REPORT

WHANGAREI DISTRICT COUNCIL

Land Zonation Mapping Geotechnical assessment level/stability hazard mapping for Hikurangi, Mid Kensington, Whangarei City Centre, East Kamo & Portland

Report prepared for:

WHANGAREI DISTRICT COUNCIL

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Distribution:

WHANGAREI DISTRICT COUNCIL	2 copies
TONKIN & TAYLOR LTD (FILE)	1 copy

June 2008

T&T Ref: 24010.002 / Volume 1

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1 Introduction

1.1 General

Tonkin and Taylor Ltd (T&T) were engaged by Whangarei District Council (WDC) to undertake an assessment of land stability in areas that were under development pressure within the Whangarei District. The purpose of the assessment in all areas is to:

- Inform Council of the level of slope instability hazard
- Inform Council of the suitability of the land for residential development
- Alert Council of the areas that are considered to have a high probability of slope instability
- Provide Council with a basis for determining the geotechnical assessment requirements to support applications for subdivision and building consent in these areas
- Assist Council with future planning of the areas.

This report presents our Geotechnical Assessment Level/ Slope Instability Hazard assessments for five large areas on the outskirts of Whangarei City. In particular the areas that have been mapped are;

- Hikurangi
- Mid Kensington
- The area east of Kamo and west of Kensington
- Whangarei city centre
- Portland.

Definitions of each zone are given, as are recommendations for the levels of geotechnical investigation that should be considered for each zone. General engineering geological characteristics of the areas are also described, as the behaviour of the slopes is very closely related to the underlying geology.

Limitations

The information contained in this document and the accompanying shapefile is presented specifically for the Council for the purposes listed above only. The land instability work has been carried out at a sub-regional scale and is not to be viewed at scales more detailed than 1:5000. Shapefiles have been developed primarily on information obtained from aerial photograph analysis and mapped onto a digital aerial photograph base. No liability is accepted for any of the information presented, as the information is only an indication of what we consider to be the general current level of stability of the land. Land at a section-scale could, in fact, be classified differently from that shown on the plans. It also must be appreciated that slope behaviour is "gradational" in many cases, ranging from very low risk land though to very high-risk. Properties that straddle two zones should be investigated based on the higher geotechnical assessment level category. The shapefiles have been checked against WDC's cadastral data, and are considered to generally lie within the lateral error that exists between the geo-referenced digital photo base and the cadastral, when viewed at 1:5000. However, the plans should not be used as a replacement for site specific assessments.

1.2 Scope of work and methodology

The assessments were carried out by engineering geologists from Tonkin & Taylor Ltd, and included;

1.2.1 Slope stability hazard potential

- A desktop study of the area: This included a review of existing geological publications for the area, and our T&T database, which includes a wide variety of geotechnical investigations that we have carried out in the area, ranging from Earthquake Commission (EQC) landslip claim assessments through to detailed slope instability and stabilisation work. WDC provided information, including ArcView compatible shape files, from their database on known areas of slippage.
- Field reconnaissance. Each area was broadly visited and assessed. Attention focussed on existing geomorphology (i.e. locations of active landsliding and erosion, landslide morphology, slope gradients), rock types based on exposures of the underlying geology and comparison to the rock-types presented on existing geological maps, the locations of seepage lines (to provide an indication of groundwater conditions), and the locations of residential dwellings in each of the areas.
- Aerial photograph analysis: This was the main method used to zone the land. Stereographic aerial photographs taken in March 1998 at a scale of 1:10,000 were primarily used, because of their high degree of observable detail. Analysis of more recent photographs (July 2002/ Jan 2004, 1:30,000 colour photographs) was also undertaken as a check, and to identify any new areas of land that have been subject to instability. These were also used to zone the land in areas the 1998 series did not cover. The difference in scale of the two series results in those areas zoned using the 2002/2004 colour photographs having a lower degree of accuracy than those zoned using the 1998 black and white photographs. Three classes of hazard were used to zone the land, based on specific characteristics described below. The information was digitised into a GIS database using a high-resolution aerial photo-base overlain by 2 m topographic contours of the area (both supplied by WDC).
- Calibration: The digital map was then calibrated in the field to check the map accuracy of the digitisation and the aerial photograph interpretation.
- Checking: A further field check was made by a senior geotechnical specialist from T&T.

1.3 Previous work

Tonkin & Taylor have previously carried out similar slope instability hazard mapping of Whangarei Heads and Langs Beach, Whangarei Heads, the area from Waipu Cove to Langs Beach, Bland Bay to Taiharuru, the Kamo, Maunu, Onerahi, Otaika and Tikipunga areas and geotechnical assessment level/ stability hazard mapping for Hikurangi, Mid Kensington, Whangarei City Centre, East Kamo and Portland.

