tasman district council

Report No:	REP11-10-02
File No:	R11003
Date:	23 September 2011
Information Only - no decision required	

REPORT SUMMARY

Report to: Environment & Planning Committee
Meeting Date: 6 October 2011
Report Author Glenn Stevens, Resource Scientist
Subject: **Preliminary Assessment of the Seismic Liquefaction Hazard in the Tasman District**

Executive Summary

As a result of the Canterbury earthquake sequence there is now a much greater public awareness of seismic liquefaction hazard. In light of this, a preliminary review of this hazard has been obtained for the Nelson and Tasman region.

The seismic liquefaction hazard in Tasman is relatively modest, particularly compared to the Christchurch experience. Furthermore, it is anticipated that over the next few years there will be research and reporting on the lessons learned from the Christchurch experience available to Tasman.

The modest extent and scale of seismic liquefaction hazard in the Tasman District is such that this hazard can continue to be assessed, and addressed where necessary on a case by case basis in the immediate future.

Council staff will continue to collate information and investigate liquefaction hazard within the District where opportunity arises as part of current work streams. Council staff will continue to keep informed of research undertaken nationally and in other regions through participation in relevant special interest groups and national forums. Council's position on seismic liquefaction hazard can be reviewed at any time as new information and research becomes available.

Draft Resolution

THAT the Environment & Planning Committee receives the report *Preliminary Assessment of the Seismic Liquefaction Hazard in the Tasman District* REP11-10-02 and the appended Johnston Report (*Preliminary Assessment of the Liquefaction Hazard in Tasman and Nelson Regions*).

Glenn Stevens
Resource Scientist

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1. Introduction

1.1 Canterbury, and Christchurch in particular, has been impacted by a sequence of strong earthquakes and associated aftershocks beginning 4 September 2010. Canterbury has been subjected to a range of earthquake hazards that include severe ground shaking, ground tilting, uplift, and subsidence, rock fall and slope failure. However, without lessening the seriousness of these impacts, there has also been an unprecedented level of ground liquefaction that has damaged buildings and rendered land unsuitable for residential development.

1.2 The Nelson Tasman region, along with much of central New Zealand, likewise is located in a seismically active part of the country. The Alpine Fault crosses the south of the District, and the Waimea/Flaxmore Fault system runs along the foot hills of the Richmond Ranges and through parts of the Richmond and Nelson urban areas. An earthquake of a similar scale to that affecting Canterbury occurring sometime in the Nelson Tasman region is a very real possibility.

1.3 In light of the widespread liquefaction that has occurred in Canterbury, it is timely to consider the potential for seismic liquefaction to occur in Tasman and the hazard that it may present. To that end a preliminary desk top assessment of the liquefaction hazard in the Nelson and Tasman region has been prepared by Dr Mike Johnston. This report is appended and presented to the Tasman District Council Environment and Planning Committee.

2. Seismic liquefaction hazard in the Tasman District

2.1 The process of soil liquefaction is where, as a result of severe earthquake ground shaking, water saturated fine grained sediments behave as a liquid rather than a solid. Most will now be familiar with the way the eastern suburbs of Christchurch have been impacted by liquefaction, which include:

- Ejection of large amounts of sand to the surface (sand volcanoes). At some locations this continued occurring for several hours after the shaking stopped.

- Subsidence of the ground as a result of the ejected sands. Often this subsidence was uneven and variable.
- Lateral spreading towards unconstrained boundaries, particularly the Avon River. This resulted in sideways movement of land, opening of large cracks in the surface and differential settlement.
- Buildings sinking into the liquefied ground.
- Extensive damage to buildings and infrastructure (such as underground services) from the above listed effects. This includes buried tanks and pipes floating in the liquefied soil due to buoyancy.

2.2 Ground liquefaction will not occur everywhere in response to ground shaking. For liquefaction to occur three factors must be present:

- Unconsolidated or loose fine-grained sediments (silts and sands).
- The sediments have to be water saturated (i.e. a relatively high groundwater table).
- A source of ground shaking (i.e. a sufficiently large earthquake).

2.3 In the Tasman area the unconsolidated or loose fine-grained sediments are confined to areas of recent geological deposits, that is, deposits that are less than 10,000 years old. The appended Johnston report provides a description of the occurrence of unconsolidated or loose fine-grained sediments across the Nelson Tasman region and on the expected levels of seismicity. The Johnston report also includes location maps of these geologically recent deposits.

2.4 Much of these recent geological deposits have considerable volumes of gravel and/or relatively deep groundwater levels and hence are not expected to liquefy. It is only where these recent sediments are predominantly sand and silt and groundwater levels are high that liquefaction could occur if subject to sufficient ground shaking. The most vulnerable areas are likely to be on the coastal and estuary margins, and possibly isolated pockets of silts and fine sands (such as infilled meander channels) on the alluvial plains of the principal river systems.

2.5 In Tasman the developed areas that are in locations where liquefaction might be expected to occur include:

- the Waimea Estuary margin to the north and northwest of Richmond (i.e. Beach Road, Lower Queen Street, Headingly Lane areas)
- Mapua and Ruby Bay coastal platform
- The coastal margins of Motueka and Riwaka
- Coastal development around Golden Bay

It is important to note that not all of these areas will be vulnerable to liquefaction hazard. Rather if liquefaction is to occur it is likely to be within these areas.

2.6 Another point to consider is that whilst the Canterbury earthquake sequence resulted in considerable and widespread damage to land and buildings as result of ground liquefaction in Christchurch, it did not result in death or serious injury to people. Liquefaction is only one of the hazards associated with large earthquakes. The Canterbury earthquake sequence also resulted in rock fall. Whilst rock falls and slope failure affected a smaller area and damage to fewer houses than ground liquefaction, at least six people lost their lives. Many more fatalities from rock fall would likely have occurred had the 22 February earthquake occurred at night instead of during the day.

2.7 To summarise, in Tasman it is considered that areas that may be subject to ground liquefaction are not widespread. Furthermore, the specific locations are not readily identifiable based on current information. The current understanding of the District's seismicity is that ground shaking sufficient to cause liquefaction is relatively infrequent.

2.8 To improve Council's understanding of the District's seismicity the Institute of Geological and Nuclear Sciences Ltd are to commence some trenching and dating of historic earthquake activity on the Waimea/Flaxmore fault system. This work is funded largely by Council and is scheduled to be undertaken in late February 2012. This is expected to lead to a better understanding on the frequency and magnitude of earthquake activity on the Waimea/Flaxmore fault system.

3. Consideration of Council's response to liquefaction hazard

3.1 Whilst the ground liquefaction hazard in the Tasman District is relatively modest, in light of the prominence given to this hazard as a result of the Canterbury earthquakes consideration needs to be given to Council's approach to managing liquefaction hazard in the immediate future.

