REPORT

Landslide Susceptibility Assessment for Whangarei District Council

Prepared for
Whangarei District Council
Prepared by
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Whangarei District Council 1 electronic copy

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Client Summary

Whangarei District Council (WDC) are proposing to extend their landslide susceptibility maps and have engaged Tonkin & Taylor Ltd (T+T) to complete a landslide susceptibility assessment for the District. The table below summarises the key outcomes and observations from this assessment[1].

Background and context (refer Section 1)	T+T have completed a landslide susceptibility assessment and map that covers the Whangarei District, for WDC use in regulatory functions. This work follows on from the existing landslide susceptibility assessment and mapping that was undertaken by T+T between 2000 and 2007, and available through WDC's GIS portal. We have: • Reviewed the existing assessment and used a similar methodology to map the unmapped areas in the District • Validated the updated mapping using the available data, field validation and numerical validation through normalised difference analysis • This report summarises our approach and the findings of our assessment.
Geological setting (refer Section 2)	The Whangarei District is covered by two geological maps (Table 2.1). We created a simplified geological model for this assessment which is outlined in Table 2.2, and discussed in Section 2.
Landslide inventory (refer Section 3)	To better understand the geological and topographical control of landslides around Whangarei, research into the location of landslides in the area was undertaken. We obtained data on existing mapped landslides from three main sources: GNS Science, geological maps, and T+T project locations. The locations of the landslides from these sources has been compiled into a mapped landslide inventory for the District (Figure 3.1). Further detail is presented in Section 3.
Susceptibility assessment (refer Section 4)	The proposed methodology for the updated susceptibility assessment broadly follows the existing methodology (Section 4.1), but using updated data and information. Given the scale of this assessment, the resulting map is based on slope angle and geology but also incorporates landslide features that have been identified in the landslide inventory and during validation. Further detail is presented in Section 4.
Validation (refer Section 5)	Validation of the initial susceptibility map has been undertaken by: 1 Comparing results of the updated assessment with the existing mapped areas. 2 Reviewing aerial imagery and LiDAR to map observed landslide features. 3 Undertaking site visits to confirm geomorphological observations/assumptions made from the aerial imagery and LiDAR data. Summarised in Section 5.3. 4 Numerical validation of the susceptibility mapping, based on landslides recorded in different geologies and slope angles. The numerical validation matched our expectations in terms of the most susceptible geology types. Further detail is presented in Section 5.
Discussion (refer Section 6)	The susceptibility map is presented in Figure A6 (Appendix A), and considerations for different geology types are summarised in Section 6. The updated mapped susceptibility zones can be considered analogous with the Low, Moderate and High "land stability hazard zones" as outlined in the EES. The information requirements stated in the EES will continue to be suitable for the updated map. This susceptibility assessment does not remove the requirement for site specific assessment by a geo-professional when applying for a resource or building consent (i.e. a Site Suitability Report). Updates to the District Plan may also require site specific assessments for other activities.

[1] This summary presents an overview of the key outcomes and observations from this assessment. It should be read in conjunction with the relevant detail included in the main body of the report.

1 Introduction

Tonkin & Taylor Ltd (T+T) was engaged by Whangarei District Council (WDC) to provide a landslide susceptibility assessment and map that covers the Whangarei District (the District). This work follows on from the existing landslide susceptibility assessment and mapping that was undertaken by T+T between 2000 and 2007, that is currently used on the WDC GIS portal.

This work has been undertaken in accordance with our Short Form Agreement dated 30 March 2020, and Variation Order (VO1) dated 11 August 2020.

The scope of work for this assessment has been split into four phases:

<u>Phase 1: Review existing mapping and undertake mapping for remaining areas</u>

- Review existing landslide susceptibility mapping methodology, including an appraisal of the criteria and approaches to landslide susceptibility as presented in the T+T land zonation stability hazard mapping reports from 2000-2007 (Tonkin + Taylor, 2000-2007).
- Provide advice on what other geological/geomorphic settings and contributory factors may be considered for inclusion.
- Provide a brief landslide inventory with details on the distribution and type of landslides that commonly occur across the study area.
- Apply the existing methodology to the unmapped areas.
- Check the currently mapped areas against the updated information.

<u>Phase 2: Validation of mapping by Normalised Difference</u>

- Numerical validation of the updated mapping using Normalised Difference. This can mathematically determine the importance of the geological unit and slope angle for landslide susceptibility in the District.

<u>Phase 3: Validation of mapping by site walkover</u>

- Visual validation of the updated mapping by an Engineering Geologist and Geotechnical Engineer familiar with the Whangarei District.

<u>Phase 4: Reporting</u>

- Prepare a report to cover the findings of the assessment including:
  - Outline the results of our review and the methodology used.
  - Review of the existing controls in the District Plan (Whangarei District Council, 2007) and the WDC Environmental Engineering Standards (Whangarei District Council, 2010) (EES).
  - A series of A3 figures showing the spatial distribution of the geological units, elevation and mapped landslides.
  - An updated landslide susceptibility map for the District.
- A GIS file in .shp format with associated metadata following the ANZLIC metadata profile (v1.1) will also be provided to update the version currently held by WDC.

This report forms the output of Phase 4, which also outlines the results of Phases 1 to 3 of this work. A workshop to discuss the findings was held with WDC on 8 September 2020 following issue of the draft report, prior to finalising the report and figures.

1.1 Study area

For the purposes of this assessment, the study area is taken to be the extents of Whangarei District. This is shown on Figure 1.1, and on Figure A1 in Appendix A.

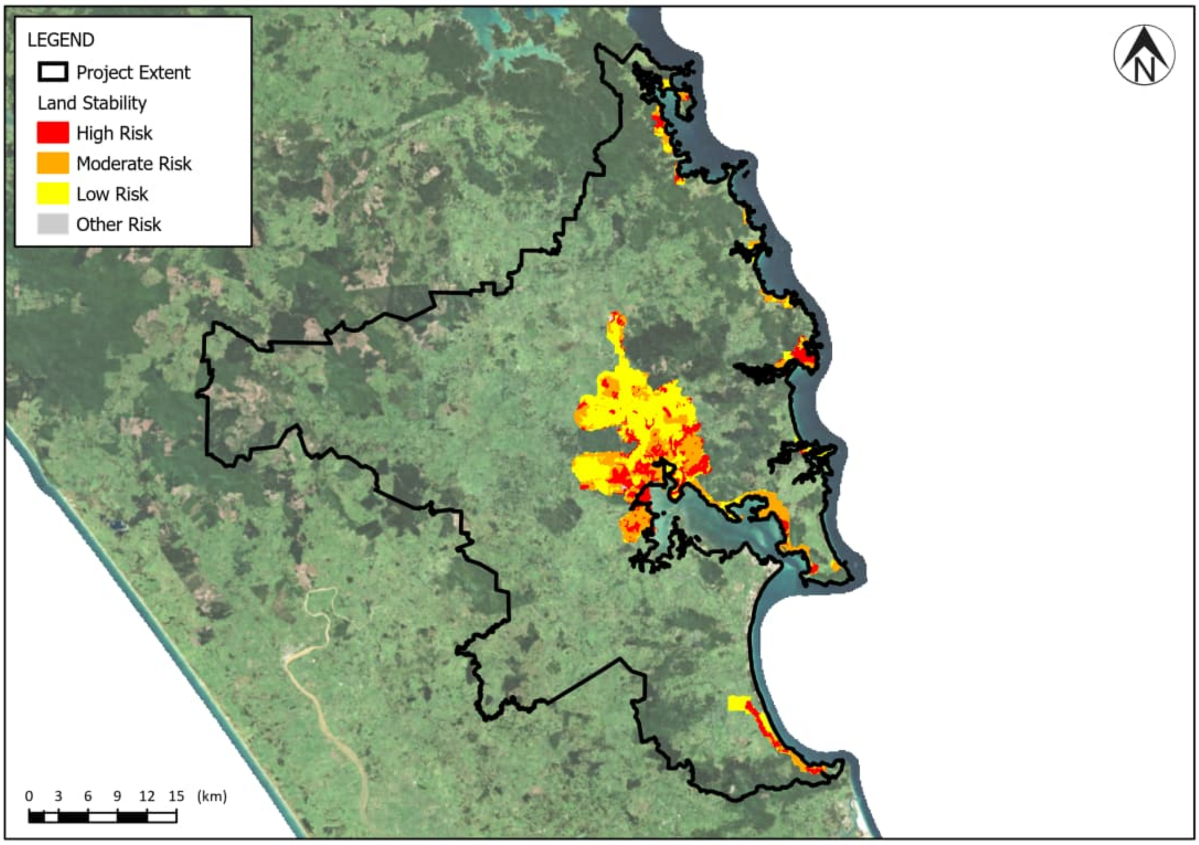


Figure 1.1: Extent of the study area is the Whangarei District Council boundary, excluding minor islands to the east. Land Stability areas taken from WDC GIS Stability overlay.

1.2 Previous work

Tonkin + Taylor was previously engaged by WDC to provide assessments of landslide susceptibility (also referred to as land stability maps) for discrete areas within the District between 2000 and 2007. The resulting maps make up the current stability overlay on the WDC GIS system.

The areas that were previously assessed include Whangarei Heads; Waipu to Langs Beach; Waikaraka to Ocean Beach; Bland Bay to Taiharuru,; Kamo, Maunu, Onerahi, Otaika and Tikipunga; East and West Kensington, Morningside and the Port; and Hikurangi, Mid-Kensington, Whangarei City Centre, East Camo and Portland (T+T Project references 18028, 18517, 22705, 22789, 24010, 24010.002 respectively). The extents of these previously assessed areas are shown on Figure 1.1.

Land in the previously assessed areas was mapped as either low, moderate or high stability hazard; corresponding to the defined characteristics of each zone and the recommended level of geotechnical assessment required to support the development of a site within each zone. We note that “land stability” and “stability hazard” have been used in previous documents (including T+T maps and WDC EES) to refer to the susceptibility of an area to landsliding. Where “land stability” is mentioned in this report it is to refer to those existing maps or documents, and it understood to be synonymous with landslide susceptibility.

Table 1.1 shows the definitions of these zones, and the geotechnical assessment recommendations. These have been incorporated into the EES to assist with development in the District.

