



Contract 448PN

Petone to Grenada Link Road Preliminary Geotechnical Appraisal

September 2013



Contract 448PN

Petone to Grenada Link Road

Preliminary Geotechnical Appraisal

September 2013

Prepared By



Doug Mason
Engineering Geologist

Opus International Consultants Ltd
Wellington Civil
L7, Majestic Centre, 100 Willis St
PO Box 12 003, Wellington 6144
New Zealand

Reviewed By



P Brabhakaran
Technical Principal, Geotechnical /
Earthquake Engineering & Resilience

Telephone: +64 4 471 7000
Facsimile: +64 4 471 1397

Date: September 2013
Reference: GER 2013-24
Status: Final

Approved for
Release By



Len Wiles
Deputy Team Leader

Project No: 5C2359.00

Contents

Summary	1
1 Introduction.....	2
1.1 Background.....	2
1.2 Scope of this Appraisal.....	2
2 The Site	3
3 Regional Setting	4
3.1 Geomorphology	4
3.2 Geology.....	8
3.3 Contaminated Land.....	11
4 Seismic Hazards.....	13
4.1 Seismicity	13
4.2 Fault Rupture	13
4.3 Earthquake Induced Slope Instability	14
4.4 Liquefaction	17
4.5 Tsunami	18
5 Previous Geotechnical Investigations.....	19
6 Proposed Development	20
6.1 Road Alignment.....	20
6.2 Key Engineering Features.....	21
7 Resilience of the Route.....	22
7.1 Resilience	22
7.2 Resilience Context.....	23
7.3 Factors Influencing Resilience	26
8 Geotechnical Engineering Issues and Solutions	27
8.1 Petone to Grenada Link	27
8.2 Cross Valley Link.....	28
8.3 Preliminary Cut and Fill Design	29
9 Proposed Geotechnical Investigations.....	30
9.1 Geotechnical Investigations Strategy.....	30
9.2 Stage 1 Geotechnical Investigations	30
9.3 Stage 2 Geotechnical Investigations	30
9.4 Stage 3 Geotechnical Assessment and Reporting	30
10 Recommendations	31

11 References 32

Tables

Table 1 Contaminated site summary table..... 11
 Table 2 Active fault summary table.....13
 Table 3 Resilience states 22
 Table 4 Key geotechnical engineering issues for the Petone to Grenada route 27
 Table 5 Key geotechnical engineering issues for the Cross Valley Link route28

Illustrations

Illustration 1 Regional map, showing the Petone to Grenada (P2G) Project Feasibility Report and Cross Valley Link (CVL) routes..... 3
 Illustration 2 Oblique aerial photo - Petone to Horokiwi..... 5
 Illustration 3 Oblique aerial photo - Horokiwi to Lincolnshire Farm 6
 Illustration 4 Oblique aerial photo - Grenada 7
 Illustration 5 Oblique aerial photo – Takapu Road 8
 Illustration 6 Geological map 10
 Illustration 7 3D block model of the Wellington Fault scarp and Lower Hutt basin14
 Illustration 8 Slope map15
 Illustration 9 Earthquake-induced landslide susceptibility map.....16
 Illustration 10 Liquefaction ground damage hazard map17
 Illustration 11 Tsunami hazard map 18
 Illustration 12 Locations of previous geotechnical investigations and studies19
 Illustration 13 Resilience of Network (after Brabhaharan *et al.*, 2006) 22
 Illustration 14 Resilience of Wellington Region: Availability state after large local earthquake (after Opus, 2012) 23
 Illustration 15 Resilience of Wellington Region: Outage state after large local earthquake (after Opus, 2012) 24
 Illustration 16 Resilience context of Petone to Grenada Link 25

Figures

Figure 1 Location map
 Figure 2 Regional geology map
 Figure 3 Greater Wellington Regional Council well locations
 Figure 4 Regional road resilience – availability state map
 Figure 5 Regional road resilience – outage state map

Appendices

Appendix A Historical photographs of the Petone and Korokoro area
 Appendix B Contaminated site records from Greater Wellington Regional Council
 Appendix C Resilience states

Summary

A preliminary geotechnical appraisal has been completed for the proposed Petone to Grenada link route. This provides information for the development of options.

Resilience is a key objective for the project. In the context of the Wellington Region, given the limited number of routes and their poor resilience, the Petone to Grenada link road provides a valuable opportunity to enhance resilience of access for the Hutt Valley and the greater Wellington area.

The active Wellington Fault passes close to the Petone end of the route and has a significant influence in terms of the hazard to the route and in particular any structures proposed in the fault zone. Any interchange structures at Petone should be carefully positioned considering the location and impact of rupture on this fault.

This is a potential for liquefaction and lateral spreading that may also impact on an interchange at the Petone end and needs to be considered in the positioning of the interchange and any ground improvement to mitigate the effects.

Much of the route runs through steep terrain particularly over the southern part between Petone and the Lincolnshire farm area. The southern hillside in Petone is likely to have poor rock conditions given the proximity of the Wellington Fault. The alignment should be selected to minimise the effect of these poor rock conditions and potential for earthquake induced landslides associated with steep slopes.

Preliminary design information is provided for earthworks slopes and the interchange structure foundations.

There is potential for soil contamination at the Petone end of the project given the industrial history of the Korokoro Stream mouth area. There are also a number of contaminated sites and the Northern Landfill located adjacent to the route. It would be prudent to avoid crossing the Northern Landfill and where possible avoid other contaminated sites.

A staged geotechnical investigation programme is proposed for the scheme and includes both geotechnical investigations and contamination investigations.

1 Introduction

1.1 Background

New Zealand Transport Agency (NZTA) is currently undertaking preliminary scoping and scheme assessment studies for the Petone to Grenada (P2G) project. This proposed Petone to Grenada link road is part of a series of transportation improvement measures identified as part of the Ngauranga Triangle strategy study (SKM, 2010) and Petone to Grenada project feasibility report (SKM, 2009). Opus International Consultants Ltd (Opus) have been commissioned by NZTA to undertake a preliminary geotechnical appraisal for the P2G project, and to provide information on the geotechnical issues and hazards for the scoping study.

1.2 Scope of this Appraisal

Opus has undertaken a review of available literature, interpretation of aerial photographs, and engineering geological reconnaissance mapping. This report presents an appraisal of the salient geotechnical issues for the P2G project based on the results of this preliminary assessment, to help inform the selection of road form and alignment for the wider scoping study.

The preliminary geotechnical appraisal has involved the following:

- » A desk study of regional geology and hazard maps.
- » A review of past relevant geological and geotechnical reports, and the results of previous investigations.
- » A desk study of the potential for contamination along the route.
- » Site reconnaissance visits by our engineering geologist, Doug Mason, and our principal geotechnical engineer, P. Brabhakaran.
- » Appraisal of the geotechnical issues that may influence the development of route alignments.
- » Recommendations for development of the route.
- » Consideration of a strategy for carrying out geotechnical investigations.

2 The Site

The Petone to Grenada (P2G) project is an approximately 6 km long new route between the Hutt Valley and northern Wellington districts. The project area lies between western Petone and the Tawa interchange on State Highway 1 at Grenada North. The project area and the alignment proposed in the Petone to Grenada project feasibility report (identified as the PFR P2G route) (SKM, 2010), is shown below in Illustration 1.

The wider study also includes project feasibility reports for the SH2 Ngauranga to Petone Corridor, SH58 Improvements, and transport access to Seaview which may include the proposed Cross Valley Link (CVL).



Illustration 1 Regional map, showing the Petone to Grenada (P2G) Project Feasibility Report and Cross Valley Link (CVL) routes

3 Regional Setting

3.1 Geomorphology

Within the Hutt Valley, the geomorphology is characterised by flat, low-lying coastal and alluvial terrace surfaces. The urban areas of Petone, Lower Hutt, Gracefield and Seaview have been developed on this land. The PFR P2G route crosses Korokoro Stream near its mouth in Wellington Harbour. This area has been used as industrial land since deforestation in the 1840s (Appendix A).

The CVL route is proposed to cross the Hutt River near the Ava Rail Bridge. In this area, the river is approximately 120 m wide and consists of a gravel channel that grades downstream into finer grained deposits (marine sands and estuarine muds) near its mouth between Petone and Seaview.

To the southwest of Petone, around the western margin of Wellington Harbour, is a narrow bench of land that was uplifted in the 1855 Wairarapa Earthquake. State Highway 2 and the Wairarapa Line railway have been constructed on this uplifted platform, which is underlain by variable reclamation fill, with rip rap protection, concrete rubble and a masonry seawall (rock held together with cement mortar) providing protection from coastal erosion.

Immediately adjacent to this area, on the western side of State Highway 2, are steep hillslopes and deeply incised gullies of the uplifted block to the northwest of the Wellington Fault (Illustration 2). The slope angles are typically 30° to 45°, and in places are steeper than 50°, which reflect the ongoing uplift and subsequent incision of land on the northwestern side of the Wellington Fault scarp (Dellow, 1988). The hills rise from sea level at the SH2 Petone Interchange up to 290 m elevation on the hilltops near Horokiwi. This area consists of bush-covered hillslopes, the active cut slopes of Horokiwi Quarry, and rural-residential land on the ridge tops.

The geomorphology along the SH2 Ngauranga to Petone corridor being considered for upgrading will have a similar geomorphology to the Horokiwi to Petone section of p2G. The geomorphology at the Hutt Valley end of State Highway 58 (SH58) would have a similar geomorphology of steep hillsides close to the Wellington Fault.



Illustration 2 Oblique aerial photo - Petone to Horokiwi

Key geomorphic features to note are the low-lying coastal flats at Petone, the steep hillslopes of the Wellington Fault scarp above State Highway 2 (SH2), incised gullies around Korokoro Stream (KS) and Horokiwi Quarry (HQ), and the broad, undulating hilltop plateaux at Lincolnshire Farm (LF). The approximate PFR P2G alignment is indicated by the dotted line.

Further to the west, the PFR P2G route passes over the hilltops in the Horokiwi to Lincolnshire Farm section. A number of hilltops in this area preserve remnants of a prominent geomorphic feature of the Wellington region – the “K-Surface”, so named for being a “Key Surface” in understanding the tectonic history of the Wellington area (IGNS, 1996). The K-Surface may have originated as a near-flat erosion surface that was formed during an early phase of the development of the Wellington landscape. This erosion surface has subsequently been uplifted and dissected so that only remnants of it are preserved as rounded ridge crests and undulating tableland surfaces (IGNS, 1996).

The PFR P2G route crosses a prominent K-Surface remnant in the Lincolnshire Farm area (Illustration 3). The geomorphology here is characterised by broad, undulating hilltops that gently dip to the northwest towards State Highway 1. This K-Surface remnant is generally of moderate relief, and has been incised by streams which are bounded by steeply sloping gully sides.



Illustration 3 Oblique aerial photo - Horokiwi to Lincolnshire Farm

The PFR P2G route crosses a K-surface remnant that forms the undulating hilltop in the Lincolnshire Farm area. The approximate route alignments are indicated by dotted lines. Other features shown include Korokoro Stream (KS) and Woodridge (W).

The northwestern end of the PFR P2G area crosses the area of the former Northern Landfill, between Mark Avenue and State Highway 1 (Illustration 4). The geomorphology in this area consists of deeply incised hillslopes and gullies with moderate to steep slope angles. The Northern Landfill area is marked by flat terraces with steep slopes between the terrace surfaces.



Illustration 4 Oblique aerial photo - Grenada

Key geomorphic features to note include the now-closed Northern Landfill, and the incised gullies and steep hillslopes above State Highway 1 (SH1). The approximate location of the PFR P2G alignment is indicated by the dotted lines. Other features shown include Korokoro Stream (KS) and the Tawa Interchange (TI).

There is an option to connect the P2G route with the proposed Transmission Gully highway in the vicinity of Takapu Substation, at the northern end of Takapu Road (Illustration 5). This section of the route passes across steep greywacke hillslopes and deeply incised gullies to the north of the Northern Landfill. This route traverses across the hillslopes before sidling down to the floor of the valley to follow Takapu Road north to the Transmission Gully route. The geomorphology of the valley is characterised by a narrow, winding valley floor, with steep side slopes and incised tributary gullies.



Illustration 5 Oblique aerial photo – Takapu Road

Key geomorphic features to note include the steep greywacke hillslopes east of Grenada North and Takapu Road, with deeply incised, steep gullies. The approximate location of the route connecting to Transmission Gully near Takapu Substation is shown by the dotted line. Other features shown include Korokoro Stream (KS) and the Tawa Interchange (TI).

3.2 Geology

The geology of the Wellington region has been mapped by the Institute of Geological and Nuclear Sciences at 1:50,000 scale (IGNS, 1996) and 1:250,000 scale (IGNS, 2000).

The regional geology of the Hutt Valley/northern Wellington area where the proposed PFR Petone to Grenada route is located is shown in Illustration 6. The geology of the wider area, including the proposed Cross Valley Link route, is shown in Figure 2.

The principal geological units in the area comprise the following:

- » Landfill – reclamation (fr) and refuse (fw).
- » Holocene age dune sand (fd), marginal marine sediments (fm), fan deposits (ff), alluvium (fa) and swamp deposits (fs).
- » Late Triassic age Wellington belt greywacke of the Torlesse Supergroup, which comprises interbedded sandstone, siltstone and mudstone (tw) and highly deformed melange and broken formation (twm).

3.2.1 Bedrock

The geology map shows the majority of the PFR P2G route crosses terrain underlain by greywacke bedrock. This consists of alternating bedded sandstone, siltstone and mudstone/argillite. The greywacke rocks are variably weathered but are typically highly fractured and deformed due to their complex geological histories, and consequently the rock mass is characterised by very closely spaced joints, with numerous sheared and crushed zones.

The orientation of bedding and other structural features in the bedrock formations is generally aligned northeast-southwest, sub-parallel to the major active fault systems in the region (Illustration 6). Bedding is typically steeply dipping. The orientation of the ridge/valley topography of the landscape in the Korokoro Stream and Takapu Road is oriented more north-south, which reflects an earlier, pre-Quaternary structural regime which is also represented by the orientation of the minor (inactive) faults in the area.

3.2.2 Quaternary Stratigraphy

Overlying the bedrock in the hill areas of the site are variable deposits of loess, colluvium and topsoil. Surficial deposits are thin at the crest of ridges, and will increase in thickness downslope, particularly in infilled paleogullies in the bedrock surface. As described in Section 3.1, the hilltops in the project area preserve remnants of the K-Surface. These areas are likely to be underlain by a thin cover of loess and topsoil, but with a deeper weathering profile (>30 m) in the underlying rock (IGNS, 1996).

The Hutt Valley is underlain by a c. 350 m thick sequence of Quaternary alluvial and marine deposits (GNS, 2010). The CVL route crosses land underlain by these strata, as described below.

The regional geology map shows a sequence of alluvial deposits exposed at the ground surface which comprise the recent Hutt River alluvium and the Holocene Taita Alluvium. These strata consist of 10 m to 15 m of gravels and sand from the Taita Gorge in the northeast down into the lower Hutt Valley. The Taita Alluvium grades laterally into the Melling Peat north and east of the Melling Bridge. The Melling Peat consists of sand, gravel, silt and peat beds.

South of the Melling Bridge, the Melling Peat grades laterally into marginal marine sediments including the Petone Marine Beds. The Petone Marine Beds are typically shelly, and sometimes gravel rich, sandy silt and silty sand and are 27 m thick in the Gear Meat drillhole near the Petone foreshore (GNS, 2010).

In the Petone area there are a series of prominent shore-parallel beach ridges, comprised of sand and gravel. Localised alluvial fan deposits are also mapped at the mouth of the Korokoro Stream gorge in the vicinity of the Petone Wool Mill site (IGNS, 1996; Figure 2).

Underlying the Holocene deposits are the Pleistocene Waiwhetu Artesian Gravels. The top of this formation is generally 20 m to 30 m below the ground surface, and these gravels are up to 60 m thick (GNS, 2010). These strata consist of brown uniformly graded, rounded to sub-angular, water-bearing alluvial gravel, and form the principal aquifer for the Lower Hutt valley. The aquifer is confined by the overlying fine grained Petone Marine Beds and swamp deposits south of the Hutt Golf Course, resulting in artesian groundwater conditions in the lower part of the Hutt Valley.

Underlying the Waiwhetu Artesian Gravels are the Wilford Shell Bed, a 25 m to 30 m thick silty sand unit, and the Moera Basal Gravels (GNS, 2010).