3.2 When determining Council's response to potential liquefaction hazard there are a number of factors that should be considered:

- Much is unknown about ground liquefaction and it can be anticipated that there will be significant research coming from the Canterbury experience in the coming years. In particular, research on what geology is susceptible to liquefaction, and just as importantly, what geology is not likely to liquefy.

- There is very little that can be done to areas that are already developed. Where residential or commercial/industrial land use and associated infrastructure are already established it is difficult and expensive to change.

- Whilst liquefaction may result in damage to the built environment, it is unlikely to result in serious injury or casualties.

- The scale of liquefaction, should it occur in the Nelson Tasman region will be much smaller than in Christchurch. The level of ground shaking required for liquefaction to occur will also have resulted in other significant damage. Any liquefaction that does occur will make little difference to the regions overall ability to respond and the subsequent recovery, both in a physical sense as well as in an economic sense.

3.3 New development projects in areas that may be vulnerable to liquefaction can and should be assessed on a case by case basis for liquefaction hazard. Projects can then include appropriate design and/or mitigation. The liquefaction hazard can be considered as part of Council's overall assessment of such projects provided relevant staff are aware of the hazard. In Tasman the number of such development projects is not anticipated to be large.

3.4 Evaluation of important buildings (such as hospitals, civil defence welfare centres, schools etc.) as well as critical infrastructure (lifelines) should include consideration of ground liquefaction. This largely already occurs as part of CDEM planning and as a result of the Nelson Tasman life lines project.

3.5 Whilst some coastal areas are likely to be vulnerable to ground liquefaction, they are also likely to be less suitable for development due to their low lying nature and potential for coastal inundation (sea level rise) and erosion. That is, development is unlikely to occur irrespective of the ground liquefaction hazard.

3.6 Given that the most at risk areas are already developed coupled with their modest spatial extent, it is considered that no parties (including Council) would be disadvantaged by adopting a "wait and see" approach in the short term. It is likely to be advantageous to consider what research and understanding of the liquefaction hazard comes out of the Christchurch experience in the coming years and to consider how other regions in New Zealand respond to their potential liquefaction hazard.

3.7 In the mean time Council staff will continue to collate information and investigate liquefaction hazard within the District where opportunity arises as part of current work streams. Council staff will continue to keep informed of research undertaken nationally and in other regions through participation in relevant special interest groups and national forums.

4. Follow Up

4.1 Though the Regional Hazard and Risk Management Group (a local government Special Interest Group), staff will support and advocate for further research into seismic liquefaction hazard and for a consistent national approach to managing seismic liquefaction risk.

4.2 The Johnston report will be circulated to relevant staff across Council, in particular Regulatory, Policy, Consents and Engineering staff with the aim of ensuring that all new developments and upgrading of existing development and/or infrastructure take into account the potential for seismic liquefaction hazard where appropriate.

4.3 Council’s position on seismic liquefaction hazard can be reviewed at any time as new information and research becomes available over the coming years.

5. Draft Resolution

THAT the Environment & Planning Committee receives the report *Preliminary Assessment of the Seismic Liquefaction Hazard in the Tasman District* REP11-10-02 and the appended Johnston Report (*Preliminary Assessment of the Liquefaction Hazard in Tasman and Nelson Regions*).

Glenn Stevens
Resource Scientist

Appendices:

Preliminary Assessment of the Liquefaction Hazard in Tasman and Nelson Regions Report prepared by Dr Mike Johnston - 30 June 2011.

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30 June 2011

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Dear Sir

RE: Preliminary Assessment of the Liquefaction Hazard in Tasman and Nelson Regions

1. INTRODUCTION

As a result of a series of shallow earthquakes in Canterbury in September 2010 and February and June 2011, there was considerable damage from the ground liquefying. This has resulted in many regional and district councils, organisations and individuals in New Zealand questioning whether liquefaction could occur elsewhere and if so where. In an email dated 24 March 2011 you asked for a summary of what is known of the liquefaction risk in Nelson and Tasman regions.

In geology, liquefaction is defined as the process by which ground that is generally firm takes on, albeit temporarily, the properties of a liquid. This can occur in sediment when an increase in pore pressure in water it contains effectively reduces the stress between its component particles, such as sand or silt grains. It largely results from severe seismic ground shaking. Thus for liquefaction to occur three factors must be present:

- Unconsolidated or loose fine-grained (silt to more commonly sand) sediments.
- The sediments have to be water saturated.
- A source of ground shaking.

When ground liquefies and loses strength it behaves, like water, as a fluid and consequently cannot support what is above it be it firm ground or structures, including buildings and services. Differential settlement of the ground is common and buildings, empty tanks and pipelines may literally float in the liquefied material. Liquefied material may also, particularly if within a confined layer, burst through to the surface or flow towards lower ground causing further disruption.

Sediments that have the potential to liquefy are geologically very young and as they have to be saturated are found close to water.

2. PREVIOUS ASSESSMENTS OF LIQUEFACTION HAZARD IN TASMAN AND NELSON

The hazard of liquefaction, and the risk it may pose, has been broadly discussed in geohazards assessments commissioned by the two councils from GNS Science[1] and more recently it has been addressed in the Natural Hazards section of the *Nelson Tasman Engineering Lifelines – Limiting the Impact*

3. POTENTIALLY LIQUEFIABLE SEDIMENTS IN NELSON AND TASMAN

The Nelson and Tasman regions have a great variety of different rocks but those that have the potential to liquefy, being loose water logged sediments of geologically Recent age[2] with a preponderance of sand or silt particles, are restricted to the coast or in river valleys (Figure 1). It should also be noted that the water table will fluctuate due to the amount of rain (the sediments, in effect, constitute unconfined aquifers) and, with a large tidal range in Golden and Tasman bays, the state of the tide may also have a bearing on the water table in coastal sediments. The Recent sediments underlie flat lying ground that commonly has a relatively high level of development. However, it is stressed that these sediments may contain materials within them that could liquefy, not that these sediments would do so. Consequently, further work is needed to determine susceptibility to liquefaction. The following sections summarise the known extent of fine-grained, water-logged sediments.

3.1 Valleys (sediments of terrestrial origin)

The terrestrial sediments filling the valleys are dominated by gravel but sand is more abundant in the Motueka catchment because of widespread, erosion-prone, Separation Point Granite. Silt-rich deposits may also be present throughout the terrestrial sediments but are mostly of small extent, such as those filling cut off, and now buried, river channels. Swamp deposits are relatively rare, the most extensive being at Maungarakau on the west coast with lesser areas near Cape Farewell and, probably grading into estuarine deposits, in the inlets of Golden Bay such as Puponga, Pakawau and Ruataniwha.