Table 1.1: Zone descriptions and geotechnical assessment recommendations

Zone	Colour	Hazard	Geotechnical Assessment Required
Low	Yellow	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.	Low level investigation
Moderate	Orange	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 land slippage suggest the land should be developed carefully.	Moderate level investigation and discussion of stability
High	Red	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.	High level investigation and stability analysis

1.3 Context

The Resource Management Act (New Zealand Government, 1991) and the Building Act (New Zealand Government, 2004) are the two primary pieces of legislation that define the responsibilities for the management of land hazards. The Regional Policy Statement for Northland (Northland Regional Council, 2016) outlines objectives, policies, and methodologies for the management of the natural hazards and the Operative District Plan (ODP) provides controls to achieve stated objectives with regards to natural hazards. These controls are normally in the form of rules to control activities based on their location in relation to a known hazard. The current WDC ODP (2007) does not specifically address landslide susceptibility, however, the EES does provide recommendations for assessments to be undertaken in areas subject to different levels of “land stability hazard”. These areas have been determined by the works outlined in Section 4 of this report. Further details on the provisions contained within each of the aforementioned documents is provided in Appendix D of this report. A high-level legislative and regulatory context and the pathway to compliance is shown schematically in Figure 1.2.

At the time of writing this report, the District Plan is being updated to incorporate controls around landslide susceptibility, we understand that this assessment is to inform part of this update.

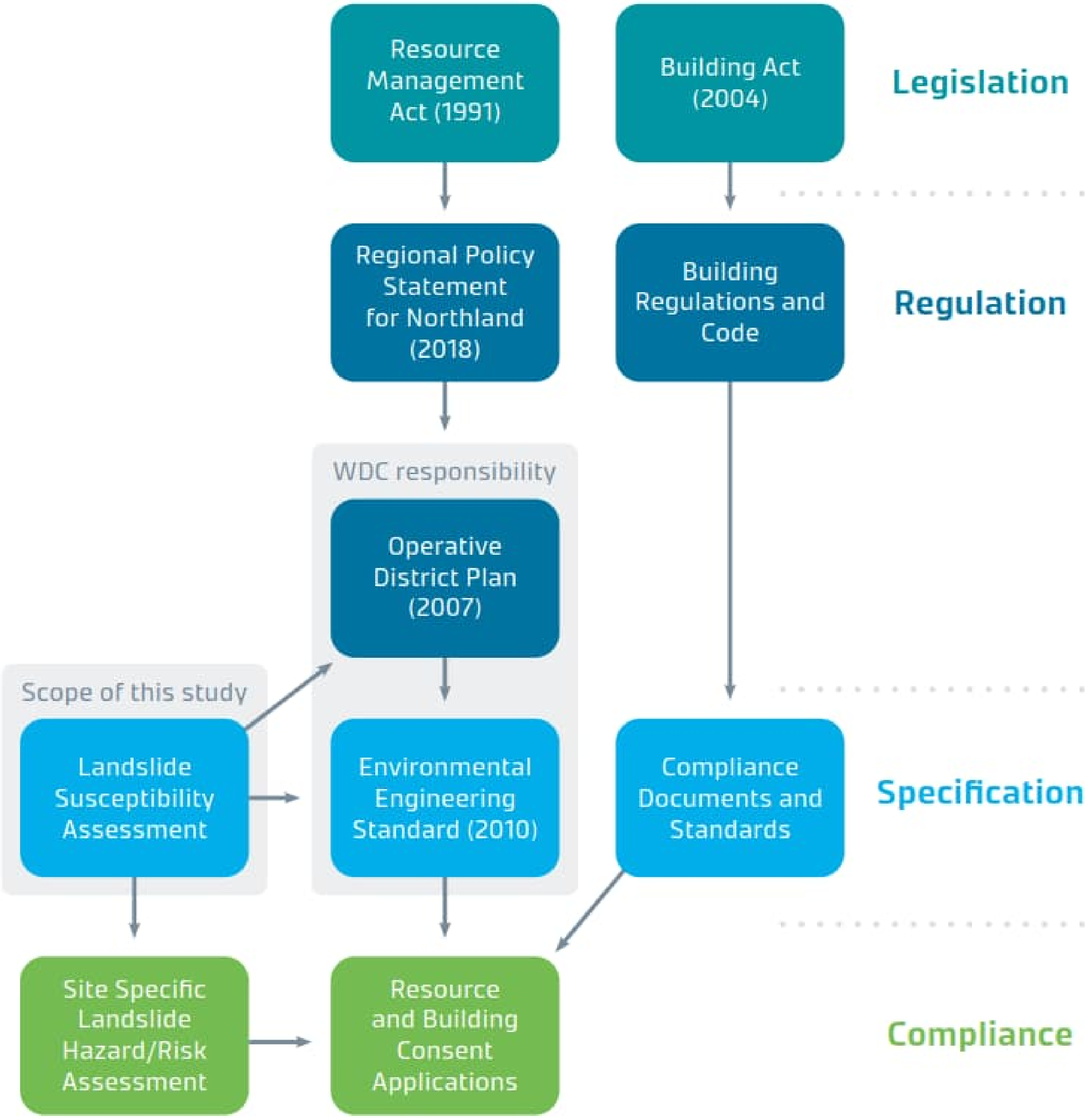


Figure 1.2: High-level legislative and regulatory context and compliance pathway to manage landslide hazards and assessments in the Whangarei District.

1.4 Information used in the assessment

In order to undertake this work, we have used information and data from various sources, including Northland Regional Council, WDC, and the Institute of Geological and Nuclear Sciences (GNS Science). Table 1.2 below summarises these.

Table 1.2: Information sources used on the project

File	File type	Information source	Comment
LiDAR	GIS Shapefile	Northland Regional Council	LiDAR coverage of the ground surface within the Whangarei District to 1 m resolution
Existing WDC landslide susceptibility areas	GIS Shapefile	WDC GIS	Low, moderate and high areas of mapped landslide susceptibility
Landslide locations	GIS Shapefile	GNS Science	Download of relevant data from the GNS Science New Zealand Landslide Database
T+T project data	GIS Shapefile	T+T database	T+T records of projects including landslide investigation and remediation.
Northland 0.1 m Urban Aerial Photos (2014-2015)	Ortho-rectified RGB GeoTIFF images	Land Information New Zealand	Aerial photography for the District.
2017 NZ-wide aerial photography	Ortho-rectified RGB GeoTIFF images	Land Information New Zealand	Aerial photography for the District.
Existing landslide susceptibility area assessments	PDF Reports	T+T database	T+T reports to WDC, 2000-2007: Land Zonation Mapping, Stability Hazard mapping /geotechnical assessment level and effluent disposal potential.
QMAP 1:25,000 geological map	PDF Map	GNS Science	1:25,000 geological map of the Whangarei Urban Area
QMAP 1:250,000 geological map	PDF Map	GNS Science	1:250,000 geological map of the Whangarei Area

1.5 Terminology and definitions

Preconceptions regarding the meaning of the terms susceptibility, hazard and risk can lead to significant confusion when communicating the results of a study such as this. The definitions applied in this report are presented in Table 1.3 for clarity. The primary distinction that needs to be made is that susceptibility relates to the potential for a landslide to occur whereas hazard relates to the likelihood of a landslide impacting people and property. Risk relates to the outcomes of such an event, should it occur and is the product of likelihood and consequence.

Table 1.3: Definition of terms

Term	Definition in Landslide Risk Management
Susceptibility	The relative potential for a landslide event to occur
Hazard	A relative potential for a landslide to cause loss of life, injury or property damage
Risk	Often expressed in terms of a combination of the consequences of a landslide event and the associated likelihood of the landslide occurrence.

This study represents a susceptibility assessment of the Whangarei District. The terminology used in the EES regarding geotechnical assessment reports for land stability suggests that “hazard” or “risk” areas have been defined whereas, in the absence of people and property, or a quantitative, frequency or consequence element being incorporated, they are better described as “susceptibility” areas.

Where reference is made in this report to “high, moderate or low stability hazard”, as the existing zones are identified on the WDC GIS, it should be noted that susceptibility is a more appropriate term and we recommend that this term is used going forward. Similarly, where reference is made to “land stability” in this report it is to highlight the existing terminology used in the EES or previous mapping, and is considered to be synonymous with “landslide susceptibility”.

2 Geological setting

2.1 Geological model

The geology of the Whangarei District can be represented by two published geological maps as summarised in Table 2.1 below. The 2009 map of the Whangarei area (Edbrooke & Brook, 2009) covers the whole of the area, shown in Figure 2.2, whereas the 2003 map (White & Perrin, 2003) is a larger scale map of the Urban area only. For the purposes of this assessment we have used the 2009 map predominantly although we have included the landslides shown on the Urban area map in the project geology layer and our landslide inventory.

Table 2.1: Published geological maps that cover the study area (GNS Science)

Title	Authors	Published date	Scale
Geology of the Whangarei Area (QMAP)	Edbrooke and Brook (compilers)	2009	1:250,000
Geology of the Whangarei Urban Area	White and Perrin	2003	1:25,000

The GNS Science geological maps are accompanied by reports that detail the geological setting of the geological units in the Whangarei area. Most of these geological units were deposited from Jurassic to Miocene periods. Low-lying terrains are predominantly made up of middle to late Quaternary age geological units.

The following is a brief summary of the geological units in the study area.

- The oldest geological units in the study area comprise sedimentary deposits. These are represented by the following:
  - Waipapa Group Greywacke which forms the basement rocks in the area.
  - Following this unit being uplifted above sea level, a period of erosion occurred (identified as a regional unconformity in the field). This represents a period of time between deposition of the Waipapa Group sediments and the Te Kuiti Group sediments that were deposited on top.
  - Te Kuiti Group sediments represent a time where sea level rose over the area.
  - Geologically older Northland Allochthon complexes were tectonically emplaced onto the Northland region. This was related to subduction of the Pacific Plate beneath the Australian Plate resulting in different Allochthon complexes being pushed and sheared over each other, depositing them on top of the Waipapa and Te Kuiti Group (Figure 2.1).
  - Waitemata Group sediments were deposited on top of the majority of these older geological units in the Whangarei basin.
- Following this, two periods of volcanic activity occurred throughout the region between 23.8 and 1.8 million years ago. These resulted in various geological formations that have been deposited within or on top of the earlier sedimentary units including lava flows and scoria cones.
- The most recent geological units are Quaternary in age, and represent alluvial, coastal and estuarine deposits. These are typically found along the coastline, inner harbour, rivers and streams that have cut into the underlying sedimentary and volcanic deposits.
- On top of these units are residual soils. These soils are weathered versions of the older rock materials, that have been weathered to the extent that they act as soils (e.g. not an intact rock

structure). These tend to vary in depth, from a couple of metres to more than 10 metres depth.