In 2000, 2001, 2002, 2004, 2006 and 2007 respectively (T&T report reference 18028, Whangarei District Council, Landslip hazards, Whangarei Heads and Langs Beach, November 2000; T&T report reference 18517, Whangarei District Council, Land Slope Stability Hazard Zonation, Waikaraka to Ocean Beach, August 2001; T&T report reference 18517, Whangarei District Council, Land Slope Stability Hazard Zonation, Langs Beach to Waipu, July 2002; T&T report reference 18517, Whangarei District Council, Slope Instability Hazard potential, Bland Bay to Taiharuru, June 2004; T & T ref 22705, Whangarei District Council , Coastal Structure Plan; Slope instability hazard potential and effluent disposal potential, Oakura to Langs Beach, August 2005; T&T report reference 22789, Whangarei District Council, Land Zonation Mapping, Stability hazard mapping/geotechnical assessment level and effluent disposal potential for Kamo, Maunu, Onerahi, Otaika and Tikipunga, July 2006; T&T report reference 24010, Whangarei District Council, Land Zonation Mapping, Stability hazard mapping/geotechnical assessment level geotechnical assessment level/ stability hazard mapping for Hikurangi, Mid Kensington, Whangarei City Centre, East Kamo and Portland, August 2007).

2 Engineering geology

2.1 General

The engineering behaviour of the areas surrounding Whangarei varies along with the geology.

This section summarises the engineering geological and soil type characteristics of the study areas, and their relationship to slope stability. The sources of geological information are described first, followed by a description of the main geological groups and their particular engineering geological characteristics.

The geological characteristics are also among the factors used in producing effluent disposal potential zones and, along with soil type, will be discussed further in the related subsections.

2.2 Sources of geological information

Much of the study area is covered by the 2003 IGNS 1:25,000 map, "The Geology of the Whangarei Urban Area" (White and Perrin, 2003).

For the areas not covered by the 1:25,000 map, the NZ Geological Survey Map 1:250,000, Sheet 2A Whangarei by Thompson (1961) is currently the most widely used publication of geological information in the Whangarei District. Although the publication is now more than 40 years old, the information provided in it is generally suitable for engineering purposes due to the overall lithological simplicity of the underlying geology.

It should be appreciated that information from any map produced at either of these scales should not be relied upon for site specific investigations.

Unfortunately modern published information showing the distribution of the geology, and summarising the stratigraphy and structure of the outskirts of the mapping areas is relatively sparse. The NZ Geological Survey Maps 1:250,000, Sheet 2A Whangarei by Thompson (1961) is limited in that the understanding of the geology of Northland has changed significantly since its publication, and the map can really only be used as a very broad indication of the underlying geology. For example the distribution of Northland Allochthon geology (described below) is far more widespread in some areas than is shown on the map. That map therefore should not be relied upon for site specific investigations. The IGNS is due to publish a new 1:250,000 "Q-Map" of the geology of the Whangarei District within the next 2 years. However information from any map produced at that scale should not be relied upon for site specific investigations.

There are some published papers describing localised geology of the Whangarei area, although these have tended to focus on specific localised geological units or structure, with little information showing the distribution of the units. Perhaps the most useful and up to date publication describing Northland Geology is "Cretaceous and Cenozoic Sedimentary Basins of Northland, New Zealand", by Isaac et al. (1994). This Monograph summarises the stratigraphy and structure of the Northland region, with a good summary of the formation of the Northland Allochthon, regional engineering geology and material characteristics.

There are significant differences in the geology of each of the study areas. The lithological units represented in each area are identified first, then each unit described in more detail.

2.2.1 Geological distribution

2.2.1.1 Hikurangi

The geology of this area can be subdivided into the following geological groups.

- Northland Allochthon: These rocks outcrop extensively in the north, covering approximately 50% of the area. The rocks typically comprise highly sheared and crushed variably calcareous and siliceous mudstones. These rocks tend to be chaotic in structure, and are generally prone to landslippage. They are also referred to as the "Onerahi Chaos".
- Te Kuiti Group: Again in the north, but much smaller outcrops. Comprising Ruatangata Sandstone, blue to green-grey glauconitic, calcareous muddy sandstone, and Kamo Coal Measures- conglomerate, sandstone, mudstone, clay and coal. The Kamo coal measures have been extensively mined, with significant subsidence occurring in some localities. This hazard has been reviewed in an earlier Tonkin and Taylor report. (T&T Ref 18596, January 2001.)
- Holocene sediments: Generally cover low lying ground in the southeast, typically comprising soft to firm alluvial sediments or swamp deposits
- Parahaki Rhyolite '(Coromandel Group): Outcrops in the southwestern part of the area, and comprises a biotite rhyolite extensively altered to halloysitic clay.
- Waipapa Group: Strong shattered greywacke and argillites outcropping in the east of the area.
- Kerikeri Volcanic Group: Mostly basaltic lava, to the south of the area.

2.2.1.2 Central Kensington

The geology of the central Kensington area is very simple

- Kerikeri Volcanic Group: Plio-Pleistocene age rocks, outcropping over 90% of the area. Basalt lavas and scoria cones
- Holocene sediments: Generally cover low lying ground in the south, typically comprising soft to firm alluvial sediments or swamp deposits.

2.2.1.3 Area between East Kamo and West Kensington

In this area there are four groups of geological materials. These are;

- Waipapa Group: These dominate, covering 75% of the area in the south. Generally strong shattered greywacke and argillite
- Northland Allochthon: Typically highly sheared and crushed mudstones, variably calcareous and siliceous mudstones, siltstones, sandstones, muddy limestones (marls), and limestones. These outcrop in a small area in the east, between the greywacke and the Kerikeri volcanics.
- Kerikeri Volcanic Group: Mostly basaltic lava, outcropping in the hills in the northwestern part of the area.

- Holocene Sediments: Typically alluvium, covering a small proportion of the area, in a low lying area in the west.