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[1] Johnston, M. R.; Hull, A. G.; Downes, G. L. 1993: *Earthquake, Landslide and Coastal Hazards in Nelson City*. GNS client report 1993/413399.21.
Coote, T. P.; Downes, G. L. 1995: *Preliminary Assessment of Earthquake and Slope Instability Hazards in Tasman District*. GNS client report 1995/41430D.16.

[2] Sediments deposited since the Last Glaciation, which ended approximately 10,000 years ago. Also referred to as Holocene.

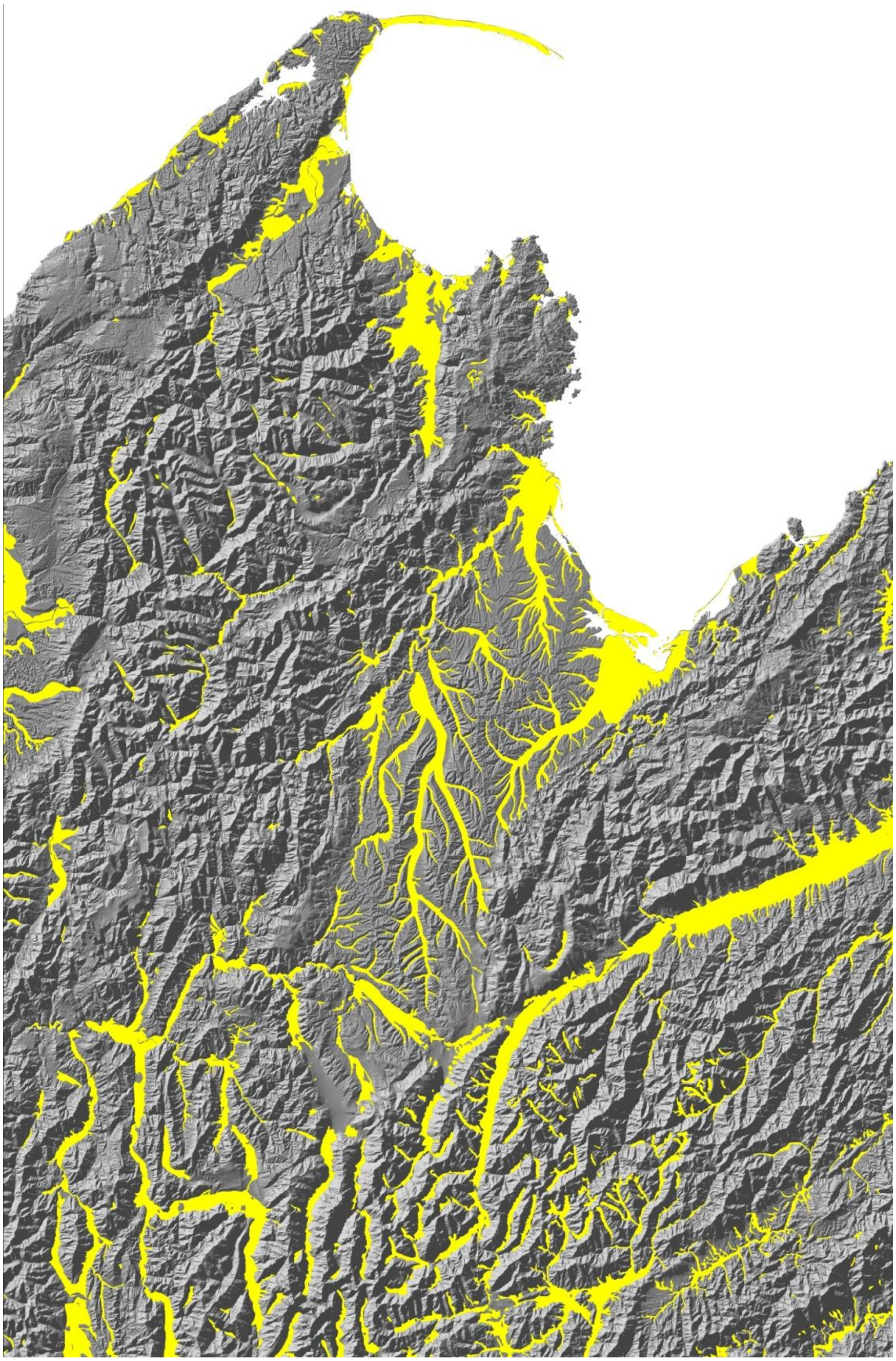

Figure 1. Hill areas (grey) contain materials that will not liquefy. Holocene floodplain, terrace, swamp, beach, estuarine and dune deposits and Last Glaciation terrace deposits (yellow) may contain fine-grained sediments that, where waterlogged, could liquefy. The remaining land (grey) is not subject to liquefaction. (*GNS Science QMAP*)

Although terrestrial sediments are relatively widespread, generally only the floodplain gravels, deposited during the past 10,000 years and filling the valley floors, are sufficiently water saturated that, where suitable deposits are present, may result in liquefaction. These deposits underlie the most populated parts of the two regions and correspondingly have significant infrastructure. However, the deposits are dominantly gravel and finer-grained materials are relatively insignificant. In valleys within the Moutere Gravel, the proportion of gravel is generally less but clay content is correspondingly higher, thereby diminishing the potential for liquefaction. Generally minor swamp deposits may be present but are probably not at high risk of liquefying.

That liquefaction is not likely to be a major problem in the alluvial sediments tends to be confirmed by the Murchison and Inangahua earthquakes. A detailed account of the 1929 Murchison Earthquake (M 7.8 on Richter Scale) makes no mention of any phenomena associated with liquefaction[3]. However, liquefaction did occur as one account states that spouts of sand and mud were ejected through a metalled gravel road (now SH6) near Lyell and near Murchison water was observed spurting over a metre into the air[4]. The lesser magnitude (M 7.1) Inangahua Earthquake caused widespread sand ejection onto the alluvial flats in the vicinity of the epicentre. However, apart from some settling and subsidence, its effects were muted as demonstrated by buildings clad in weatherboards and with iron roofs on well constructed foundations suffering minimal structural damage[5]. Similarly during the 1929 earthquake in Murchison township it was reported that “on the whole the injury to reasonably well-built houses was relatively slight”. During both earthquakes in centres distant from the epicentres, including Westport, Greymouth, Karamea and Nelson, there was apparently relatively little disruption to infrastructure in natural gravel although cracking parallel to river banks appeared in alluvium, particularly where it overlies estuarine deposits, on the West Coast.

Thus potentially liquefiable deposits are likely to be restricted in their distribution and may include silt in buried cut off meanders, localised swamp deposits and, more commonly in the lower Motueka Valley, clean sand filling former river channels.