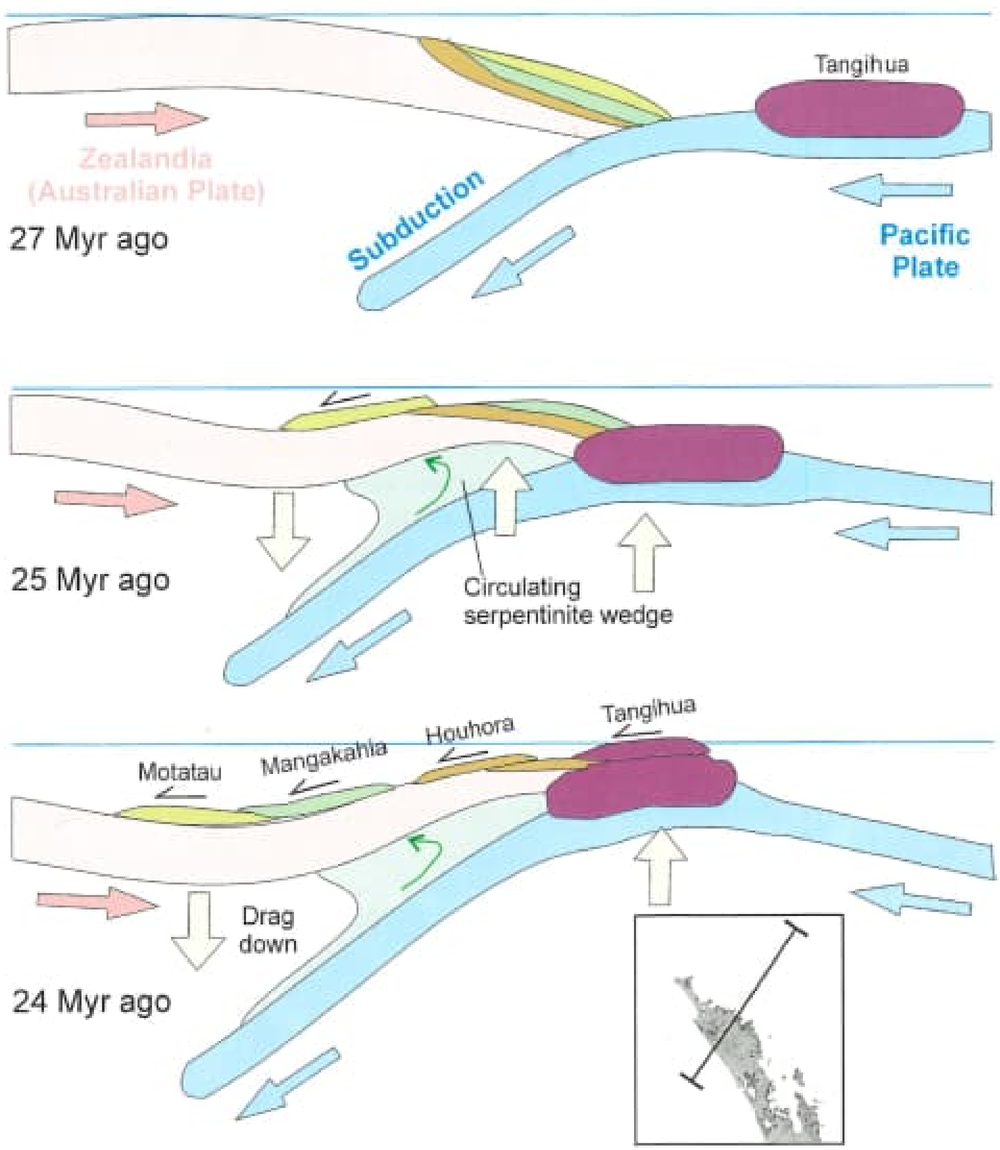


Figure 2.1: Diagram of emplacement sequence of Northland Allochthon units from Hayward (2017).

The simplified geological model of the area that we have used for our assessment is provided in Table 2.2. The geological map of the study area is provided in Figure 2.2, and Figure A.2 in Appendix A.

Further details for each of the main geological units are provided in separate tables for each unit within Appendix B. These tables also outline any engineering geology characteristics that can define those units, as well as typical landslide features identified from the GNS Science geology textbooks and local experience.

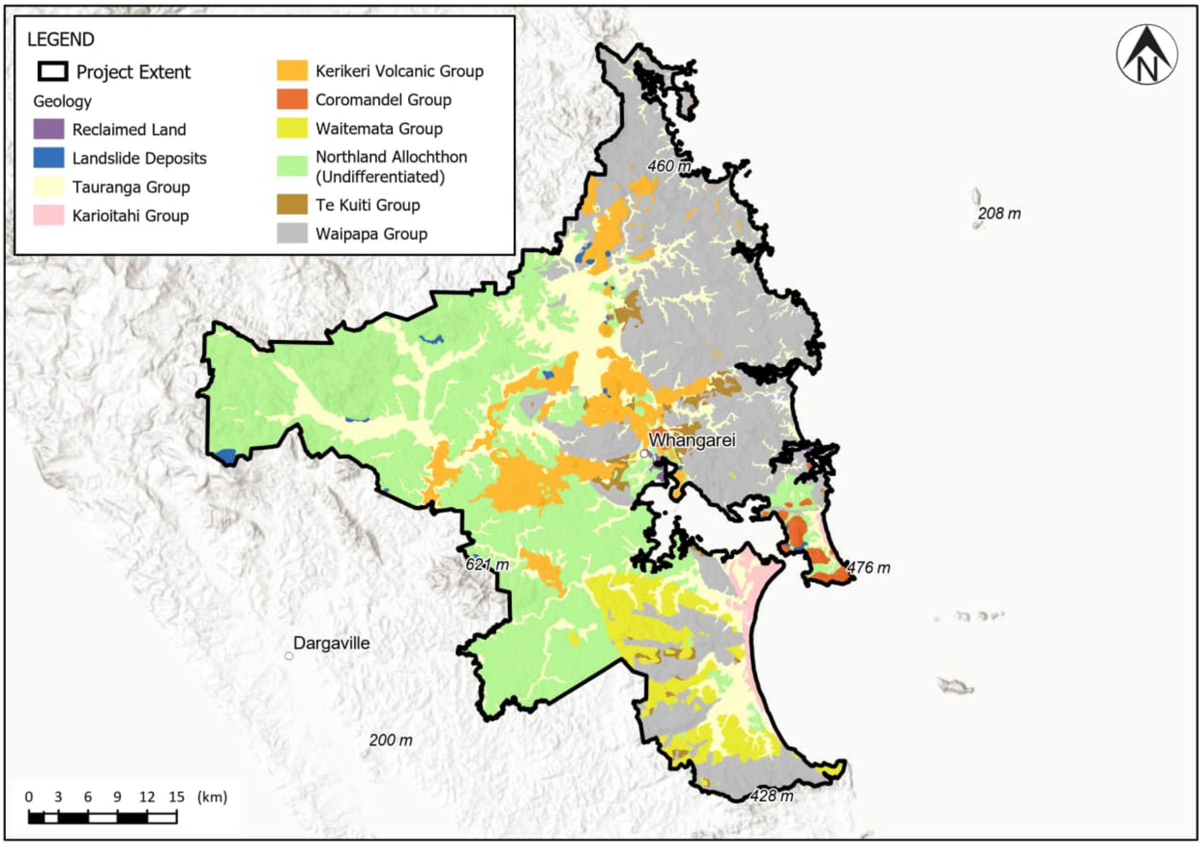


Figure 2.2: Geological map for the Whangarei District based on (Edbrooke & Brook, 2009)

We have assumed that different formations and subgroups within the geological units will act the same, and that these differences will not materially affect the susceptibility within that geological group. While this allowed for a more simplified analysis, we do note that some finer detail can be lost; however, this level of detail would be expected to be collected during site specific geotechnical assessments. A sensitivity check has been undertaken using normalised difference to assess if any significant changes were observed if the geological units were broken down into subgroups or separate formations. The results of this sensitivity check on the geological mapping showed little change between this detailed approach and our simplified geological model, and we therefore consider our approach to be appropriate for the purposes and scale of this susceptibility assessment.

2.2 Geomorphology

The Whangarei District is dominated by rolling hills, with few large areas of flat land. Any flat land is usually restricted to flood plains and the coastal fringe. These landforms are typically controlled by the underlying geology.

The study area can be roughly split into larger geomorphic zones (Edbrooke & Brook, 2009) as outlined briefly below:

- Northern and eastern hills: these are formed predominantly from Waipapa Group greywacke rocks. These hills have been dissected by streams over time to form gullies and channels, with some prominent ridges forming due to more resistant, steeply dipping beds. The area inland of Bream Bay to the south can be characterised by a series of east-west oriented structures with hills of basement greywacke and valleys infilled with sedimentary rocks (typically Te Kuiti Group and Waitemata Group).

- Central rolling hills: these hills are formed predominantly from Northland Allochthon rock. The hills are moderately rolling, underlain by deeply weathered sedimentary rock. Some of the more resistant beds (volcanic rich sandstones or bioclastic limestones) form ridges with steeper slopes and some cliffs. Areas of hummocky topography or slumped ground are commonly underlain by deformed, weathered mudstones and melange of Northland Allochthon rock. These various rock types are undifferentiated in this study.
- Volcanic plateaus: these have typically been formed from small basaltic volcanoes. Gently sloping lava flows are common, as well as scoria cones.
- Fluvial and coastal plains: the large Hikurangi swamp north of Whangarei is underlain by alluvium and peat, developing when a lava flow to the south blocked the valley drainage. A broad coastal plain has formed inland of Bream Bay by dune accretion, as well as some smaller coastal plains along the coastline.
- Additionally, smaller geomorphic zones within the District can be identified that include areas of reclaimed land, swamps and landslide related landforms. These zones present their own distinctive landforms and are present on a much smaller scale than the other zones above.

A digital elevation model (DEM) produced from the regional 2019 LiDAR data commissioned by Northland Regional Council, is shown in Figure 2.3, and Figure A3, Appendix A. This shows the general distribution of high elevation land along the northern and western boundaries of the District, and low-lying land along the coastline and rivers in the area.

