BLENHEIM URBAN GROWTH STUDY
GEOTECHNICAL EVALUATION

OPUS

PRELIMINARY GEOTECHNICAL APPRAISAL
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Blenheim Urban Growth Study Geotechnical Evaluation

Preliminary Geotechnical Appraisal

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CONTENTS

1 Introduction

Marlborough District Council is developing a strategy for the urban growth and development of southern Marlborough. The Council has identified a number of potential urban growth areas for Blenheim, that lie on the northern and eastern periphery of the city. Opus International Consultants Ltd (Opus) has been commissioned by the Council to carry out a geotechnical evaluation of the proposed growth areas. The objective is to define a strategic planning horizon and assess seismic hazards of relevance to Blenheim, followed by development of parameters that would help the Council to assess the acceptability of geotechnical hazards and conclusions presented in support of any development.

This report has been prepared as the first part of this study. Here we present the results of a preliminary geotechnical appraisal of the ground conditions and geo-hazards, based on a desk study of available information.

2 Site Description

2.1 Geomorphology

The proposed urban growth areas are located on the outskirts of Blenheim's urban area, to the north (area Na:Nb) and to the east (areas E1, E2 and SE). The sites are situated on predominantly flat to gently undulating alluvial plains. The land is currently under agricultural use with few existing dwellings.

Opawa River forms the north western and south-western boundary of area E1 and the northern boundary of E2. Stop banks have been constructed along the Opawa River for flood protection.

2.2 Geology

The geology of the Marlborough Area has been mapped at 1:25,000 scale by the New Zealand Geological Survey (NZGS, 1981) and at 1:250,000 scale by the Institute of Geological and Nuclear Sciences (IGNS, 2000). The mapping shows the Blenheim area is underlain by Holocene age marine/estuarine silts and sands of the Dillons Point Formation and alluvial gravels and sands of the Rapaura Formation. These strata are underlain by older, clay-bound alluvial gravels of the Speargrass Formation (NZGS, 1981; Landcare Research, 1995; MCRWB, 1987; Davidson and Wilson, 2011).

2.3 Seismicity

The plate boundary between the Pacific and Australian plates passes through Marlborough, and consequently this region is an area of high seismicity. Relative motion between the tectonic plates is accommodated across a zone of active strike-slip faults (the Marlborough fault system), which links the Alpine fault transform plate boundary to the south with the westward-directed Hikurangi subduction margin to the north. The Marlborough fault system comprises four principal strike-slip faults and a number of smaller faults. Those within 15 km of the study area are summarised in Table 1 and are discussed below.

Table 1 Active fault summary table

Fault	Characteristic Event Magnitude	Recurrence Interval (years)	Distance from site (km)	Direction
Wairau Fault	7.1 – 7.6	1,150 – 1,400	1.6	Northwest
Vernon Fault	?	2,000 – 3,500	8	Southeast
Awatere Fault	7.5	820 – 950	14	Southeast

Source: Benson et al. (2001); Geotech Consulting Ltd (2003a, 2003b, 2005); Mason et al. (2006a, 2006b); Zachariasen et al. (2006)

The Wairau Fault is the closest active fault to the site, lying approximately 1.6 km to the northwest of area Na:Nb and approximately 4.7 km to the northwest of areas E1, E2 and SE. This fault is capable of rupturing in earthquakes of characteristic magnitude 7.1 to 7.6, with horizontal surface displacements of 5 to 7 m and an average return period of 1150 to 1400 years (Geotech Consulting, 2003a, 2003b, 2005; Zachariasen et al., 2006).

The Vernon Fault is a secondary fault that splays north off the Awatere Fault at Dumgree, southeast of Blenheim. Little paleoseismic information is available for this fault and its potential surface rupture hazard is therefore not well defined. The slip rate of the fault is estimated to be low (less than 2 mm/year; Benson *et al.*, 2001), and it consequently has been assigned a longer return period than the Awatere Fault (GNS Active Faults Database). Rupture of the Vernon Fault is most likely to be associated with rupture of the Awatere Fault (Geotech Consulting, 2003a).

The Awatere Fault is located approximately 14 km southeast of Blenheim. This fault ruptures in earthquakes of characteristic magnitude 7.5 at an average recurrence interval of 820 to 950 years, with surface displacements of between 4 and 7 m. This fault last ruptured in the M_w 7.5 Marlborough earthquake of 1848 (Benson *et al.*, 2001; Mason *et al.*, 2006a, 2006b).