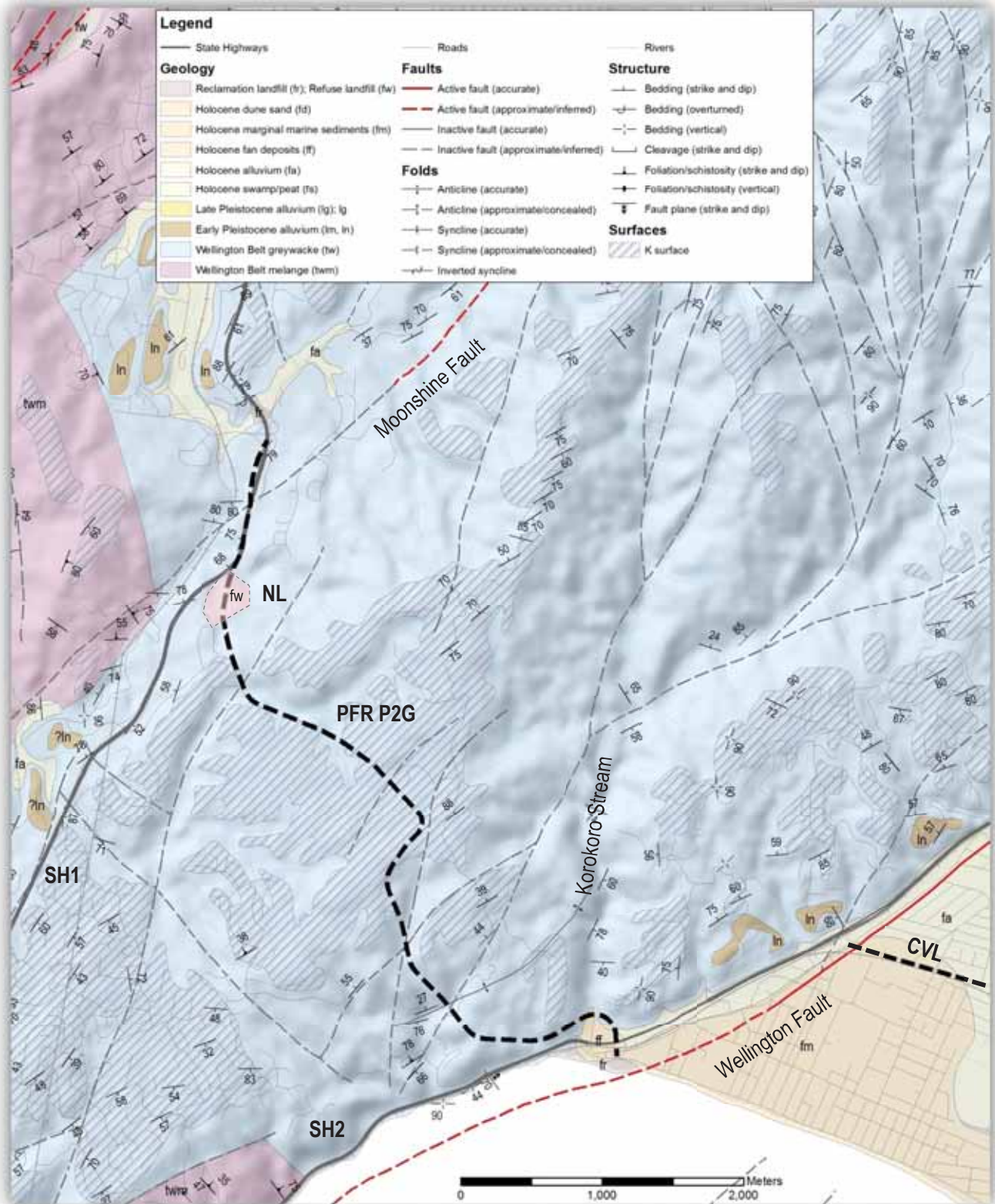


Illustration 6 Geological map

This map shows the geology of the study area (after IGNS, 1996); the PFR P2G and CVL alignments are indicated by the dotted lines. The indicative area of the Northern Landfill (NL) is shown.

3.3 Contaminated Land

Contaminated site information for sites in the vicinity was obtained through Greater Wellington Regional Council's selected land use register (SLUR). The SLUR is a database of sites that have, or may have, been used for activities and industries from the Hazardous Activities and Industries List (HAIL) established by the Ministry for the Environment. Further explanation on the HAIL and each of the categories in the SLUR database are provided in Appendix B.

The information provided is indicative only of the levels of contamination and expected contaminants. A map showing the site locations, along with the complete records from Greater Wellington's database, are included in Appendix B.

A summary of contaminated sites in close proximity to the P2G and CVL routes is provided in Table 1 below.

Table 1 Contaminated site summary table

Site (GWRC File No)	Proximity to Route	Age/Closure	Nature of Land Use	Identified/Potential Contaminants
Northern Landfill (SN/05/323/02)	0 m (P2G)	2002	Refuse landfill	Hydrocarbons, metals, landfill gas
Cottles Landfill (SN/05/030/02)	0 m (P2G)	1960s – 1980s	Refuse landfill	Hydrocarbons, metals, pesticides, herbicides, landfill gas
Pavements Asphalt Ltd (SN/05/118/02)	100 m (P2G)	Current	Asphalt and bitumen production/storage	Hydrocarbons
Horokiwi Quarry (SN/05/121/02)	< 100 m (P2G)	Current	Asphalt and bitumen production/storage	Hydrocarbons
Horokiwi Landfill	400 m (P2G)	-	Refuse landfill (uncontrolled)	Hydrocarbons, metals, pesticides, herbicides, landfill gas
Ex Safety Kleen / ERS New Zealand (SN/03/106/02)	0 m (P2G)	1996	Site of former Wellington Woollen Mill followed by waste treatment operators	Hydrocarbons
Disa Print / ex Pengellys (SN/03/130/02)	< 100 m (P2G)	-	Service station, storage, commercial printing	Hydrocarbons, solvents
Mainfreight Logistics (SN/03/088/02)	0 m (P2G)	Current	Prior: railway land, military stores, motor industries, timber storage. Current: storage, vehicle maintenance	Unknown; possible heavy metals, solvents, hydrocarbons
Ex Wellington Foundry Ltd (SN/03/028/02)	50 m (P2G)	-	Foundry, smelting, refining	Unknown; possible heavy metals
Ex Todd Motors / Bowland Petone (SN/03/102/02)	20 m (P2G)	1975	Motor vehicle workshops	Unknown; possibly hydrocarbons

Site (GWRC File No)	Proximity to Route	Age/ Closure	Nature of Land Use	Identified/Potential Contaminants
Ex Odilins Ltd / Te Puni Mail Centre (SN/03/006/02)	200 m (P2G)	1926-1980s	Timber treatment	Heavy metals, arsenic
Ex Ados Chemical Co Ltd (SN/03/090/02)	0 m (CVL)	-	Resins/synthetics manufacture	Hydrocarbons, solvents
Ex General Motors / Mitre 10 Mega (SN/03/115/02)	20 m (CVL)	1984	Motor vehicle workshops	Hydrocarbons
Ex Turnbull and Jones Ltd; Currently Acme Engineering (SN/03/091/02)	0 m (CVL)	1940s-1978; Current	Electrical manufacturing, iron and steel works	Asbestos, metals
Ex Turnbull and Jones Ltd; Currently Hutt Valley Polytech (SN/03/092/02)	0 m (CVL)	1940s-1978; Current	Electrical manufacturing, iron and steel works	Asbestos, metals
Pacific Container Park (SN/03/127/02)	170 m (CVL)	Current	Transport depot: storage/use/disposal of hazardous substances	Hydrocarbons, solvents
Ava Park landfill (SN/03/151/02)	0 m (CVL)	1940s – unknown	Refuse landfill	Hydrocarbons, metals, landfill gas
Mobil Ludlam (SN/03/119/02)	0 m (CVL)	1995 – current	Service station	Hydrocarbons

Records of asbestos are only held for 2 of the sites listed in Table 1 above (the ex-Turnbull and Jones factory buildings on Wakefield Street). However, given the age and nature of land use at the remaining sites in the project area, asbestos may be present at a number of these sites.

The 2011 National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NES), sets out a framework for assessing the risks associated with land contamination. The NES requires a Preliminary Site Investigation (PSI), comprising a detailed desk study, to be undertaken in the first instance to classify the nature and distribution of potentially hazardous land uses in the project area and to develop the scope of necessary intrusive investigations and laboratory chemical testing to quantify the hazard posed by soil contaminants. The distribution of potentially contaminated sites in the project area shows that land contamination could pose significant issues for the route options under consideration, and therefore we recommend a PSI be undertaken in conjunction with developing concepts for the P2G and CVL routes. This will be followed at a later stage by detailed site investigations and laboratory testing, when the preferred alignments have been selected.

4 Seismic Hazards

4.1 Seismicity

The project area lies within the Wellington region, which is exposed to a high level of seismicity. The region has a number of major active faults and a subduction zone associated with the active plate boundary between the Pacific and Australian plates. These structures are capable of generating large earthquakes of magnitude 7.5 to 8+, and together these represent earthquake sources that contribute significantly to the seismic hazard in the Wellington region. The principal active faults within 20 km of the site are summarised in Table 2.

Table 2 Active fault summary table

Fault	Characteristic Event Magnitude	Recurrence Interval (years)	Distance from site (km)	Direction
Wellington Fault	7.5	610-1,100	0 (Petone)	-
Moonshine Fault	7.1	11,150-12,540	0 (Grenada)	-
Ohariu Fault	7.1-7.5	2,200	3 (Grenada)	Northwest
Wairarapa Fault	8.0-8.3	1,200	20	Southeast

Source: GNS Science (2008); Heron et al. (1998); Langridge et al. (2011); Litchfield et al. (2004, 2006, 2010); Little et al. (2009, 2010); Schermer et al. (2004); Stirling et al. (2012).

In addition, the subduction interface between the Pacific and Australian plates has the potential to generate very large magnitude earthquakes (M_w 8.2-8.6) that would generate strong ground shaking in the Wellington region (Holden and Zhao, 2011).

4.2 Fault Rupture

The Wellington Fault is located in close proximity to the proposed PFR P2G route in the vicinity of the interchange at Petone (Illustration 6). The fault has a recurrence interval of 610 to 1,100 years and ruptures in large earthquakes of magnitude 7.5 with typical coseismic displacements of the ground surface of 5 m horizontally and 1 m vertically (Little et al., 2010).

The active trace of the Wellington Fault is indicated on geological maps to lie approximately 200 m from the proposed P2G interchange at Petone (IGNS, 1996). However, recent studies of the fault suggest that the area to the west of the fault could be comprised of a wider zone of discontinuous crushed, sheared and gouge zones, as shown in Illustration 7 (Begg et al., 2008). The exact location of the active fault trace, as well as the width and characteristics of the fault zone are not well known in the Petone area, which is a significant issue for the siting of any interchange structures.

The route also crosses the Moonshine Fault trace near the proposed interchange with State Highway 1 at Grenada North (Illustration 6). The location, width, characteristics and form of the fault zone are poorly defined. This fault has a very long recurrence interval (>11,000 years) and accordingly has a very low probability of rupture. Therefore this fault is of lesser importance than the Wellington Fault to the selection of the P2G route and conceptual designs.

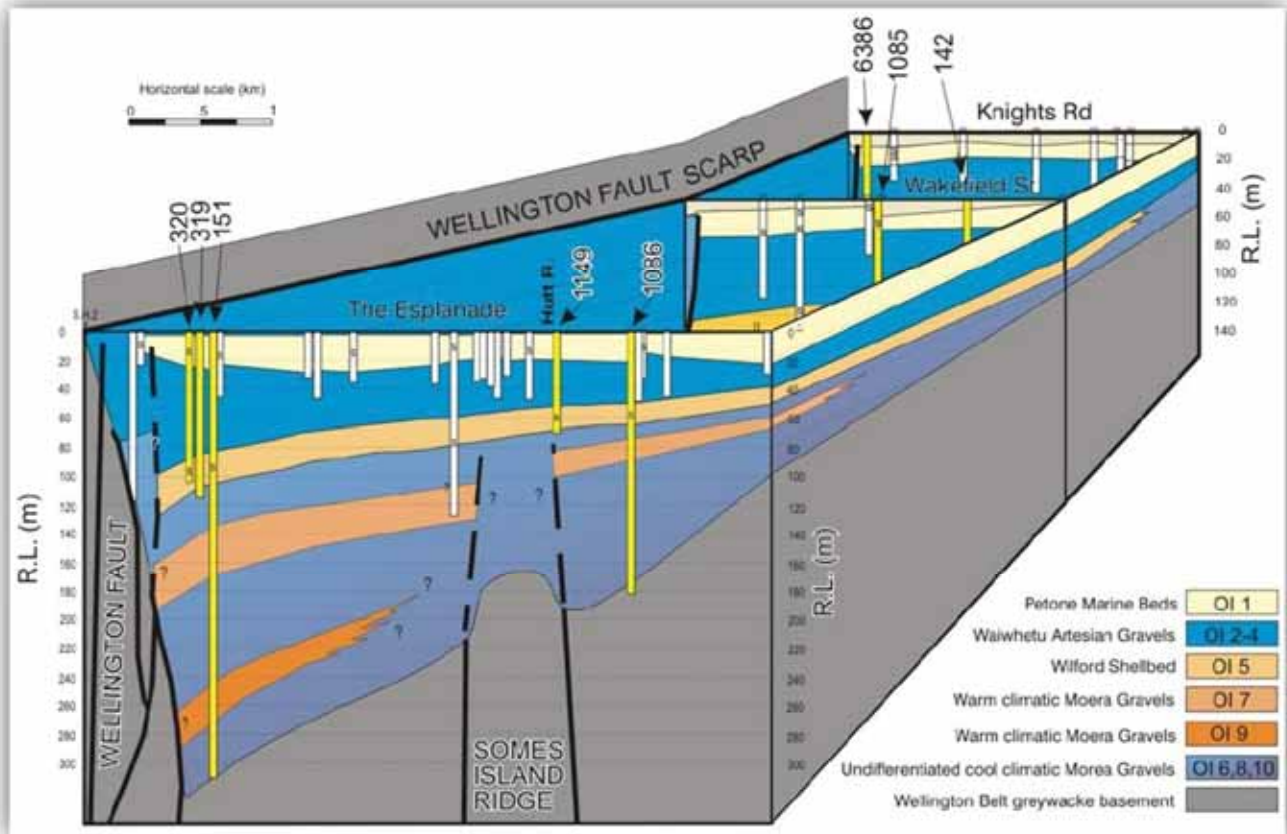


Illustration 7 3D block model of the Wellington Fault scarp and Lower Hutt basin

This diagram shows the relationship of the Wellington Fault to the alluvial and marine deposits in the Lower Hutt basin. The alluvial deposits are in excess of 300 m thick at the western end of the Esplanade in Petone (Begg *et al.*, 2008).

4.3 Earthquake Induced Slope Instability

The PFR P2G traverses hills with moderate to steep slopes, particularly at the southern section between Petone and Horokiwi as shown in Illustration 7.

Moderate to large earthquakes can lead to slope failures in steep to very steep slopes, including cuttings which are generally steeper than the natural hillslopes. The PFR P2G route crosses steep, hilly terrain at its eastern end, between Petone and the hilltops at Horokiwi. The hillslopes in this area have been mapped as high susceptibility to earthquake induced landslides (Illustration 9).

Large landslide blocks have also been identified in this area, such as the Ngauranga-Horokiwi gravity slide, which includes Gold’s Landslide, and lies 0.5 km to the southwest of Horokiwi Quarry (Dellow, 1988). Strong ground shaking during the 1855 earthquake triggered slope failures in this area, such as Gold’s Landslide near Horokiwi (Dellow, 1988).

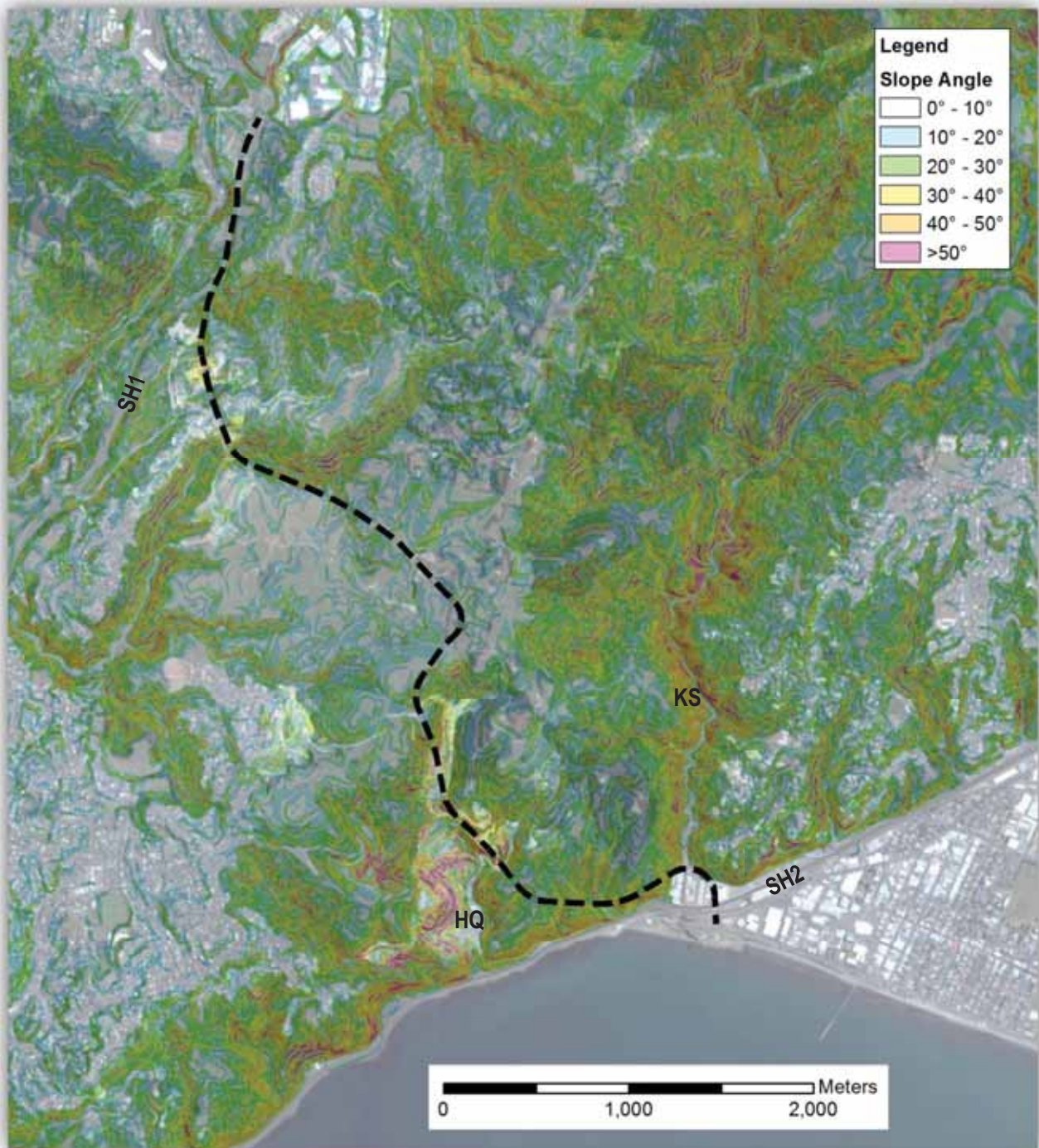


Illustration 8 Slope map

This map shows the slope angles in the project area; the PFR P2G alignment is indicated by the dotted line. Very steep slope angles (>50°) are present around Horokiwi Quarry (HQ) and the Korokoro Stream (KS) valley.