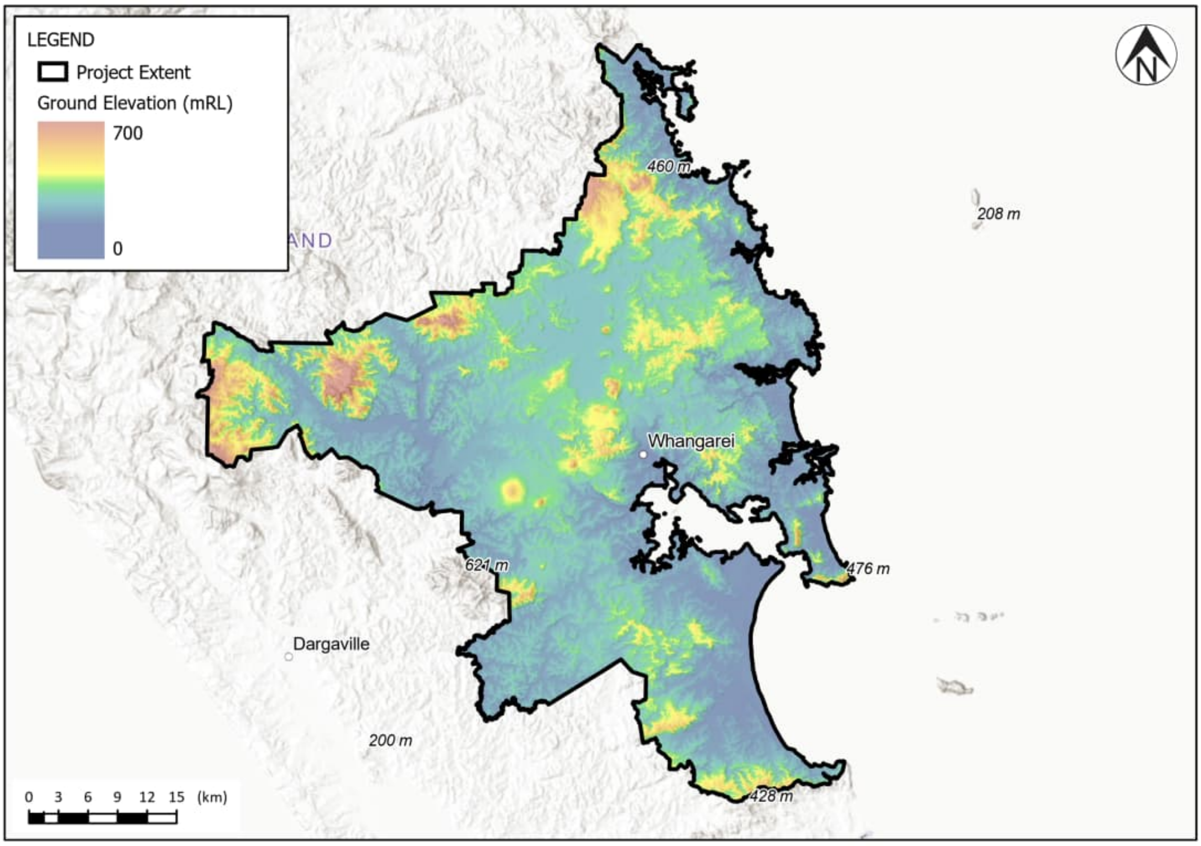


Figure 2.3: Elevations over the Whangarei District.

Table 2.2: Simplified geological model of Whangarei District

Geological Unit	Main rock types	Age (Ma)[1]	Depositional environment	Typical extent in Whangarei District
Landslide Debris	Colluvium	Recent	Gently to moderately sloping land throughout the District where landsliding has occurred.	Landslides have been mapped typically on or at the base of hill slopes throughout the District.
Reclamation Fill	Clays, sands and gravels	Recent	Man-made construction fill or land reclamation in areas typically around the harbour at the port, that are likely to have been dredged from the Whangarei Harbour.	The main area of this unit is located at the port in Whangarei. Other areas have been identified at dams and landfills.
Tauranga Group	Silt, sands, gravels and local peat	Early Pleistocene to Holocene 1.8 Ma to Present	Alluvial deposits along stream/river channels, flood plains and gullies, typically relating to river sediment deposition or erosional processes from hillsides.	These units cover the majority of the District in flood plains, alluvial terraces and channels, as well as within gullies in the hills
Karioitahi Group	Beach and dune sands	Early Pleistocene to Holocene 1.8 Ma to present	Dune complexes formed as sea level remained steady in the District and sands were deposited along the coastline. Older dunes are inland of the current coastline, with active sand dunes and beaches along the coast, either in bays between headlands or long beaches.	These units are typically observed along the eastern coastline and within the harbour.
Kerikeri Volcanic Group	Basalts and scoria cones	Late Miocene to Quaternary 11.2-1.8 Ma	Volcanism occurred in the Northland Volcanic Arc as a result of subduction of the Pacific Plate beneath the Australian Plate. Multiple small volcanoes are observed in the District with lava flows and scoria cones forming plateaus and small hills.	These volcanic deposits are typically located in the central parts of the District and are typically identified capping the hills.
Coromandel Group	Rhyolite domes	Early to Middle Miocene 23.8-11.2 Ma	Volcanism occurred in the Northland Volcanic Arc as a result of subduction of the Pacific Plate beneath the Australian Plate. Intrusive rocks are found within the Waipapa Group and Northland Allochthon units. Ridges in the Whangarei Heads area are the remains of a volcanic cone.	These volcanic deposits are predominantly located in the Whangarei Heads area.
Waitemata Group	Sandstone	Late Eocene to late Oligocene 23.8-11.2 Ma	These units were formed in a deep marine environment of the Northland Basin, and are found beneath, within and on top of the Northland Allochthon sediments.	This unit is typically located to the south of the District, adjacent to Te Kuiti Group and Waipapa Group rocks.
Northland Allochthon	Marine sandstone, mudstone, and submarine basalts	Cretaceous to Miocene 145-23.8 Ma	The Northland Allochthon units were originally deposited in marine environments to the north-east of the area and were tectonically deposited in thrust slices into the Northland Basin over the District as the basin likely subsided. This includes submarine volcanic pillow lavas and sheet flows, comparable to mid-ocean ridge basalts, which likely represents the sea floor at the time.	These units cover the majority of the western part of the District, with some traces of these units to the east and along the coastline.
Unconformity – emplacement of older Northland Allochthon units into the Northland Basin.				
Te Kuiti Group	Limestone	Late Eocene to late Oligocene 55.5-23.8 Ma	Swamp deposits formed at the start of a period of continental extension and subsidence in the District, which resulted in rising sea levels. As the sea level rose or land subsided, marine sediments were deposited over the area.	These rocks are observed to the west of the Waipapa Group rocks, in the centre of the District.
Regional Unconformity				
Waipapa Group	Greywacke	Permian to Jurassic 299-145.5 Ma	The sandstone likely accumulated on the ocean floor along the eastern margin of Gondwanaland, which became accreted onto the continental margin as part of an arc-trench complex resulting in metamorphism and uplift.	These rocks form the hills in the east of the District, north of the Whangarei Harbour, with some outcrops to the south of the Harbour.
[1] Ma = Million years, inferred from Edbrooke & Brooke (2009)				

3 Landslide inventory

To better understand the geological and topographical control of landslides around Whangarei, research into the location of landslides in the area was undertaken. To do this, we obtained data on existing mapped landslides from three main sources:

- GNS Science: They have a publicly available landslide database (GNS, accessed 2020) which provides locations and extents of mapped landslides in New Zealand.
- Geological maps: Both of the geological maps we are using in this study have landslides mapped across the District.
- T+T project locations: We have identified locations where we have completed natural hazard assessments on residential sites throughout the District.

The locations of the landslides from these sources has been compiled into a mapped landslide inventory for the District, which is shown on Figure 3.1 and Figure A4 in Appendix A.

It should be observed that the data sources operate at fundamentally different scales, with the GNS Science and geological map data sourced primarily from large scale landslides, whereas T+T project data is derived from relatively small scale landslides affecting properties. The GNS Science and geological map data therefore tends to under-represent the number of landslides in the area, and the T+T project data is strongly skewed towards urban developed areas.

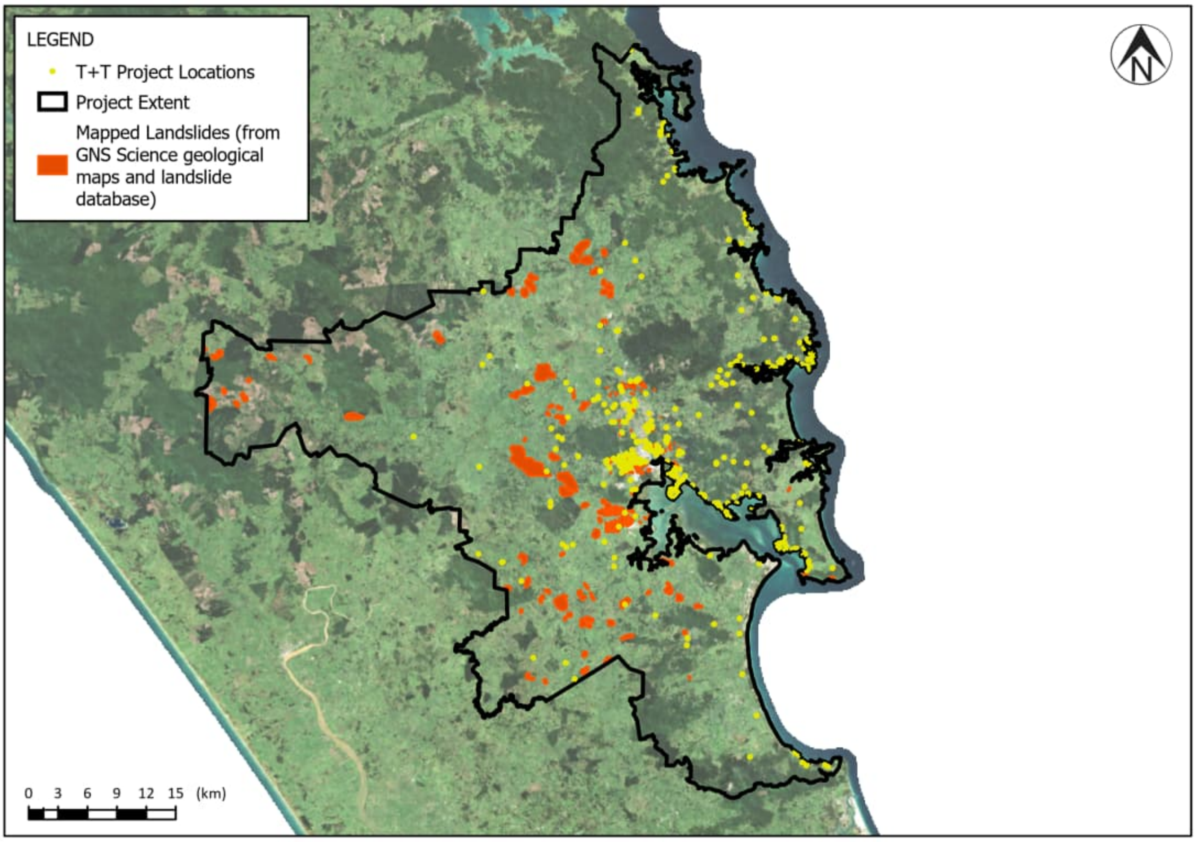


Figure 3.1: Distribution of GNS Science landslides, geologically mapped landslides, and T+T project locations for landslide related projects in the District.