2.2.1.4 City Centre

There are five main groups of rocks in the area.

- Kerikeri Volcanic Group: these basaltic lavas underlie the higher ground to the north of the city centre.
- Man-made Fill comprises the reclaimed land in the east and south of the city centre. This amounts to more than a third of the area.
- Northland Allochthon, outcropping in the south, in the area around the rugby ground. Mid Eocene to late Oliocene age, highly sheared and crushed sandstones and interbedded mudstones and siltstones with some minor conglomerate.
- Purua Formation, consisting of gravel, sand and mud of late Miocene-Pleistocene age, outcrops alongside the Northland Allochthon, by Okara Park.
- Early Pleistocene-Holocene alluvial sediments cover the low lying areas in the west of the city centre, to the north of the outcrops of allochthon and Purua Formation.

2.2.1.5 Portland

This is the largest area in the study. There are five main groups of rocks in the area.

- Waipapa Group: Strong shattered greywacke and argillites outcrop a west-east running ridge in the north of the area.
- Northland Allochthon underlies more than half the Portland area. Whangai Formation, grey-white siliceous and locally calcareous shattered and sheared muds outcrops in the west. Mahurangi Limestone, which is grey-white muddy limestone and is also shattered and sheared, outcrops on the higher ground underlying the quarry in the central-southwest Portland area. The undifferentiated Northland Allochthon rocks outcropping in the southeast of the area include highly sheared and crushed calcareous glauconitic sandstones and interbedded mudstones and siltstones and minor conglomerate. The Northland Allochthon rocks range from late Cretaceous to early Miocene age.
- Te Kuiti Group: Comprising Onemama Formation sandstone, flaggy glauconitic, calcareous sandstone and sandy limestone, some tuff and allochthon-derived conglomerate, of late Oligocene age. Outcrops in the eastern half of the area, from Tapu Point to Onemama Point, with a smaller outcrop further south.
- Early Pleistocene-Holocene alluvial, swamp and estuarine sediments cover a small proportion of the Portland area. They are present in the low lying areas along the rivers in the north and south, and along the coast.
- Man-made Fill comprises a small area of reclaimed land on the southeast coast of the area.

2.2.2 Engineering geology of the Lithological Groups

The engineering geological characteristics of the above geology are given in the following subsections. Description of the structural geology, however, is not given as it is outside the scope of this study. The unweathered intact rock types are described first, followed by information on the predominant rock mass characteristics, typical weathering profile groundwater.

2.2.2.1 Waipapa Group

The Waipapa Group of rocks predominantly comprises shattered Triassic to Jurassic age (140 to 200 million years old) greywacke and argillite. In their unweathered form these rocks are dark bluish grey, and strong (typically with unconfined compressive strength greater than 50 MPa), due to low-grade metamorphism of the sediments.

Waipapa Group rockmass generally comprises very closely to extremely closely spaced (<20 mm to 60 mm) joints, present in numerous joint sets at various orientations. The greywacke rockmass also tends to contain many sheared and crushed zones. However, despite the rock being very fractured, the high intact rock strength gives the Waipapa Group a relatively high overall rockmass shear strength.

The Waipapa Group usually has a deep weathering profile ranging from unweathered greywacke and argillite at 10 m to 20 m below the surface; through to highly weathered to completely weathered rock close to the surface. The latter materials typically form a soil mass (i.e. a regolith) of very stiff to hard light brown gravelly and clayey silts. Residual soil derived from these materials typically comprises very stiff silty clays and clayey silts, typically containing predominantly non-swelling kaolinitic clays (i.e. not subject to large changes in volume due to changes in moisture content). These soils are generally only present in the top 2 m on low gradient slopes, such as ridgelines and flats, and in the top 1 m on steep slopes.

Groundwater is usually deeper than 5 m due to the relatively high fracture permeability of the rockmass, the steepness and relatively high relief of the slopes.

Slopes that are underlain by Waipapa Group materials are generally characterised by moderate to steep sided slopes (15° to >30°) with minor shallow seated slippage and gully erosion within the soil mantle generally only within the steepest slopes (i.e. >30°). The slopes can generally stand at moderately steep gradients due to the relatively high strength of the rockmass and overlying soil mass.

2.2.2.2 Northland Allochthon

a Whangai Formation and Undifferentiated Northland Allochthon

Northland Allochthon rocks underlie a significant proportion of the study areas, particularly Portland and Hikurangi. The “Northland Allochthon” is a collective name that refers to a wide variety of Late Cretaceous to Early Tertiary Age (110 to 23 million years old) predominantly marine sedimentary rocks that have been tectonically emplaced (regionally displaced) from the north over the Waipapa Group basement rocks. The lithologies within the Northland Allochthon have not been differentiated on the geological plan due to the internal complexity of the group of rocks. Northland Allochthon materials were previously widely referred to as the “Onerahi Formation”, “Onerahi Chaos”, and “Onerahi Chaos-breccia”. These names are still widely used by the geotechnical and civil engineering community.

The Northland Allochthon rocks range from non-calcareous (very weak to weak) mudstones and sandstones, through to highly calcareous and/or siliceous moderately strong (20 to 50 MPa) mudstones (marls) and limestones. The colouring of these rocks is also highly variable, ranging between greyish green, dark grey, reddish brown and purplish grey rocks through to light grey, and light greenish grey and greyish white. Swelling clays of the smectite group (e.g. montmorillonite) are present in differing quantities within almost all of the lithologies.