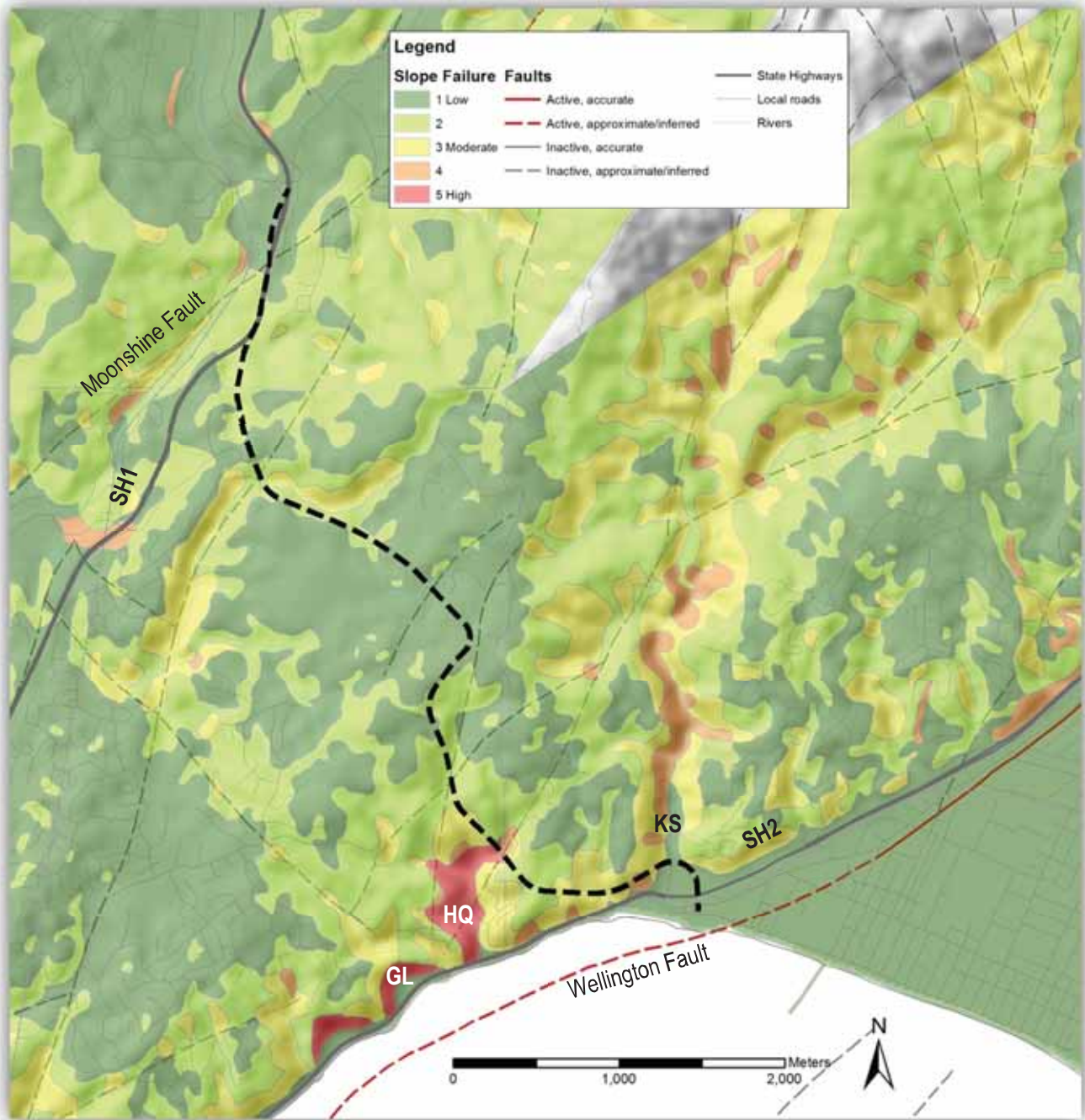


Illustration 9 Earthquake-induced landslide susceptibility map

This map shows the earthquake-induced slope instability of the PFR P2G route (after IGNS, 1996); the PFR alignment is indicated by the dotted line. The principal area of slope hazard is at the southern end of the route, where the alignment crosses steep hillslopes associated with the western side of the lower Korokoro Stream valley and the Wellington Fault scarp (Dellow, 1988). KS – Korokoro Stream; HQ – Horokiwi Quarry; GL – Gold's Landslide.

4.4 Liquefaction

A liquefaction hazard study for the Wellington Region was carried out by Works Consultancy Services (now Opus) in 1992 and the results of the study were published by the Wellington Regional Council (WRC, 1993). This study indicates a variable liquefaction potential across the site, from low to high, which reflects the variable compositions of the alluvial, marine and fan deposits. The liquefaction-induced ground damage hazard mapping is shown in Illustration 10.

Liquefaction will occur when submerged loose to medium dense granular materials and silt are subjected to ground shaking. Liquefiable materials such as loose to medium dense silt, sand and gravel are likely to be present in the area, particularly around the Petone foreshore, along the Hutt River and possibly at the Cornish Street area at the bottom of the Korokoro Stream valley.

The groundwater table at Petone is likely to be about 2 m deep (Works Consultancy Services, 1996a) and this part of the site may therefore be susceptible to liquefaction. The Cross Valley Link being considered is located in areas of variable potential for liquefaction, ground subsidence and lateral spreading.

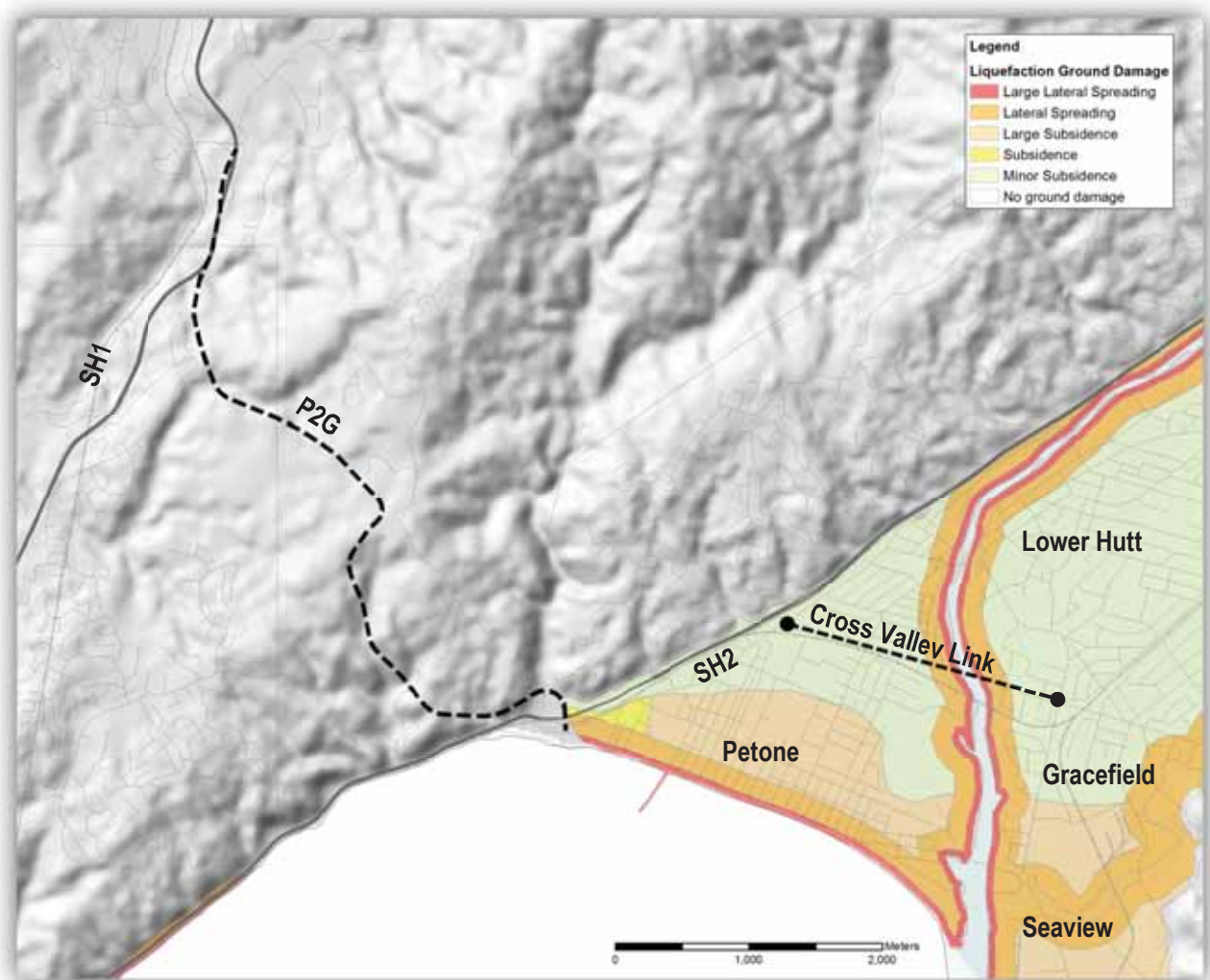


Illustration 10 Liquefaction ground damage hazard map

The liquefaction-induced ground damage hazard map (Illustration 10) indicates potential for lateral spreading along the Petone foreshore and Seaview areas, and along the banks of Hutt River. Site investigations are required to quantify this hazard and the consequences to the project, and to develop mitigation measures.

4.5 Tsunami

The Wellington Regional Council tsunami evacuation zones are shown in Illustration 11 below. The Petone interchange area and the Cross Valley Link (CVL) are exposed to tsunami hazards. The Cross Valley Link would be exposed a lower height tsunami inundation than the Esplanade. The PFR P2G route, west of the Petone interchange, crosses the hillslopes above Horokiwi Quarry and accordingly the risk of tsunami inundation is very low.

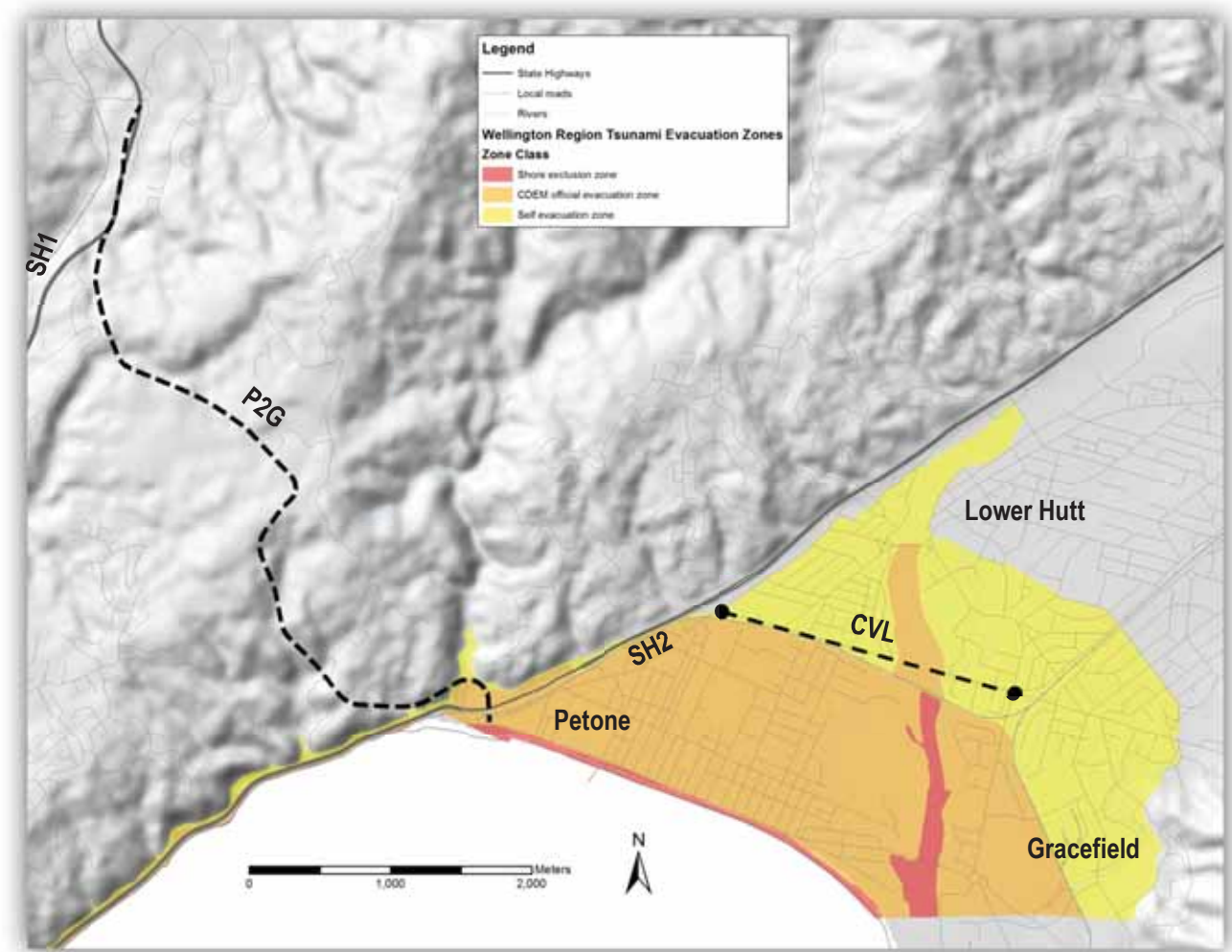


Illustration 11 Tsunami hazard map

5 Previous Geotechnical Investigations

Limited geotechnical information is available from previous investigations in the project area. Previous geotechnical investigations and studies relevant to the project are indicated on the map below (Illustration 12).



Illustration 12 Locations of previous geotechnical investigations and studies

- A. Earthquake generated landslides in Wellington (Dellow, 1988)
- B. SH1 Grenada Interchange (Works Consultancy Services, 1992a)
- C. SH2 Petone Overbridge (Works Consultancy Services, 1992b)
- D. Korokoro valve chamber (Works Consultancy Services, 1996a)
- E. Grenada mobile cell site (Works Consultancy Services, 1996b)
- F. SH2 Melling to Petone (Beca, 1998)
- G. Earthquake vulnerability of Flood Protection Assets (Opus, 2005)
- H. SH2 Dowse to Petone (Beca, 2003)
- I. Northern Landfill (MWH, 2003)

In addition, Greater Wellington Regional Council hold borehole information in their wells database for the Hutt valley. The locations of available well data in the project area and borehole information from the other studies are shown on Figure 3.

6 Proposed Development

6.1 Road Alignment

6.1.1 PFR Scheme for P2G

A project scope and alignment were developed as part of the Ngauranga Triangle study and associated Project Feasibility Report (PFR) (SKM, 2010). The project involved realignment of State Highway 2 (SH2) slightly to the north between the Petone off-ramp and Korokoro, with an interchange of the new PFR P2G alignment in the Cornish Street area of Petone.

The PFR P2G alignment then runs west towards the Horokiwi access through the hills sub-parallel to SH2 before swinging northwest-north and running through the Lincolnshire farm area. The alignment then turns north and crosses the Northern Landfill before joining with State Highway 1 (SH1) at the existing Tawa Interchange.

Interchanges are proposed with SH2 at Petone, Lincolnshire Farm area and with SH1 at Grenada North. These are likely to involve bridges, retaining walls and embankments.

The potential alignments for the P2G link are being reconsidered as part of the current study by Opus.

