Waikato District Council
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Ngaruawahia Structure Plan

Geotechnical Suitability Assessment

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Client: Waikato District Council

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Executive Summary

The Waikato District Council (WDC) engaged AECOM New Zealand Limited (AECOM) to undertake an assessment of the geotechnical constraints within the study area for the Ngaruawahia Structure Plan. Geotechnical constraints are natural hazards (geohazards) that can impact on developments or be adversely affected by development.

AECOM has undertaken a desk study of the potential geohazards within the Ngaruawahia Structure Plan study area. The desk study has comprised:

- A review of natural hazard regulations related to development,
- A review of relevant geological maps and topographical maps,
- A review of aerial photography within the public domain,
- Experience of development issues within the study area, and
- Review of site hazard information supplied by the Waikato District Council.

The Ngaruawahia Structure Plan study area is approximately 9,600 Hectares of predominately rural farmland. The topography can be broadly grouped into the “Lowlands” and the “Hill Country”.

The lowlands are typically near level to gently undulating with river and stream gully systems incised across the surface. The soils of the lowlands are highly variable due to the alluvial deposition, and organic soils can also be present. Rolling hills up to 20 metres high can protrude above the alluvial terraces of the lowlands. The rolling hills have a volcanic ash mantle covering, ancient alluvial deposits, and ignimbrite flows.

The Hill Country is located in the western part of the study area and includes the Hakarimata Range, the Taupiri Range and the hills west of the Hakarimata Range. The slopes angles can range from gently sloping to very steep. Residual soils have formed by the weathering of bedrock. A mantle of volcanic ash may be present above the residual soils.

The key geohazards identified within the Ngaruawahia Structure Plan study area are:

- Settlement of soft soils and shrinkage of peat has potential to damage structures and infrastructure within the lowlands.
- Slope instability has the potential to affect both the lowlands and the hill country. Within the hill country there is a significant risk of deep seated landslides and debris flows that can travel a significant distance from the source.
- Soil liquefaction is a geohazard applicable to the lowlands. Soil liquefaction can result in vertical settlement and horizontal displacement. This hazard has potential to do widespread damage to structures, roads and infrastructure.

A number of development practices have been identified as having potential to instigate, accelerate or make worse geohazards. Earthworks and tracking within the hill country have previously resulted in slips and erosion. Discharges to ground for managing stormwater and on-site effluent systems can reduce the stability of slopes and result in erosion.

AECOM has assessed the land within the study areas against four development suitability categories. The suitability categories do not imply that a site is subject to natural hazard, but that the hazard is associated with that area and needs to be specifically assessed. The development suitability categories and the areas assessed as fitting the categories are:

Category A – Low risk - No land mapped within the study area.

Category B – Some risk - Rolling hills within the lowlands.

Category C – Moderate risk - Alluvial soils of the lowlands, flanks of rolling hills.

Category D – High risk - Hill country, peat swamps, alluvial terraces within 200m of gullies and streams.

In addition to the development suitability categories, AECOM has made several recommendations for modifications to the Waikato District Plan to address geohazards. It is recommended that:

- A land instability policy layer is incorporated into the District Plan to guide and restrict development in areas recognised as having a high risk of land instability such as the Hill Country within the study area.
- A mine workings policy layer is recommended to identify areas that have previously been affected by mining activities.
- Liquefaction risk mapping is advisable. As a minimum, systems to record liquefaction risk assessments that are submitted as part of consent documentation should be put in place.
- The engineering standards within the District Plan should have an increased focus on the importance of geotechnical engineering in the identification and management of geohazards.
- Definitions should be added to the District Plan for the terms “Natural hazard” and “Geotechnical suitability”.

1.0 Introduction

Waikato District Council (WDC) engaged AECOM New Zealand Limited (AECOM) to assess geotechnical constraints and issues for the proposed development of a Ngaruawahia Structure Plan. The Structure Plan area of interest was provided by WDC and includes the rural areas around Ngaruawahia Township and the nearby villages of Taupiri, Horotiu and Te Kowhai, as shown on Sheet A1 in Appendix A.

The purpose of the Structure Plan is to provide a framework for sustainable development within the district. Recent changes to the District Plan have reduced the potential for further subdivision of rural land; however it is likely that the Structure Plan will result in some areas of rural land adjacent to the existing towns and villages being rezoned to allow for residential and commercial growth.

Geotechnical constraints are development constraints that are due to the potential for a geohazard to impact on the development or other land if the geohazard is not addressed. A geohazard is a broad term that refers to geological hazards caused by a combination of the structure, type, strength and topography of the land. Geohazards may be obvious such a large land slide, or revealed only by thorough investigation like the settlement potential of buried soil, or unknown until they occur such as an earthquake generated by an unknown fault.

The purpose of this assessment is to advise WDC of the potential geohazards within the area being considered under the Ngaruawahia Structure Plan and provide advice regarding the suitability of the land for development.

2.0 Scope of assessment

This assessment is a desk study and comprises:

- A review of natural hazard regulations related to development,
- A review of relevant geological maps and topographical maps,
- A review of aerial photography in the public domain,
- Experience of development issues within the study area, and
- Review of site hazard information supplied by the Waikato District Council.

This assessment focuses on geohazards and therefore excludes other natural hazards such as flooding, surface ponding and wind.

The purpose of the assessment is to identify the geohazards that may be present within the study area. Identifying the actual location and extent of any geohazard is beyond the scope of this assessment.

3.0 Legal framework

Geotechnical suitability of land for development is concerned with the avoidance and mitigation of geohazards. The foundation framework is outlined in Legislation, District Plans, and New Zealand Standards.

A brief outline how these documents address the Natural Hazards is provided in the following sections.

3.1 Resource Management Act 1992

The Resource Management Act 1992 gives Territorial Authorities the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of the avoidance or mitigation of natural hazards.

In the case of subdivisions, the territorial Authority may refuse to grant subdivision consent, or may grant subdivision consent subject to conditions, if it considers that:

- *the land in respect of which a consent is sought, or any structure on the land, is or is likely to be subject to material damage by erosion, falling debris, subsidence, slippage, or inundation from any source; or*
- *any subsequent use that is likely to be made of the land is likely to accelerate, worsen, or result in material damage to the land, other land, or structure by erosion, falling debris, subsidence, slippage, or inundation from any source; or*

- *sufficient provision has not been made for legal and physical access to each allotment to be created by the subdivision.*

3.2 Building Act 2004

The Building Act, 2004 defines a Natural Hazard as:

- *erosion (including coastal erosion, bank erosion, and sheet erosion)*
- *falling debris (including soil, rock, snow, and ice)*
- *subsidence*
- *inundation (including flooding, overland flow, storm surge, tidal effects, and ponding) or*
- *slippage.*

The Building Act addresses natural hazards by requiring that the building consent authority refuse to grant building consent for construction of a building, or major alterations to a building, if:

- *the land on which the building work is to be carried out is subject or is likely to be subject to 1 or more natural hazards or*
- *the building work is likely to accelerate, worsen, or result in a natural hazard on that land or any other property.*

The Building Control Authority can issue a building consent if the building consent authority is satisfied that suitable provision has been or will be made to:

- *protect the land, building work, or other property referred to in that subsection from the natural hazard or hazards or*
- *restore any damage to that land or other property as a result of the building work.*

The Building Act includes all site work within the definition of building work. Site work is defined as "*work on a building site, including earthworks, preparatory to, or associated with, the construction, alteration, demolition, or removal of a building*".

3.3 Waikato District Plan

The Waikato District Plan has objectives and policies to manage development in areas prone to natural hazards. However the District Plan does not provide a definition of a Natural Hazard. Flooding, wind, erosion and mine subsidence are all mentioned in discussion, and reference is given to the Building Act 2004.

The objectives and policies favour avoidance over mitigation and notes that the development should not increase natural hazards.

Planning maps provide information on flood hazard, riverbank stability zones and the Huntly East Subsidence Zone. A land stability policy area is mapped near Raglan and while there are rules related to development in that area, there is no additional guidance apparent for developers or council staff.

The District Plan rules relating to building and subdivision refer to geotechnical suitability as a matter that council may consider. Geotechnical suitability is however, undefined.

3.4 NZS4404:2010 Land Development and Subdivision Infrastructure

NZS4404 outlines the geotechnical considerations for assessing the suitability of land for subdivision and designing new landforms (recontouring by earthworks). In addition to addressing the natural hazards that are defined in the RMA, this standard also includes the assessment of special soil types, which includes but is not limited to:

- *Soils with high shrinkage and expansion*
- *Compressible soils*
- *Volcanic soils*
- *Soils subject to liquefaction*

- *Soils prone to dispersion*

3.5 NZS3604:2011 Timber Framed Buildings

NZS3604 provides a definition of “good ground” which is suitable for buildings that are within the scope of the standard and also NZS4229:1999 Concrete Masonry Structures Not Requiring Specific Engineering Design.