Caption (page 5)
Figure 2. Recent terrestrial (floodplain) deposits (yellow). These sediments are anticipated to give rise to areas of sand and silt ejection when subjected to MM VII or greater levels of ground shaking as measured on the Modified Mercalli Scale. As such sediments are dominantly gravel, large scale liquefaction is unlikely. Sediments such as sand lenses, swamp deposits and silt occur throughout and may result in localised liquefaction. The extent of the areas in yellow are shown in more detail in Appendix One.
Major faults (generalised) shown are: 1 = Alpine Fault, 2 = White Creek Fault, 3 = Cape Foulwind Fault Zone, 4 = Wakamarama Fault, 5 = Karamea-Pikikiruna Fault, 6 = Waimea-Flaxmore Fault System (*Base map: GNS Science QMAP*)

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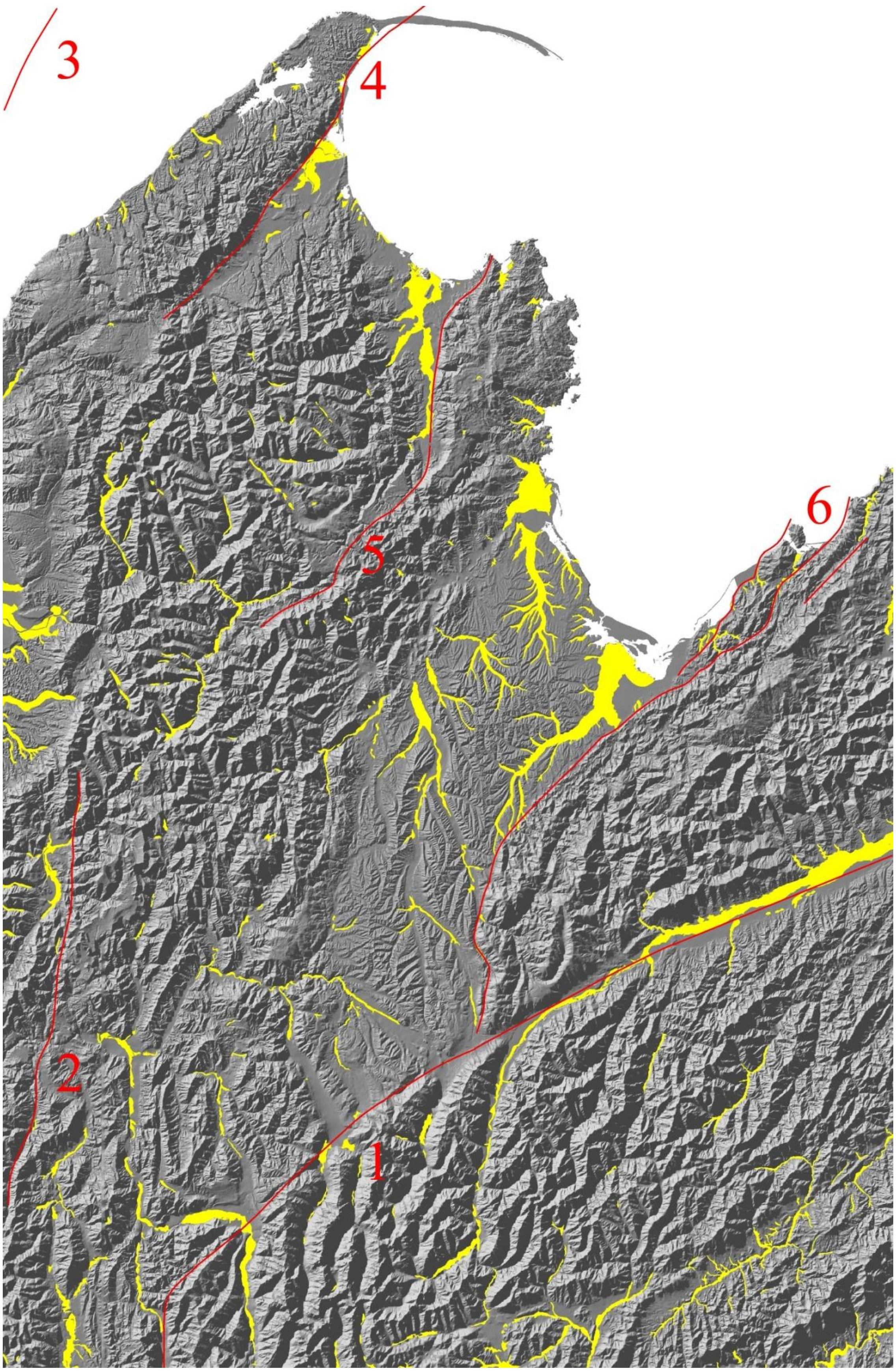
[3] Henderson, J. 1937: *The West Nelson Earthquakes of 1929*. DSIR bulletin 55.
[4] Lammas, K. 1979 and Peacock, A. 1979: *In* Stories of Murchison Earthquake 17th June, 1929. Murchison District Museum and Historical Society.
[5] Lensen, G. J.; Suggate, R. P. 1968: *Inangahua Earthquake-preliminary account of the geology In* DSIR bulletin 193.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3.2 Coastal Areas (sediments of marine origin)

The marine sediments comprise marine sands and gravel that have been deposited over approximately the last 7,000 years when, following the last glacial period, sea level rose to its existing height. In favourable locations this resulted in a progradation of the coastline.

3.2.1 Whangamoa Inlet

Fine grained sediments, ranging from silty clay to sand fill the inlet and it is possible that they also interfinger with terrestrial gravel deposited by the Whangamoa River. The extent of any fine-grained sediments underlying the flood plain of the river is expected to be very restricted and, although subsurface information is lacking, are probably also of no great thickness. Also because of the flood risk, development within areas that may contain liquefiable materials is likely to be extremely limited.

3.2.2 Delaware Inlet

Similar comments to those made with regard to the Whangamoa Inlet apply to Delaware Bay. Marine and estuarine deposits are likely to be thin and much of the low-lying land is either flood plain gravel deposited by the Wakapuaka River or the coastal margins of fans deposited by creeks draining westward into the inlet.

3.2.3 The Glen

The head of Nelson Haven is slowly infilling with fine-grained low-lying and poorly drained sediments. As part of farm development an extensive drainage system has been installed but despite this, the area remains prone to flooding. The sediments are reported, from seismic and gravity observations, to be in the order of 100 m thick[6], although this has not been confirmed. Nevertheless, the sediments are extensive and may be not sufficiently fine-grained to liquefy. However, until it is shown otherwise it should be assumed that under suitable conditions there could be liquefaction. Furthermore, it is possible that there are confined water bearing layers at depth. Around the eastern margin of the head of the haven the sediments are likely to be more variable with a mixture of material, including clay and weathered angular rock fragments, washed off the adjacent hillsides. This material would be expected to have a lower risk of liquefaction.