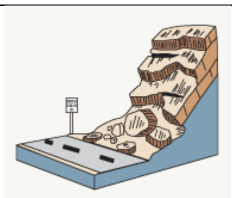
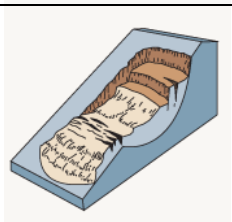
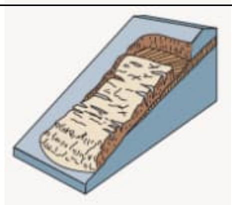
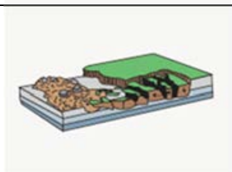
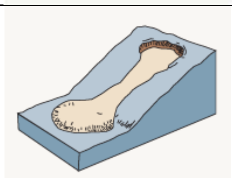
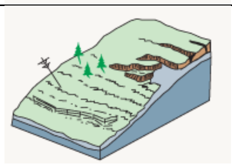
The landslide inventory allows us to establish links and/or patterns with mapped landslides across the different geological units in the area. From looking at the distribution of features on Figure 3.1, we can make the following observations:

- The distribution of the landslides identified by GNS Science are predominantly to the centre and west of the District, typically within Northland Allochthon and Waitemata Group units. These landslides generally appear quite large.
- The landslides mapped on the geological maps are also predominantly found on Northland Allochthon slopes, and also notably on the edges of volcanic units. The size of these landslides is typically smaller.
- T+T project locations that relate to landslides are grouped around the residential areas of the District. We note these are only those recorded from early 2000's.

We compared the locations of landslides mapped by GNS Science, the geological maps and T+T project locations to the existing landslide susceptibility map as shown on the WDC GIS system. We observed that these landslides were typically marked as "high stability hazard" in those locations, indicating that the existing mapping included these landslides in the assessment. We note also that the majority of the landslides mapped on the geological maps are within or close to residential areas of the District. This observation is verified by the predominant location of residential landslide projects in the T+T database.

For reference, different types of landslide and their failure mechanisms have been summarised in Table 3.1.

Table 3.1: Types of landslide and relevance to Whangarei District

Types of Landslips[1]		Description[1]
Falls		Masses are detached from steep slope/cliff surface with little or no shear displacement and descend mostly through air by free fall, bouncing or rolling. There is evidence of this type of landslide along the edges of volcanic units in areas such as Whangarei Heads.
Topples		Movement by forward rotation about a pivot point. Typically observed along the edges of volcanic units where softer underlying units have eroded preferentially or started to slide themselves.
Rotational slides		Masses slide outwards and downwards on one or more concave-upward failure surfaces that impart a backward tilt to the slipping mass, which sinks at the rear and heaves at the toe. Can be observed in the mudstones of the Northland Allochthon units, as well as some Waitemata Group units.
Translational slides		Movements occur along planar failure surfaces that may run more or less parallel to the slope. Instances of this type of failure have been observed around the steeper slopes of the Waipapa Group greywacke hills, as well as Northland Allochthon and some volcanic hills.
Lateral spreads		Spreads involve the fracturing and lateral extension of coherent rock or soil masses due to plastic flow or liquefaction of subjacent material. Could be observed along the river banks through Whangarei.
Flows		Slow to rapid movements of saturated or dry materials which advance by flowing like a viscous fluid, usually following an initial sliding movement. Movement of the displaced material is predominantly by flow. Not typically observed around Whangarei.
Creep		Imperceptibly slow, steady, downward movement of slope-forming soil or rock. Movement is caused by shear stress sufficient to produce permanent deformation, but too small to produce shear failure. Typically observed in the mudstone units around the Whangarei District, especially within the Northland Allochthon units.

1 (United States Geological Society, 2019)

3.1 Typical landslide features

Within Whangarei, as well as other regions around New Zealand, the main factors contributing to the occurrence of the landslides include weak geology and steep geomorphology/topography, although the primary trigger for landslide occurrence is prolonged or intense periods of rainfall.

Based on our initial landslide inventory, and local knowledge, we had some initial observations for landslide features within the District.

- Northland Allochthon: The types of landslides observed in Northland Allochthon units were predominantly observed as rotational, translational or creep type landslides. The movement within Northland Allochthon soils is typically a result of shear failure surfaces that formed when this unit was emplaced over the pre-existing topography. The residual soils of Northland Allochthon are clay rich soils that are identified as being not only weak, but susceptible to changes in moisture content, shrink-swell processes and slow slip-stick movement. Deeper cracks in the soils generated by seasonal shrink-swell can allow water to penetrate deeper into the rock when rainfall occurs, which further encourages creep movement of slopes over the hillsides.
- Waipapa Group: Some landslides are also observed in the Greywacke basement rocks. These are often observed to show signs of shallow, surficial (translational) landslides, which is typically related to movement in thin layers of residual soils on very steep slopes.
- Volcanic units: We also observed toppling or falls from the volcanic deposits, especially when they are exposed rock faces, or underlain by weaker mudstones (such as Northland Allochthon).
- Alluvium: Shallow landslides can be seen within the alluvium, primarily along rivers and streams.

For this susceptibility assessment the landslide inventory acts as a guide for particular conditions that could be prone to landslides, that we can focus our assessment on. Based on our initial observations we understand that Northland Allochthon, Waipapa Group and areas around the volcanic geological units are more likely to show signs of landsliding.

With regards to rock fall type landslide features, we were able to identify some areas of rock fall debris, using aerial imagery and field observations. Where this rock fall debris was observed, we mapped those areas as “high susceptibility”. Where they could be identified, we have also mapped some source areas for the rockfall as “high susceptibility” features. We note that we have not undertaken a rock fall analysis as part of this work.

There may be a chance that rock fall could impact land further downslope of a rock fall source area, or downslope of areas where debris has been identified. However, due to distance from a possible source, these areas have not been mapped specifically as “high susceptibility” relating to observed rock fall potential nearby. The slope angles adopted in the susceptibility assessment should incorporate possible run out areas as Moderately Susceptible. Where this is the case, the rules adopted in the District Plan will require practitioners to undertake a site-specific assessment and prompts should be included to ensure that inundation from rock or soil is considered.

4 Landslide susceptibility assessment

Landslide susceptibility is a measure of a particular area's propensity to either generate, or be affected (inundated), by landsliding. The assessment of susceptibility is based on the following two assumptions (AGS, 2007):

- That the past is a guide to the future (i.e. areas that have experienced landsliding in the past are likely to experience landsliding in the future); and
- Areas with similar topography and geology that have experienced landsliding in the past are also likely to experience landsliding in the future.

In line with this, we have reviewed the methodology used in the previous T+T reports and made recommendations for updates that could be included in this extension and update of the susceptibility assessment.

4.1 Review of previous methodology

The current stability zones shown on the WDC GIS (low, moderate and high), are based on the results of previous T+T reports, as discussed in Section 1.2. The methodology used in those assessments is summarised below:

- Desktop study: This included a review of the geological and soil type publications for the area, as well as the T+T database at the time, which included geotechnical investigations and assessments through to slope stability and stabilisation work.
- Field reconnaissance: This included broad site assessments for each area. These focused on existing geomorphology (areas of active landsliding, erosion, landslide morphology or steep slope gradients), rock and soil types of interest based on exposures (to compare to the geological maps), any locations of seepage on slopes, and areas of residential development.
- Aerial photograph analysis: This was the main method used to zone the land. Analysis of aerial imagery was undertaken to check areas of known landslides, and to identify any new areas of landslides. Stereographic aerial photographs at scales of 1:10,000 and 1:30,000 were used.
- Calibration: Once the land had been zoned into low, moderate or high stability hazards from the previous steps, a digital map was created and then calibrated in the field to check the accuracy of the digitisation of the map and aerial imagery interpretation.

The geological maps used for some of these areas were the 2003 GNS Science Geology of the Whangarei Urban Area map (White & Perrin, 2003) and the New Zealand Geotechnical Society map of Whangarei, Sheet 2A (Thompson, 1961).

This method used the (AGS, 2007) assumptions detailed above: that evidence of landslides in the field will guide whether land is likely to be susceptible or not to landslides, and those features can be inferred for the same geological units over a larger area. This work focussed primarily on the landslide features observed for the different geological units in the area.

One additional factor that was not specifically considered in the previous methodology, that could be included in this type of study is the slope angle of the topography or landform. This could help understand if features are observed at certain angles more than others and allow those to be differentiated. As a result, we have incorporated consideration of slope angles and topography in our updated susceptibility mapping.

4.2 Updated susceptibility assessment

The proposed methodology for the updated susceptibility assessment broadly follows the existing methodology described in Section 4.1 with the benefit of updated geological data, access to electronic data sources and aerial imagery, and high quality topographical information. Advances in analytical tools and techniques also allow us to use the data to provide additional assurances on the validity of the mapped susceptibility zones by comparing the geological context of mapped landslides.

Given the scale of this assessment, additional reliance has been placed on geology and slope angle classes that are likely to be susceptible to landsliding. The resulting map is therefore based on the slope angle and geology but also incorporates landslide features that have been identified in the landslide inventory and during the validation process. In order to undertake the landslide susceptibility assessment across the Whangarei District, and create a draft susceptibility map, the following tasks were undertaken:

1. Create an updated geological map of Whangarei District.

   Using the updated geological map (Edbrooke & Brook, 2009) *we created a simplified geological model of the main units observed in the District, as discussed in Section 2.*
2. Create a slope angle map using the 1 m contour data.

   LiDAR data was analysed at different slope angle ranges to understand the geomorphic features in the District, as outlined in Section 2.
3. Create a landslide inventory using mapped landslides.

   The available information was utilised to compile an inventory of known areas of landsliding as outlined in Section 3.
4. Create a draft susceptibility map utilising data from the above.

   A matrix of slope angle ranges was analysed that we believe are representative of low, moderate or high susceptibility for each of the geological units. These ranges came from discussions with multiple Senior Engineering Geologists and Geotechnical Engineers within T+T who have experience in these soils and landslides in the area and are considered experts in their field. Mapped landslides were given a classification of high susceptibility.
5. Complete multiple validation assessments of the updated map.

   Details of the validation assessment undertaken are provided in Section 5.
6. Finalise the susceptibility map for the District.

   Based on the findings of the validation assessments, we reviewed the susceptibility zones and calibrated this information to produce the final map.

The main tool for determining the landslide susceptibility for both the existing mapping and the updated mapping has been the geomorphic evidence for prior land movement, as the past is the best predictor of the future. For the previous mapping of largely urban areas, the geomorphic evidence was derived from both remote sensing (aerial imagery) and extensive ground proving in the field.

In areas of the District where the existing WDC landslide susceptibility map had already classified the land, we took a conservative approach to classifying that land in the updated assessment. Our analysis was able to compare the existing landslide susceptibility zones with the result of the updated assessment, and choose the higher, more conservative susceptibility zone to reflect the susceptibility of those areas. This means that we can use the data and findings from the existing mapping, alongside the more recent assessment which has utilised more detailed topographic information through the recent LiDAR surveys. The final susceptibility map is therefore a composite of the two exercises and as such the descriptions of the different zones can be updated to include a statement on the geology and slope class susceptibility as provided in Table 4.1 below.