The intent of the site requirements section in NZS3604 is to enable compliance with the building code to be readily established for most residential type buildings, without the need for soil bearing capacity and settlement calculations.

Land with instability in the “immediate locality”, compressible soil, subsidence, organic soil, and expansive soil are excluded from “good ground”.

4.0 Study area description

4.1 Overview

The study area covers approximately 9,600 Hectares of predominately rural farmland. The topography can be broadly grouped into the "Lowlands" and the "Hill Country". A topographic map is presented on Sheet A2 in Appendix A.

The lowlands are typically flat to gently undulating. The Waikato River and the Waipa River are the major river systems. The topography adjacent to the rivers includes flood terraces, gentle slopes and steep banks. Incised tributary gully systems traverse the lowlands and are more prominent close to the rivers. A network of rolling hills rise up to 20 metres above the surrounding lowlands. Swamps with shallow lakes are present in areas of poor surface drainage.

The hill country is in the western part of the study area and includes the Hakarimata Range, Taupiri Range and the hills west of the Hakarimata Range. The slopes range from gentle to very steep.

Land use on the flat, gentle and rolling lowlands is predominantly dairy farms with some cropping, while dry stock and sheep farming predominates on the steep hills west of the lowlands. Light industrial and commercial development is limited to Ngaruawahia and Horotiu. A decommissioned landfill occupies the narrow strip of land south-west of SH1 on the south side of Ngaruawahia and is a reserve. The disused Hopuhopu army facility is located on the rolling hills west and south of Lake Hotoananga, a few kilometres east of Ngaruawahia.

4.2 Settlements

4.2.1 Ngaruawahia

Ngaruawahia Township is located at the confluence of the Waikato and Waipa rivers approximately 20 kilometres north-west of Hamilton City. The township has been developed on near level to gently undulating land and is generally elevated approximately 20 metres above mean sea level (RL20).

There are several shallow gully systems within the township. To the west of the Waipa River and the Waikato River north of the confluence is the Hakarimata Range, which has peak evaluations of approximately RL370.

4.2.2 Glen Massey

Glen Massey village is west of the Hakarimata Range and approximately 7 kilometres west of Ngaruawahia. Glen Massey is nestled in the base of a stream valley at approximately RL100. It is surrounded by steep to very steep hills that rise to approximately RL200. The hills in general have been cleared for agriculture.

4.2.3 Taupiri

Taupiri village is on the eastern side of the Waikato River, where the Mangawara Stream and several smaller tributaries meet prior to discharging into the Waikato River. At Taupiri the Waikato River turns to the west and flows between the Hakarimata Range and the Taupiri Range. The village is separated from the range by Mangawara Stream. Taupiri has been developed primarily on the near level to gently undulating topography adjacent to the waterways.

4.2.4 Te Kowhai

Te Kowhai village is approximately 8 kilometres to the south of Ngaruawahia on near level to gently undulating topography. A prominent gully runs east to west through, and along the northern side of the village.

4.2.5 Horotiu

Horotiu is approximately 5 kilometres south east of Ngaruawahia. It is located on near level to gently undulating land and alluvial terraces near the banks of the Waikato River. A tributary stream gully is at the southern end of the village.

5.0 Geology

5.1 General

The landforms of the study area and many potential geohazards are substantially related to the underlying geology. A geological map of the study area is shown on Sheet A3 in Appendix A. The map is an extract from the published Q-Map.

The geology is considered here in terms of the dominant landforms (geomorphology). The landform units are Hill Country, Rolling Hills of the Lowlands, Alluvial Soils of the Lowlands, and Valley Floor Soils.

5.2 Hill country

The hill country in the project area is the mapped as Newcastle Group indurated sedimentary siltstone and sandstone, which commonly are collectively termed greywacke. The greywacke is typically deeply weathered, resulting in stiff to hard clay soils. A thin (less than 1 m) mantle of weathered volcanic ashes may also be present. On steeper slopes the depth of weathering and thickness of ash mantle is reduced due to erosion processes.

The greywacke is very closely fractured, with common faults and folds. The Hakarimata Anticline trends north south and generally follows the crest of the Hakarimata Range. A syncline is mapped approximately 1 km east of Glen Massey and a secondary Anticline approximately 600 m east of Glen Massey.

The Wilton Fault trends north to south approximately 400 m west of Glen Massey. Numerous other faults are mapped west of the Wilton Fault. All faults in the immediate vicinity of the study area considered to be inactive.

The greywacke when unweathered is strong to very strong and strength decreases as weathering increases. While the intact rock strength is high, the strength of the rockmass is considerably less due to the closely spaced joints and shear zones. A weathered zone up to 15 m in thickness can form where the rock has completely weathered to clay soil, but with rockmass fractures still present, creating weak zones.

5.3 Rolling hills of the lowlands

The sinuous lowland rolling hills are mapped as the Walton Subgroup, which comprises the Puketoka and Karapiro Formations and dates from about 1 to 0.4 million years ago. These formations typically comprise silt, sand and clay of volcanic (rhyolitic) origin and were deposited by the proto-Waikato River along with ignimbrite flows from the Taupo Volcanic Zone. Peat, breccia and non-welded ignimbrite may also be present. Soil type and strength can be highly variable. Some of the Walton Subgroup soils can undergo a significant strength loss when the in-situ structure is destroyed by earthworks. The Walton Subgroup is typically not a surface deposit in the Ngaruawahia area, as it is mantled by the Hamilton Ash Formation. The Walton Subgroup can be exposed in cuttings and or in areas where erosion or instability has occurred.

The Hamilton Ash is a series of completely weathered, clay-rich rhyolitic volcanic ash beds (airfall tephra). The ash beds were deposited between 80 and 380 thousand years ago. The ashes mantled the pre-existing landscape (eroded Walton Subgroup) and locally can be up to 6 metres in thickness, but are typically less than 2 metres on the flanks of slopes in the Ngaruawahia area. The Hamilton Ash is generally a stiff clay soil and does not undergo a significant strength loss when worked due to earthworks.

5.4 Alluvial soil of the lowlands

The rolling hills are surrounded by a gently north-westward sloping plain (Hinuera Surface) constructed of alluvial sediments deposited by the ancestral Waikato River. The alluvial sediments are mapped as the Hinuera Formation, and were deposited between 50 and 17 thousand years ago by the ancient braided river system, with the bulk of the sediments being deposited following the voluminous Oruanui eruption 26 thousand years ago. Following cessation of rapid sedimentation, the river became entrenched in its current course and formed the modern Waikato River. As the Waikato River became more deeply entrenched so did the tributary gullies and streams.

The Hinuera Formation consists of variably pumiceous and rhyolitic gravel, sand and silt. Young surface and old subsurface peat and organic silt (lacustrine) deposits can be present. There is distinct cross-bedding throughout the formation, and soil conditions can be highly variable.

In areas with poor drainage, peat swamps have formed. These swamps (and associated lakes) were formed by the Hinuera Formation sediments damming valleys in the rolling hills. Some of the valleys are broad, forming large areas of peat, for example the Driver Road valley (Kainui bog) to the east of Ngaruawahia. Smaller swamps are present in the Te Kowhai area.

The Taupo Formation was deposited following the Taupo Ignimbrite eruption approximately two thousand years ago. The eruption blocked Lake Taupo (as did the earlier Oruanui eruption), raising its level. The eventual breakout flood resulted in rapid sedimentation that, in the Hamilton Basin, did not overtop the entrenched channel of Waikato River, but formed low terraces of pumiceous sand and silt within the channel. Undifferentiated alluvial and colluvial deposits have accumulated in the incised tributary gullies.

5.5 Valley floor soils

The soils in the valley floors around Glen Massey are mapped as young alluvial and colluvial deposits resulting from erosion of the surrounding Greywacke hills.

6.0 Geohazards

6.1 Introduction

The geological hazards (geohazards) considered relevant to the study area include slope instability, river bank erosion, seismicity and liquefaction, volcanic hazard and poor ground conditions (e.g. peat). Related issues of possible subsidence due to past underground mining activity and decommissioned industrial sites and landfills are also addressed.

6.2 Soil strength and characteristics

6.2.1 Overview

The study area is large and encompasses a variety of terrains and soil types. Soil strength is an important consideration when assessing the suitability of land for development, in particular the potential for unacceptable settlement and subsidence of buildings and infrastructure.

6.2.2 Static settlement

Static settlement results from compression of the ground underlying a structure or fill embankment due to the increased load. Generally, if uniform settlement occurs and it is of limited magnitude, structures typically do not sustain structural damage and the settlement can be undetectable without reference levels. When settlement occurs it is common for the land adjacent to the structure to also be affected as a depression is created towards the loaded area.

Differential settlement occurs when there is non-uniform settlement across a structure. This can be due to lateral variability in applied loads or differences in the thickness and/or compressibility of the materials underlying the loaded area.