3.2.4 Southern end of Nelson Haven

The southern end of the haven is largely infilled with gravel deposited by the Maitai River. As well as forming the now highly modified delta of the present river, Maitai

[6] Dickinson, W. W.; Woolfe, K. J. 1996: An *in situ* transgressive barrier for the Nelson Boulder Bank, New Zealand. *Journal of Coastal Research 13*: 937-952.

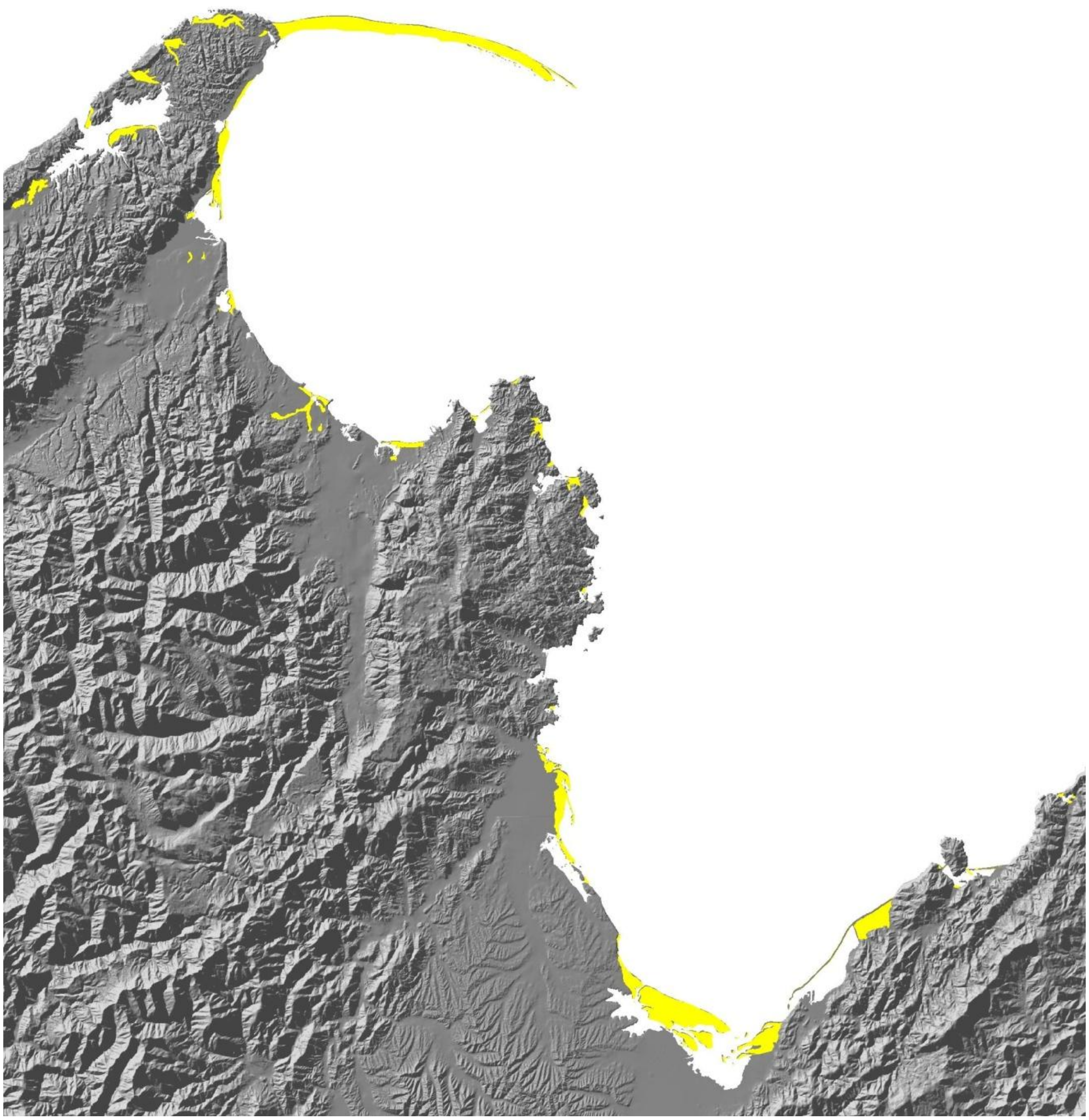

Figure 3. Recent marine and estuarine deposits and associated swamp deposits (yellow). These sediments have the greatest potential to contain sediments that may liquefy during MM VII or greater ground shaking. However, the areas that could liquefy are not known and the deposits should be more appropriately regarded as highlighting where further investigation is warranted, particularly land that already contains infrastructure or is proposed for development. The extent of the areas in yellow are shown in more detail in Appendix One. (*GNS Science QMAP*).

gravel extends under the estuarine and marine sediments of the haven to as far west as Port Nelson. However, to the southwest of the present delta an embayment extended into Toi Toi

Valley and is filled with silty sediments which must be regarded as suspect as far as liquefaction is concerned. However, the sediments are likely to become more clay-rich with increasing distance from the haven with a decreasing potential for liquefaction. Most of these sediments are overlain by fill comprising Port Hills Gravel quarried from the Port Hills or, such as Anzac Park and to the east of Saltwater Creek landfill materials, largely domestic rubbish. During the 1893 Nelson Earthquake (M 7) the greatest concentration of damage was to structures, mostly chimneys, on the softer sediments extending from the lower Maitai River west to Haven Road-Vanguard Street[7]. No liquefaction was reported but ground shaking levels do not appear to have reached MM VII.

Fine-grained sediments are also present in the valleys immediately either side of Church Hill (lower Rutherford and middle Collingwood streets) although they are terrestrial rather than estuarine in origin. Although commonly water saturated, they appear to be more clay rich than estuarine sediments and this would also considerably diminish the risk of liquefaction.

3.2.5 Port Nelson

The port area comprises reclaimed land arising from infilling with Port Hills Gravel formation or hydraulic fill dredged from the bed of Nelson Haven and retained by bunds sitting on estuarine and silty, locally sandy, sediments. All of this area must be regarded as suspect in that under severe seismic shaking some of the fill materials, more particularly those rich in sand, could liquefy. There is also an elevated risk of settlement of the materials, including in response to lateral movement of the bunds.