6.1.2 SH2 Ngauranga to Petone Upgrade

A project feasibility report is proposed for the Ngauranga to Petone section of SH2. Although the form of the potential improvements are yet to be developed, it is envisaged that they would be generally be restricted to the existing road corridor, but might involve limited cuttings into the hillside.

6.1.3 SH58 Upgrade

A project feasibility report is being undertaken for SH58. Although the form of the upgrade is yet to be developed, any widening or realignments at the Hutt Valley end of the route would involve high cuttings into the hillside. At other locations east of Moonshine Road, small embankments and retaining walls may be required.

6.1.4 Cross Valley Link

The Seaview Links Project Feasibility Report may include options which result in changes to The Esplanade or reconsideration of the Cross Valley Link which was considered as part of the Ngauranga Triangle study. If the Cross Valley Link is progressed, it could involve at-grade or low height embankments along Wakefield Street, embankments and a bridge across the Hutt River flood plain and low height embankments to the east of the river.

6.2 Key Engineering Features

6.2.1 Petone to Grenada

Key engineering features of the PFR P2G route are:

- » Interchange structure in the Petone/Korokoro area.
- » Large cuttings and embankments between Petone and the hilltop at Horokiwi.
- » Small cuttings and embankments in the Lincolnshire Farm area.
- » Long elevated structures and embankments as the new road grades down towards State Highway 1 at Grenada.

The proposed PFR scheme proposes cuttings and embankments up to about 30 m high over the northern 3 km section of the route, and cuttings up to 65 m high and embankments up to 45 m high over the southern 3 km section. The cuttings up to 24 m height are proposed at a 35° slope, and those higher than 24 m are proposed at a 70° slope “retaining wall”. These 70° “retaining walls” would be up to 65 m height.

Embankments are proposed at a 35° slope over the upper 24 m height, with any sections higher than 24 m having a 70° “Reinforced Earth”.

The PFR estimate allows for retaining wall costs of about \$ 34 Million.

6.2.2 Cross Valley Link

Key engineering features of the CVL route are:

- » Large areas of road pavement at present ground level along Wakefield St and Whites Line West.
- » New bridge over Hutt River, upstream of or alongside the Ava Rail Bridge.
- » Small embankments and retaining walls at the approaches and abutments to the new bridge.

7 Resilience of the Route

7.1 Resilience

In the development of new sections of roads it is important to consider the resilience expectations for that route. This will help enhance the resilience of the overall road network (Brabhaharan et al, 2003). Resilience is one of the key objectives for the project.

Resilience of infrastructure lifelines such as roads is dependent on the loss of quality or serviceability, and the time taken to bring the road back into its original usage state after the reduction or loss of access due to an event. This is shown conceptually in Illustration 13. The smaller the shaded green area, the more resilient is the lifeline. The greater the area, the poorer is the performance.

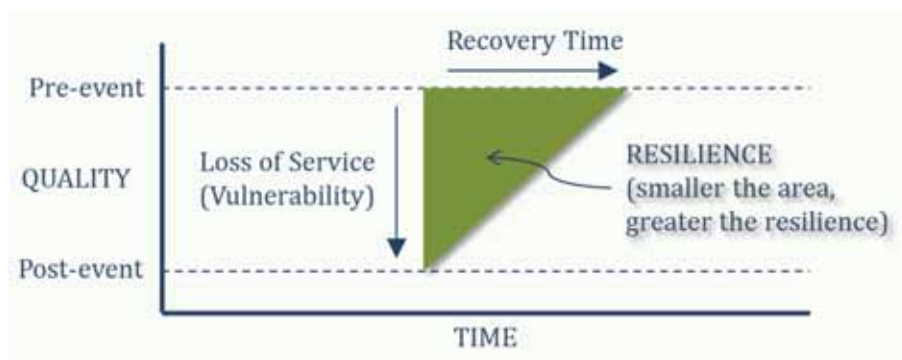


Illustration 13 Resilience of Network (after Brabhaharan *et al.*, 2006)

It is important to recognise that enhancing resilience is not just about reducing the vulnerability of the route, but also design, construct and operate it in a way that it can be quickly brought back into service. It is important to consider options which can enable a holistic achievement of resilience.

“Performance States” or “Resilience States” representing the performance of the road network have been developed to consider the impact of various natural hazards on the road network on a similar basis (Brabhaharan *et al.*, 2006). These states are summarised in Table 3.

Table 3 Resilience states

Resilience State	Description of State
Damage state	Damage State represents the severity of damage to the road and represents the severity of damage (and cost of damage repairs); see Table C-1 in Appendix C.
Availability state	Availability State indicates whether the road section would be able to be used either at full level, at various reduced levels or not at all, see Table C-2 in Appendix C. This gives an indication of the degree of access on that section of the road network after an event.
Outage state	Outage State indicates the duration over which the road will be in the Availability State above, see Table C-3 in Appendix C. This gives an indication of the duration of loss or reduced access in links along the road network.

7.2 Resilience Context

The resilience of the Wellington Region’s road network has been assessed by Opus International Consultants since 1998 (Opus, 2012). This provides a valuable insight into the resilience of the road network in the region including the state highways and the local arterial road networks of Wellington, Hutt Valley, Porirua and Kapiti.

The study by Opus (2012) indicates the poor resilience of access into the region in the aftermath of hazard events such as a large earthquake. The resilience of the road networks in the region is illustrated in the resilience state maps of “availability state” and “outage state” presented in Illustration 14 and Illustration 15, respectively. These maps are also shown on Figures 4 and 5.

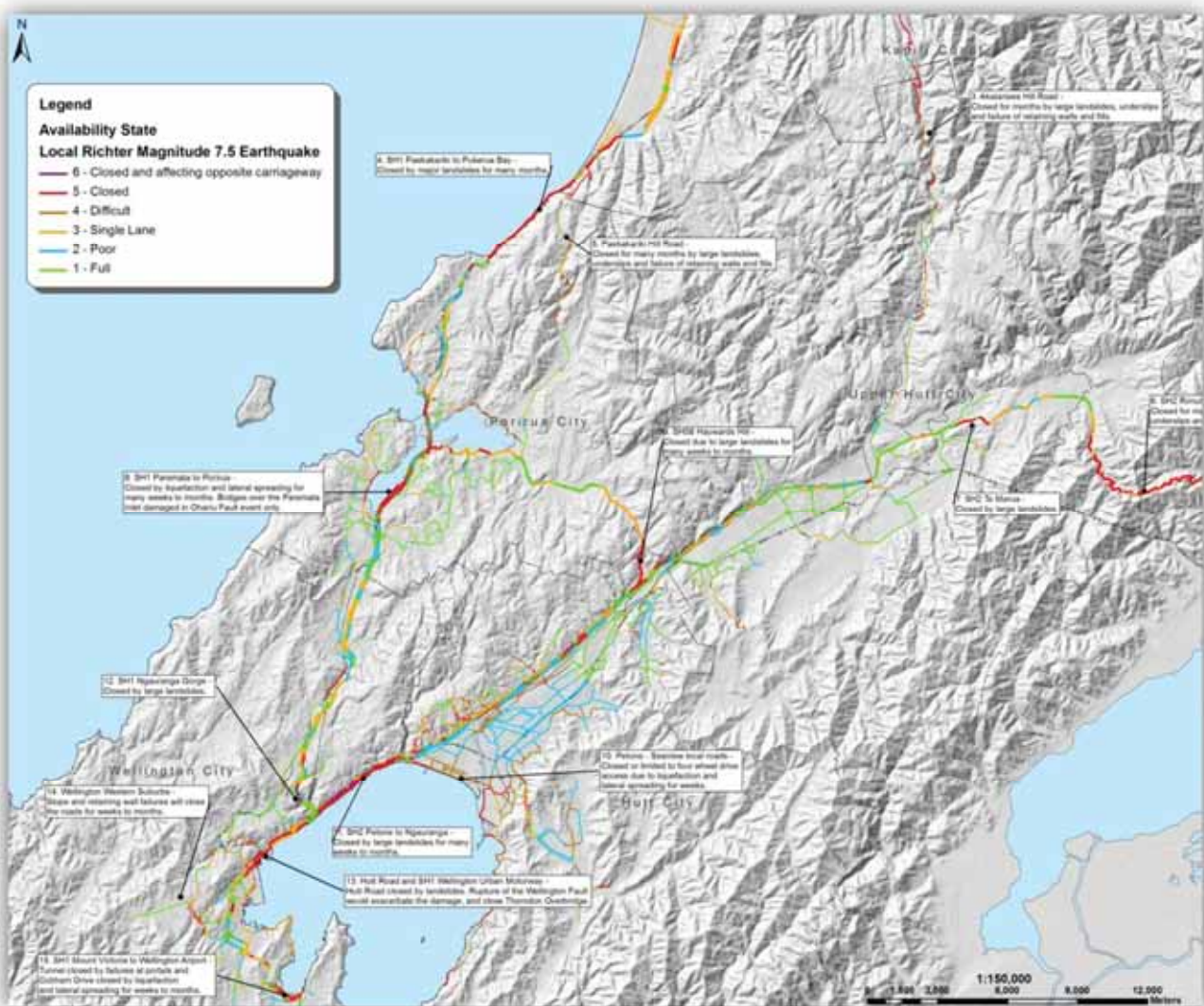


Illustration 14 Resilience of Wellington Region: Availability state after large local earthquake (after Opus, 2012)

The maps show that in the aftermath of a large magnitude 7.5 earthquake in the region, land access to the Greater Wellington area comprising Wellington, Hutt Valley and Porirua will be cut off for many months – four to six months or more. This is due to the vulnerability of SH1 and SH2 to

large landslides and liquefaction. This will severely impact the bringing in essential goods and services such as food and medicine as well as materials and equipment for response and recovery. Not only will the region be cut off, the individual districts will be cut off from each other, making it difficult for the districts to help each other. This was highlighted in a Wellington Lifelines Group report that was based on the Opus study (Wellington Lifelines Group, 2012).

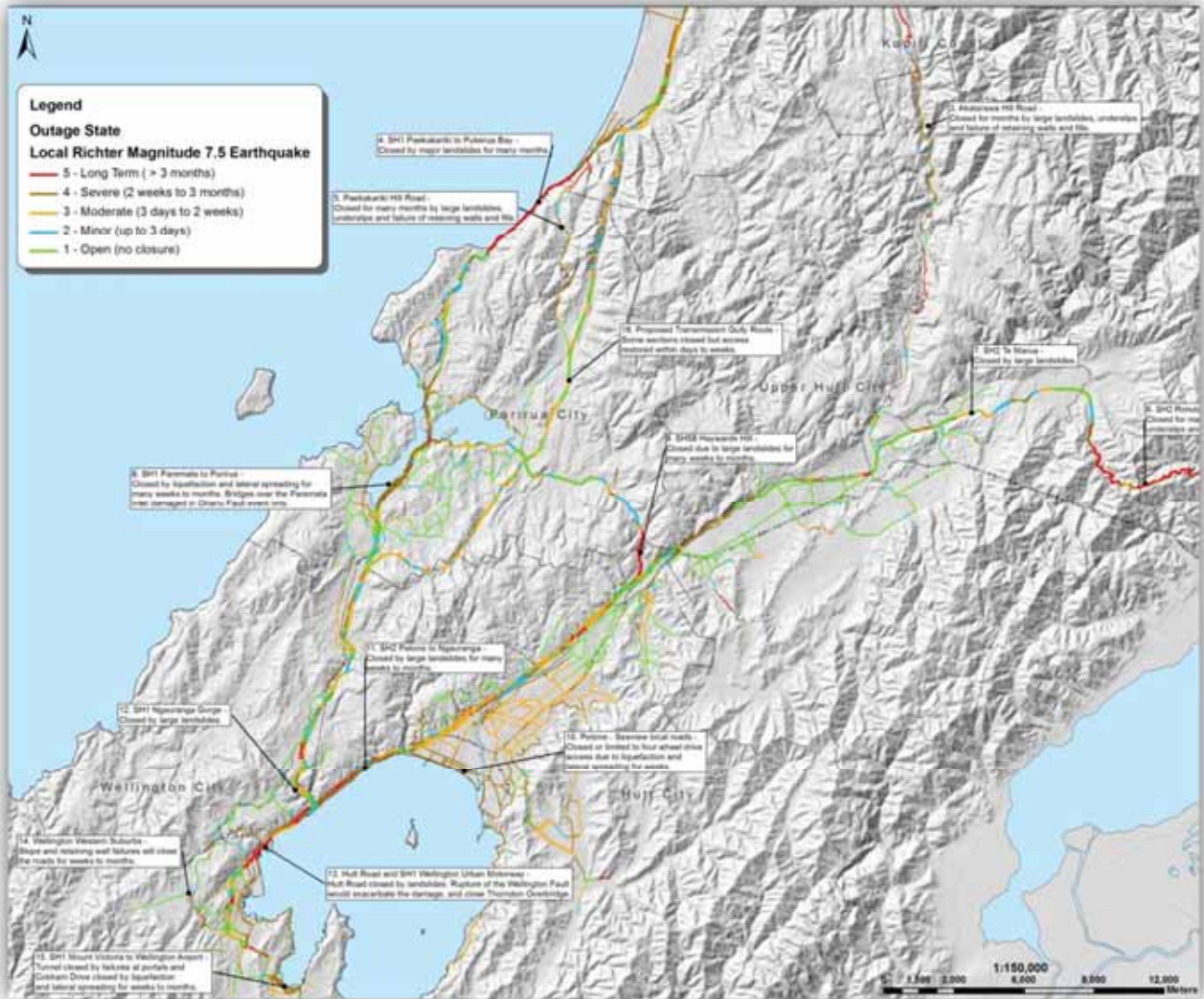


Illustration 15 Resilience of Wellington Region: Outage state after large local earthquake (after Opus, 2012)

Projects such as Transmission Gully expressway and the Peka Peka to Otaki expressway will help enhance resilience of access into the region and will enable quicker restoration of access into Porirua and Wellington, see Illustration 16. However, the Hutt Valley will remain isolated because SH2 will be cut off between Wellington and Petone, and Upper Hutt and Featherston (Rimutaka Hills), and SH58 will be cut off between Paremata and Pauatahanui, and Judgeford and Manor Park (Haywards Hill).

In this context, the Petone to Grenada link, provides an ideal opportunity to enhance access resilience into the Hutt Valley in the aftermath of hazard events such as earthquakes and storms. In addition, it also has the potential to significantly enhance day to day operational resilience of access into Wellington by providing an alternative to the Ngauranga Gorge to Grenada section of SH1 in the event of other incidents such as accidents, spills or fire.

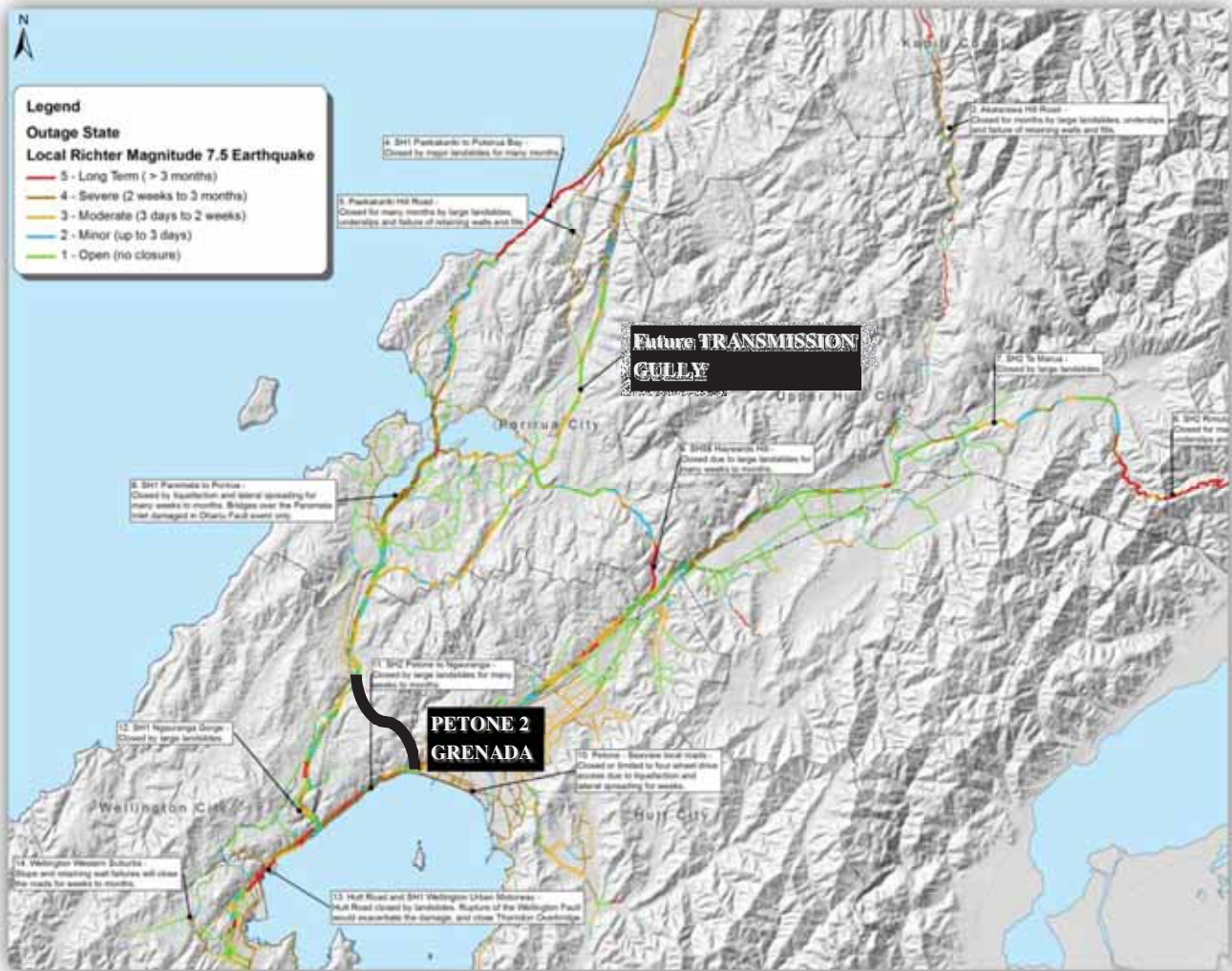


Illustration 16 Resilience context of Petone to Grenada Link

7.3 Factors Influencing Resilience

The following factors need to be considered in the assessment of resilience of options:

1. Ability to provide overall resilience of access in the region in the event of natural hazards.
2. Ability to provide alternative route in the event of operation and technological hazards such as hazardous spills or accidents, or wild fire.