When differential settlement occurs, the walls and cladding of buildings are susceptible to cracking, floors become uneven, and doors and windows become tight and prone to jamming. The integrity and function of onsite services can also be compromised when settlement affects auxiliary structures such as water tanks. Connections between buried services and buildings can also be adversely affected.

Roads and buried services are generally at low risk of issues related to static settlement, unless the works include embankments or structures as part of the works or in close proximity to the infrastructure.

6.2.3 Peat shrinkage

Peat is a difficult material with respect to land development. It is highly compressible and therefore settlements can be large under fill and structure loads unless mitigated or accommodated in design. In addition, where surface peat has been or is being drained, peat shrinkage is a significant issue due to the resulting potentially large ground settlements. Settlement due to peat shrinkage can be exacerbated due to applied loads.

Buildings can be readily isolated from the effects of peat shrinkage by ensuring that the building loads are transferred to underlying competent soil. This is typically done by either excavating the peat and replacing it or supporting the structure on deep foundations. Buildings however, are seldom isolated structures and are typically connected to on-site or reticulated services, leading to problems with connections as the surrounding land settles while the building remains fixed.

Roads and buried services are both prone to differential settlement due to peat compression and shrinkage. This can lead to disruption of services and costly remediation. Mitigation can be achieved by excavating shallow peat or adopting pile support when cost-effective excavation is not possible.

Areas with undrained surface peat will generally have a water table close to or at the ground surface. In drained peat, as the peat shrinks over time, the water table depth decreases relative to the ground surface and surface ponding can recur. Land owners respond by deepening the drains which can lead to reactivation or acceleration of the shrinkage as the peat re-stabilises to the new hydrogeological conditions.

6.2.4 Expansive soils

Expansive soils are those that contain clay minerals that shrink and swell significantly upon wetting and drying. These soils can apply significant pressure to foundations, resulting in differential movements and damage similar to that experienced due to settlement. Expansive soils can be mitigated by specific design of foundations;

however as laboratory testing is required it is more efficient to address the presence of expansive soils during subdivision consent.

6.3 Slope instability

6.3.1 Lowland river and gully slopes

The slopes that define the gullies and banks associated with the Waikato River and tributaries are generally steep to very steep. There is typically a sharp slope break at the crest of gullies. Slope materials tend to consist of sub-horizontally bedded layers of silt and sand. Full slope saturation is unusual, as percolating rainfall tends to be impeded by the less permeable layers (e.g. silt) and track horizontally to the slope face.

Slope failures tend to be of the shallow regressive type, and commonly associated with rainfall or slope modification. Stream and river bank erosion can remove toe support, which destabilises the slope above. Deeper-seated failures can occur but they tend to exit at the base of the slope and not extend below the toe level. Debris from slips generally accumulates at the toe of the slope forming a protective ramp; subsequent stream erosion however can progressively remove the debris leading to further slope failures.

Except for the riverside terraces associated with the Waikato and Waipa rivers, building development generally has not occurred at the toe of gully slopes.

Within the Waikato region, typical practice for residential subdivision and building in the vicinity of gully slopes has been to project a 1V:2H line from the toe of the slope to obtain a development setback line. With sharp slope breaks being typical of gully slopes, this development restriction line is readily defined on site. Conventional development is restricted within the zone defined by the setback line, although development within the zone may be acceptable provided the potential for instability within the zone is addressed by specific engineering provisions in the foundation design. However, while simple and easily applied and interpreted this method of restricting development close to gully slopes does not address seismic conditions and how groundwater changes could affect stability.

Stormwater soakage is currently encouraged as the preferable method for managing stormwater. This increases the percentage of rainfall entering the ground containing the soakage facility compared to what would have naturally infiltrated from the surface, as rainfall is collected from a larger area and concentrated in the soakage field. This can alter the hydrogeological conditions near gullies and reduce stability.

6.3.2 Hill country and rolling hills

The foot hills of the Hakarimata Range and the Rolling Hills of the Waikato Lowlands have slopes ranging from 5° to 35°.

Three types of instability are readily identifiable in this terrain.

- Soil creep
- Shallow slumping
- Deep-seated instability

Soil creep is common on slopes steeper than approximately 20°. Soil creep is the gradual downslope movement of the soil profile, which is generally limited to the zone about 1 m below the ground surface. Land owners typically refer to the visible manifestation of soil creep as sheep or cattle tracks.

Shallow instability that occurs in this terrain is generally rotational slumping that affects the uppermost 1 m to 2 m of the soil profile on the steeper slopes. Hummocky ground may be present where this has previously occurred.

Aerial photography of the Hakarimata Range and Glen Massey area show that the hill slopes in those areas have relatively large scale deep-seated landslide scars.

Debris from these slips can be fluid and travel a significant distance down slope and across adjacent level ground. Landslide debris from rapid failures poses a significant hazard to property and life. Case Study 2 in Appendix C, discusses a recent slip and debris flow within this area.

Typical building and subdivision practise has been to undertake shallow hand auger investigations within the building site, including determining the slope profile below the building site. Provided that the slope is less than 26° and the investigations indicate soils of at least stiff consistency, the slope is typically reported as stable and suitable for building. A setback of 3 m to 5 m from the edge of the steep slope would be common; however, as lateral changes in the slope gradient tend to be gradual and rounded, this can lead to ambiguous recommendations and misinterpretation.

This approach to stability assessment and defining development restriction also fails to recognise that the most significant risks to property and life are the deep-seated landslides that may be generated upslope of a dwelling.

It is also significant that the area most likely to generate a landslide that affects a property may be located beyond the property boundaries, which can be a barrier to access for further detailed assessment, should it be warranted.

6.4 Seismic hazard

6.4.1 Introduction

Earthquakes can result widespread damage to land and buildings. Land damage has traditionally been considered in this context as destabilisation of slopes and ground surface movement associated with shaking and fault rupture.

Building codes and standards such as NZS3604 Timber Framed Buildings have generally ensured that buildings are structurally designed to withstand earthquake shaking.

Since the occurrence of the Canterbury Earthquake Sequence (2011 to present) there has been heightened awareness of the effects of soil liquefaction on both buildings and infrastructure. Soil liquefaction is addressed in greater detail in Section 6.5.

6.4.2 Tectonic setting

New Zealand is on the boundary of the Australian and Pacific tectonic plates. Ngaruawahia is approximately 350 kilometres west of the plate boundary.

The Newcastle Group greywacke has been extensively faulted and folded by intra-plate stresses in the past. The Hakarimata Anticline trends north south and generally follows the crest of the ridge of the Hakarimata Range. There is a syncline approximately 1 km east of Glen Massey and a secondary anticline approximately 600 m east of Glen Massey.

The Waipa Fault is concealed by the Hinuera Formation and Walton Subgroup, and trends south to north from North Taranaki to Ngaruawahia. The Wilton Fault also has a north to south trending surface expression approximately 400 m west of Glen Massey. Numerous other faults are mapped west of the Wilton Fault. All faults in the vicinity of the study area mapped as inactive.

The closest faults that are currently identified as active are the Turi Fault, Wairoa Fault and the Kerepehi Fault. The Turi Fault is located off the west coast of the Waikato, approximately 100 km south west of Ngaruawahia, and is estimated to be capable of generating a M7.2 earthquake approximately every 1,600 years. The Wairoa Fault (50 km north of Ngaruawahia) and the Kerepehi Fault (40 km west of Ngaruawahia) are estimated to be capable of generating M6.6 earthquakes, with return periods of 22,000 and 2,500 years respectively.

6.4.3 Seismic history

Sheet B1 in Appendix B shows the locations of shallow earthquakes M3.5 or greater within and near the Waikato Q-Map area from 1840 to 2003. The three significant shallow earthquakes closest to Ngaruawahia Study Area are:

- 1891 Port Waikato M5.9
- 1912 Te Awamutu M5.5
- 1972 Te Aroha M5.3

The New Zealand Institute of Geological and Nuclear Sciences online earthquake search tool indicates shallow earthquakes having a magnitude less than M3.5 occur relatively frequently in the hill country within 5 km of Ngaruawahia. It is not clear if these are related to intra-plate stress or blasting that was recorded by the seismograph network.

It is a feature of both information sources that the vast majority of earthquakes that have been recorded have not occurred on the faults that are recognised as being active. Although there is a low frequency of large earthquakes, the records cover a period much less than the return event that needs to be considered for building code compliance.

6.4.4 Managing the seismic hazard

The Zealand Building Code requires that structures perform to a requisite standard during an earthquake. The design earthquake strength is a factor of the structures importance level (determines the return period event to be considered) and the location. This means that the more seismically active regions have stronger earthquake actions in design.

While seismic forces are taken into account as a routine part of structural engineering it is often overlooked when assessing civil works, land modification and stability, yet these works can equally affect the structural integrity of buildings. Case Study 1 in Appendix C discusses liquefaction knowledge and the lack of mitigation in Canterbury prior to 2010.