3.2.6 Tahunanui

Much of the Tahunanui area, north from a sea cliff extending from Monaco to the SH6 roundabout at Annesbrook and cut in Stoke fan Gravels, comprises marine sand with, particularly in the east, some sandy gravel. The sand and gravel formed beach ridges parallel to the sea cliff but these have been largely destroyed by development. While the ridges have been deposited by longshore drift southwest into the head of Tasman Bay, much of the sand within them has originated from the west of the bay. Thin swampy peat deposits accumulated between the ridges and extensive dunes, also highly modified, are present in the west. The sand is 29 m thick at the western end of Tahunanui Beach[8]. Unless it is shown otherwise by further investigation, it should be assumed that both the sand and, in the east, the sandy gravel have an elevated risk of liquefaction under high levels of seismic shaking.

3.2.7 Waimea Inlet to Riwaka

The islands of the Waimea Inlet and Mapua, from the township to the McKee Domain, are of similar materials to Tahunanui although gravel is more abundant in the southern parts of the islands and at Mapua. The marine deposits have been progressively built up by beach ridges formed by southeast longshore drift transporting sand and gravel into the head of Tasman Bay. On the eastern end of Rabbit Island the sand is up to 30 m thick but in the west the deposits are considerably thinner, thereby reducing the risk if sediments prone to liquefaction

[7] Colonist (newspaper) 13 February 1893.
[8] Johnston, M. R. 1981: *Sheet 027AC Dun Mountain*. Geological Map of New Zealand 1: 50 000. NZ Department of Scientific and Industrial Research.

are present[9]. Adjacent to the margins of the inlet, apparently minor and probably relatively thin, estuarine or swamp deposits are locally present.

Marine deposits between the Moutere Inlet and Riwaka are a mixture of sand and gravel with minor swamp deposits. Like the deposits at the head of Tasman Bay they have been deposited by longshore drift transporting materials, largely from the Riwaka and Motueka rivers, southeast. However, because of this southeast drift the sand and gravel tends not to accumulate and therefore the deposits form relatively narrow strips along the coast. In Motueka the deposits front, and may partially overlie, estuarine and perhaps swamp, deposits. All of the sediments are water saturated and there is potential for liquefaction.

3.2.8 Abel Tasman Coast

Marine sand and estuarine silt and mud are present in the larger bays and inlets around the Abel Tasman coast, such as Kaiteriteri, Marahau and Totaranui. However, the area of such sediments is not extensive and although little is known of their subsurface properties, they are probably only locally prone to liquefaction.

3.2.9 Golden Bay

Around the shores of Golden Bay, marine and estuarine sediments, along with dune sands, that are potentially liquefiable are, except for Farewell Spit, limited. South of the spit the greatest extend of these sediments is from Pakawau to Ruataniwha Inlet, with much smaller areas elsewhere such as Collingwood, Parapara, Pariwhakaoho, Patons Rock, Rangihaeata and Pohara[10]. While some fine-grained estuarine deposits will be present these are thought to be relatively restricted.

4. SEISMIC HAZARD

The presence of water logged silty to sandy sediments in themselves do not pose a liquefaction hazard. Instead what is needed is sufficient ground shaking so that the particles in the sediments lose cohesion and become a fluid. Beneath Christchurch potentially liquefiable materials had been known for many years. What was difficult to ascertain was the risk of seismic shaking that would be sufficient to induce liquefaction although this hazard was assessed as relatively low. However, even prior to the 2010 earthquake, perception of the risk was increasing as a greater understanding of the structure of the crust beneath and adjacent to Christchurch became known. For liquefaction to occur, felt intensities need to be at least MM 7 on the Modified Mercalli Scale. In Christchurch the February 2011 earthquake resulted in felt intensities of MM 8 and this had been calculated, from a statistical analysis prior to the earthquake, as having a mean return period of 630 years[11].

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[9] Johnston, M. R. 1981: *Sheet N27pt Richmond*. Geological Map of New Zealand 1: 50 000. NZ Department of Scientific and Industrial Research.

[10] Bishop, D. G. 1971: *Sheet S1 and S3 Farewell-Collingwood*. Geological Map of New Zealand 1: 63 360. NZ Department of Scientific and Industrial Research.

Grindley, G. W. 1971: *Sheet S8 Takaka*. Geological Map of New Zealand 1: 63 360. NZ Department of Scientific and Industrial Research.

[11] Forsyth, P. J.; Barrell, D. J. A.; Jongens, R. 2008: *Geology of the Christchurch Area*. Institute of Geological & Nuclear Sciences 1: 250 000 Geological Map 16.

In the Nelson and Tasman regions, MM 8 intensities have been calculated as having mean return periods of <200 years[12]. Identifying the potential faults that could give rise to this level of ground shaking is not a straightforward exercise in that the activity of many faults has not been determined and there may be concealed faults that could, like Christchurch, be the source of damaging earthquakes.

4.1 Alpine Fault

Of the known faults in or close to the Nelson and Tasman regions, the most active is the Alpine Fault (Figure 2), which extends through the south of the Tasman Region and thence down the Wairau Valley. A paleoseismic investigation of the Alpine Fault in 2002[13] provided estimates for ground shaking intensities arising from three scenarios of fault rupture:

- Fault rupture along its full length in the South Island would result in ground shaking levels that would reach MM 8 in most of the lowlands, or Moutere Depression, extending inland from Tasman Bay. Northwest and northeast of the depression, including most of the Nelson and Tasman coastline a MM7 level of ground shaking would prevail.
- If rupture was confined to the section of the Alpine Fault between Lake Roto-iti and Cloudy Bay the pattern and level of shaking intensities would be similar to that if the whole of the fault was involved.
- If the fault ruptured along a relatively short length extending southwest from Lake Rotoroa the Modified Mercalli intensities would be one level lower than predicted for the other two scenarios.

The scenarios giving MM8 levels of shaking would therefore be capable of producing liquefaction in any sediments prone to this phenomenon in the Moutere Depression, including the marine deposits between the Whangamoa Inlet and the vicinity of Motueka. The investigation also showed that Alpine Fault has ruptured since AD 200 but the timing of this event is uncertain. Nevertheless, the investigation concluded that it was likely that sufficient strain had built up on the fault in the Tophouse area to an extent that there was a high risk of surface rupture. Trenching in the lower Wairau valley indicated that the stress may not be as high as previously assessed. If this is so, then the risk of an earthquake from this source is reduced but not removed[14]. Further work is needed to confirm the activity on the fault in the lower Wairau valley.

4.2 Southwest Tasman Faults

Branching of the Alpine Fault, southwest of Nelson Lakes, there are a number of faults that trend north through the Tasman Region and Buller District. These include the White Creek and Mt William faults that gave rise to the Murchison and Inangahua earthquakes of 1929 and

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[12] Rattenbury, Cooper, R. A.; Johnston, M. R. 1998: *Geology of the Nelson Area*. Institute of Geological & Nuclear Sciences 1: 250 000 Geological Map 9.