The Northland Allochthon lithologies are typically moderately to pervasively sheared and crushed, generally depending on lithology (rock type). Tectonic deformation, as a result of the regional displacement of the strata, appears to have mostly taken place in the softer lithologies, which are consequently highly to pervasively sheared and crushed. The harder lithologies have still undergone significant deformation, but to a lesser degree. The shear fabric within the rocks is variable, but is commonly at a low angle (generally between 0 and 30°), and the shear surfaces are typically highly polished and coated in clay. The rock mass strength therefore tends to have a relatively low horizontal shear strength. The shear strength of the Northland Allochthon mudstones is typically the lowest, due to the intense shearing, and also due to the high proportion of swelling clay minerals of the smectite group (e.g. montmorillonite) within the rocks. These materials usually have low residual friction angles between 8° and 16°. On the other hand, limestones and very calcareous and/or siliceous mudstones typically have the highest rockmass shear strength within the Northland Allochthon due to the strength of the intact rock.

The Northland Allochthon rocks tend to have a very shallow weathering profile, generally ranging from about 1.5 m to 3 m in thickness for the soft mudstone lithologies, progressively increasing in thickness through to about 5 m to 6 m thick for the harder calcareous and siliceous lithologies. Soils developed as a result of weathering are typically mottled light greyish white, light yellow, and light brown. The soils are also generally wet, highly plastic, and of low material shear strength (usually firm to stiff). The shear fabric within the parent materials is typically preserved, forming defects within the soil mass.

Groundwater is usually very close to the surface for the soft mudstone lithologies (<2 m) due to their very low permeability, increasing with depth in the more competent calcareous and siliceous rocks, which have higher rock mass permeabilities.

Slopes that are underlain by Northland Allochthon geology typically reflect the strength of the rockmass of the predominant lithology. Consequently, slopes underlain by these materials stand only at gentle to moderate gradients due to their general low to very low overall rockmass strength. For example, non-calcareous and non-siliceous mudstone lithologies (e.g. "Hukerenui Mudstone") tend to stand between 7° and 14°, calcareous and/ or siliceous mudstone lithologies (e.g. "Whangarei Formation") usually stand between 14° and 30°, whilst limestones and marls naturally stand at gradients greater than 30°.

The surface morphology of slopes underlain by Northland Allochthon lithologies is also typically (and distinctively) hummocked and undulating, mainly due to the susceptibility of the materials to slope instability. Localised "floaters" of harder Northland Allochthon lithologies incorporated within the sheared and crushed softer lithologies tend to stand proud, also providing a hummocked surface morphology.

The low rockmass strength and the generally high natural groundwater table within the highly sheared and crushed mudstones make this lithology the most unstable. It is also likely that most of the slopes underlain by these rocks are only just above equilibrium (with Factors of Safety less than 1.2), in addition to being generally the most sensitive to small changes in slope gradients.

Some mudstones and sandstones of the Northland Allochthon (called the "Whangai Formation" mudstone and "Omahutu sandstone") are particularly unstable, and may slip even on slopes of less than 10°. Steeper slopes underlain by Whangai Formation, such as some in the Otaika area, tend to be made up of a series of complex, creeping landslides, probably about 5 m deep, but possibly up to 20 m deep in some places. Generally, areas underlain by these soft rocks of the Northland Allochthon are considered to have a high risk of failure where they have a gradient of 15° or more. This includes parts of Raumanga, Kioreroa, Morningside, Riverside, and much of the land south of the Otaika Fault.

There are many known examples of ancient and active landslides in the Whangarei area that are in Northland Allochthon lithologies. These include some very large slides such as the one at the Onerahi end of Riverside Drive, near Sherwood Rise, and another north of Otaika Creek. The former exhibits no signs of recent movement but the latter is probably currently creeping. There are also areas of known creeping in Morningside, Maunu, and Kamo. Much of this may be attributed to the effects of deforestation, although as slopes tend to settle to a semi-stable lower slope angle, and movement has generally been decreasing since the 1940's. Nonetheless, it is important that any modification of slopes underlain by rocks of the Northland Allochthon, or of drainage, accounts for the possibility of renewed instability.

b Mahurangi Limestone

The Mahurangi Limestone differs from most rocks of the Northland Allochthon in that it is generally significantly more stable, less prone to slumping, stronger and more resistant to erosion. The large outcrop at Portland, where the limestone is quarried for use by the cement works, forms Tikorangi Hill, high ground surrounded by lower lying, softer mudstones of the Whangai Formation.

The limestone is pale grey to white, muddy and sheared. It is strong, flaggy and closely jointed. It has approximately 70-80% CaCO3. Thin calcite veins are common, and small kink folds are present in some localities. The limestone is made up of plankitic foraminifera, radiolaria, coccolits, spone spicules and terrigenous mud. The microfossils indicate bathyal depths of deposition and early Oliocene age. Macrofossils are very rare in the Mahurangi Limestone and none have been found in this area.

In addition to being used for the manufacture of cement, Mahurangi Limestone is used for roading aggregate on secondary roads and farm tracks, although it is not ideal for the purpose due to its being softer and less stable than many other aggregates, and consequently less durable.