6.5 Soil liquefaction

6.5.1 Liquefaction mechanism

The cyclic ground motion induced by earthquakes can cause a build-up of excess pore pressure within the soil. If the excess pore pressure exceeds overburden pressure, liquefaction can occur, which causes a loss of strength and commonly ejection of material at the surface (e.g. sand boils). As the excess pore pressure dissipates following cessation of shaking, densification of the soil can occur that, together with the loss of ejected material, causes settlement that may damage structures.

Such liquefaction and densification typically occurs in geologically young, loose, saturated, fine to medium grained, non-cohesive and low plasticity soils.

6.5.2 Potential effects of soil liquefaction

When soil liquefaction occurs there is a significant decrease in the soil strength. While this is a temporary situation, foundation bearing capacity failure can occur if the liquefied soil is sufficiently close to the foundations.

Liquefied material adjacent to a free face, such as a terrace, gully or river, can allow un-liquefied material above it to move towards the free face (lateral spreading). Lateral spreading can result in ground displacement and cracks developing several hundred metres from the slope. Lateral spreading is particularly damaging to buildings, roads and services with the zone of displacement.

Services such as buried pipelines, manholes and tanks can become buoyant resulting in damage to infrastructure. This can also be worsened by ground surface settlement. Roads can be damaged by ground settlement and lateral spreading.

6.5.3 Soil liquefaction potential

Within the study area, the alluvial soils of the lowlands (e.g. Hinuera Formation) can contain significant beds of loose sand and silt which are commonly saturated close to the surface, particularly at locations distant from incised gullies. As these soils are also relatively young there is a potential liquefaction hazard throughout the Hamilton lowlands.

6.5.4 Soil liquefaction mitigation

Engineering solutions are available to mitigate the effects of soil liquefaction should assessment indicate that the effects are significant and warrant mitigation. Some of the commonly adopted methods are:

- raft foundations
- ground improvement (replacement, stabilisation, deep soil mixing)
- piles

The final solution will depend on the end use, the degree of deformation estimated, and the depth to underlying non-liquefiable strata.

Infrastructure can also be protected by using non-rigid pipes, slip joins and mass blocks to prevent buoyancy.

6.6 Volcanic hazard

There are no active volcanoes in the study area or within the wider surrounds. Distant large rhyolitic and andesitic volcanoes in the Central North Island could result in volcanic ash fallout in the study area. The risk of a direct volcanic hazard affecting the study area is very low.

6.7 Subsidence

6.7.1 Mine subsidence

Coal mining was undertaken in the in the Glen Massey and Taupiri Areas in the early to mid-twentieth century. AECOM has reviewed the Glen Massey Coalfield Map which indicates that underground mining was not undertaken within the study area.

A similar map for Taupiri was not readily available, however the study area does not include the Taupiri Range and it is unlikely that coal mining was undertaken beneath the alluvial terrace.

6.7.2 Rolling hill subsidence

Subsurface conduits and voids (tomos) can occur within the rolling hills of the Waikato lowlands. While they are rare, tomos have been exposed or collapsed during development earthworks on the northern fringes of Hamilton. The mechanism for the formation of these voids is unclear and the distribution is not known. Given their rarity, specific exploration to detect these features is not warranted and they are best managed during project construction.

6.8 Non-engineered fill

Non-engineered fill can be prone to settlement and instability. Hazard maps supplied by Waikato District Council show locations where non-engineered fill (including some landfills) has been recorded by Council. It is likely that there are more instances of non-engineered fill throughout the study area. It is appropriate to deal with any non-engineered fill during subdivision planning and construction.

7.0 Development issues

Development of flat ground is generally straightforward. Aside from erosion of exposed soils and potential to alter land drainage paths, there is little risk of subdivision works contributing to natural hazards or environmental issues.

On sloping ground or near gullies, certain activities have the potential to result in environmental damage or alter the stability of the natural ground. Earthworks are often required for access to lots and then the building platforms within the lots.

Cuttings have the potential to destabilise land above the cutting and can increase the erosion potential of the site. Cuttings within stiff clay soil such as Hamilton Ash or soils derived from weathered greywacke can also stand steeply and unsupported when initially excavated. Over time the cutting will fritter back to a more stable angle through erosion processes. In some instances sudden collapse can occur, which can be shortly after excavation or some time later.

Filling has the potential to increase load on a slope, which can result in instability in the underlying in-situ soil. Side-casting over unprepared ground is inherently unstable increasing both the erosion and instability potential of the slope.

Effluent discharges to ground continually add water to the slope. This can reduce soil strength and lead to slope destabilisation. Effluent discharge fields are defined as building work and are subject to the same requirements to avoid or mitigate natural hazards as the building itself.

Stormwater discharges to ground have the potential to decrease the stability of nearby slopes. Poorly located dispersion systems can increase erosion potential and also result in instability. Where development is intensified, the cumulative effects of the discharges to ground need to be addressed.

Tracks or driveways constructed through sloping terrain capture and concentrate stormwater runoff from both the track itself and also the land upslope of the track. Runoff volumes can far exceed what would be generated by the track alone. This concentration of stormwater can lead to soil erosion and instability.

8.0 Development suitability recommendations

8.1 Development suitability categories

8.1.1 Overview

A map has been developed (Sheet A4, Appendix A) that classifies the development suitability of the study area land based on landforms and geological and geotechnical constraints. The map provides a high level classification of the land suitable for Structure Planning purposes.

The categorisation does not imply that all of the land within any category is subject to the geohazards typical of the zoning. The intent of the plan is to provide guidance to Council on the general suitability of the land and the starting point for engineering assessment that should accompany development proposals. It is possible that a specific assessment could either upgrade or downgrade the risk.

8.1.2 Category A – Low Risk

Category A represents land that is likely to be suitable for development with minimal geotechnical input. There is little risk to buildings and infrastructure. Residential buildings are likely to be able to be developed using foundation details from NZS3604. There is also little environmental risk from developments within the Category A land; however the cumulative effects of stormwater discharges onto or into the land should be addressed as it may affect land beyond this zone. There is no Category A land shown within the Ngaruawahia Structure Plan study area due to the scale of the map presented. Category A land may be identified as part of a development specific proposal.

8.1.3 Category B – Some Risk

Category B represents land that is likely to be suitable for development with some geotechnical input. Although pockets of land that are unsuitable for development may occur, most land is suitable for residential buildings developed using foundation details from NZS3604 but with shallow ground improvement (e.g. undercut and replacement or foundations that are deepened to more competent materials).

There is some environmental risk from developments within the Category B land, which will typically be related to earthworks for building sites and accesses. Consideration to the management of development induced water discharges and the cumulative effects of increased runoff volumes or soakage to ground volumes is required.

8.1.4 Category C – Moderate Risk

Category C land has a moderate development risk. There are likely to be development constraints that will need specific and detailed geotechnical assessment to identify how the potential hazards could impact on the development. It may be costly and difficult to develop land in Category C.

There can be significant environmental risk from developments within the Category C land, which will typically be related to earthworks for building sites and accesses. Assessment of the cumulative effects of development induced water discharges, in particular increased runoff or soakage to ground volumes and how these may affect the geohazards is required.

8.1.5 Category D – High Risk

Land within Category D is assessed as having a high risk of being subject to a significant geohazard within the zone. Where such hazards are present, mitigation is unlikely to be possible in a safe and economically viable manner and avoidance should be the expectation. Development is not recommended without extensive engineering assessment and design. Hazards may be due to geological conditions beyond the property boundary, and assessment of the wider area is recommended in Category D areas near slopes.

There can be significant environmental risk from developments within the Category D land, which will typically be related to earthworks for building sites and accesses, and development induced water discharges. Assessment of the cumulative effects of development induced water discharges, in particular increased runoff volumes or the volume discharged to ground, and how these may affect the geohazards is required.

8.2 Geomorphological categories

8.2.1 Alluvial Terraces of the Lowlands

The alluvial terraces of the lowlands can generally be considered suitable for urban development or country living zoning, subject to a detailed assessment during the consenting process. Due to variability of soil type and strength, the potential for soil liquefaction and settlement and compression and settlement of soft and/or peaty soils will need to be assessed on a case by case basis. Assessment will need to address risks to both building and infrastructure. It is likely that engineering solutions to mitigate hazards will be required. The alluvial terraces are therefore generally considered to be Category C.

Category D is applicable near the toe of the hill country and steep slopes associated with the rolling hills due to potential for inundation from landslide debris.

Development adjacent to the gullies and water bodies (streams, rivers, lakes, open drains) will need to address the stability of the slopes. Due to the potential for soil liquefaction to result in lateral displacements that extend considerable distances from slopes, land within 200 metres of the gullies and waterways is considered to be Category D.

Areas mapped as surface peat swamps are also included in Category D.

8.2.2 Rolling Hills

The rolling hills that protrude above the alluvial terrace have a mantle of Hamilton Ash which is typically stiff and has a negligible risk of soil liquefaction. Earthworks may expose lower strength soil which can likely be mitigated during the building consent process.