Table 4.1: Updated descriptions of susceptibility zones.

Zone	Colour	Hazard	Geotechnical Assessment Required
Low	Yellow	Erosion or landslide morphology is not apparent *and/or the combination of geology and slope angle is not commonly associated with landslides*. 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.	Low level investigation
Moderate	Orange	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 land slippage suggest the land should be developed carefully.	Moderate level investigation and discussion of stability
High	Red	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 *and/or the combination of geology and slope angle*. This land is generally considered to be geotechnically unsuitable for development, unless works can be undertaken to avoid, remedy or mitigate the hazard.	High level investigation and stability analysis
Notes: Additional wording shown in italics, moderate description unchanged.			

Further details on the data sources that were used to support classification of land as low, moderate or high susceptibility to landsliding are outlined in us Table 4.2 below.

Table 4.2: Data sources for classifying susceptibility zones

Data source	Description
Aerial maps	Aerial maps were used to identify areas of current and ongoing development, areas displaying landslide features, and to help understand local processes that could impact landslide susceptibility e.g. locations of water courses.
Elevation data (LiDAR)	LiDAR data was used to understand the topography of the District, to identify trends in areas where landslide features were observed (e.g. along the edges of volcanic deposits), and to create a layer which divided the topography into different slope angle ranges which was used in our matrix for the assessment.
Geological maps	Two main geological maps by GNS were used to understand the spatial distribution of geological units that could be more or less susceptible to landsliding, and to identify areas already mapped as being landslide features. This was incorporated into our matrix for the assessment.
Existing mapping	The existing landslide mapping on the WDC GIS system was used to double check areas where mapping already existed, to verify classification of zones.
T+T project locations	We used the spatial distribution of T+T projects relating to slope instability to get an understanding of the conditions in residential areas that could appear more susceptible to landslide issues, as well as using relevant ground investigation from these projects where available and suitable.
GNS Landslide Database	Publicly available data from GNS has locations and extents of previously mapped large landslides across the District, that had been mapped from aerial images in the past. This provided information on locations likely to be affected by instability in the less developed areas of the District.
Landslide inventory	The landslide inventory we compiled from the GNS database, geological map landslide features, and the T+T project locations, was used to classify areas as "high susceptibility" as they "appear 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".
Fieldwork	Fieldwork was undertaken to validate areas in the District that were mapped as low, moderate or high susceptibility, to ensure our GIS results were representative of the conditions in the field, and to gain a better understanding of the surficial conditions of the different geological units.

5 Validation of susceptibility map

Validation of the initial susceptibility map has been undertaken with a range of assessments, as outlined below:

1. Compare the results of the draft susceptibility map with the existing landslide susceptibility map on the WDC GIS and highlight any areas of gross contradiction.
2. Review aerial photography and LiDAR - map any observed features of landslides that can be added to the landslide inventory.
3. Undertake site visits to identified locations to confirm geomorphological observations or assumptions made from the aerial photography and LiDAR data.
4. Complete Normalised Difference numerical validation of the geology and slope angle classes.

This mix of methods allows our assumptions for each of the low, moderate and high zones to be validated across the District for each of the geological units. This is especially important in an area of this size. Field mapping the whole area would be a large task in itself, with limited additional value, particularly for rural areas with low density of development/population.

5.1 Comparison between the existing and updated susceptibility map

When comparing the existing and updated susceptibility map, the majority of the mapped areas were found to be broadly consistent; confirming that the methodologies are similar, and similar features have been mapped the same. While the results are broadly consistent, there were some differences identified which we consider to be a consequence of the increased detail in the updated datasets (e.g. high-resolution LiDAR data).

One of our key observations when comparing these areas related to the mapped landslides. These areas were mapped as a mix of low, moderate and high stability hazards in the existing map, likely reflecting field observations. However, we believe that mapping these areas as moderate or high would be more appropriate, due to the inherent susceptibility of developing on landslide debris material. Site suitability assessments should allow for a more detailed analysis of a site to determine the appropriate level of susceptibility for such areas.

Another difference observed, when comparing the maps, was around boundaries of volcanic deposits. These areas were identified as high risk in the existing susceptibility map, due to the relationship between volcanic deposits and the underlying weaker, more susceptible, geological units (see Section 3). Due to the slope angles in these locations, the updated map did not initially pick these areas up as high susceptibility, verifying the importance of local knowledge and field work. From identifying this difference, we were able to map the landslide features along these boundaries in the aerial validation, as well as checking these areas through field validation. These boundary features were then incorporated into the final susceptibility map.

5.2 Aerial validation

Following the initial map comparison, the next phase was aerial validation across the District. This was undertaken by engineering geologists and utilised aerial imagery, hill shade maps and contour maps of the District in conjunction with the geological mapping, to aerially map landslide features. In order to manage the mapping exercise and to provide reference points, the area was split into a 10x10 km grid.

The observed features of landslides were mapped at 1:10,000 scale, however developed residential areas were mapped at 1:5,000 scale. The predominant features observed included evidence of shallow translational movement, slump or creep movement, and rock fall debris. We outlined the area of these features on a map, so the features could then be added to our landslide inventory.

From the aerial mapping and developed landslide inventory, we were able to identify trends in the locations and topography of the different types of landslides features, which we were able to link to the underlying geology. This validated our assumptions for the type of failures likely to be exhibited by different geological units (Table 3.1, and tables in Appendix B). This also confirmed that our initial spread of low, moderate and high landslide susceptibility areas was appropriate.

5.2.1 Quality assurance

Quality Assurance of the aerial mapping exercise was achieved by independent mapping of randomly selected grid cells. This was undertaken both by the Engineering Geologists completing the mapping, and also by T+T Senior Engineering Geologists. This allowed us to compare the mapping by different members of the team and ensure that features were identified consistently across such a large area.

5.3 Field validation

Our observations from the comparison of the existing vs updated and aerial mapping exercise were tested by undertaking a programme of field validation. Multiple site visits were undertaken by an Engineering Geologist and Geotechnical Engineer between 21 and 31 July 2020. Figure A.5 in Appendix A show the areas that have had field validation undertaken. These areas were chosen as representative of the District with regards to the landslide features observed in the various geology and slope classes, as well as representing areas where we had less confidence in the features mapped in the aerial validation.

Prior to the site visits, the Whangarei District was subject to a significant rainfall event. This rainfall triggered many landslides across the District, of which some resulted in road closures. From the routes undertaken for the field validation, a few of the road closures were observed in Northland Allochthon areas, as well as some shallow failures in Waipapa Group areas. Evidence from this rainfall event helped to clearly identify how some geological units responded to rainfall, the predominant natural trigger for landslides in Whangarei District.

During the site visits we drove only on public roads and did not travel over private land. While this has not allowed us to check some specific, smaller areas of the District, the level of validation undertaken is deemed appropriate for this scale of analysis. Views of the surrounding hill slopes from roads were deemed suitable to illustrate the conditions of those hills, and evidence of landslides was still observed at this scale.

Once site visits were completed, and photographs analysed by Engineering Geologists, we added any new landslide features to our landslide inventory. Select photographs from the site walkovers are presented in Appendix C.

5.4 Numerical validation – normalised difference

Following the aerial and field validation stages, the draft susceptibility map was updated to include additional landslide inventory features that were identified during these two stages. This provided a more accurate data set to complete the numerical validation of the susceptibility mapping.

By overlaying the landslide inventory, geology and slope class maps it is possible to determine the proportion of the mapped landslide population associated with different combinations of geology and slope class/angle. By normalising this data relative to the actual proportion of the study area occupied by each geology-slope class combination, the conditions most often associated with landsliding can be identified. This is called normalised difference.

The equation for normalised difference is as follows:

$$ND = \frac{A_L - A_T}{A_T} = \frac{A_L}{A_T} - 1$$

where:

A_L is the percentage of the mapped landslide population associated with a given combination of geological unit and slope class.

A_T is the percentage of the study area represented by the same combination of geological unit and slope class as A_L.

A positive normalised difference value indicates that a particular combination of geology and slope class has a greater proportion of its area affected by landsliding than its relative abundance would suggest. The greater the normalised difference value, the greater the statistical association with landsliding to be associated with those particular conditions. The minimum value for normalised difference is -1.0. Theoretically there is no limit to positive values, although any value more than approximately 0.5 shows a strong association, these boundaries are marked by colours green (negative), yellow (positive) and red (strong positive association). Therefore, the normalised difference provides a numerical basis for comparing those conditions most associated with landsliding.

Figure 5.1 shows the Normalised Difference ratio for geological unit only. This shows that the geological units that are more susceptible to landsliding are Northland Allochthon, Kerikeri Volcanic Group and the Waitemata Group. While this may be expected it does provide added certainty that these units statistically result in more landslides than the other units based on the proportional representation of that geological unit.

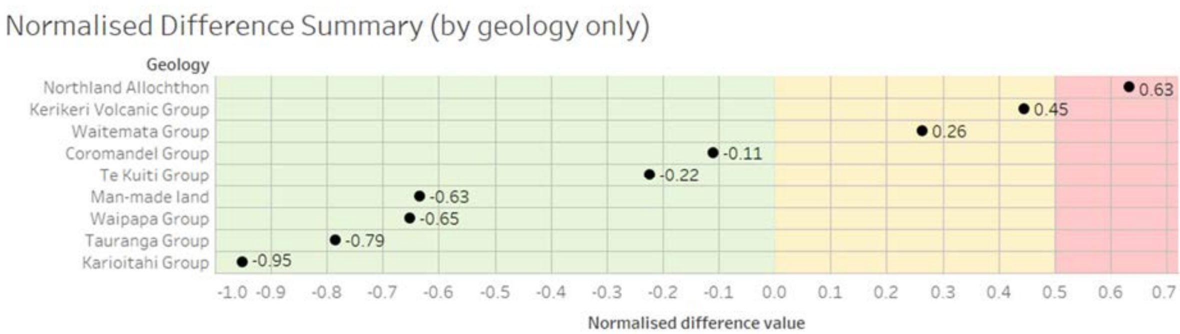


Figure 5.1: Normalised difference values based on Geological Unit only. Landslide debris ratio has been removed from this chart in order to keep a consistent scale. Please see tabulated figures below for ratios for landslide debris.

Adding slope angle to the Normalised Difference analysis gives further insight into the occurrence of landsliding. Figure 5.2 shows this relationship in chart form, these figures are also presented in Table 5.1. Of the more susceptible units (plotted above the dashed line), the Northland Allochthon is seen to be unstable at angles less than 10 degrees. The Kerikeri Volcanic group appears to have a threshold in the 10 to 20-degree range, although this is likely to be related to the underlying Northland Allochthon. Where we see higher Normalised Difference values in the Coromandel Group at higher slope angles it is likely that these are related to rock fall issues. The Waitemata Group has a stronger correlation with landsliding from slopes starting from 20-30 degrees. In response to the findings of these assessments we were able to adjust the slope thresholds used in our final susceptibility map.