3 Ground Conditions

3.1 Ground Conditions

The area under investigation is located on semi-rural land on the outskirts of Blenheim. The sites lie on flat to gently undulating alluvial terrace surfaces, which are underlain by young (Holocene and late Pleistocene age) interbedded alluvial and estuarine/swamp deposits.

No site-specific geotechnical investigation results are available for the proposed development sites, however recent site investigations have been carried out in the wider Blenheim area (Geotech Consulting, 2004; Nelson Consulting Engineers, 2007; CH2M Beca, 2008; MDC borehole database). These investigations show the surficial soil layers in the local area consist of interbedded silts, clays and sands of the Dillons Point Formation, underlain by sands and gravels of the Rapaura Formation.

The estuarine deposits of the Dillons Point Formation are observed to vary significantly in their composition and degree of consolidation, both laterally and with depth, from loose sands and soft silts to very dense sands and very stiff clayey silts. The Rapaura Formation deposits consist of dense to very dense alluvial gravels, with a sandy matrix and some interbedded sand layers.

3.2 Groundwater Conditions

Mapping of historic river and drainage features in the lower Wairau valley shows the area to the east and southeast of Blenheim (development areas E1, E2 and SE) consisted of swamps prior to development of the town (MCRWB, 1987).

A study by Marlborough District Council (Davidson and Wilson, 2011) provides a thorough description of the groundwater regime of the lower Wairau Valley. As part of this study, a series of boreholes in the Blenheim area show the static groundwater levels in this area. This analysis shows that shallow groundwater lies approximately 2 m below ground level in the vicinity of the study areas, and flows from west to east.

3.3 Site Subsoil Class

The 1:250,000 geological map (IGNS, 2000) shows the recent alluvial deposits beneath the site are approximately 400 m thick, with older Quaternary alluvium (Hillersden Gravels) and greywacke basement rock underneath. The site subsoil class is thus considered to be Class D (deep soil) according to the New Zealand Standard on Structural Design Actions Part 5: Earthquake Actions New Zealand, NZS 1170.5: 2004 (Standards New Zealand, 2004). For Blenheim, NZS 1170.5 provides a hazard factor, Z, of 0.33.

4 Hazards

The study area is exposed to a number of geotechnical hazards. These are summarised in Table 2 below and discussed in the following sections.

Table 2 Hazard summary table

Type of Hazard	Level of Hazard
Fault rupture	Low
Ground shaking	Moderate to high
Liquefaction	Moderate to high
Slope failure	Very low

4.1 Fault Rupture

The closest active fault to the study areas is the Wairau Fault. This fault has a distinct trace over much of its length, except for the lower Wairau Valley where the trace is intermittent and subdued. The fault is inferred from available geological evidence to lie approximately

1.6 km from area Na:Nb at its closest point (Geotech Consulting, 2003a). Rupture of this fault is expected to result in 3.4 m to 7 m of lateral displacement of the ground surface at the fault trace (Geotech Consulting Ltd, 2003b, 2005; Zachariasen *et al.*, 2006). The distance of the fault from the study areas suggests the risk of fault rupture at the site is low.

4.2 Ground Shaking

Blenheim's principal earthquake hazard derives from the close proximity of the active Wairau and Awatere faults. In particular, the Wairau Fault is located 1.6 km from the northern growth area (Na:Nb) and approximately 5 km from the eastern growth areas. Geotech Consulting (2003a, 2003b) conclude there is a moderate to high likelihood of a surface rupturing earthquake on this fault in the next 50-100 years.

A study of seismic site response in the Blenheim area (Robertson and Smith, 2004) indicated the widespread potential for amplifications of ground motions and an M_w 7.5 earthquake on the Wairau or Awatere Fault could generate peak ground accelerations of up to 1.4g, and intensities from MM VII to more than IX.

Other principal active faults in the region include the Clarence, Kekerengu, Elliot, Jordon and Hope faults. All of these faults are capable of producing large magnitude earthquakes (Stirling *et al.*, 2002), and collectively these faults have an average return period of between 28 and 51 years (Robertson and Smith, 2004). Ground shaking is therefore a significant hazard to the Blenheim area.

4.3 Slope Failure

The slope failure hazard at the site is very low due to the flat, low-lying topography of the land. Areas in close proximity to river banks will be susceptible to collapse or lateral spreading of the banks as a possible consequence of liquefaction-induced ground damage. However these issues are related to the liquefaction hazard at the site, which is described in Section 4.4 below.

4.4 Liquefaction

Liquefaction will occur when submerged loose to medium dense granular materials and silt are subjected to ground shaking. Soil deformation induced by liquefaction can cause sand boils, subsidence, lateral spreading and flow slides. Damage from such deformation can include floatation of buried structures, fissuring of the ground, subsidence of large areas, differential subsidence, and foundation failure caused by loss of support as the liquefied soil loses its shear strength.