Slope instability can be present on the steeper flanks of the rolling hills; however it is typically shallow and regressive. Deep-seated failures and debris flows are not typical of the hills.

The rolling hills are mapped into Category B. Category C and D land occurs on the flanks of the rolling hills.

8.2.3 Hill Country

The hill country contains a significant deep seated landslide risk and debris flow risk that is a potential threat to property and life. There is also a significant risk of development works destabilising the land or resulting in environmental damage. This area is mapped in Category D and a detailed geotechnical assessment is required. Simplistic approaches to assessing suitability for building are not appropriate.

9.0 Policy recommendations

9.1 Land instability policy area

Future intensification of development of the hill country has the potential to expose Council to significant risk should the current development model and processes continue.

An option is to remove the living and country living zones from undeveloped land within the hill country area. This approach however, would likely be met with resistance by the owners of land that has not yet been subdivided or developed. This would also not address the geohazard issue as new buildings can still be built on rural land as permitted activities.

The recommended approach is for Waikato District to consider a Land Instability Policy Layer for such land. To be effective the Land Instability Policy Area would need to outline the issues, objectives and policies so that it provides guidance to developers, builders and council officers of the significant potential for land instability within this area. Key to such a policy is additional assessment of the existing instability through mapping, examination of current and historic aerial photos, and an estimation of the frequency of landslide-generated debris flows and run out distances.

Development proposals for hill country land will need to consider that not all land will be suitable for development and that greater costs will be incurred to develop the land.

It is also recommended that there is greater emphasis on the developer to undertake the engineering works, including the formation of building sites and accesses within the policy zone. Wherever possible domestic discharges onto and into slopes should be prevented, and provision may be required during subdivision planning and engineering to establish appropriate discharge locations and easements.

9.2 Mine workings policy layer

It is recommended that Waikato District Council obtains all available information regarding areas that have been subjected to underground mining and mine / quarry tailings disposal for inclusion in future revisions of the Waikato District Plan. A development policy should also be formulated for managing consent applications within areas that have been previously mined.

9.3 Liquefaction risk mapping

Many New Zealand Territorial Authorities, particularly those that have alluvial soils, now have high level liquefaction risk maps available to guide development. These maps are often accompanied by guidance on the minimum level of assessment for development and building consent. It is recommended that preliminary mapping be undertaken within the living and country living zones to guide future development and building.

The Hazard information that Council provided AECOM had no information on liquefaction. This appears to be a gap in how information is collected and used to the Council's advantage.

As a minimum it is recommended that engineering reports that contain an analytical liquefaction assessment be added to the Hazard Register with a hazard grading. To aid the usefulness of the information would be to require that all liquefaction assessments be supplied with the raw CPT data in electronic form for future area wide analysis.

9.4 Increased geotechnical focus

AECOM also recommends that the Waikato District Plan and Structure Plans include an update to Appendix B engineering standards to include an increased focus on best practise geotechnical engineering and integration with the other engineering standards.

9.5 Definitions

AECOM recommends that future revisions of the Waikato District Plan and Structure Plans include definitions in Appendix P for the following:

- Natural hazard

- Geotechnical suitability

10.0 References

Edbrooke, S.W. (compiler) 2005. Geology of the Waikato Area. Institute of Geological and Nuclear Sciences 1:250:0000 Geological map 4. 1 sheet + 68p. Lower Hutt, New Zealand: Institute of Geological and Nuclear Sciences Limited.

Kear, D. and Petty, D. R. 1976, Waikato Coalfiields: Glen Massey Coalfield, 1:15 840, New Zealand Geological Survey Miscellaneous Series Maps 7 (Geology) & 8 (Mining) and notes (14p), New Zealand Department of Scientific and Industrial Research, Wellington.

New Zealand Institute of Geological and Nuclear Sciences, Quakesearch, http://quakesearch.geonet.org.nz/

Taylor, M. 2012, Geohazard Mitigation in New Zealand - In Search of a normative and informative balance. New Zealand Geomechanic News, Bulletin of the New Zealand Geotechnical Society, Issue 83, June 2012.

Waikato District Council, 2013, Ngaruawahia Structure Plan Preliminary Assessment Scoping Report.

Waikato Regional Council, 2003, Waikato Region Earthquake Hazard Map.

11.0 Limitations

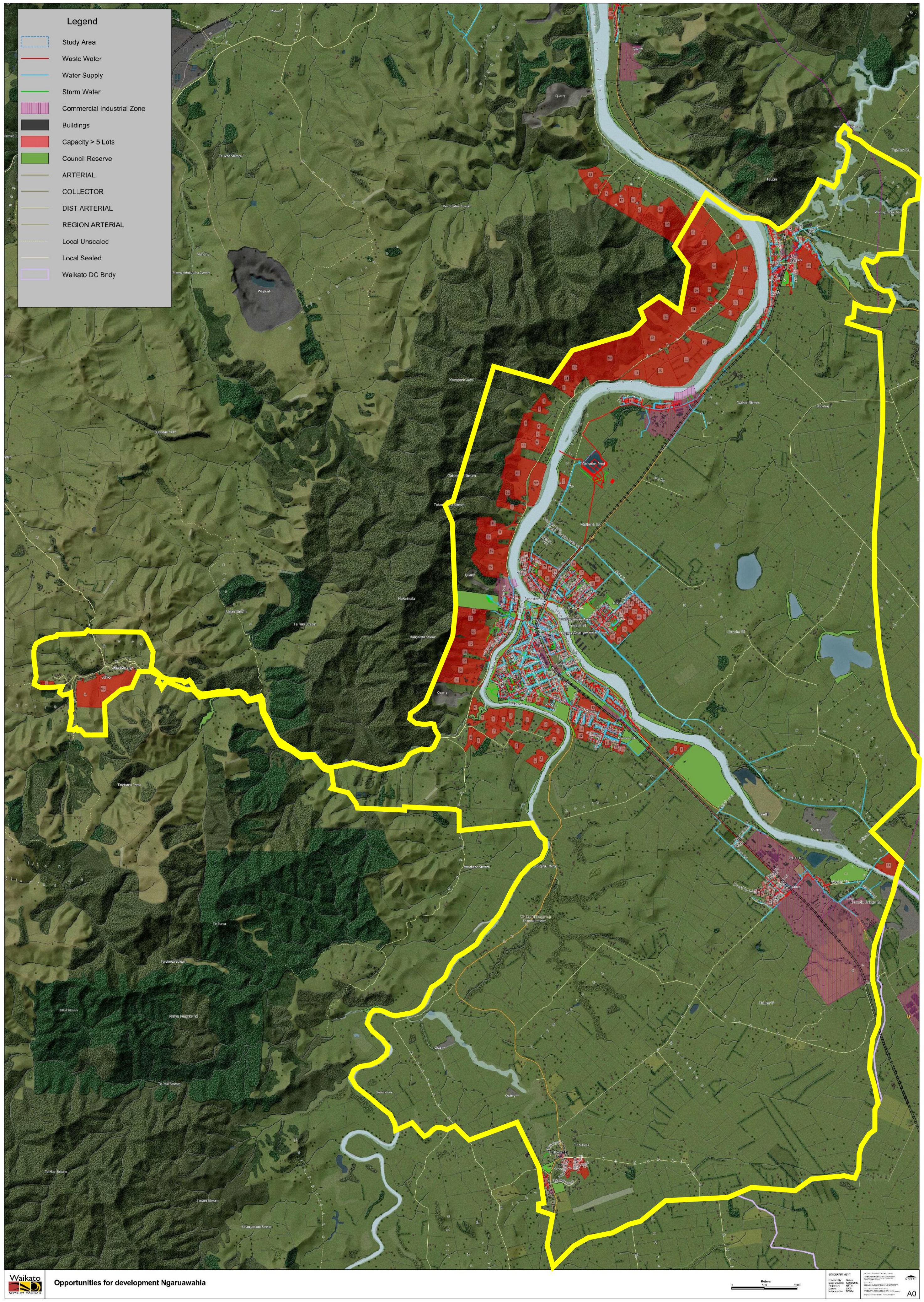
The recommendations and opinions contained in this report are based upon topography, geological maps and engineering experience of the issues within the areas considered. Inferences about the nature and continuity of geohazards are made using geological principles and engineering judgement. However it is possible that ground conditions over the site may vary and therefore it is not possible to guarantee that all hazards have been identified and appropriately zoned.

This report has been prepared for the particular project described in the owner's brief to us and no responsibility is accepted for the use of any part of this report in other contexts or for any other purposes.