[13] Yetton, M. D. 2002: *Paloeseismic investigation of the North and West Wairau sections of the Alpine Fault, South Island, New Zealand*. Unpublished report EQC 99/353 prepared by Geotech Consulting Ltd for the Earthquake Commission Research Foundation and Tasman District Council.

[14] Yetton, M. D. 2002: *Paloeseismic trench investigation of the active trace of the Wairau section of the Alpine Fault, Renwick area, Marlborough District*. Unpublished report 1490 prepared by Geotech Consulting Ltd for the Marlborough District Council.

1968 respectively. The largest of these (Murchison) gave MM 8 levels of ground shaking in most of the Tasman and Nelson regions[15] although liquefaction was not reported as a major problem in the vicinity of the epicentres (see Sec 3.1 above) although, for instance, in the lower Motueka valley there was ground cracking as well as “little cones like miniature volcanoes in cultivated paddocks where water jets had emerged”[16]. In the north of the two regions it is likely that the earthquake were responsible for some minor differential settlement and lateral spreading in unconsolidated sediments.

4.3 Golden Bay Faults

There are three major northeast trending faults in the Golden Bay area. These are, from east to west, the Pikikiruna and Wakamarama faults and, off shore of the west coast, the Cape Foulwind Fault Zone. Only the latter fault is considered to be active but more information on it is not known. Because the Pikikiruna (and to the southwest the Karamea Fault) and Wakamarama faults are responsible for impressive range fronts they should not be regarded as dead faults. Nevertheless, earthquakes originating on any of these faults are likely to have a long recurrence interval. Movement on any one of these faults, plus others such as the Golden Bay Fault extending from Parapara south into the Takaka valley, would likely produce ground shaking levels sufficiently high to induce liquefaction in any suitable water logged sediments.

4.4 Waimea-Flaxmore Fault System

The Waimea-Flaxmore Fault System branches off the Alpine Fault in the vicinity of Lake Roto-iti and extends NNE to northeast through the east of the Tasman Region and Nelson City. This fault system comprises several major faults, such as the Waimea, Flaxmore, Eighty-eight, Heslington and Whangamoa, as well as numerous smaller cross faults. The system is active with most of the faults in the south having ruptured the ground surface. However, from about northeast of the Wairoa River, fault ruptures are intermittent and are generally of short length. North of the river, ground ruptures are present on the Eight-eight, Whangamoa, Bishopdale and probably also Waimea Fault in the vicinity of Hope and possibly the Flaxmore Fault between Bishopdale and Stoke. These faults are in or close to the Nelson-Richmond urban area and the marine sediments within or adjacent to the Waimea Inlet. The activity on the fault system is poorly known but at Mt Heslington, the Waimea Fault (northwestern branch) has ruptured the ground surface three times in the past 18,000 years. Although the last movement was approximately 6000 years ago the two earlier events are poorly dated so it is not possible to conclude that the fault ruptures every 6000 years or thereabouts. There is unconfirmed evidence that the Flaxmore Fault moved also about 6000 years ago. The presence of large landslides in the hills from Atawhai overlooking Nelson Haven to the foothills of the Barnicoat Range at Hope were most likely initiated by severe earthquake ground shaking. If so the obvious source of this shaking would be nearby faults of the Waimea-Flaxmore Fault System.

Because of the large number of faults in the system this will reduce the interval between earthquakes. In the southern part of the fault system, rupture during an earthquake on an

[15] Coote, T. P.; Downes, G. L. 1995: *Preliminary assessment of earthquake and slope instability hazards in Tasman District*. Unpublished GNS report 1995/41430D.16.
[16] Beatson, K.; Whelan, H. 1993: *The River Flows On*. Published by the authors.

individual fault could be in the order of tens of kilometres. Further north, as judged by the fault traces that are preserved, rupture lengths are much less being 1.5 (Eighty-eight Fault at Hope) to 13 km (Whangamoa Fault in the Whangamoa valley) in length. Using these figures earthquakes of magnitudes up to 7.4 and 6.5 could be expected in the south and north of the fault system respectively[17]. These magnitudes would be enough to result in ground shaking sufficient to cause liquefaction in suitable sediments in the Moutere Depression and in eastern Tasman Bay.

5. CONCLUSIONS

Within the Tasman and Nelson regions, sediments that are water saturated and have properties that make them potentially susceptible to liquefaction are very restricted, being confined largely to the marine and estuarine sands and silts adjacent to the coast (Figure 3). Nevertheless, these sediments are commonly built on with both above and below ground infrastructure, particularly adjacent to the south end of Nelson Haven, including Port Nelson, Tahunanui and coastal Motueka. Elsewhere the only sediments that may contain liquefiable materials are the flood plain deposits of the major river. However, these are not thought to be extensive as the main lithology is gravel, but unconsolidated sand is more abundant in the floodplain deposits of the Motueka valley (Figure 2).

Although potentially liquefiable sediments are likely to be present, there remains considerable uncertainty as to the frequency of earthquakes that will result in MM VII or greater levels of ground shaking that would be sufficient to induce liquefaction in any sediments prone to this process. This is a matter that is being currently addressed by Tasman and Nelson councils, in conjunction with GNS Science and others, in undertaking investigations into the major faults within the north of the South Island, including the Alpine Fault and the Waimea-Flaxmore Fault System. Of these faults the Waimea-Flaxmore Fault System remains the one with the greatest potential to generate ground shaking sufficient to cause liquefaction in any waterlogged sediments with the potential to liquefy in the vicinity of Tasman Bay. However, while the earthquake risk has been refined, including demonstrating that the Waimea-Flaxmore Fault System is more active that previously supposed, more work is needed to determine what the seismic risk is.

In the meantime, it would be prudent to assume, until proved otherwise, that the waterlogged marine or estuarine deposits (Figure 3), along with very localised and poorly defined sediments in the floodplains, could liquefy during ground shaking of MMVII or greater.

6. RECOMMENDATIONS

It is recommended that:

1. The areas identified in Figure 3, which may contain within them sediments that have the potential to liquefy, should be representatively assessed, such as by seismic cone penetration testing, with priority to areas with developed infrastructure.

[17] Fraser, J. G.; Nicol, A.; Pettinga, J. R.; Johnston, M. R. 2006: *Paleoearthquake investigation of the Waimea-Flaxmore Fault System, Nelson, New Zealand*. *In:* Earthquakes and urban development: New Zealand Geotechnical Society 2006 Symposium, Nelson, February 2006. Institution of Professional Engineers. Proceedings of Technical Groups 31(1): 59-67.