The geology of the area indicates that the study areas are likely to be underlain by silty and sandy estuarine soils of the Dillons Point Formation underlain by alluvial gravels. Investigations of the Dillons Point formation in other areas on the town indicate that these soils are likely to be susceptible to liquefaction e.g. Geotech Consulting Ltd, 2004; Nelson Consulting Engineers, 2007; CH2M Beca, 2008). However, there is no information on the soils in the areas covered by the study areas, and there is no specific knowledge of the liquefaction hazards in the study areas. Geotechnical investigations are necessary to characterise the liquefaction hazards in these areas.

The level of hazard posed by liquefaction is moderate to high. Damage from liquefaction would be greatest where there is potential for lateral spreading of the ground towards the Opawa River, other water courses or other free surface.

5 Geotechnical Investigations

Site specific geotechnical information is required to confirm the ground conditions in the proposed growth areas and assess the liquefaction susceptibility of the Dillons Point Formation strata. This information is necessary to assess the hazard posed by liquefaction.

Although static cone penetration tests (CPTs) were initially proposed, following discussion with MDC, and based on the desk study, in addition to the CPTs it would be very beneficial to carry out boreholes to collect samples and carry out laboratory tests to characterise the properties of the soils. The grading of the soils and the fines content has an importance influence on liquefaction. The boreholes will also penetrate layers of gravel and confirm the extent of layers susceptible to liquefaction, in case there are layers of loose to medium dense sand underlain by some dense gravel layers. The following investigations are proposed, to assess the geotechnical risks to each proposed growth area.

Static Cone Penetration Tests (CPTs)

- We recommend carrying out approximately 10 to 15 CPTs, to provide geotechnical data on the strength and thickness of the strata, for use in assessing the liquefaction susceptibility of the soils.

Boreholes

- We recommend drilling boreholes to approximately 15 m depth, with in situ testing and collecting samples of the materials encountered. These boreholes would complement the CPTs and provide information on the grading of the soils, which has an important effect on the potential for liquefaction and ground damage, and where the CPT may not be able to penetrate dense deposits. These will provide information to characterise the thickness, composition and strength of the Dillons Point Formation strata.

Laboratory Testing

- Laboratory classification tests will be performed on samples recovered from the boreholes, to provide data on the physical characteristics of the soils and for use in the liquefaction assessment.

6 Conclusions

A desk study of the ground conditions and hazards in the Blenheim area has been completed. This assessment resulted in the following conclusions and recommendations as described below.

- The geomorphology of the Blenheim area consists of low-lying, flat to gently sloping plains. The proposed growth areas are located on flat agricultural land, often in close proximity to the Opawa River.
- Geological mapping and recent geotechnical investigations shows the surficial geology of the area is comprised of poorly consolidated alluvial and estuarine soils. Older alluvial gravels and sands are preserved beneath the young deposits.
- Geotechnical investigations are needed to confirm the ground conditions in areas proposed for future urban growth where no pre-existing information is available.
- The Wairau Fault passes approximately 1.6 km from the northern growth area and approximately 5 km from the eastern growth areas. The level of risk posed by the fault is considered to be low.
- Seismic ground shaking is a significant hazard in the region.
- The proposed urban growth areas under consideration in this study are likely to be susceptible to liquefaction where the low-lying plains are underlain by liquefiable alluvial and estuarine soils.

7 Recommendations

1. Carry out geotechnical investigations as proposed in Section 5.
2. Carry out an assessment of the ground conditions and characterise the Dillons Point Formation and other soils encountered during the site investigation.
3. Assess the susceptibility of the materials to liquefaction and characterise the areas with respect to their vulnerability to liquefaction-induced ground damage.
4. Prepare hazard maps for use in landuse planning.