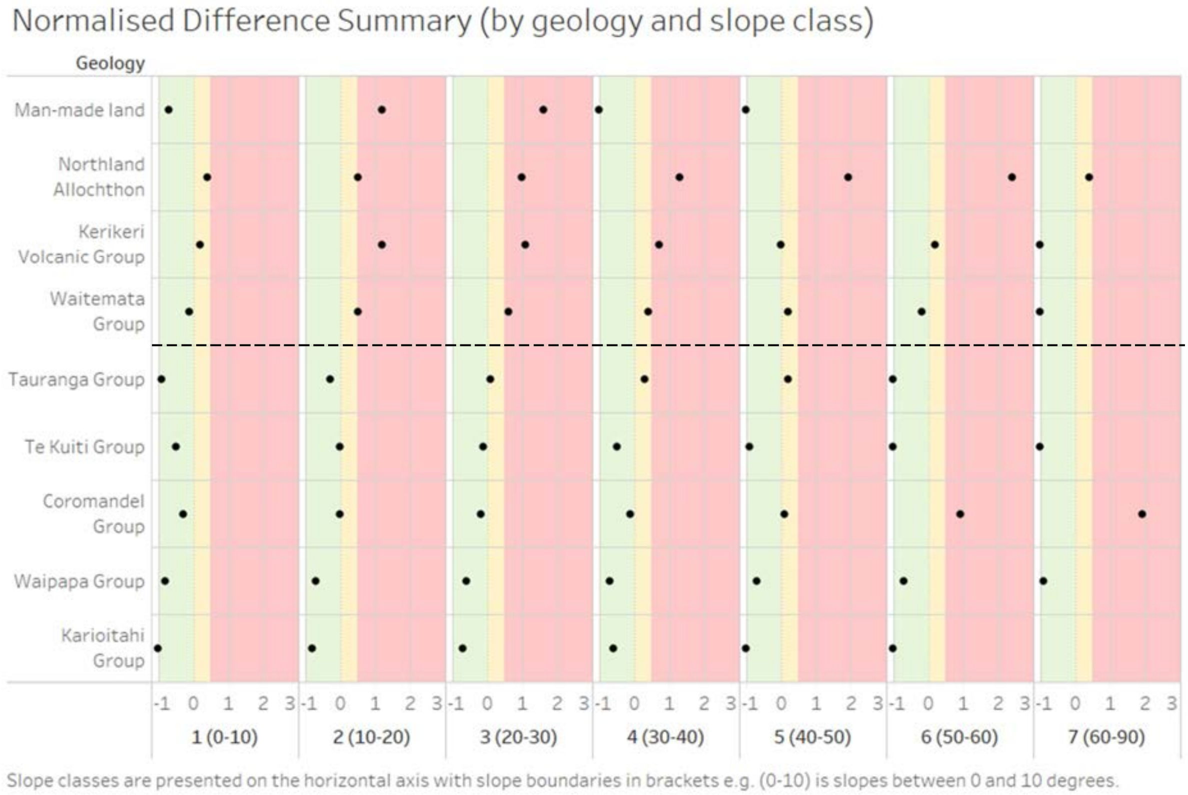


Figure 5.2: Normalised difference values based on Geological Unit and slope angle. Landslide debris ratios have been removed from this chart in order to keep a consistent scale. Please see tabulated figures below for ratios for landslide debris.

The normalised difference analysis provides us with greater certainty on the susceptibility of the geological units at different slope angles and has allowed us to refine our final susceptibility map and gain insights into the occurrence of landslides in the study area. There are some limitations to the values that are generated from the analysis, and these should be considered in the reliance of this data. The analysis has been undertaken using the same base information which introduces the same uncertainties related to the scale and resolution of the information. The area affected by landslides is based on mapping undertaken at 1:10,000 scale. Smaller scale landslide features are likely to be present; however, for the purposes of a district wide susceptibility assessment, the scale is considered appropriate. Site specific assessments will be required in any case to understand the susceptibility and risk at a particular site where development is proposed.

Table 5.1: Normalised difference results sorted by slope class and geological group.

	Slope Class (degrees)						
Geology	0-10	10-20	20-30	30-40	40-50	50-60	60-90
Landslide Debris	16.2	16.0	15.2	14.5	12.3	-1*	N/A**
Man-made Land	-0.7	1.2	1.6	-1	-1	N/A	N/A
Northland Allochthon	0.4	0.5	1.0	1.3	1.9	2.4	0.4
Kerikeri Volcanic Group	0.2	1.2	1.1	0.7	0.0	0.2	-1
Waitemata Group	-0.1	0.5	0.6	0.4	0.2	-0.2	-1
Coromandel Group	-0.3	0.0	-0.2	-0.1	0.1	0.9	1.9
Te Kuiti Group	-0.5	0.0	-0.1	-0.5	-0.9	-1	-1
Waipapa Group	-0.8	-0.7	-0.6	-0.7	-0.7	-0.7	-0.9
Tauranga Group	-0.9	-0.3	0.1	0.3	0.2	-1	N/A
Karioitahi Group	-1	-0.8	-0.7	-0.6	-1	-1	N/A

<u>*Notes*</u>

** A -1 represents a slope class where no landslide features were mapped in that geological unit.*

*** N/A is shown when a slope class range was not identified in a particular geology, meaning slopes for example over 60 degrees in the Karioitahi Group were not observed.*

The minimum value for normalised difference is -1.0. Theoretically there is no limit to positive values, although any value more than approximately 0.5 shows a strong association, these boundaries are marked by colours green (negative), yellow (positive) and red (strong positive association).

6 Discussion

Following all stages of validation for this susceptibility assessment, we updated our susceptibility map to create the final susceptibility zones for the Whangarei District.

The landslide susceptibility map is provided in Figure A6, and Figure A7, Appendix A.

6.1 Landslide Susceptibility by Geological Unit

The key observations and assumptions for the behaviour of the different geological units in the District, verified by aerial and field mapping, are discussed in this section. Comments on the normalised difference results are also included.

6.1.1 Waipapa Group

- This unit was typically observed as steep greywacke hills along the east of the District (Photograph Appendix C.1).
- The landslide features observed were surficial, translational landslides, likely to be related to the residual soils (Photograph Appendix C.2). These were typically small landslides with often long runout areas down the hillsides.
- The surficial landslides were more obvious in areas where road cuttings were present, and where deforestation had occurred, as these have likely affected the stability of residual soils.
- Some of the greywacke hills were observed to be gently dipping towards the west (Edbrooke & Brook, 2009), resulting in steeper east facing slopes. In these areas, more landslide features were observed on the steeper eastern slopes, than the gentler western slopes.
- Observations from field validation confirmed that steep slopes showing surface slumping or shallow landslides were mapped as high susceptibility areas. Landslides were still observed on more moderate slope angles, but not as often as on steeper slope angles.
- Normalised difference did not show a strong correlation in any slope angle class. This is likely due to the high proportional representation of this geological unit and the relative lack of identifiable landslide features at the scale of mapping undertaken.
- The susceptibility zones are representative of the conditions observed in the field.

6.1.2 Te Kuiti Group

- Small areas of Te Kuiti Group are mapped within the District and they are generally not as susceptible to landsliding (Edbrooke & Brook, 2009).
- Some features of translational failures were observed. Features were more common near the boundary with Tauranga Group or Northland Allochthon.
- Field mapping confirmed that Te Kuiti Group landforms showed areas of minor surficial movement (Photograph Appendix C.3).
- Normalised difference did not show a strong correlation in the majority of the slope angle classes, as expected, due to few landslide features being observed within this geological unit.
- The susceptibility zones are representative of the conditions observed in the field.

6.1.3 Northland Allochthon

- The Northland Allochthon unit covers a large portion of the District, predominantly towards the west but also in areas within Whangarei township.
- The Northland Allochthon unit is well known for being unstable due to the conditions of its emplacement (Figure 2.1), and the resulting shear fabric within the rock mass.

- From aerial images, the Allochthon geomorphology looks to be predominated by gentle slopes with hummocky features. The hummocky surface likely relates to large areas of deep seated, slow moving creep landslides (Photograph Appendix C.4).
- Where some flat areas of Allochthon were observed, it is likely that these have been covered with alluvial deposits, and therefore show fewer signs of landslide features at the surface. These could still have some inherent risks at depth that would need to be investigated on a site-specific basis.
- Steeper areas of Allochthon to the far western boundary of the District typically comprise more volcanic rock types. In these areas (part of the Tangihua Complex), landslide features were observed to be more surficial, translational landslides (possibly relating to residual soils) in comparison to deeper seated landslides (Photograph Appendix C.6).
- Field mapping confirmed large areas of Allochthon show signs of landslides. Multiple roads were closed after the rainfall event due to landslides within this unit. Swampy, wet zones were observed in the field, even on higher elevation areas of Allochthon throughout the District.
- Normalised difference ratio for this unit was positive across all slope angles and the ratio increased with slope angle suggesting that all areas underlain by this unit should be treated with caution.
- Landslides of the Northland Allochthon have been verified in aerial and field mapping. This was confirmed from large areas of landslide features even on gentle slopes (Photograph Appendix C.5). Due to the inherent risks in this unit, the majority is mapped as high susceptibility.

6.1.4 Waitemata Group

- The Waitemata Group is typically found in alongside Waipapa Group to the south of the District.
- The aerial mapping showed gently sloping hills of Waitemata Group to have large areas of hummocky ground, as well as areas of boggy ground and springs (Photograph Appendix C.7).
- Field mapping confirmed the Waitemata Group had large areas of hummocky land evident of rotational movement (Photograph Appendix C.8), and that boggy areas with springs were common.
- The normalised difference results show a maximum positive correlation for this unit for slopes between 20 and 30 degrees, suggesting that the critical angle for this unit is within this range. Steeper slopes may show fewer signs of instability; however, the scale of the mapping undertaken may under represent the area of landsliding.
- Overall, the Waitemata Group can be represented by moderate to high susceptibility. This was verified by the field observations.

6.1.5 Kerikeri Volcanic Group

- This volcanic group can be identified as deposits typically on top of older sedimentary deposits, predominantly throughout the centre of the District.
- This unit is predominantly flat to gently sloping lava flows with few landslide features observed, other than along the edges of the deposits. These edges were more often subject to block topple or block sliding, related to undercutting from, or movement of, weaker units beneath.
- Some steep areas of volcanic deposits relate to scoria cone features. These are more often mapped as high susceptibility due to the steepness of these features (Photograph Appendix C.9).