2.2.2.3 Te Kuiti Group

The Te Kuiti Group in this area is represented by the Ruatangata Sandstone Kamo Coal Measures in the Hikurangi area and Onemama Formation in Portland. Whangarei Limestone is not present.

a Kamo Coal Measures

Kamo Coal Measures are present only in small outcrops in the Hikurangi area, although mining and exploration drilling have shown them to be extensive at depth in these areas. They unconformably overlie the Waipapa Group greywacke and are conformably overlain by the Ruatangata sandstone or in tectonic contact with rocks of the Northland Allochthon. Kamo Coal Measures comprise basal sandstones overlain by one or two coal seams up to 8 m thick, separated by 20 m of carbonaceous mudstone, sandstone and fireclay. The top member of the formation is a conglomerate. The Coal Measures appear to have formed in a series of west-draining, WSW-ENE oriented half grabens and are therefore variable in thickness and pinch out completely in many areas.

At Kamo the Coal Measures are 1-49 m thick. The fine grained clastic facies predominate, and the two main coal seams are a total of 10 m thick. In the Kiripaka half-graben, the coal measures are at least 100 m thick. The lower coal measures consist of conglomerates derived from Waipapa Group argillites, sandstones, chert and vein quartz intercalated with upward-fining quartzose sandstones and capped by thin mudstones. Middle Coal Measures are predominantly mudstones and include a seam up to 9 m thick. The Upper Measures are several 2-10 m thick, unstratified/poorly stratified pebble-cobble conglomerates of Waipapa Group sandstone and argillite clasts intercalated with thin mudstone units.

A late Eocene age is generally quoted for the Kamo Coal Measures, although different authors quote a slightly different age range. Isaac et al. (1995) say that the pollen included in the coal measures indicates an age in the order of 42.5 39 million years whilst White et al (2003) have them in the range of 38 to 36 million years.

In the Tikipunga area, the sediments are mostly coarse sandstones derived from greywacke, quartz and chert with conglomerate, rarer mudstone and coal seams up to 1 m thick. The coal is of sub-bituminous A to high-volatile bituminous C ASTM rank. They were deposited in a mostly non-marine coastal plain environment, with swampy ground and an accumulation of fluviatile sand, gravel and mud.

The Kamo Coal Measures are moderately strong and apparently stable. Weathering products can be very clay rich and impermeable.

There are some areas underlain by old mine workings that are subject to subsidence due to collapse of the drive roof or punching of pillars into underlying fireclay. This is worst where the coal seam was within 50 m of the surface, or where more than one coal seam was worked. Where subsidence propagates upwards to the surface it creates crater-like depressions in the order of 1 m deep and 3-4 m across, also causing cracking of concrete and brick structures.

b Ruatangata Sandstone

Ruatangata Sandstone is present in small outcrops in Hikurangi, where it unconformably overlies Waipapa Group greywacke and is probably in faulted contact with the Northland Allochthon. It is hard, massive or incipiently bedded, blue to greenish grey, with some purplish or brownish-grey units in the lower beds, calcite cemented, glauconitic, fine to medium grained muddy sandstone. Beds may be several decimetres thick, fine upwards and may exhibit hummocky cross stratification. It is fossiliferous, with abundant foraminifera and scattered shell fragments. These indicate formation in inner to outer shelf paleo environments and an early Oligocene age (in the order of 36.5-34 million years). The sandstone is typically in the range of 45-65 m thick, although it can reach thicknesses of 204 m, as at Whareora. The formation thins north of Kamo and at Hikurangi is less than 7 m thick. In some areas there is an associated basal conglomerate of 1-3 m (e.g. at Otaika Quarry).

The Ruatangata Sandstone is very variable, but usually moderately weak where it is slightly weathered to very weak where it is highly weathered. It is normally stable, and may stand in tall bluffs but the weaker units can be unstable and minor landslides are reported.

The porosity and permeability of the Ruatangata Sandstone are high enough to make it a fair to good aquifer. Calcareous members may contain solution cavities.

c Onemama Formation Sandstone

The Onemama Formation is most typically comprised of flaggy, planar bedded glauconitic sandy limestone and calcareous sandstone. These are worked for decorative flagstones at Paradise Quarry. Some non-calcareous siltstone beds occur locally, especially towards the top of the unit. The Paradise Tuff Member, which is an altered redeposited tuff of dacite composition and up to 5.3m thickness, is exposed in Paradise Quarry. Also present are coarse polymict breccias, pebble conglomerates and thrust slices of Northland Allochthon units. The smaller, southern outcrop of Onemama Formation, forming the point just north of the cement works, is apparently a block incorporated within the Northland Allochthon. The Onemama Formation rocks are generally stable, tend not to be susceptible to landsliding, with strong rock, wide joint spacing, flaggy partings and solution channels. The tuff member is strong and brittle, extensively jointed, in places cut by many small displacement faults, and is slightly weathered.

2.2.2.4 Coromandel Group Volcanics

The rhyolite of the Parahaki dome , in East Kensington, is the only representative of the Coromandel Group in the study area. Parahaki Rhyolite is medium grained and porphyritic, with 73% silica. The groundmass comprises quartz, plagioclase, orthoclase, biotite and magnetite, with accessory apatite and zircon, whilst phenocysts are plagioclase, quartz and biotite. The rhyolite is frequently altered and/or completely weathered to low-temperature clays and silica minerals. Over large areas the rhyolite is only represented by white clay-rich soils with scattered quartz crystals. Exposures that are close to sea level tend to be moderately weathered, weak to moderately strong and have joint spacing of 1-2 m. The rhyolite is of Early Miocene age (around 20 million years).