2. If sediments are confirmed as having a high risk of liquefaction then a review of the infrastructure within the areas involved be initiated.
3. For new subdivisions, either for housing or other buildings, within the areas that have been confirmed as being subject to, or potentially subject to, liquefaction that this potential hazard be assessed as a condition of resource consent. If necessary appropriate mitigation measures should be implemented during development, including adopting the most appropriate design for infrastructure, to minimise the risk of this hazard.
4. Investigation of the faulting hazard that could potentially induce liquefaction be continued, including an offshore survey to determine whether active faults are present close to the coastline (such a survey would also be of considerable benefit in quantifying the risk from locally induced tsunamis).

Yours faithfully

Mike Johnston

Limitations
This report is based largely on existing geological databases, principally geological maps at scales of 1: 50 000, 1: 63,360 and 1: 250 000. No specific on site investigations have been undertaken to assess whether sediments that are fine-grained and waterlogged would in fact liquefy although this work should be undertaken, particularly in areas with significant infrastructure.

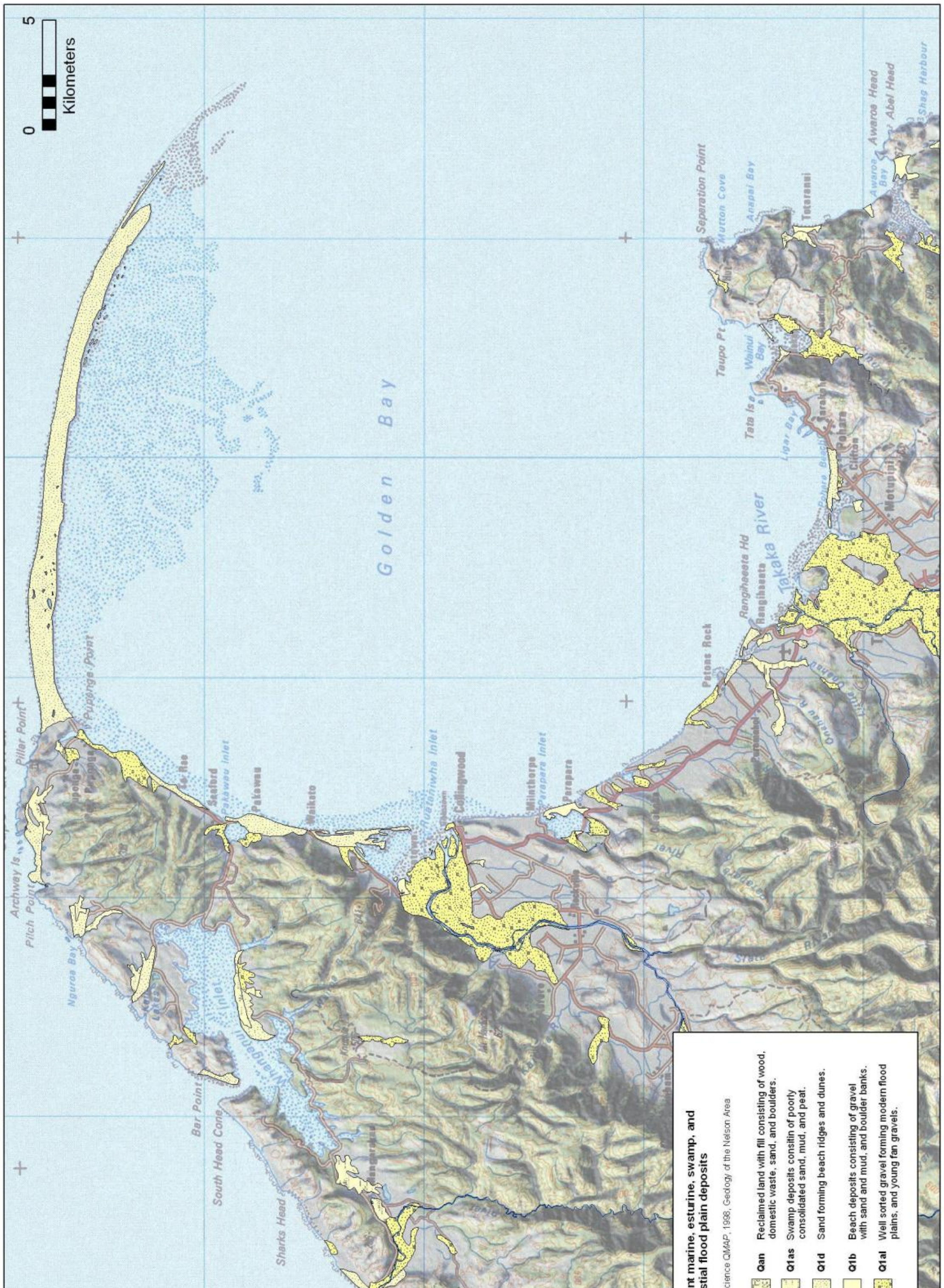
Appendix One

Maps showing in greater detail the areas depicted on Figures 2 and 3:

Map 1 - Tasman Bay
Map 2 - Golden Bay

Explanatory Note: The area shown as yellow of Fig 2 and 3 are depicted on the maps as Q1al and Qan, Q1as, Q1d and Q1b respectively.


0
5
Kilometers
Recent marine, esturine, swamp, and terrestial flood plain deposits
GNS Science QMAP, 1998, Geology of the Nelson Area
Qan Reclaimed land with fill consisting of wood, domestic waste, sand, and boulders.
Q1as Swamp deposits consitin of poorly consolidated sand, mud, and peat.
Q1d Sand forming beach ridges and dunes.
Q1b Beach deposits consisting of gravel with sand and mud, and boulder banks.
Q1al Well sorted gravel forming modern flood plains, and young fan gravels.
Tasman Bay
NELSON
Rabbit Island
Pepin Island
Delaware Bay
Whangamoa Head
Cape Soucis
Moutere Bluff
Ruby Bay
Motueka River
Adele Island
Fisherman I
Sandy Bay
Tokongawa Pt
Haulashore I
Richmond
Hope


0
5
Kilometers
Golden Bay
Takaka River
Farewell Spit
Pillar Point
Puponga Point
Archway Is
Pitch Point
Bar Point
South Head Cone
Sharks Head
Separation Point
Taupo Pt
Tata Is
Abel Head
Awaroa Head
Shag Harbour
Ruataniwha Inlet
Parapara Inlet
Pakawau Inlet
Collingwood
Pakawau
Patons Rock
Rangihaeata Hd
Rangihaeata
Recent marine, esturine, swamp, and terrestial flood plain deposits
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Qan Reclaimed land with fill consisting of wood, domestic waste, sand, and boulders.
Q1as Swamp deposits consitin of poorly consolidated sand, mud, and peat.
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Q1al Well sorted gravel forming modern flood plains, and young fan gravels.