The key issues affecting resilience in natural hazard events are:

- a. The relationship with the Wellington Fault Zone and the impact on the proposed road;
- b. Liquefaction and lateral spreading hazards and the impact on the route;
- c. Rock conditions along the route, steepness of the terrain along the route and the potential for landslides in earthquakes;
- d. The extent of cuts and fills and their stability in earthquakes.

8 Geotechnical Engineering Issues and Solutions

8.1 Petone to Grenada Link

Geotechnical issues have the potential to influence the development of the road alignment and form along the P2G route. The principal geotechnical engineering issues have been considered based on the outcomes of the desk study, review of regional geology and hazard maps, and the reconnaissance site visits. The principal issues for the Petone to Grenada route are summarised in Table 4.

Table 4 Key geotechnical engineering issues for the Petone to Grenada route

Location	Road Form	Key Geotechnical Engineering Issues	Risk Management Measures and Possible Concepts
State Highway 2 interchange (Petone)	<ul style="list-style-type: none"> » Bridge » Retaining walls » Embankments 	<ul style="list-style-type: none"> » Proximity to active Wellington Fault. » Variable ground conditions. » Shallow groundwater table. » Liquefaction hazard in earthquakes and impact on embankments and structures. » Foundations for structures at SH2 interchange. » Potentially contaminated ground. 	<ul style="list-style-type: none"> » Geological investigations to confirm location, width and characteristics of the Wellington Fault zone. Locate structures away from fault zone. » Geotechnical investigations to confirm ground conditions and liquefaction hazard. » Site investigations to assess levels of contaminated land and risks to the proposed development. » Drainage of pavement through provision of sub-soil drainage.
Petone to Horokiwi	<ul style="list-style-type: none"> » Large cuttings » Large embankments 	<ul style="list-style-type: none"> » The degree of weathering and rock mass conditions. » Thickness and composition of any overburden deposits. » Stability of very high cuttings in fractured Wellington greywacke. » Stability of high embankment fills in steep terrain. » Earthquake and rainfall induced slope stability hazards. 	<ul style="list-style-type: none"> » Geotechnical investigations to confirm degree of weathering, rock mass properties and the nature of rock defects. » Consider route alignment that minimises height of cuttings, and avoids areas of steep slopes. » Avoid large cuttings oriented parallel to regional geological structure, to reduce potential for adversely oriented defects.
Lincolnshire Farm	<ul style="list-style-type: none"> » Road at grade or with low height cuttings » Embankments across incised gullies 	<ul style="list-style-type: none"> » Degree and depth of weathering and rock mass conditions. » Properties and thickness of any overburden deposits (loess, colluvium) on the K-Surface remnant at the hilltop. » Stability of cuttings in highly weathered and fractured Wellington greywacke. » Thickness of compressible weak deposits in incised gullies. 	<ul style="list-style-type: none"> » Geotechnical investigations to confirm degree and depth of weathering of rock mass. » Geotechnical investigations to confirm ground conditions and thickness of overburden deposits.

Location	Road Form	Key Geotechnical Engineering Issues	Risk Management Measures and Possible Concepts
Northern Landfill	» Embankments	<ul style="list-style-type: none"> » Road crossing areas underlain by refuse landfill on embankments » Variable and very poor ground conditions. » Thickness and properties of landfill materials. » Stability, settlement and secondary compression of embankments on poor ground. » Ongoing settlement and hazards such as landfill gas. 	<ul style="list-style-type: none"> » Choose route alignment to avoid landfill area. » Geotechnical investigations to confirm the extent, thickness, composition and properties of landfill materials if unavoidable. » Preloading embankments where underlain by landfill materials to minimise post-construction settlements; Allow time for settlement during construction.
State Highway 1 interchange (Grenada North)	<ul style="list-style-type: none"> » Bridge at SH1 interchange » Retaining walls » Embankments » Cuttings 	<ul style="list-style-type: none"> » Variable ground conditions. » Foundations for structures at SH1 interchange. » Proximity to active Moonshine Fault. » Earthquake and rainfall induced slope stability hazards. 	<ul style="list-style-type: none"> » Geotechnical investigations to confirm ground conditions. » Investigations to confirm location and width of Moonshine Fault zone. » Locate structures away from fault zone.

In addition to the specific issues identified in Table 4, the properties of the overburden materials and weathered greywacke materials and their suitability for use as construction fill is also a key issue that would influence earthworks quantities, cut/fill balance and the need for borrow and disposal sites.

8.2 Cross Valley Link

The principal issues for the Cross Valley Link route are summarised in Table 5.

Table 5 Key geotechnical engineering issues for the Cross Valley Link route

Location	Road Form	Key Geotechnical Engineering Issues	Risk Management Measures and Possible Concepts
At-grade along Wakefield St and Whites Line West	» Road on existing ground	<ul style="list-style-type: none"> » Proximity to active Wellington Fault. » Variable ground conditions. » High groundwater levels, including artesian groundwater. » Liquefaction hazard in earthquakes and impact on embankments and structures. » Potentially contaminated ground. 	<ul style="list-style-type: none"> » Geotechnical investigations to confirm ground and groundwater conditions and liquefaction hazard. » Geological investigations to confirm location, width, characteristics and form of the Wellington Fault zone. » Locate structures away from fault zone. » Undercut of soft ground and drainage measures.

Location	Road Form	Key Geotechnical Engineering Issues	Risk Management Measures and Possible Concepts
Hutt River crossing	<ul style="list-style-type: none"> » Bridge » Retaining walls » Embankments 	<ul style="list-style-type: none"> » Foundation conditions for bridge and retaining walls on alluvial deposits. » Artesian groundwater pressures. » Instability of bridge abutments and embankments due to liquefaction and lateral spreading in earthquake events. 	<ul style="list-style-type: none"> » Geotechnical investigations to confirm ground and groundwater conditions and liquefaction hazard. » Pile foundations to support bridge structure. » Pile construction to resist artesian groundwater pressure and prevent aquifer contamination.

The geotechnical issues described above in Table 4 and Table 5 can be resolved through:

- » An appropriate level of geotechnical and investigations.
- » Early consideration of issues during concept development and preliminary design.
- » Integrated consideration of the geotechnical issues with the development of the project, to achieve an appropriate road form, reduce construction costs, reduce potential hazards and improve the overall performance and resilience of the new road.

8.3 Preliminary Cut and Fill Design

The cut and fill design should be based on information from geotechnical investigations along the route. Until the geotechnical investigations are carried out, it would be appropriate to use the following preliminary design for the development and comparison of options:

1. Cuttings – In rock, formed at 45° (1H:1V), with 3 m wide benches formed at 10 m height intervals, and some allowance made for targeted stabilisation of rock using rock anchors, rock bolting and mesh and sub-horizontal drainage holes. In soil, formed at 26° (2H:1V) and rounded at the top of the cuttings.
2. Embankments – formed at 26° (2H:1V), with 3 m wide berms that 10 m height intervals, where these cannot be fitted into the terrain, reinforced soil embankments may be adopted with steeper 45° (1H:1V) slopes and using geogrid reinforcement.
3. Bridges requiring abutment walls incorporate Reinforced Soil Walls with inextensible (steel) reinforcement.
4. Bridges at the Petone end be piled, with ground improvement under the bridge abutments to provide protection against liquefaction.

9 Proposed Geotechnical Investigations

9.1 Geotechnical Investigations Strategy

We propose a staged geotechnical investigation programme, given the development of concepts and design is currently in progress. The information obtained from the earlier stages will ensure that the following stages of work can be better targeted. This will ensure the investigations are cost effective.

9.2 Stage 1 Geotechnical Investigations

The purpose of these investigations will be to obtain information on the terrain, engineering geology and more detailed information on the hazards including contamination. These investigations will gain valuable information at a modest cost on the geology, geomorphology and hazards to help inform the concept development.

This may be carried out in three phases:

- a. Phase 1 A - Preliminary desk top assessment of the Petone foreshore area, including characterisation of the location, width and nature of the Wellington Fault in the Petone area.
- b. Phase 1B - Aerial photograph assessment, engineering geological mapping, and evaluation of the geomorphology of the hill areas north and west of the Petone area.
- c. Phase 1C - In parallel with the geotechnical investigations, we recommend a Preliminary Site Investigation (PSI) be undertaken to classify the nature and distribution of potential soil contamination within the study area, as described in Section 3.3.

9.3 Stage 2 Geotechnical Investigations

Stage 2 geotechnical investigations will be scoped and carried out based on the results of the Stage 1 geotechnical investigations, and when the preferred alignment options have been developed as part of the scoping study.

This may also be carried out in three phases:

- a. Phase 2 A - Physical on site geotechnical investigations in the flat Petone area, which is likely to comprise trial pits, sonic drilled boreholes with Standard Penetration Tests, engineering geological logging and piezo-cone penetration tests.
- b. Phase 2B – Geotechnical investigations in the hilly areas north of Petone, which is likely to comprise trial pits, cored boreholes, Acoustic Televiewer (ATV) surveys, and laboratory testing including rock testing.
- c. Phase 2C – Contamination investigations as determined by the Phase 1C preliminary contamination investigation.

9.4 Stage 3 Geotechnical Assessment and Reporting

On completion of the geotechnical site investigations and testing, a geotechnical assessment will be carried out for the scheme assessment options that are considered, and a geotechnical assessment report will be prepared.

10 Recommendations

We recommend that:

1. The resilience of the options developed be assessed as an integral part of the option development process, as it is at the early stages of project development, that resilient alignments and design forms can be achieved.
2. Geotechnical issues and recommendations identified in Table 4 and Table 5 are considered in the option development and preliminary design.
3. Preliminary geotechnical design recommendations for the earthworks and bridge sites are used for the options study.
4. NZTA accepts the staged geotechnical investigation programme.
5. NZTA provide approval to proceed with the Stage 1 geotechnical investigations, which will comprise the three phases:
 - a) Phase 1A – Engineering geological mapping of Petone Area, which will include preliminary investigations into the Wellington Fault at Petone.
 - b) Phase 2A – Engineering geological mapping of the Hill areas north of Petone, including aerial photograph assessment, engineering geology mapping and geomorphological assessment.
 - c) Phase 3A – Preliminary Site Investigation for contaminated ground, in accordance with the National Environmental Standard (2011), which will comprise a detailed desk study of the nature and distribution of potentially contaminated sites and the development of the scope of necessary intrusive investigations and testing to quantify the hazard posed by soil contaminants.

The costs for the Phase 1 geotechnical investigations will be provided separately.

11 References

- Beca Carter Hollings and Ferner Ltd (1998). State Highway 2 Melling – Petone upgrade. Preliminary design phase geotechnical investigations. Project ref. 3401049. Report ref. 1WR95866.DOC.
- Beca Carter Hollings and Ferner Ltd (2003). SH2 Dowse – Petone upgrade. Geotechnical investigations for detailed design. Project ref. 3202860/20. Report ref. W3:4858-MWJ32R01.DOC.
- Begg, J.G., Langridge, R., Van Dissen, R.J., Little, T.A. (2008). Wellington Fault: Neotectonics and earthquake geology of the Wellington-Hutt Valley segment. Field Trip 1, GeoSciences '08 Field Trip Guides, pp. 5-66. Geoscience Society of New Zealand.
- Begg, J.G., Van Dissen, R.J., Rhoades, D.A. (2004). Subsidence in the Lower Hutt Valley and the interplay between Wellington and Wairarapa Fault earthquakes. Proceedings of the New Zealand Society of Earthquake Engineering 2004 Conference. Paper number 43.
- Brabhaharan, P., Wiles, L.M., Freitag, S. (2006). Natural Hazard Road Risk Management Part III: Performance Criteria. Land Transport New Zealand Research Report 296. 117p.
- Dellow, G. (1988). Earthquake Generated Landslides in the Wellington and Lower Hutt Area. Unpublished MSc thesis, University of Canterbury, Christchurch.
- GNS Science (2008). Estimation of earthquake spectra for Transmission Gully. GNS Science Consultancy Report 2008/92. Prepared by McVerry, G.H. and Destegul, U.
- GNS Science (2010). It's Our Fault – Geological and geotechnical characterisation and site class revision of the Lower Hutt Valley. GNS Science Consultancy Report 2010/163. 62p. Prepared by Boon, D.P., Dellow, G.D., Perrin, N.D., Lukovic, B.
- Heron, D.W., Van Dissen, R.J., Sawa, M. (1998). Late Quaternary movement on the Ohariu Fault, Tongue Point to MacKays Crossing, North Island, New Zealand. *New Zealand Journal of Geology and Geophysics* 41: 419-439.
- Holden, C. and Zhao, J.X. (2011). Modelling strong ground motions for subduction events in the Wellington region, New Zealand. Proceedings of the Ninth Pacific Conference on Earthquake Engineering- Building an Earthquake-Resilient Society. Paper no. 229, 8 p.
- Institute of Geological and Nuclear Sciences (1996). Geology of the Wellington area, scale 1:50,000. Institute of Geological & Nuclear Sciences 1:50,000 geological map 22. Lower Hutt, New Zealand. Compiled by Begg, J.G. and Mazengarb, C.
- Institute of Geological and Nuclear Sciences (2000). Geology of the Wellington area, scale 1:250,000. Institute of Geological and Nuclear Sciences 1:250 000 geological map 10. Lower Hutt, New Zealand. Compiled by Begg, J.G and Johnston, M.R.
- Langridge, R., Van Dissen, R., Rhoades, D., Villamor, P., Little, T., Litchfield, N., Clark, K., Clark, D. (2011). Five thousand years of surface ruptures on the Wellington Fault, New Zealand: Implications for recurrence and fault segmentation. *Bulletin of the Seismological Society of America* 101: 2088-2107.

- Litchfield, N., Van Dissen, R.J., Langridge, R., Heron, D.W., Prentice, C. (2004). Timing of the most recent surface rupture event on the Ohariu Fault near Paraparaumu, New Zealand. *New Zealand Journal of Geology and Geophysics* 47: 123-127.
- Litchfield, N., Van Dissen, R.J., Heron, D.W., Rhoades, D. (2006). Constraints on the timing of the three most recent surface rupture events and recurrence interval for the Ohariu Fault: trenching results from MacKays Crossing, Wellington, New Zealand. *New Zealand Journal of Geology and Geophysics* 49: 57-61.
- Litchfield, N.; Van Dissen, R.J.; Hemphill-Haley, M.; Townsend, D.; Heron, D.W. (2010). Post c. 300 year rupture of the Ohariu Fault in Ohariu Valley, New Zealand. *New Zealand Journal of Geology and Geophysics* 53: 43-56.
- Little, T.A.; Van Dissen, R.J.; Schermer, E.; Carne, R. (2009). Late Holocene surface ruptures on the southern Wairarapa fault, New Zealand : link between earthquakes and the uplifting of beach ridges on a rocky coast. *Lithosphere* 1: 4-28; doi:10.1130/L7.1
- Little, T.A.; Van Dissen, R.J.; Rieser, U.; Smith, E.G.C.; Langridge, R.M. (2010). Coseismic strike slip at a point during the last four earthquakes on the Wellington Fault near Wellington, New Zealand. *Journal of Geophysical Research. Solid Earth*, 115: B05403, doi:10.1029/2009JB006589.
- MWH (2003). Wellington City Council Northern Landfill consents – Assessment of environmental effects.
- Ninis, D., Little, T.A., Van Dissen, R.J., Litchfield, N.J., Smith, E.G.C., Wang, N., Rieser, U., Henderson, C.M. (2013). Slip rate on the Wellington Fault, New Zealand, during the late Quaternary: Evidence for variable slip during the Holocene. *Bulletin of the Seismological Society of America* 103: 559-579.
- Opus International Consultants (2012). Wellington region road network earthquake resilience study. Risk study report. Report ref GER 2012-21. Prepared by Brabhaharan, P., and Mason, D., for the New Zealand Transport Agency, Wellington City Council, The Hutt City Council, Upper Hutt City Council, Porirua City Council and Kapiti Coast District Council.
- Rhoades, D.A., Van Dissen, R.J., Langridge, R.M., Little, T.A., Ninis, D., Smith, E.G.C., Robinson, R. (2011). Re-evaluation of conditional probability of rupture of the Wellington-Hutt Valley segment of the Wellington Fault. *Bulletin of the New Zealand Society for Earthquake Engineering* 44: 77-86.
- Schermer, E.R., Van Dissen, R.J., Berryman, K.R., Kelsey, H.M., Cashman, S.M. (2004). Active faults, paleoseismology, and historical fault rupture in northern Wairarapa, North Island, New Zealand. *New Zealand Journal of Geology & Geophysics* 47: 101–122.
- Sinclair Knight Merz (2010). Ngauranga Triangle Strategy Study. Petone to Grenada Link Road Project Feasibility Report. Revision D. 21 January 2010. SKM project number ZB00938.10.
- Sinclair Knight Merz (2010). The Ngauranga triangle strategy study. Detailed technical report. SKM project number ZB00938.
- Stirling, M., McVerry, G., Gerstenberger, M., Litchfield, N., Van Dissen, R., Berryman, K., Barnes, P., Wallace, L., Villamor, P., Langridge, R., Lamarche, G., Nodder, S., Reyners, M., Bradley, B., Rhoades, D., Smith, W., Nicol, A., Pettinga, J., Clark, K., Jacobs, K. (2012). National seismic hazard model for New Zealand: 2010 update. *Bulletin of the Seismological Society of America* 102: 1514-1542.