Minor regolith failures may be associated with the Parahaki Rhyolite, especially in zones where they are deeply weathered or hydrothermally altered, but these are usually no more than 2 m deep. Such landslides tend to incorporate topsoil and colluvium sliding on the clayey contact with underlying weathered bedrock. Gully erosion can be a problem, and there are some large ancient rock slides on the northwest slopes of Parahaki, and small rock falls.

2.2.2.5 Kerikeri Volcanics

The Kerikeri Volcanics are at ground surface over a small proportion of the east and west Kensington and Morningside areas. They are predominantly basaltic but some are dacitic. The lavas erupted sub-aerially and are inferred to be intra-plate. They consist of tuffs, scoria cones and ridge-top remnants and flows, constrained by modern topography. They are up to 80 m thick and tend to be very well drained. Scoria cones are usually made up of tightly packed, moderately weak to moderately strong clasts of diameter 50 mm to 1 m, with a firm to stiff groundmass. Basaltic lavas tend to be unweathered to slightly weathered, strong to very strong, columnar jointed and capped by up to 4 m of soil, ash and blocks of lava. Kerikeri basalts overlie blue clays, sands and greywacke gravels. They are of Plio-Pleistocene age (around 2-4 million years).

Land underlain by scoria cones of the Kerikeri Volcanics can be steep but tends to be stable. Where there are basalt lava flows, the land also tends to be stable unless underlain by soft rocks. In this case the soft rocks are subject to oversteepening of natural slopes and saturation by groundwater, which leads to a high degree of instability. The harder basaltic rocks may then be rafted down the slope by creep in the underlying lithologies. In the northern part of Tikipunga there are three ancient landslides that are still active with large-scale deep-seated creep. Failure on the edge of a large basalt flow has occurred as a result of failure of the underlying weak rocks. One of these slides, in the Mangakino Stream, contains large, semi-intact basalt blocks.

2.2.2.6 Late Miocene to Recent Sediments

The oldest of these sediments, the Purua Formation, may be as old as Late Miocene. Near Okara Park the formation overlies the Whangai Formation of the Northland Allochthon. The outcrop comprises highly weathered, carbonaceous gravels, including clasts of allochthonous material and greywacke, but lacks basaltic clasts, implying that the deposit predates the Kerikeri Volcanics. This outcrop is several metres higher than modern alluvial sediments. There is a potential for minor slumping in this unit where water inflows at the base. In addition, further stability problems are an issue at outcrops such as the one at Okura Park, due to movement in the underlying, and notoriously unstable, Whangai Formation of the Northland Allochthon.

Holocene age estuarine and fluvial sediments are present close to sea level underlying much of the low-lying areas within the study area. Locally peat is present.

Along the Whangarei Harbour coastline, the Holocene Sediments predominantly comprise deltas that have formed at the mouths of streams running into the sea. These deltaic deposits are likely to comprise loose sands and gravels with some silty zones. Softer estuarine muds are also expected.

There are fairly large areas of man-made fill on the reclaimed land around the edge of the harbour in the Port and running into the Morningside and East Kensington areas. The nature of this fill varies widely, as does its suitability as a foundation for building, even though the land is usually very flat. Consequently areas underlain by man- made fill are zoned as moderate Geotechnical assessment level, because all such areas should be examined by an expert to assess the suitability of the ground for building.

3 Geotechnical assessment recommendations and instability hazard

3.1 Summary

Table 1 below presents a summary description of each zone and the level of geotechnical assessment that is recommended for applications for Building Consent. Details of the geotechnical assessments are given in the following section.

Table 1: Zone description and geotechnical assessment recommendations

Zone	Colour	Geotechnical Assessment	Hazard
Low	Yellow	Low level investigation	Erosion or landslide morphology is not apparent. Not considered to be at risk of instability. May, however, be at risk as a result of natural events, or development. Steeper slopes may be subject to soil creep.
Mod	Orange	Moderate level investigation	Land exhibits evidence of past slippage or erosion, and could be subject to inundation from landslide debris and slope deformation. Geology, slope and/or geomorphic evidence of past or ancient landslippage suggest the land should be developed carefully.
High	Red	High level investigation	This land appears to be either subject to erosion or slippage, or is likely to be subject to erosion or slippage within the next 100 years based on geomorphic evidence. This land is generally considered to be geotechnically unsuitable for development, unless works can be undertaken to avoid, remedy or mitigate the hazard.

3.2 Geotechnical assessment details

The following recommended geotechnical assessment and land development criteria apply to the three land classes defined in Section 3.1. It is important to note that these criteria apply only to erosion or landslippage. Even where these matters have been addressed to the satisfaction of Council, site-specific geotechnical investigations may still be required to satisfy Council as to the adequacy of foundation conditions with respect to bearing capacity and settlement (under both static or seismic loads). Flood risk may also need to be determined, which would include the main floodways and secondary, or overland, flow paths.

