Closed by landslides to single lane access and possibly completely for many days to weeks.

Availability State, Earthquake Event
- 6 - Closed and affecting opposite carriageway
- 5 - Closed
- 4 - Difficult
- 3 - Single Lane
- 2 - Poor
- 1 - Full

Wellington Harbour
Wellington
Linden
Tawa
New Zealand Transverse Mercator Projection
NZGD 2000
1:200,000

Project:
Contract 233PN - Transmission Gully Route Security Study
Prepared for:
NZ Transport Agency
Prepared by:
OPUS
Datum:
S-C1101.10
June 2009
Figure: C1

Availability State
Local Magnitude 7.5 Earthquake Event
e.g. Wellington Fault Event
Outage State
- 6 - Very Long Term (> 6 months)
- 5 - Long Term (3 - 6 months)
- 4 - Severe (2 weeks to 3 months)
- 3 - Moderate (3 days to 2 weeks)
- 2 - Minor (up to 3 days)
- 1 - Open (no closure)

Outage State
Local Magnitude 7.5 Earthquake Event
e.g. Wellington Fault Event

Project: Contract 233PN - Transmission Gully
Route Security Study

Prepared for: NZ TRANSPORT AGENCY
Prepared by: OPUS