Wellington Lifelines Group (2012). Lifeline utilities restoration times for metropolitan Wellington following a Wellington Fault earthquake, Report to the Wellington CDEM Group Joint Committee from the Wellington Lifelines Group. November 2012.

Wellington Regional Council (1993). Seismic hazard map series: Liquefaction hazard map sheet 3 Hutt Valley (first edition) 1:75,000. Wellington Regional Council Publication WRC/PP-T-93/74. Compiled by Kingsbury, P.A., and Hastie, W.J.

Works Consultancy Services (1992a). Grenada Interchange: Geotechnical advice on sidling fills. Reference C1086.17/PB. Works Consultancy Services, Wellington.

Works Consultancy Services (1992b). State Highway 2 realignment at Petone Overbridge. Design Statement. Reference C8486.00. Works Consultancy Services, Wellington.



Works Consultancy Services (1996a). Korokoro Valve Chamber, Petone, Lower Hutt Seismic Protection – Geotechnical Report. Works Consultancy Services, Wellington.

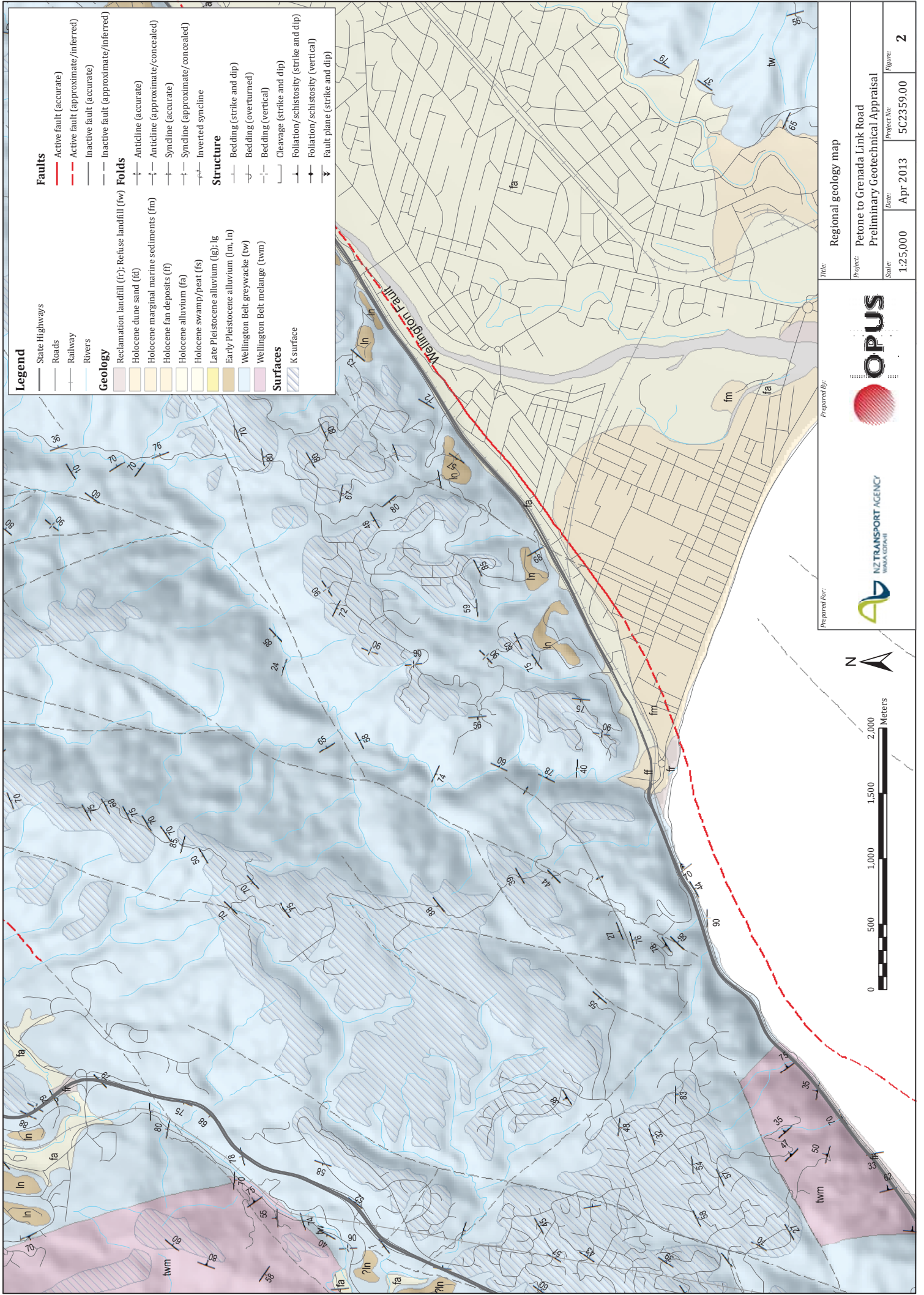
Works Consultancy Services (1996b). Telecom Mobile Grenada Cell Site Investigations. Reference 5C5500.01. Works Consultancy Services, Wellington.

Figures





Prepared For:		Prepared By:		Title:	
 NZ TRANSPORT AGENCY WAKA KOTAHU		 OPUS		Site location map	
				Project: Petone to Grenada Link Road Preliminary Geotechnical Appraisal	
Scale:	Date:	Project No:	Figure:		
1:100,000	Apr 2013	5C2128.01	1		



Legend

- State Highways
- Roads
- Railway
- Rivers

Faults

- Active fault (accurate)
- Active fault (approximate/inferred)
- Inactive fault (accurate)
- Inactive fault (approximate/inferred)

Geology

- Reclamation landfill (fr); Refuse landfill (fw)
- Holocene dune sand (fd)
- Holocene marginal marine sediments (fm)
- Holocene fan deposits (ff)
- Holocene alluvium (fa)
- Holocene swamp/peat (fs)
- Late Pleistocene alluvium (lg); lg
- Early Pleistocene alluvium (lm, ln)
- Wellington Belt greywacke (tw)
- Wellington Belt melange (twm)

Surfaces

- K surface


Folds

- Anticline (accurate)
- Anticline (approximate/concealed)
- Syncline (accurate)
- Syncline (approximate/concealed)
- Inverted syncline

Structure

- Bedding (strike and dip)
- Bedding (overturned)
- Bedding (vertical)
- Cleavage (strike and dip)
- Foliation/schistosity (strike and dip)
- Foliation/schistosity (vertical)
- Fault plane (strike and dip)

Prepared for:



NZ TRANSPORT AGENCY
WAIKATO REGION

Project: Petone to Grenada Link Road
Preliminary Geotechnical Appraisal


Scale: 1:25,000 Date: Apr 2013 Project No: 5C2359.00 Figure: 2

Regional geology map

Title:

Scale: 1:25,000 Date: Apr 2013 Project No: 5C2359.00 Figure: 2

0 500 1,000 1,500 2,000 Meters







Legend

GWRC boreholes

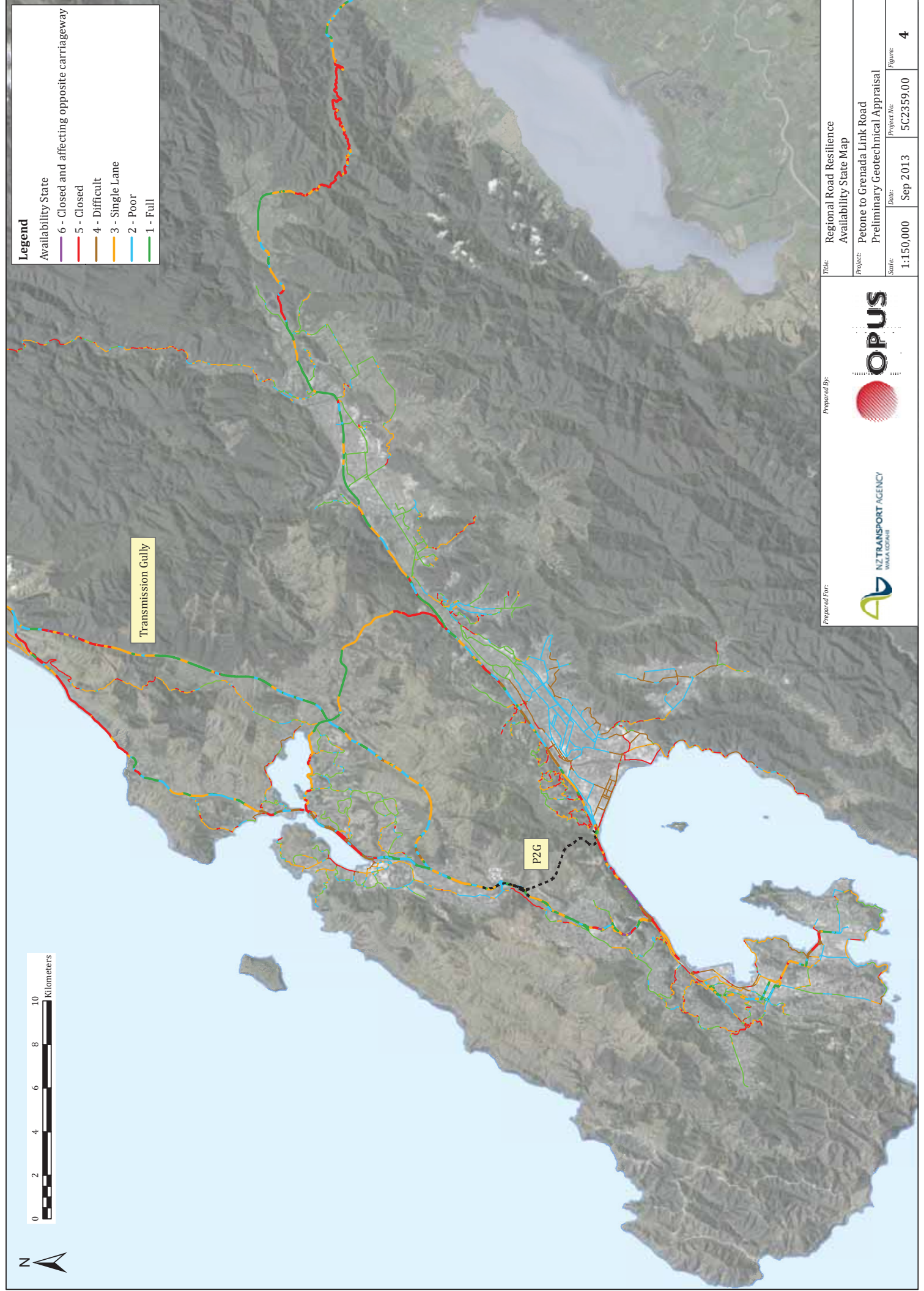
Wellington Regional Council well locations		
Project:	Petone to Grenada Link Road Preliminary Geotechnical Appraisal	
Scale:	1:12,500	Date: Mar 2013
Project No:	5C2359.00	Figure: 3

Prepared for:

Wellington Regional Council





Legend

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

Transmission Gully

P2G



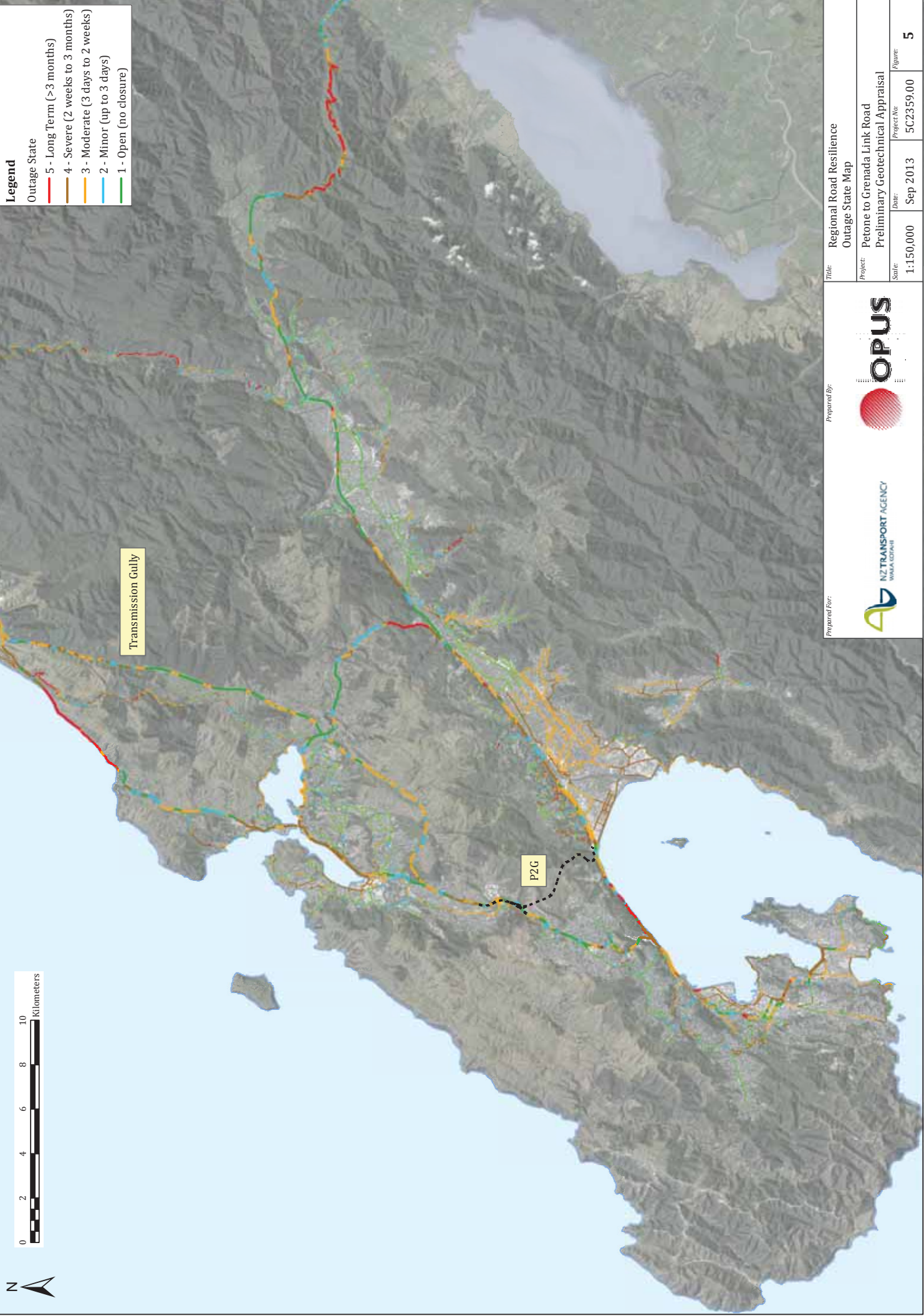
Title: Regional Road Resilience Availability State Map	
Project: Petone to Grenada Link Road Preliminary Geotechnical Appraisal	
Scale: 1:150,000	Date: Sep 2013
Project No: 5C2359.00	Figure: 4

Prepared for:



Prepared By:





Legend
Outage State
5 - Long Term (>3 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)

Transmission Gully

P2G

Prepared for:



Prepared by:



Title: Regional Road Resilience
Outage State Map

Project: Petone to Grenada Link Road
Preliminary Geotechnical Appraisal

Scale: 1:150,000
Date: Sep 2013
Project No: 5C2359.00

Figure: 5

Appendix A

Historical photographs of Petone and Korokoro (Source: Alexander Turnbull Library)





Petone area prior to deforestation and European settlement



(By Courtesy Wellington Harbour Board)

BRITANNIA (PITO-ONE) 1840, from a sketch drawn by Captain W. Mein-Smith, R.A., taken from the Korokoro Hill.
Tents and houses are on the Beach and Emigrant ships near Somes Island.