Appendix A

Figures

ISO A1 594mm x 841mm



Plan showing the study area
supplied by Waikato District Council

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SHEET TITLE

Study Area

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A1

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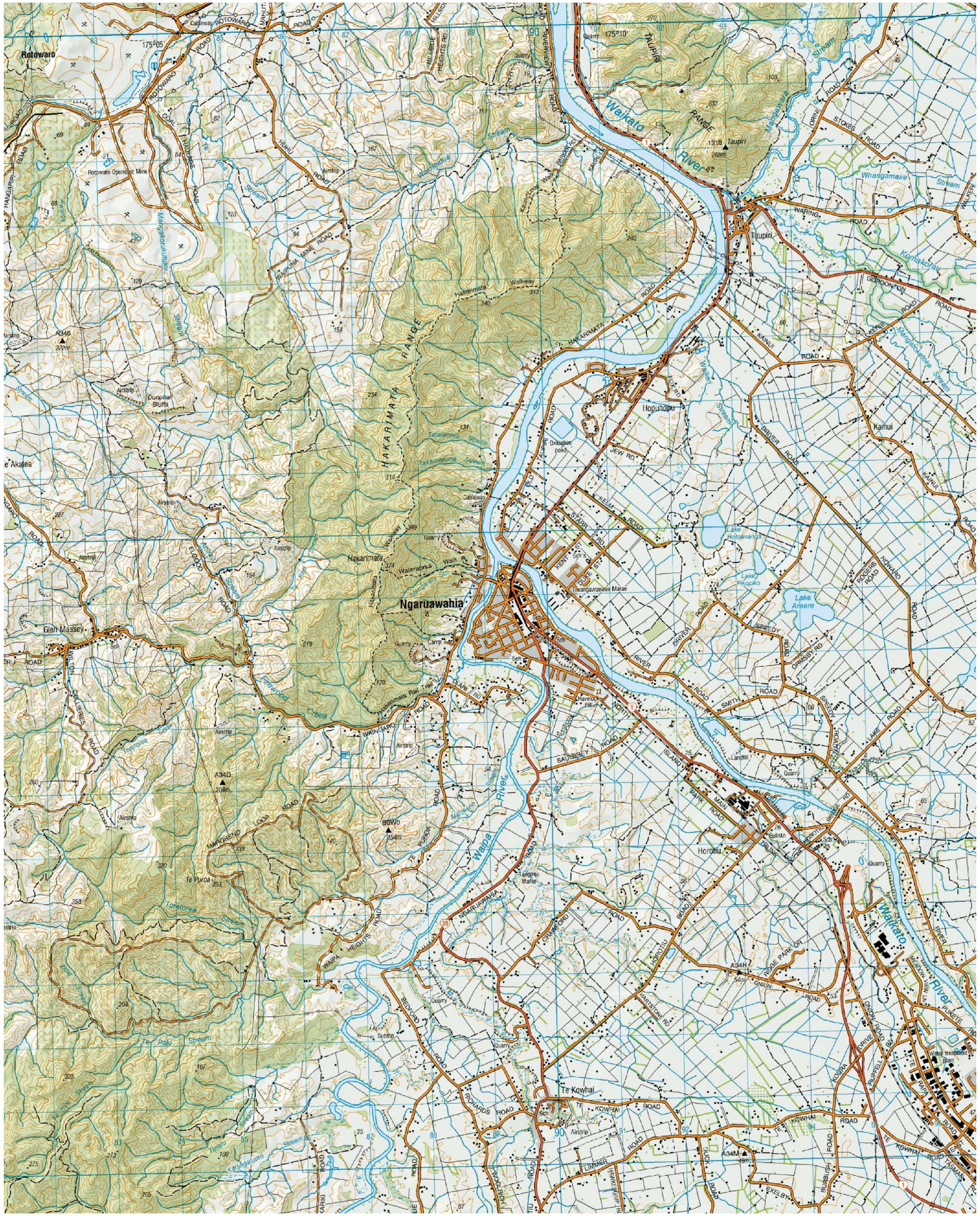

Topographic Map sourced from
Topomap.co.nz
Land Information New Zealand (LINZ)

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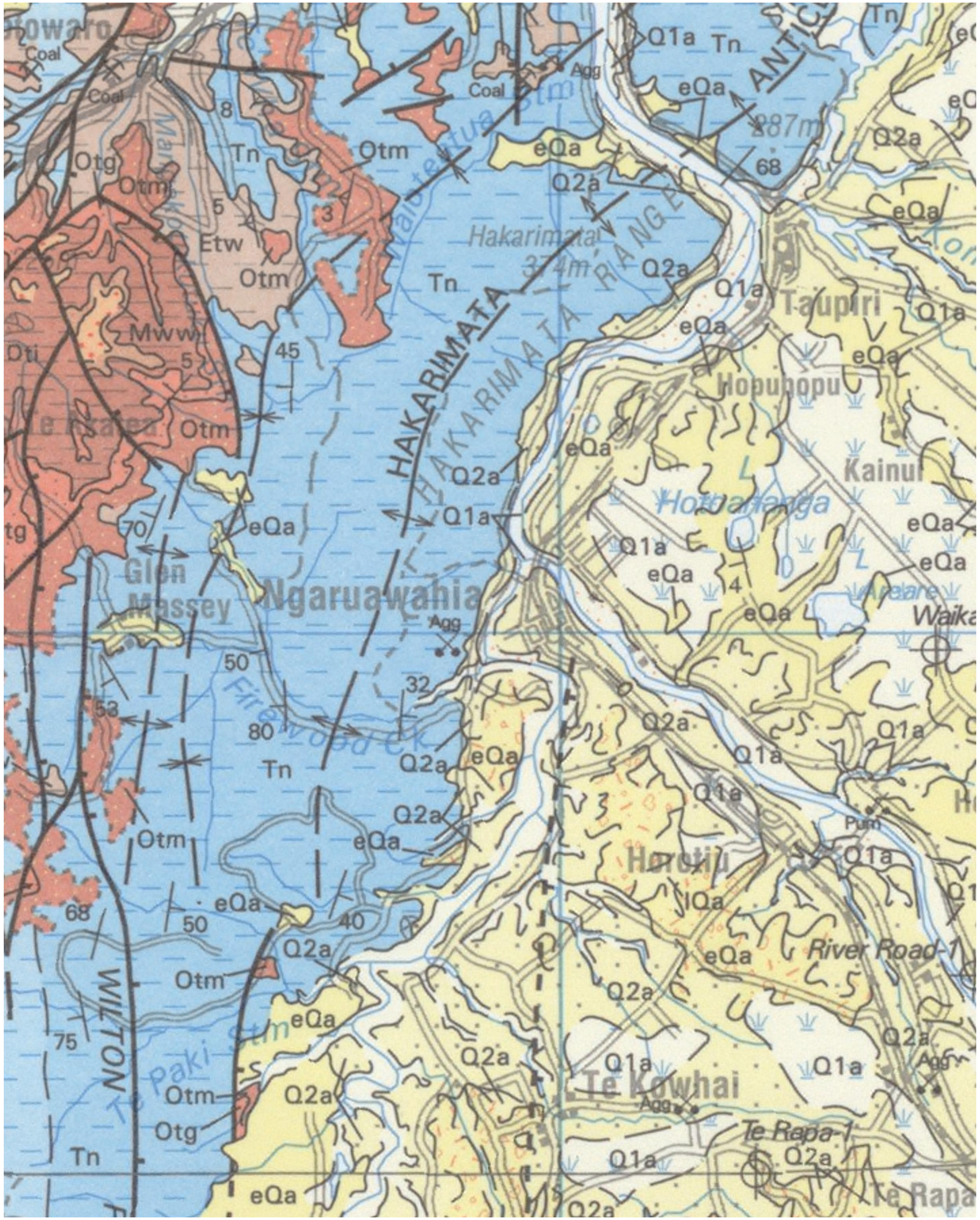
SHEET TITLE

Topographic Map

SHEET NUMBER

A2



Alluvium/ colluvium	Swamp/peat deposits	Pumice alluvium	
		Q1a	TAUPO FORMATION (Q1a) Pumice sand, silt and gravel alluvium with charcoal fragments.
Q1a			Alluvial and colluvial sand, silt, mud and clay with local gravel and peat beds (Q1a).
	Q1a		Swamp deposits consisting of soft, dark brown to black, organic-rich mud, muddy peat and woody peat (Q1a).

Q2a	HINUERA FORMATION (Q2a) Cross-bedded pumice sand, silt and gravel with interbedded peat.
Q2a	Predominantly lacustrine mud, silt, sand and gravel with interbedded peat (Q2a).
lQa	Alluvial and colluvial pumiceous clay, sandy clay, silt and gravel with local muddy peat (lQa).

eQa	WALTON SUBGROUP (eQa) Pumiceous alluvium and colluvium dominated by primary and reworked, non-welded ignimbrite.

NEWCASTLE GROUP (Tn) Predominantly thin-bedded to massive siltstone with fine- to coarse-grained sandstone, mainly in the upper part, and rare shellbeds. Common zeolite veins and some tuff beds. Thick conglomerate (> 1000 m) south of Kiritehere.	Tn

FOLD

Anticline

Syncline

FAULT *

Fault (tick on downthrown side)

Reference:
Edbrooke, S.W. (compiler) 2005. Geology of the Waikato Area.
Institute of Geological and Nuclear Sciences 1:250:0000 Geological map 4.
1 sheet + 68p. Lower Hutt,
New Zealand: Institute of Geological and Nuclear Sciences Limited.