In addition to erosion and landslippage of natural ground triggered by rainfall and/or seismic events, development works can accelerate, worsen or result in erosion and/or landslippage. These works include over-steepening of the land by cutting, surcharging the land by filling, increasing groundwater levels and/or piezometric pressures by putting stormwater and/or effluent waste water onto or into the land, and removal of vegetation (principally removing the effective cohesion provided by the roots).

3.2.1 Low geotechnical assessment level/ stability hazard

On this land erosion or landslippage is not apparent. However, sloping areas may be sufficiently sensitive to erosion or slippage that could occur due to inappropriate cutting, filling, and/or site disposal of stormwater and/or effluent waste water, and natural events (e.g. cyclonic short term high intensity rainfall events). These slopes could also be subject to soil creep.

Accordingly, applications for development of this land should be accompanied by a brief geotechnical report which summarises the results of a walk-over survey and a geological/geomorphological assessment (which describes how the particular landform has been formed, what it is made up of and what slope processes are, or are likely to be occurring) and provides an informed opinion on the suitability of the land for the intended purpose.

The geological/geomorphological assessment should entail most or all of the following steps, and the brief report should specifically address the expected effects of the subdivisional and/or building development on the land.

The geotechnical assessment of low risk land would be expected to include most or all of the following steps:

a Walk-over inspection of the site and the surrounding land

b Inspection of aerial photographs taken at various times to provide insight into the local geomorphology and evidence of any previous instability

c Review of geological data (maps, bulletins)

d Enquiry after local information about stability/instability of the ground

e Seek existing data about the soil and rock profile (look for nearby exposures) or perform some simple subsurface investigation

f Examination of the soil profile to confirm that if the soil is in-situ and not colluvium (slide debris)

g Examination of the existing survey records for evidence of movement (slippage or erosion)

h An opinion stated by a geotechnical specialist as to the stability of the land for development (including an assessment of the effects of development such as excavation, filling, removal of vegetation, disposal of stormwater or effluent wastewater into or over the area).

3.2.2 Moderate geotechnical assessment level/ stability hazard

This land does not exhibit any evidence of any recent instability but does display "relic" landslide geomorphology, or is sufficiently sloping to be potentially subject to instability due to either natural events (e.g. high intensity rainfall events or earthquake), or as a result of inappropriate cutting, filling, and/or site disposal of stormwater and/or effluent waste water.

The presence of any man-made fill also leads to a moderate geotechnical assessment level zonation, as the nature of such fill should be investigated before building.

Accordingly, applications for subdivision, building or other development (such as excavation, filling, removal of vegetation, disposal of stormwater or domestic wastewater into or over the area) may be allowed to proceed subject to consent conditions. These would include a requirement for a supporting geotechnical report which includes a stability assessment demonstrating that the proposed development will not accelerate, worsen or result in the land being subject to, or likely to be subject to, erosion or slippage, to the satisfaction of Council.

A geotechnical assessment on moderate risk land would be expected to include:

a Topographic survey (if not already available) or slope profiles.

b A description of the geology and geomorphology of the area, including comment on the areas surrounding the development site.

c Definition of the nature and continuity of the strata over the whole area of land which is proposed to be developed (buildings, access and services) and to a depth below which slipping is most unlikely, by means of test pit and/or drilling and/or augering (unless existing exposures are adequate). Where man-made fill is present, the nature of the fill should be investigated over its full depth.

d Assessment of the relative strength and the sensitivity of the soil in each stratum in which, or interface on which, sliding is possible.

e Assessment of likely groundwater levels and piezometric pressures in the strata during extreme infiltration conditions.

f An opinion stated by a geotechnical specialist as to the stability and suitability of the land for development. The stability of the whole slope (upon which the site may only form a part of) and the effects of the development (such as excavation, filling, removal of vegetation, disposal of stormwater or effluent waste water into or over the area) on this should be given.

3.2.3 High geotechnical assessment level/ stability hazard

This land exhibits evidence of recent or present slippage or erosion and/or is subject to processes such that slippage or erosion is considered likely to occur within the next 100 years, especially where the slope is devegetated or oversteepened during development. Accordingly, development of this land presents an identifiable hazard to property and could also, in some circumstances, threaten life.

On, above and especially below this land, no subdivision, building or other development including excavation, filling, removal of vegetation, disposal of stormwater or domestic wastewater into or over the area should be permitted unless a geotechnical report including an appropriate and adequately detailed stability analysis is produced to the satisfaction of Council.

The geotechnical report must demonstrate that the proposed development area will not be subject to erosion, or slippage, or inundation by debris from upslope. It should also show the proposed development, through preventative works or other measures, will ensure that any structure will not become damaged by erosion or slippage arising on or off the site, and that development will not accelerate, or worsen, erosion or slippage.

A geotechnical report on high landslip hazard areas land would be expected to include:

a Topographic Survey (if not already available)

b A description of the geology and geomorphology of the area and immediate surrounding areas.

c Definition of the nature and continuity of the strata over the whole area of land involved, and to a depth below which slipping is most likely, by means of test pits and/or continuous recovery core drilling (unless existing exposures are adequate).

d Determination of the peak and residual shear strength parameters (either from laboratory tests or back analysis of relevant slope failures) and the sensitivity of the soil in each stratum in which, or interface on which, sliding is possible.

e Assessment of groundwater levels and piezometric pressures in the strata during extreme infiltration conditions.

f Analysis of possible failure mechanisms, relevant to the specific geology and geomorphology of the site using effective stresses.

g An opinion stated by a geotechnical specialist as to the stability of the ground and the preventative (or remedial) measures to be incorporated in the development. The stability of the whole slope (upon which the development site may form only part of) and the effects of the development (such as excavation, filling, removal of vegetation, disposal of stormwater or effluent waste water into or over the area) on this should be given.