Contrast Modern Petone, page 12.



WELLINGTON WOOLLEN MILLS, PETONE.

Wool mill at Korokoro



Wool mill at Korokoro



View of Petone (1911)



Korokoro Woollen Manufacturing Company (c. 1920s)

Appendix B
Contaminated site records from Greater Wellington
Regional Council



Selected Land Use Register (SLUR) factsheet

Sites that are registered on Greater Wellington's SLUR are known (or suspected) to have been involved (historically or currently) in the use, storage or disposal of substances from one or more hazardous activities/industries identified by the Ministry for the Environment. In some cases the sites on SLUR will be "contaminated sites" and in others not.

SLUR classifies sites under six categories:

Category I – Verified History of Hazardous Activity or Industry

A site classified as "Verified History of Hazardous Activity or Industry" is a site for which a past or present use has been confirmed as falling within one of the definitions on the Hazardous Activities and Industries List (HAIL). Assignment to this category does not imply the site is contaminated, but merely that hazardous substances have been used, stored or disposed of on the site and therefore there is a potential for site contamination to have occurred.

Category II – Unverified History of Hazardous Activity or Industry

A site classified as "Unverified History of Hazardous Activity or Industry" is a site for which its past or present use is the subject of an unconfirmed report that indicates that it falls within one of the definitions on the HAIL. Assignment to this category does not imply the site is contaminated, but merely that there is a possibility that hazardous substances have been used, stored or disposed of on the site and site contamination may have occurred. The reports could be from an external source or from a general information search carried out by Greater Wellington. A site remains under this category until further information is available that enables it to be transferred to another category.

Category III – Contamination Confirmed

A site classified as "Contamination Confirmed" is a site where there is evidence that hazardous substances exist above background concentrations AND it is a likely that adverse effects on human health (subject to exposure path) or the environment will occur based on the current or foreseeable site use. This category is for sites that the council holds information on, typically as a result of a site investigation that shows contaminants are present on the site at concentrations that exceed relevant guidelines. A site remains in this category until it is remediated or managed in such a way that it can be transferred to Category IV.

Category IV – Contamination Acceptable, Managed/Remediated

A site classified as "Contamination Acceptable, Managed/Remediated" is a site where there is clear evidence that residues of hazardous substances exist above background concentrations BUT the level of risk of adverse effects on human health or the environment is shown to be acceptable for the particular land use. Either the concentrations are below relevant guideline levels OR remedial or management action has been taken to reduce the risks to an acceptable level. Sites may be placed in this category either because an investigation report has been received that shows the site has contaminants present in environmental media but the concentrations are below relevant guideline values, or the site has previously been registered in Category I or III and further investigation or remediation has been undertaken.

Category V – No Identified Contamination

Sites are placed in the “No Identified Contamination” category when an investigation report has been received that demonstrates an absence of contaminants above background concentrations. The investigation will have considered contaminants that could have resulted from the past or present use. Sites would be placed in this category either because the site had not been previously registered on SLUR, but an investigation report has been received, or the site had previously been registered as Category I or II and further investigation was undertaken.

Category VI – Entered on Register in Error

A site classified as “Entered on Register in Error” is a site that has been classified under any other category, but subsequent investigation has found that the site has never been associated with any of the uses on the HAIL and there is no possibility of contamination of the site. This category is used for sites entered onto the SLUR or into the initial registration category as a result of incorrect information. The site is not removed from the register; it remains on SLUR to correctly record the site’s history. The reasons for the original entry and reasons for the change to this category are recorded

Hazardous Activities and Industries List (HAIL)

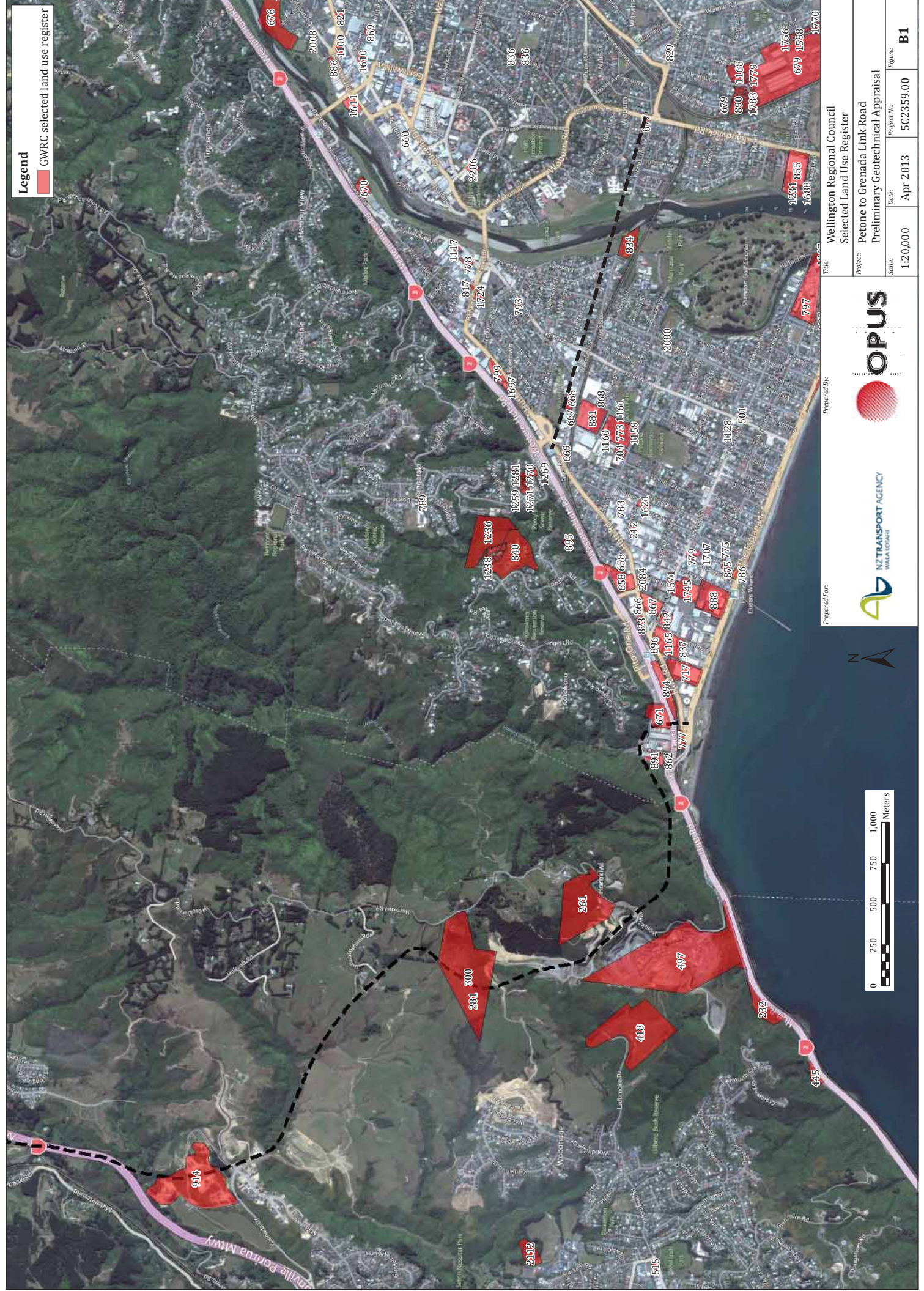
The Hazardous Activities and Industries List (HAIL) is a compilation by the Ministry for the Environment of activities and industries that are considered likely to cause environmental contamination resulting from hazardous substance use, storage or disposal.

HAIL was last updated in October 2011 and contains a range of activities/industries, including:

- a) Chemical manufacture, application and bulk storage
- b) Electrical and electronic works, power generation and transmission
- c) Explosives and ordnances production, storage and use
- d) Metal extraction, refining and reprocessing, storage and use
- e) Mineral extraction, refining and reprocessing, storage and use
- f) Vehicle refuelling, service and repair
- g) Cemeteries and waste recycling, treatment and disposal
- h) Any land that has been subject to the migration of hazardous substances from adjacent land in sufficient quantity that it could be a risk to human health or the environment
- i) Any other land that has been subject to the intentional or accidental release of a hazardous substance in sufficient quantity that it could be a risk to human health or the environment

Further information and the full HAIL list is available from:

<http://www.mfe.govt.nz/issues/hazardous/contaminated/hazardous-activities-industries-list.html>



Prepared for: **OPUS**
 WAAIACIARI

Prepared By: **OPUS**

Title: Wellington Regional Council
 Selected Land Use Register

Project: Petone to Grenada Link Road
 Preliminary Geotechnical / Appraisal

Scale: 1:20,000 Date: Apr 2013 Project No: 5C2359.00 Figure: B1

GREATER WELLINGTON REGIONAL COUNCIL
SELECTED LAND USE REGISTER

GIS ID	Site Name	File No	ANZECC	ANZECSUB	Category	Street No	Street Name	TA	VAL NO	Legal Description	Site History
83	Tawa Service and Repairs	SN/05288/02	Motor Vehicle Workshops, Service Stations	Workshops, Service Stations	Verified History of Hazardous Activity or Industry	80	MAIN RD	WELLINGTON CITY	16590 514.00	LOT 1 DP 45 183	This site has previously been used as a service station and motor vehicle workshop. Six underground storage tanks were removed in February 1999. The entire site is covered with concrete. A report prepared by Geocon Ltd dated 11/11/99 states that the site is contaminated with petroleum hydrocarbons. The site is currently used for storage of materials. The site is not used for residential purposes. The site is currently used for storage of materials. The site is currently used for storage of materials. The site is currently used for storage of materials.
212	Ex. Maculauy Metals	SN/03234/02	Scrap Yards	Scrap Metal Merchants	Verified History of Hazardous Activity or Industry	80	FITZHERBERT ST PETON	HUTT CITY	16590 420.00	LOT 32 DP 205 LOTS 1 TO 2 DP 5323	The site has been used for the recycling of ferrous and non ferrous metals. Maculauy Metals was established in 1959, and moved from this site to 45 Sawley Rd in 1988. See Site No SN/03078/02. According to the Hutt City Council contamination of soil may have occurred. As part of these operations hydrocarbons have been stored on the site. Greater Wellington has no record of any environmental investigations having taken place on the site.
261	Pavements Asphalt Ltd	SN/05118/02	Asphalt and Blumen Prod/Storage	Production	Verified History of Hazardous Activity or Industry	211	HOKOKIWI RD	WELLINGTON CITY	16590 588.00	LOT 8 DP 28 139	The site has been used for the production of asphalt. As part of these operations hydrocarbons have been stored on the site. Greater Wellington has no record of any environmental investigations having taken place on the site.
272	Dries Smart (ex. Southcorp NZ Ltd)	SN/05053/02	Drum and Tank Reconditioning or Recycling	Reconditioning	Contamination Acceptable/Managed/Remediated for	24-32	MAIN RD	WELLINGTON CITY	16590 522.00	LOT 6 PT LOTS 34 DP 20567 TO ROW	The site was previously used for the production and reconditioning of drums. Environmental investigations undertaken show elevated concentration of hydrocarbons and heavy metals to be present on the site. An assessment of the environmental investigations results shows that the concentrations of contaminants on the site did not exceed industrial/commercial guideline values.
279	Ex. A.C. Hickick (NZ) Ltd	SN/05054/02	Chem. Manufacture/Formulation	Reins/Synthetics manufacture	Contamination Acceptable/Managed/Remediated for	42-58	MAIN RD	WELLINGTON CITY	16590 518.00	LOT 1 DP 62560 - SUBJ LOTS 261-262 - SUBJ DP 55817 UP 98340	This site has been used for chemical manufacture of synthetic rears. Raw materials used were alkyds, olefin, toluene, xylene, styrene, polyethylene glycol and emulsion. Potentially contaminated organic compounds, volatile organic compounds, semi volatile organic compounds, and inorganic compounds, including heavy metals which have found their way into the Porirua stream. The site was previously used for chemical manufacture of synthetic rears. Raw materials used were alkyds, olefin, toluene, xylene, styrene, polyethylene glycol and emulsion. Potentially contaminated organic compounds, volatile organic compounds, semi volatile organic compounds, and inorganic compounds, including heavy metals which have found their way into the Porirua stream.
281	Former Cottles Tip	SN/05030/02	Landfill	General landfill sites	Verified History of Hazardous Activity or Industry	279	HOKOKIWI RD	WELLINGTON CITY	16590 596.00	LOT 1 DP 28 139	This site was used as a landfill from the early 1970s to the early 1980s. Initially the tip took solid waste but in the early 1970s it accepted most material including timber, bricks and masonry, car bodies and tyres, glass, large appliances, drums of hazardous waste, iron shelling and plastics, metal wastes. There were a number of fires at the site to remove coated or sheathed cable over copper. Notes on file indicate that the landfill was not well managed and the landfill accepted industrial waste not suitable for disposal elsewhere in Wellington. Sampling undertaken of the site by Greater Wellington found that average levels of zinc exceeded aquatic ecosystem levels. Lead levels and suspended solids below the tip face were also exceeded for both aquatic ecosystems and stock watering guidelines (1995-1997). In 2001 concern was raised about the possibility of perchloroethane and other herbicides/pesticides being dumped at the site. Results indicated that Sem Volatile Organic Compounds (SVOCs) were not detected. In 2002 further testing was undertaken for polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenz-p-dioxins (PCDDs) these results found.
285	Tawa Junction (ex. Armstrong Timber & Papanumakes)	SN/05054/02	Timber Treatment, Motor Vehicle Workshops	Timber Treatment, Workshops	Verified History of Hazardous Activity or Industry	10	SURREY ST	WELLINGTON CITY	16590 325.00	PT LOT 1 DP 86557	The site was established in the early 1940s as a timber treatment plant and engineering works. Timber treatment and engineering continued on the site until 1987, when the plant was demolished. In 1988 the continuation of the Tawa Junction Shopping Centre commenced. Greater Wellington was informed that prior to the complex being built, the whole site was excavated and unstable fill removed (including soft bog and sandstone deposits). The site was then filled to design levels with imported landfill. Greater Wellington does not record any of the environmental investigations undertaken on the site. The site is currently used for storage of materials. The site is currently used for storage of materials. The site is currently used for storage of materials.
300	Former Cottles Landfill	SN/05030/02	Landfill	General Landfill Sites	Verified History of Hazardous Activity or Industry	277	HOKOKIWI RD	WELLINGTON CITY	16590 595.00	LOT 2 DP 28 139 BLK XII BELMONT SD	This site was used as a landfill from the early 1970s to the early 1980s. Initially the tip took solid waste but in the early 1970s it accepted most material including timber, bricks and masonry, car bodies and tyres, glass, large appliances, drums of hazardous waste, iron shelling and plastics, metal wastes. There were a number of fires at the site to remove coated or sheathed cable over copper. Notes on file indicate that the landfill was not well managed and the landfill accepted industrial waste not suitable for disposal elsewhere in Wellington. Sampling undertaken of the site by Greater Wellington found that average levels of zinc exceeded aquatic ecosystem levels. Lead levels and suspended solids below the tip face were also exceeded for both aquatic ecosystems and stock watering guidelines (1995-1997). In 2001 concern was raised about the possibility of perchloroethane and other herbicides/pesticides being dumped at the site. Results indicated that Sem Volatile Organic Compounds (SVOCs) were not detected. In 2002 further testing was undertaken for polychlorinated dibenzofurans (PCDFs) and polychlorinated dibenz-p-dioxins (PCDDs) these results found.
306	Pilrow - Diesel Storage	SN/05291/02	Motor Vehicle Workshops, Storage	Workshops, Chemicals	Verified History of Hazardous Activity or Industry	59	TAKAPU RD	WELLINGTON CITY	16590 512.00	LOT 4 DP 31 569	This site has been used for the underground storage of hydrocarbons. The waste of tank and its associated infrastructure were removed in September 2005. A limited site investigation was undertaken, which indicated the concentration of hydrocarbons on the site were appropriate for the proposed industrial/commercial land use. During the site investigation waste oil was observed floating on the groundwater and according to the Takapu Stream. However, no assessments of the potential effects on either the groundwater or the Takapu Stream or any other potential contaminants were undertaken. Therefore the extent and nature of the potential contamination resulting from the use of the waste oil tank on the site is not known. The site is currently used for storage of materials. The site is currently used for storage of materials. The site is currently used for storage of materials.
307	Fletcher Construction	SN/05288/02	Storage	Fuel	No Identified Contamination	21	TAKAPU RD	WELLINGTON CITY	16590 506.00	LOT 1 DP 31 009	Information received from the site assessment (see section 2.1.2.1) indicates that the site is currently used for storage of materials. The site is currently used for storage of materials. The site is currently used for storage of materials.
310	Mexico Motors Ltd	SN/05287/02	Service Stations	Service Stations	Verified History of Hazardous Activity or Industry	47	MAIN RD	WELLINGTON CITY	16590 393.00	LOT 1 DP 15 453	This site has stored large quantities of hydrocarbons in bulk since 1926. The Wellington City Council Dangerous Goods Licence from 1991 to 1998 does not list these tanks on site. The current owner has stated however that the tanks were removed in 1999 under the supervision of a Wellington City Council Dangerous Goods Officer. The tanks removed were described as not being live. No any fill report has been provided to Greater Wellington and therefore the extent of contamination, if any, is unknown.
312	Deneroff Springs Systems Ltd	SN/05285/02	Storage	Fuel	Verified History of Hazardous Activity or Industry	76	MAIN RD	WELLINGTON CITY	16590 515.00	LOT 1 DP 15 008 - SUBJ TO ROW	This site has stored Class 3 hazardous substances. The Dangerous Goods Licence was issued to the business on this site by Wellington City Council in 1991 for containers to store up to 1500 litres and 500 litres, however from 1992 this amount was reduced to 450 litres and 200 litres. No detailed site investigation is held by Greater Wellington. Information received (Spencer Holmes Ltd, December 2007) shows that the site is proposed to be developed into a Storage King complex. As part of an assessment of effects a site monitoring plan is outlined for the management of any contamination. The plan involves a preliminary assessment, and procedures to remove and remediate any contaminated soil that may be present. Greater Wellington notes no further information.
314	Aquathair Industries Ltd	SN/05285/02	Iron and Steel Works, Storage	Engineering workshop/boiler makers, Fuel	Verified History of Hazardous Activity or Industry	92	MAIN RD	WELLINGTON CITY	16590 512.00	LOT 1 DP 14 746 LOT 2 DP 23 975	This site has been used as an engineering workshop. An underground storage tank (Class 3) and fifty large quantities of hazardous substances in other drums and containers (Class 2 and 3) are stored on site (Wellington City Council Dangerous Goods Licence). No detailed site investigation is held by Greater Wellington and therefore the extent of contamination, if any, is unknown.
317	Advance Coasters Ltd	SN/05279/02	Storage	Fuel	Verified History of Hazardous Activity or Industry	2	DRAGON ST	WELLINGTON CITY	16710 134.00	LOT 9 DP 45 628 LOT 10 DP 46 983 LOT 21 DP 46 983	This site, or has, stored hydrocarbons in two large underground storage tanks. A Wellington City Council Dangerous Goods Licence was issued for these tanks from 1991 to 1995. There is no record of removal and future site investigation is held by Greater Wellington.
372	Suprema Paints & Powder Co (Industrial) Ltd	SN/05240/02	Storage, Iron and Steel Works	Fuel, Engineering Workshops/Boiler Makers	Verified History of Hazardous Activity or Industry	32, 34	DRAGON ST	WELLINGTON CITY	16710 134.01	LOTS 33, 34 DP 49 414	As part of the site operation significant quantities of hydrocarbons have been stored on site. Previous land uses have included an engineering workshop, which undertook fabrication from steel metal. Potential contaminants could include solvents, rears, hydrocarbons and heavy metals. However, Greater Wellington is not aware of any environmental investigations having taken place.
418	Closed Hokoaki Landfill	SN/05020/02	Landfill	General landfill sites	Contamination Confirmed	33	LABROOKE DR	WELLINGTON CITY	16590 584.01	LOT 2 DP 30 392	This site has been used as a landfill which has accepted both community and industrial waste. A report on file notes that the entrance to the site was not matted and therefore industrial and commercial refuse was unable to properly inspected or controlled. Hazardous wastes were accepted on rare occasions. A report in 1990 noted that leachate was twice as strong as secondary treated sewage and was discharged to the stream. Areas of the tip were clear-filled after closure. The landfill gas was identified as of risk to the public in 1995. This gas generated was proposed to be collected and used for power generation (1995), however it is unknown if this has happened. The area was intended to be used as reserve land. Information received (URS report, February 2007) shows that a Phase 2 site investigation was undertaken at the closed landfill at Hokoaki. The report notes that the landfill has a leachate discharge and treatment system authorised by the way of consent (WGN 00046 2012), which was due to expire in 2006, and for which a new consent is reportedly being sought. The surface of the site was found to be in good condition with the GPR results indicating the cap is likely to be approximately 0.5m in thickness, and continuous across the landfill. The report states that heavy metal and TPH concentrations in the landfill cap samples were all below MIE (1999) Guideline A1 Pathway values, and generally consistent with or slightly exceeding background levels.
481	BP Express Tawa	SN/05139/02	Service Stations	Service Stations	Verified History of Hazardous Activity or Industry	100	MAIN RD	WELLINGTON CITY	16590 510.00	LOT 1 DP 70 329	This site has been used as a service station. There are three underground storage tanks containing hydrocarbons on site (2004 Dangerous Goods Licence). No further information is held by Greater Wellington regarding the site. The site is currently used for storage of materials. The site is currently used for storage of materials. The site is currently used for storage of materials.
497	Hokoaki Quarries	SN/05121/02	Storage, Asphalt and Blumen Prod/Storage	Fuel	Verified History of Hazardous Activity or Industry	39	HOKOKIWI RD	WELLINGTON CITY	16590 595.00	PT PLAN A 690 LOT 1 DP 55444 LOT 1 DP 59444 SUBJ TO ESMT ON DP 68 158	The site has been used for the production of asphalt and Blumen Prod. The site is currently used for storage of materials. The site is currently used for storage of materials. The site is currently used for storage of materials.
558	Felix Rubber	SN/03216/02	Storage, Motor Vehicle Workshops	Chemicals, Workshops	Verified History of Hazardous Activity or Industry	35-43	HUTT RD	HUTT CITY	16590 894.00	PT SEC 3 HUTT DIST AL DP 3025 LOTS 1 TO 12 DP 23022 LOT 14 PT LOTS 1 & 16 DP - 1819	The main site was owned by William Cook and Sons Limited from 1929 until 1958, when Fletcher Hardware Company Limited bought the site. It is unknown what processes took place on the site during this period. Then Todd Motors bought the site comprising the site between 1961 and 1974 and used it for the assembly of motor vehicles. In 1974, the site was leased, and subsequently sold to Felix, who used it for the production of underlay and bowser. Until the 1960s, the three lots bordering the Hutt Road were residential dwellings, since 1994 they have been used for the retail of hardware, process timber and laminate production. The current owners acquired the site in 1994. In 1993, Felix Commissioned O'Brien International Pty Ltd to undertake an environmental assessment of the site and their operations. The report highlighted that there were three underground storage tanks on the site, two of these tanks were removed prior to the site inspection and the third storage tank was removed from the site in 1994. A tank pull report for the three underground storage tanks was prepared by O'Brien International Pty Ltd in 1994. Greater Wellington does not have a record of any environmental investigations undertaken on the site. The site is currently used for storage of materials. The site is currently used for storage of materials. The site is currently used for storage of materials.
667	Acme Engineering Ltd	SN/03091/02	Electrical Manufacturing (Trams) and Steel Works	Transformer manufacture, Iron and Steel Product Manufacture/Fabrication	Verified History of Hazardous Activity or Industry	25	WAKEFIELD ST	HUTT CITY	16591 807.00	LOT 1 DP 53584	This site has been used as an Acme Engineering workshop which they have occupied for 8 or 9 years (2003). The site, from the 1940s to 1978, was operated by Turnbull and Lovell Ltd, an ex transformer manufacturer. The building had an asbestos roof. No detailed site assessment has been undertaken and it is therefore not known what contaminants, if any, remain on site.