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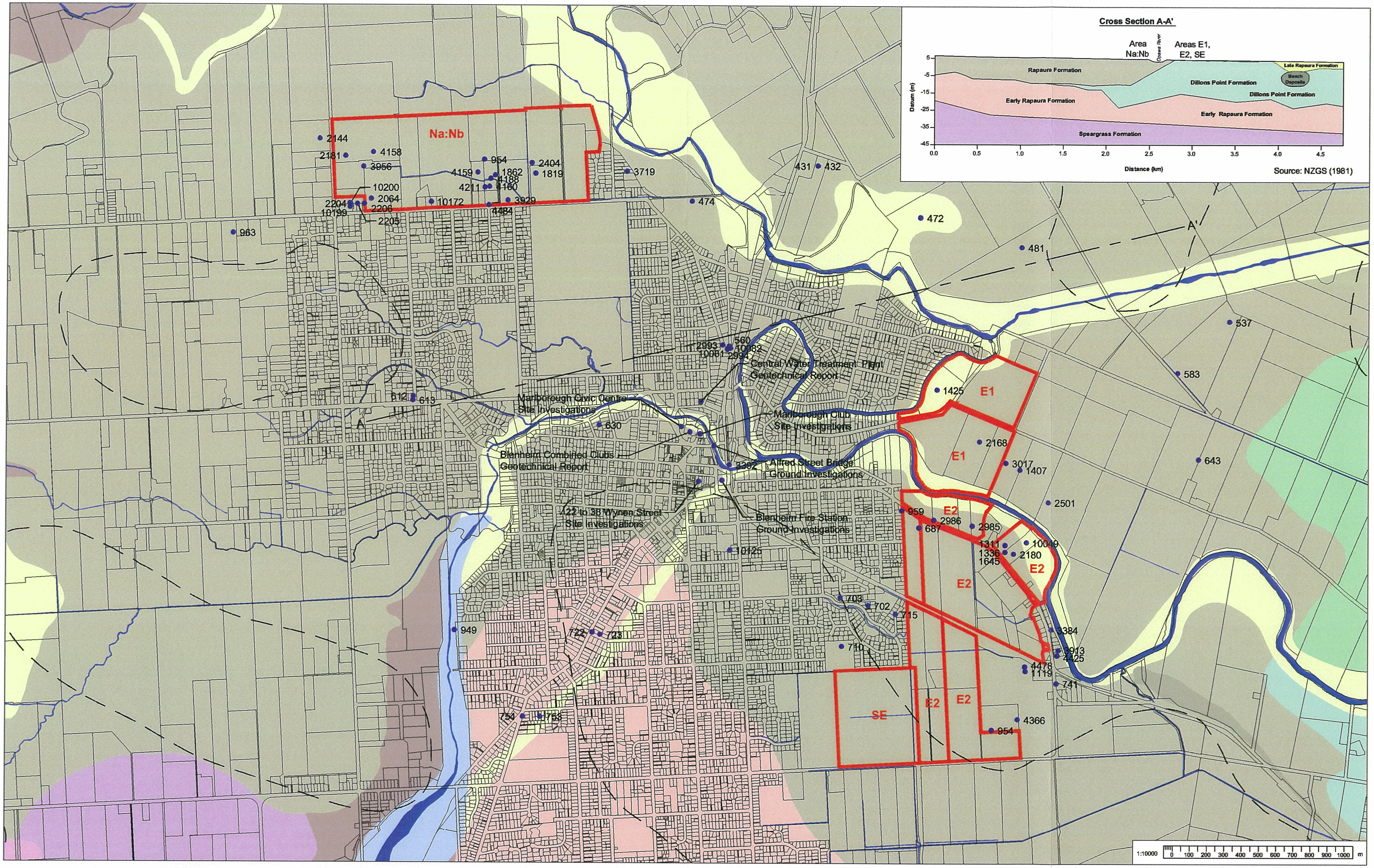
FIGURES



Prepared for:

MARLBOROUGH DISTRICT COUNCIL

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OPUS

Key:

- Parcel Boundary
- Old Swamp Land
- Area for Assessment
- MDC Well Records
- River Location

Surficial Geology (after NZGS, 1981)

- fa - Unstabilised river silt, sand, and gravel in present river beds.
- Rapaura Formation:
  - rg - Gravel, sand, and silt in river flood channels occupied during historic flooding, or in modern time prior to river flood protection constructions.
  - ra_2 - Alluvial silt adjacent to present or historic river flood or man made diversion channels and reclaimed or drained swamps.
  - ra_1 - Alluvial gravel, sand, and silt.
  - ra - Alluvial gravel, sand, and silt at higher level and well drained
- Dillons Point Formation:
  - dl_1 - Sand, silt, and mud lagoon deposits
  - dl - Sand, silt, and mud lagoon deposits better drained and less saline.
  - dd - Sand dunes
- Speargrass Formation: sp - Fluvial (glacial outwash) brown and blue gravel, sand, and silt.
- Tophouse Formation: to - Glacial outwash of weathered to slightyweathered brown gravel, sand, andsilt; covered by a layer of loess up to i m thick

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Title:	Blenheim Urban Growth Strategy Liquefaction Study
Project:	Site Locations and Regional Geology

Scale:	Date:	Project No:	Figure:
1:20,000 (A3)	November 2011	5C2128.00	1