Even with a thorough geotechnical report, which includes a stability analysis, complete avoidance of all risk may not be possible and no guarantee of absolute safety should be expected. Site development works in particular need to be carefully planned to ensure development does not result in slippage or erosion.

Works which can be undertaken to protect or restore the land include earthworks (to reduce slope angles or place buttress fills), drainage works (trench drains, buttress or counterfort drains aligned down the true slope angle are particularly effective), retaining structures, erosion protection structures, and planting.

4 Statutory responsibilities in relation to instability hazard

There are two primary pieces of legislation which define the responsibilities of WDC for the management of land hazards including instability (slippage). These are the Resource Management Act 1991 (RMAct) and the Building Act 2004 (BAct).

4.1 Resource Management Act 1991

The overall purpose of the RMAct is to promote the sustainable management of natural and physical resources. Under the Act WDC also have responsibilities for the avoidance and mitigation of natural hazards.

The specific functions of WDC are defined under Section 31 of the RMA, and include the avoidance and mitigation of natural hazards through the control of land use and subdivision.

Section 31(b) states that every District Council has, as a function:

> *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.*

To carry out these functions, WDC must produce a District Plan, which describes how resource management issues will be managed to achieve the sustainable management of natural and physical resources. Section 74 of the Act requires that the District Plan be consistent with the relevant Regional Plan and Regional Policy Statement, thereby ensuring the integrated management of the natural and physical resources of the region and district.

With respect to the subdivision and use of land, WDC has requirements relevant to the avoidance or mitigation of natural hazards. Section 106 (l) specifies that a consent authority shall not grant subdivision consent for:

> *"(a) Any land … or any structure on that land (which) is or is likely to be subject to material damage by erosion, falling debris, subsidence, slippage, or inundation from any source; or*
>
> *(b) Any subsequent use that is likely to be made of the land (that) is likely to accelerate, worsen, or result in material damage to that land, other land, or structure, by erosion, falling debris, subsidence, slippage, or inundation from any source."*

unless the consent authority is satisfied the effects of the proposed subdivision will be avoided, remedied or mitigated.

With small-scale slippage, remedial or preventative works may be practicable. It may, however, be impractical to remedy or mitigate the hazard which large-scale slippage presents, and hence one approach to address the hazard is to avoid it by preventing development.

4.2 Building Act 2004

The purpose of the BAct is to provide the necessary controls over building works, use and safety. Under this Act the obligations for managing building works in relation to natural hazards are solely the responsibility of the District Council.

The BAct requires WDC to refuse the granting of a building consent for construction of a building, or major alterations to a building, if:

Section 71 (1) *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*

(a) *the building work is likely to accelerate, worsen, or result in a natural hazards on that land or any other property.*

Unless (2) *the building consent authority is satisfied that adequate provision has been or will be made to:*

(a) *protect the land, building work, or other property referred to in that subsection from the natural hazard or hazards; or*

(b) *restore any damage to that land or other property as a result of the building work.*

(3) *In this section and sections 72 to 74, natural hazard means any of the following:*

(a) *erosion (including coastal erosion, bank erosion, and sheet erosion)*

(b) *falling debris (including soil, rock, snow, and ice)*

(c) *subsidence*

(d) *inundation (including flooding, overland flow, storm surge, tidal effects, and ponding)*

(e) *slippage.*

72 *Building consent for building on land subject to natural hazards must be granted in certain cases*

Despite section 71, a building consent authority must grant a building consent if the building consent authority considers that:

(a) *the building work to which an application for a building consent relates will not accelerate, worsen, or result in a natural hazard on the land on which the building work is to be carried out or any other property; and*

(b) *the land is subject or is likely to be subject to one or more natural hazards; and*

(c) *it is reasonable to grant a wavier or modification of the building code in respect of the natural hazard concerned.*

73 *Conditions on building consents granted under section 72*

(1) *A building consent authority that grants a building consent under section 72 must include, as a condition of the consent, that the building consent authority will, on issuing the consent, notify the consent to:*

(a) *in the case of an application made by, or on behalf of, the Crown, the appropriate Minister and the Surveyor-General; and*

(b) *in the case of an application made by, or on behalf of, the owners of Maori land, the Registrar of the Maori Land Court; and*

(c) *in any other case, the Registrar-General of Land.*

(2) *The notification under subsection (1)(a) or (b) must be accompanied by a copy of the project information memorandum that relates to the building consent in question.*

(3) *The notification under subsection (1)(c) must identify the natural hazard concerned.*

4.3 Community expectations

No amount of controls on development can produce zero risk in the urban areas of Whangarei District, and we do not believe that the community expects that to be achieved.

What the community can rightly expect, however, is that the actual and potential hazards are properly identified, and that the potential consequences are clearly explained. This assessment is undertaken specifically to enable WDC to appropriately fulfil this expectation.

5 Applicability

This report has been prepared for the benefit of Whangarei District Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

Environmental and Engineering Consultants

Report prepared by: Authorised for Tonkin & Taylor by:

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