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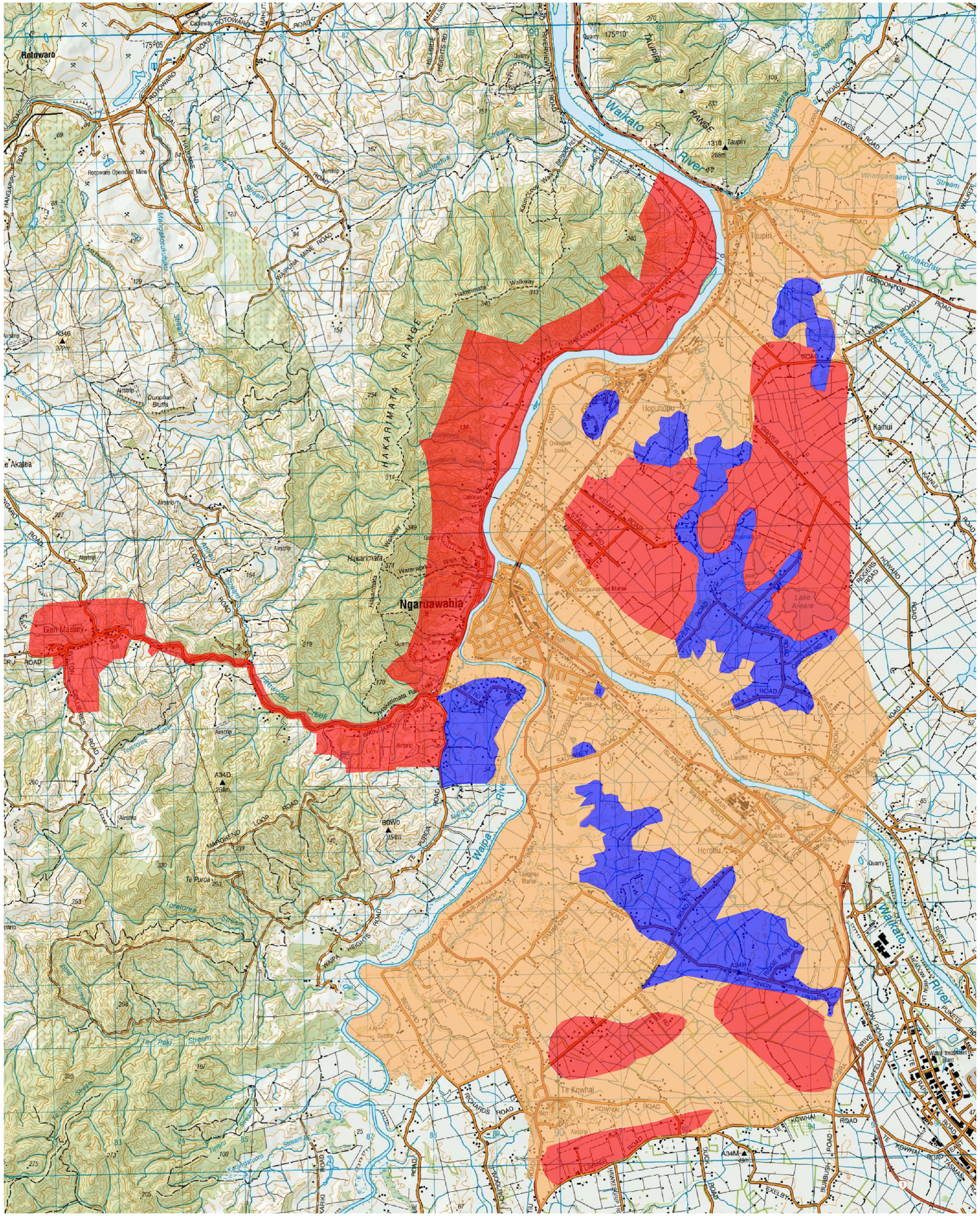
Geological Map

SHEET NUMBER

A3



Land Development Suitability Categories

Category A - Low Risk

- Geohazrds unlikely
- Residential buildings likely to adopt NZS3604 with no ground improvement
- Minimal engineering input required
- Bulk earthworks are unlikley
- Cumulative effects of stormwater and wastewater discharges still require assessment
- No Category A land mapped within study area due to scale of map

Category B - Some Risk

- Possible for geohazards to be present
- Moderate level of engineering input appropriate
- Residential buildings likely to adopt NZS3604 with shallow ground improvement or foundation deeepening away from geohazards
- Some risk of bulk earthworks being undertaken
- Individual and cumulative effects of stormwater and wastewater discharges to be assessed
- Mapped as Rolling Hill Topography
- Flanks of some hills may include pockets more appropriately considered Category C or D

Category C - Moderate Risk

- Likely for geohazrds to be present
- Detailed engineering assesment required to adress impacts on buildings roads and infrastructure
- Some risk of bulk earthworks being undertaken
- Individual and cumulative effects of stormwater and wastewater discharges to be assessed
- Mapped as alluvial soil - Note Category D is applicable within 200m of waterways, lakes and open drains and gully/river terrace slopes

Category D - High Risk

- Likely that a significant geohazrds is present
- Detailed engineerign assesment required to adress impacts on buildings roads and infrastructure
- If the potential geohazard confirmed then mitigation is unlikley to be possible in a safe and economically viable manner
- High environmental risk due to earthworks
- Individual and cumulative effects of stormwater and wastewater discharges to be assessed
- Hill Country and adjacent land due to potential for large landslides and debris flows
- Peat swamps with settlement and liquefaction potential
- Includes alluvuial soil within 200m of waterways and gully/river terrace slopes (not shown on map)

NOTES:
1. Boundaries are approximate and based on large scale topographic and geological maps
2. Classification zones do not adress flood hazard
3. This map does not imply that all of the land within any category is subject to the geohazards typical of the zoning. The intent of the plan is to provide guidance to Council on the general suitability of the land and the starting point for engineering assessment that should accompany development proposals. It is possible that a specific assessment could either upgrade or downgrade the risk within any given property.

Topographic Map sourced from
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Land Information New Zealand (LINZ)

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SHEET TITLE
Development Suitability Categories