GIS ID	Site Name	File No	ANZECC	Category	Street No	Street Name	TA	VALNO	Legal Description	Site History
888	Ex Clear Meatsworks, BM and Pak n Save	SN/03/05/02	Storage, Tanning and Ass. Trades	Verified History of Hazardous Activity or Industry	25	VICTORIA ST PETONE	HUTT CITY	16500 773 03	LOT 1 DP 1371067	The site was previously the site of the Clear Meat Company. As part of the meat works, paint shop, lithography and an engine room operations were undertaken on the site. A number of underground storage tanks were also present on the site. Our records show that the tanks were removed during the redevelopment of the site. Greater Wellington is not aware of any environmental investigation having taken place at the site. Information received (PDP 2009) shows that some diesel spillage has been removed from parts of the site following an accidental spill of 60L diesel from an above ground storage tank during installation of a generator next to the new building. The report states that validation soil sampling from the site of contamination. Findings of this report are not known. There are currently no underground storage tanks remaining on the site (2020). These were installed in 1989 and are of the type commonly used for diesel storage. The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
891	Ex Selen Klean (ERS New Zealand)	SN/03/10/02	Waste Storage/Treatment/Disposal	Contamination Acceptable Managed/Remediated for or Industry	12	CORNISH ST	HUTT CITY	16600 004 11F	UNIT 6 & ALUGION UNIT PLAN 52648	Verdict on this site is unknown. The site was previously used for the storage of waste. The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
894	Bowland Palove (Ex. Todd Motors)	SN/03/10/02	Motor Vehicle Workshops	Verified History of Hazardous Activity or Industry	2-Dec	WESTERN HUTT RD	HUTT CITY	16500 959 00	PT LOT 19 LOTS 14-18 DP 10134 LOTS 1-2 DP 15004 LOT 1 DP 6027 LOT 1 DP 743-27 LOTS 2-3 DP 77141	This site has been used for the production of motor vehicles from at least the 1930's. Todd Motors closed down in 1975. No detailed site investigation is held by Greater Wellington, therefore contamination, if any, is unknown.
896	Shell Petone	SN/03/10/02	Service Stations, Bulk Storage Requiring Land Use Consent	Verified History of Hazardous Activity or Industry	60	HUTT RD	HUTT CITY	16500 769 00	LOT 1 & 4 DP 56252	This site has been a Shell franchise since the mid 1980's. Prior to the present land use the site was a meat works. In 1992 there was a spill of approximately 30,000 litres of product to ground from a corroded pipe in which petrol flowed through the ground to Pelone Foreshore. Approximately 14,000 litres was recovered. The corroded pipe was replaced however it is unknown whether the contamination was also removed. The site is above an aquifer which supplies water to Pelone. A monitoring programme was set up to assess the site of contamination. Findings of this report are not known. There are currently no underground storage tanks remaining on the site (2020). These were installed in 1989 and are of the type commonly used for diesel storage. The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
914	Northern Landfill	SN/05/23/02	Landfill	Verified History of Hazardous Activity or Industry	299	MARK AVE	WELLINGTON CITY	16600 710 01	LOT 1 DP 417072- SUB TO ESMT	Verdict on this site is unknown. The site was previously used for the storage of waste. The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1130	WCC Tawa depot	SN/03/20/02	Storage	Contamination Acceptable Managed/Remediated for or Industry	86	OXFORD ST	WELLINGTON CITY	16500 223 00	LOTS 3 & 4 DP 70008 - SUB TO ROW	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1159	Ex Pelone Gasworks	SN/03/03/02	Gasworks	Contamination Confirmed	38	BOUVIERE ST	HUTT CITY	16500 125 00	LOT 1 DP 410202	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1160	Ex Pelone Gasworks	SN/03/03/02	Gasworks	Contamination Confirmed	38	BOUVIERE ST	HUTT CITY	16500 125 00	LOT 1 DP 410202	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1161	Ex Pelone Gasworks	SN/03/03/02	Gasworks	Contamination Confirmed	46-47	UDY ST	HUTT CITY	16500 126 00B	PT LOT 4 DP 32703 LOT 2 DP 49897 - BALANCE OF ASSMT	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1164	Ex Cogdale Palmolive Ltd	SN/03/01/02	Chem Manufacture/Formulation	Verified History of Hazardous Activity or Industry	25	TE PUNI ST	HUTT CITY	16500 765 01	LOT 3 DP 60637	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1165	Ex Cogdale Palmolive Ltd	SN/03/01/02	Chem Manufacture/Formulation	Verified History of Hazardous Activity or Industry	27	TE PUNI ST	HUTT CITY	16500 769 03	LOT 3 DP 56252	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1166	Ex Cogdale Palmolive Ltd	SN/03/01/02	Chem Manufacture/Formulation	Verified History of Hazardous Activity or Industry	0	JACKSON ST	HUTT CITY	16500 769 04	LOT 2 DP 85622	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1229	McDole Felt Constructors Ltd	SN/05/23/02	Service Stations	Verified History of Hazardous Activity or Industry	24	CASHEW ST	WELLINGTON CITY	16710 417 03	LOT 4 DP 318413	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1571	Caltex KBL Motors	SN/03/21/02	Service Stations	Verified History of Hazardous Activity or Industry	59	JACKSON ST	HUTT CITY	16500 818 00	LOTS 19-21 27 DP 567	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1614	Ex Pelone Gasworks	SN/03/03/02	Gasworks	Contamination Confirmed	38	BOUVIERE ST	HUTT CITY	16500 125 02	LOT 2 DP 87775 SUBJ TO & INT IN RW	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1615	Ex Pelone Gasworks(01107)	SN/03/03/02	Gasworks	Contamination Confirmed	46-47	UDY ST	HUTT CITY	16500 126 00A	PT LOT 4 DP 32703 LOT 2 DP 49897 - LICENSED PREMISES	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1621	Dominion Dyer Ltd	SN/03/23/02	Dye/cleaning, Storage	Verified History of Hazardous Activity or Industry	94	NELSON ST	HUTT CITY	16500 337 00	LOT 1 DP 36348	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1707	Protective Panels Ltd	SN/03/07/02	Paint Manufacture and Formulation	Verified History of Hazardous Activity or Industry	29/35	SYDNEY ST	HUTT CITY	16500 658 00	LOTS 1 2 DP 6711 LOTS 7 12 DP 59	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1719	Arden New Zealand Ltd	SN/03/25/02	Chem Manufacture/Formulation	Verified History of Hazardous Activity or Industry	5-Jul	HUTT RD	HUTT CITY	16500 879 00	LOT 2 DP 75310	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
1745	Ex Clear Meatsworks, BM and Pak n Save	SN/03/10/02	Tanning and Ass. Trades, Storage	Verified History of Hazardous Activity or Industry	114	JACKSON ST	HUTT CITY	16500 773 12	LOTS 1 DP 84227	The site has been used for the manufacture of panels and paint. A Wellington City Council Test Certificate, and Historic Dangerous Goods documents shows that various types and amounts of chemicals are stored on site. The site is occupied by Sovereign Panel & Paint. A Wellington City Council Test Certificate, and Historic Dangerous Goods documents shows that various types and amounts of chemicals are stored on site.
2083	BP Shepards Autos	SN/03/21/02	NULL	NULL	25-27	GEAR ST	HUTT CITY	16500 866 00	LOT 1 DP 49837	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
2084	BP Shepards Autos	SN/03/21/02	Storage, Motor Vehicle Workshops	Verified History of Hazardous Activity or Industry	25-27	GEAR ST	HUTT CITY	16500 866 00	LOT 1 DP 49937	This site was a gasworks which closed in 1981. One gasometer was removed immediately and the others were removed in 1972. By 1965 GM cars had taken over some of the gasworks site. Site investigations undertaken in 1996 have shown elevated levels of heavy metals, poly-aromatic, cyanide, hydrocarbons, and other organic contaminants. The concentration of these contaminants exceeded the maximum levels for industrial/commercial use given in the Guidelines for Assessing and Managing Contaminated Gasworks Sites in New Zealand (MIE 1997). The site is near a school. The deep aquifer is protected by a significant confining layer. A site management plan was prepared by PDP in 1997 to manage the risk to maintenance and excavation workers.
2089	Caltex self service station	SN/05/76/02	Storage	Contamination Acceptable Managed/Remediated for or Industry	34	JAMAICA DR	WELLINGTON CITY	16710 001 04	LOT 2 DP 44965- SUB TO & INT IN ROW & ESMT	Part of the site contained a petroleum refuelling facility. Information received (ERM 2010) shows that the two underground storage tanks (USTs) containing petrol and diesel were removed from the site. At the time of the UST removals, impacter materials were taken to an appropriate facility, and soil samples were taken and analysed to assess any residual contamination. All samples representing soil remaining on site contained TPH and BTEX concentrations below the site assessment criteria.
2226	Sovereign Panels & Paint	SN/05/47/02	Storage	Verified History of Hazardous Activity or Industry	20	MAN RD	WELLINGTON CITY	16500 527 00	LOT 7 P1 LOT 8 DP 12284	The site is occupied by Sovereign Panel & Paint. A Wellington City Council Test Certificate, and Historic Dangerous Goods documents shows that various types and amounts of chemicals are stored on site.

Appendix C

Resilience States



Table C-1 Damage state

Damage Level	Damage State	Damage Description
1	Slight	Only slight damage that requires routine maintenance
2	Light	Minor damage requiring clean up of small slips (few cubic metres) and debris and culverts
3	Moderate	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
4	Severe	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.
5	Extensive	Extensive damage requiring clearing of major volumes of landslides and stabilisation, large structures to repair underslips, damages to walls and other structures.

Table C-2 Availability state

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

Table C-3 Outage state

Outage Level	Outage State	Damage Description
1	Open	No closure, except for maintenance
2	Minor	Condition persists for up to 3 days
3	Moderate	Condition persists for 3 days to 2 weeks
4	Severe	Condition persists for 2 weeks to 3 months
5	Long term	Condition persists for > 3 months



Opus International Consultants Ltd

L7, Majestic Centre, 100 Willis St
PO Box 12 003, Wellington 6144
New Zealand

t: +64 4 471 7000

f: +64 4 471 1397

w: www.opus.co.nz