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A4

Appendix B

Seismic history

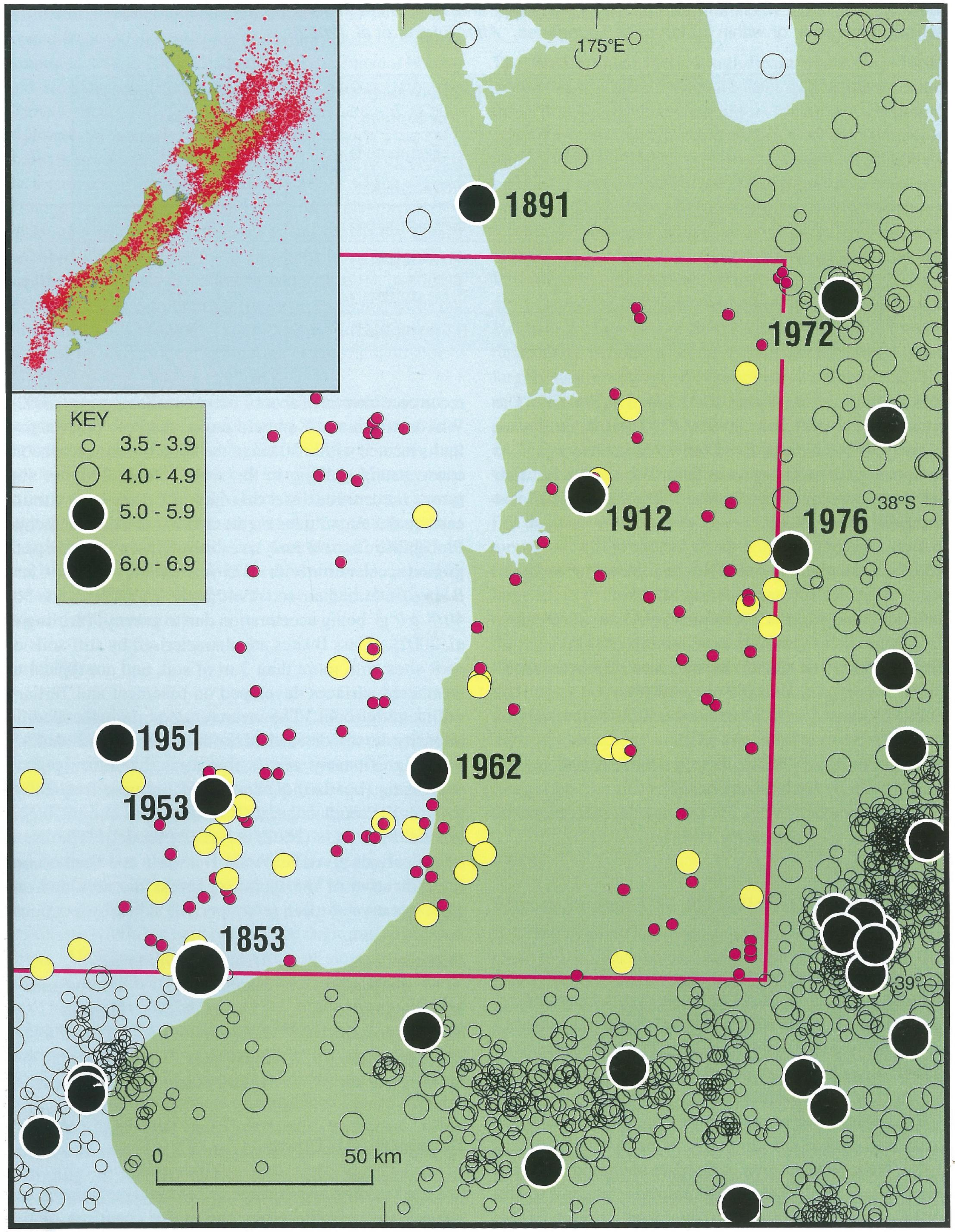

Figure 61 Locations of shallow (depth ≤40 km) earthquakes in the Waikato map and surrounding area, with magnitudes M≥3.5 (January 1840-June 2003). Note that the record of small earthquakes is incomplete before 1964, and the record of moderate to large earthquakes is probably incomplete before 1900. Inset: Shallow earthquakes recorded in the New Zealand region from 1964 to 2002.

Reproduced From:
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Seismic History

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B1

Appendix C

Case studies

Appendix C Case studies

Case Study1 – Canterbury development prior to 2010

Following the Canterbury Earthquake sequence that commenced in September 2010, councils, central government and insurance companies have incurred enormous costs repairing the damage to public and private property.

The New Zealand Geotechnical Society has published a paper by Merrick Taylor which delves into what was known about liquefaction in Canterbury pre 2010 and the processes for development and building consents.

Despite the existence of liquefaction hazard maps produced in the 1990s and the inclusion of these in the Regional Plan, only two developments considered the potential for liquefaction. This was due to the reliance on engineers acting for the developer, and a lack of direction from council officers.

The situation arises from the developers' profit motives and desire to do the minimum required to get a consent. The engineers were operating in a competitive market and generally followed their clients brief to do the minimum required. The minimum required was based on the engineers' experience with previous consents.

Taylor concluded that the reliance on individual engineers and the absence of clear direction from council officers resulted in development and building occurring in areas that had been previously identified as hazard prone without addressing the hazard. The developments that did include mitigation measures had engineers that had a "full awareness of such hazards and international best practice with regards to the evaluation and mitigation".

There is potential that local authorities could be exposed to risk if new developments are consented without reasonable consideration of natural hazards, if a reasonably foreseeable hazard occurred.

Hazard avoidance and mitigation requires appropriate zoning, the collection and dissemination of information regarding hazards, and policies and rules that direct developers and their engineers to assess those hazards.

Case Study 2 – Hakarimata Road, Ngaruawahia

In July 2012 a slip occurred on the ridge supporting a dwelling that had been recently relocated to the site. A series of aerial photographs from Google Earth Pro follow this discussion.

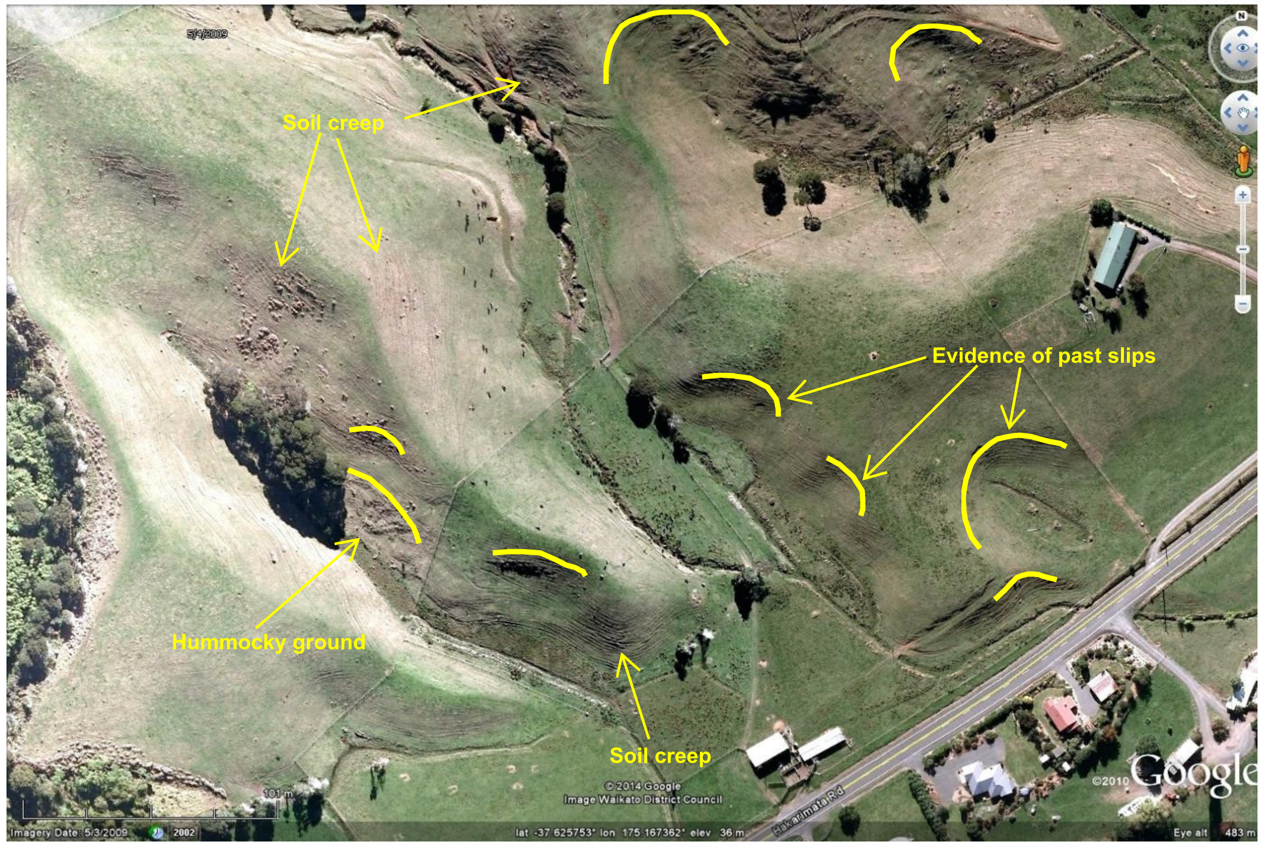
The pre-existing ridge slope is estimated to be 30 to 32 degrees. Following a period of normal winter rainfall a slip occurred with a back scarp estimated to be 8 to 10 metres high and 15 to 20 metres long. The resulting debris flow is still visible in the August 2012 image, which shows the debris travelled in excess of 100 metres from the scarp. The debris also had enough velocity to travel up the adjacent ridge. When the debris came to rest it was approximately 2 metres thick at the toe.

Prior to the slip occurring the there was a stream near the toe of the ridge, with a stream bank height of approximately 0.5 metres. The aerial image taken in May 2012, shows the house positioned on the site and the formation of the access driveway up the ridge. Comparing these two photos indicates that the track did not cut into the toe of the slip.

The 2009 aerial photograph is very clear and shows numerous large slips in the vicinity of the site, indicating that slips of this size and magnitude have happened in this area previously and can be expected to happen in the future. Examination of aerial photographs along Hakarimata Road indicates instability of this size is not unusual, and much larger slips have occurred in the past.

Had this house been positioned on the slip or in the path of debris flow it would have been destroyed, and any occupants would have been unlikely to survive.

ISO A1 594mm x 841mm



1. This image was taken in May 2009. It shows multiple slips have occurred in the past. Associated with these slips are evidence of hummocky grounds and soil creep.

2. This image was taken in July 2010. No major change in slope.

3. By May 2012 a house was relocated to the risge. The image indicates that the driveway did not interfere with the toe of the slope, which subsequently failed in July 2012. The image also indicates that no earthworks were undertaken on the slope.

4. This image was taken in August 2012 approximately 6 weeks after the slip occurred. Note the soil has flowed approximately 100 metres from the headscarp. Works have cleared the driveway however surge marks are still visible on the opposite ridge.

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All images are sourced from Google Earth Pro 2014

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Case Study 2 - Aerial Photos

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C1

5. Looking across slip backscarp towards Hakarimata Road.

7. The size and depth of back scarp is apparent in this photo

6. Note debris flow had sufficient velocity to travel several metres up adjacent slope and topple mature trees.

8. View from Hakarimata Road. Note the thickness of the debris 100m from the source.

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Case Study 2 - Site Photos

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C2