- Along the edges of the lava flows there is also a susceptibility to rock fall which should also be considered in geotechnical assessments (Photograph Appendix C.10).
- Aerial and field mapping, along with local knowledge, confirmed that an important stability issue is identified where volcanic units are underlain by softer units, especially Northland Allochthon (Photograph Appendix C.11). A large number of landslides were mapped in areas where this combination of geological units was observed.
- The Kerikeri Group geology shows a positive normalised difference in slope angles up to 30-40 degrees with a maximum value in the 10 to 20 degree range. Our observations from this unit suggest that the instability is a function of the underlying Northland Allochthon rather than inherent instability within the unit itself.
- This volcanic unit is mapped representatively as low to high susceptibility zones. High and moderate zones are normally associated with underlying geology at geological boundaries and low susceptibility away from geological boundaries.

6.1.6 Coromandel Volcanic Group

- This volcanic group is predominantly located around Whangarei Heads.
- These units represent more intrusive volcanic activity, with some steep areas of volcanic deposits relating to volcanic dome features. These are more often mapped as high susceptibility due to the steepness of these features (Photograph Appendix C.9).
- Where pinnacles of the volcanic deposits were identified, there is also a susceptibility to rock fall which should also be considered in geotechnical assessments (Photograph Appendix C.10).
- Field observations show more evidence for rockfall or topple landslide features for this geological unit.
- The Coromandel Group geology shows negative normalised difference ratios until slope angles reach 40-50 degrees with a maximum ratio observed in the 60 to 90 degree range. This reflects the susceptibility to rock fall within this unit.
- This volcanic unit is mapped representatively with low to high susceptibility zones. High and moderate zones are normally associated with steeper slopes and rock fall susceptibility.

6.1.7 Karioitahi Group and Tauranga Group

- These units are the more recent coastal and alluvial deposits respectively and as such are predominantly found along the coastline and along rivers and streams.
- Coastal and beach areas are mostly low lying and have gentle undulations mostly relating to sand dune formation (Photograph Appendix C.12). Small areas of landslides observed on the active sand dunes are more likely to relate to erosional processes than landslides.
- Alluvial areas are typically low lying or gently sloping. Small landslides were observed along edges of waterways, but this is more likely related to erosional processes. This was especially observed in the field validation after the rainfall event (Photograph Appendix C.13).
- From local knowledge, some low lying alluvial areas are likely to be underlain by Allochthon soils, so care should be taken when Allochthon is nearby, to ensure geotechnical investigations are taken to a depth to identify if there could be any susceptibility for landslides at depth.
- The Karioitahi Group had the lowest relationship results from the normalised difference, as expected due to the low number of features identified on this usually flat geological unit.
- The Tauranga Group has a positive relationship for landslide features observed between slope angles of 20 and 50 degrees. The steeper slope classes could be representative of features

that were mapped on steep stream banks or where the mapped geological boundaries are not reflective of the actual site conditions.

- Overall, the field observations in these areas confirmed there were limited stability issues and a low susceptibility is typically representative (unless other geology types are influencing stability beneath these deposits).

6.1.8 Reclaimed land

- Areas of reclaimed land and fill were typically observed in low-lying, flat areas around the coastline, including the Port (Photograph Appendix C.14).
- Few landslides were observed in these areas, other than on edges that are more likely related to other geological units. These areas were also observed to be swampy.
- Reclaimed land is typically mapped as moderate to high susceptibility on the existing mapping, which likely relates to the unknown material types and compaction/density within the area, and therefore the strength or stability of that material.
- Areas of reclaimed land showed a positive correlation in the normalised difference results between 10 and 30 degrees. Reclaimed land is likely to be largely flat, therefore the positive correlations observed may represent cuts or batters in these areas or the geological mapping may be inaccurate.
- Overall, reclaimed land has been mapped as high susceptibility due to the unknowns in the material making up that area, and therefore should be developed with caution.

6.1.9 Landslide debris

- Areas mapped as landslides by GNS Science and the geological maps are located typically on Northland Allochthon soils, and on the edges of volcanic units where underlain by Allochthon soils, across the majority of the District.
- The mapped features are often clear to see in the aerial and field mapping, both in developed and undeveloped areas of the District (Photograph Appendix C.15). However, some of these landslides were hard to identify due to the level of development. Identification of these features should be included in site specific geotechnical assessments for these areas.
- The field mapping confirmed that areas of mapped landslide had hummocky features, irregular slopes and swampy patches. Offsets were often seen in the local roads.
- Normalised difference shows the highest positive correlation relationship between geologically mapped landslides and slope angles between 0 and 50 degrees. This is a due to the aerial mapping and field validation methods confirming that land mapped as landslide debris (from the landslide database and geological maps) is represented by landslide features in those areas.
- We consider that areas mapped as landslides in our inventory should be high susceptibility due to unknowns in the underlying geology and levels of strength in the soils, so have classed any mapped landslide as high susceptibility in our susceptibility analysis.
- The high susceptibility zone is representative of the conditions observed in the field.

6.2 Scale and Pixilation

The final landslide susceptibility map is designed to be viewed at a 1:10,000 scale, in line with the viewing scale used for aerial validation. Similarly, the LiDAR data used was sampled on a 10 m square in order to smooth out smaller undulations and to characterise the general slopes. When zooming into the map beyond 1:10,000 scale, these 10 m squares result in distinct pixelation of the image, which gets more pronounced the further the map is zoomed in. We consider this to be appropriate to represent the accuracy of the mapping, as the scales of the source data used would not allow for accurate characterisation within that 10 m square.

The intention is that the maps be enabled for zooming beyond 1:10,000 so they are more user-friendly, but that the pixelation remain to emphasise the level of accuracy used for the mapping. One could then zoom into a property, see which susceptibility zone(s) are mapped within the boundary, and conduct a site specific assessment to a commensurate level to the zoning.

The landslide susceptibility mapping does not remove the need for a site specific assessment at property level, as described in the EES. We also note that the geological mapping for the District (part of our source data) is provided at a 1:250,000 scale which is not accurate to the property level; geotechnical investigation and assessment is needed to accurately define the ground conditions for a specific site.

6.3 Limitations

This assessment is intended to be a high-level tool for identifying areas that are susceptible to landsliding across the District, based on mapped landslide and instability features and the relationship between geology and slope angles. The updated mapped susceptibility zones can be considered analogous with the Low, Moderate and High “land stability hazard zones” as outlined in the EES, and the information requirements stated in the EES will continue to be suitable for the updated mapped land in the District.

This susceptibility assessment does not remove the requirement for site specific assessment at the time of subdivision, change in land use, or building works that would require consent in a site suitability report. Updates to the District Plan may also require site specific assessments for other activities.

Below are a few limitations of this project which should be considered when completing site specific assessments:

- Due to the size of the District, we were not able to field validate all areas.
- The susceptibility maps are reliant on the published geological maps. Due to the scale of the mapping undertaken and the potential for areas to be mapped incorrectly it is important to confirm the geological unit in a site-specific assessment.
- We have based this assessment on a simplified geological model. The normalised difference results indicate that some smaller subgroups of these units may have lower susceptibility than the overall unit.
- Where weaker units are overlain by more stable units (e.g. alluvium or volcanics on top of Northland Allochthon) or where paleosols (soils at depth) are identified, these can result in movement at depth that may not be seen at the surface initially. Where this is a possibility (e.g. near geological boundaries), ground investigations should be undertaken to sufficient depths in order to understand the specific constraints of the site.
- The depth of residual soil and the underlying geology is important to understand, as the depth of the weathered soil can also control some landslides. The depth should be understood on a site to establish how to mitigate that potential hazard.
- Where a site has multiple susceptibility zones shown it is considered prudent to assume the highest level of susceptibility and undertake the corresponding level of assessment recommended in the EES (e.g. a site with areas of low, moderate and high susceptibility would require an assessment meeting criteria of a high level investigation outlined in Table 1.1).
- In addition to erosion and land slippage of natural ground triggered by rainfall and/or seismic events, development works can accelerate, worsen or result in erosion and/or land slippage. 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).

- All geotechnical hazards (i.e. not landslide susceptibility alone) should be assessed as part of a site suitability assessment and the combined effects of hazards should be considered in the mitigation measures. This assessment relates to landsliding only and does not include other hazards such as mining subsidence, coastal erosion and flooding, which are known to affect the mapped area, and which would require consideration in a site suitability assessment.
- The landslide mapping undertaken for WDC represents the susceptibility of the land in the District to movement. This is different from a risk map, which also looks at off-site impacts from the site under investigation, as well as the on-site impacts from instability arising off-site. Accordingly, when looking at a particular property it has always been necessary to view the property in the wider context, to see if land with a higher susceptibility to landslides could impact the subject site. This includes the potential for rock fall and other debris to impact land downslope, and landslide head scarp regression to impact land upslope. The advantage of the district wide susceptibility mapping is that the stability of land adjoining previously mapped areas has now been assessed, so that off-site impacts can be consistently evaluated.

6.4 District Plan provisions

As discussed in Section 1.3 of this report. The current Operative District Plan (Whangarei District Council, 2007) does not specifically provide controls on the development of land that is susceptible to landsliding. We understand that this assessment is to be used in conjunction with rules to be developed and incorporated into a Plan review that is currently underway. The approach to managing development on land that is susceptible to landslides that is outlined in the EES (Whangarei District Council, 2010) is considered reasonable and applicable to the updated assessment.

With regards to limiting activities within each zone, it is considered prudent for any subdivision to provide a site suitability report to confirm the susceptibility zone. When considering applications requiring earthworks or vegetation removal, this should be limited in the moderate zone without further geotechnical engineering assessment. Any earthworks or vegetation removal in the high susceptibility zone will require geotechnical engineering assessment. The siting of water tanks, effluent fields or other water disposal in the high susceptibility zones will also require geotechnical engineering assessment for suitability.

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8 Applicability

This report has been prepared for the exclusive use of our client 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, or by any person other than our client, without our prior written agreement.

We understand and agree that this report will be used by Whangarei District Council in undertaking its regulatory functions in connection with hazard assessments. As further discussed in this report (in particular in Section 6.2 above regarding Limitations), this assessment is intended to be a high level tool for identifying areas that are susceptible to landslides across the District, based on mapped landslide and instability features and the relationship between geology and slope angles. This information is general in nature, and a more detailed site-specific landslide susceptibility assessment may be required for some purposes (e.g. for subdivision, change in land use, or building works).

Tonkin & Taylor Ltd

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Nick Rogers

Project Director

Reviewed by John Brzeski (Senior Engineering Geologist) & Jen Smith (Project Manager)

Attached Appendices:

1 Appendix A: Figures
2 Appendix B: Geological summary
3 Appendix C: Photographs
4 Appendix D: Legislative/regulatory context

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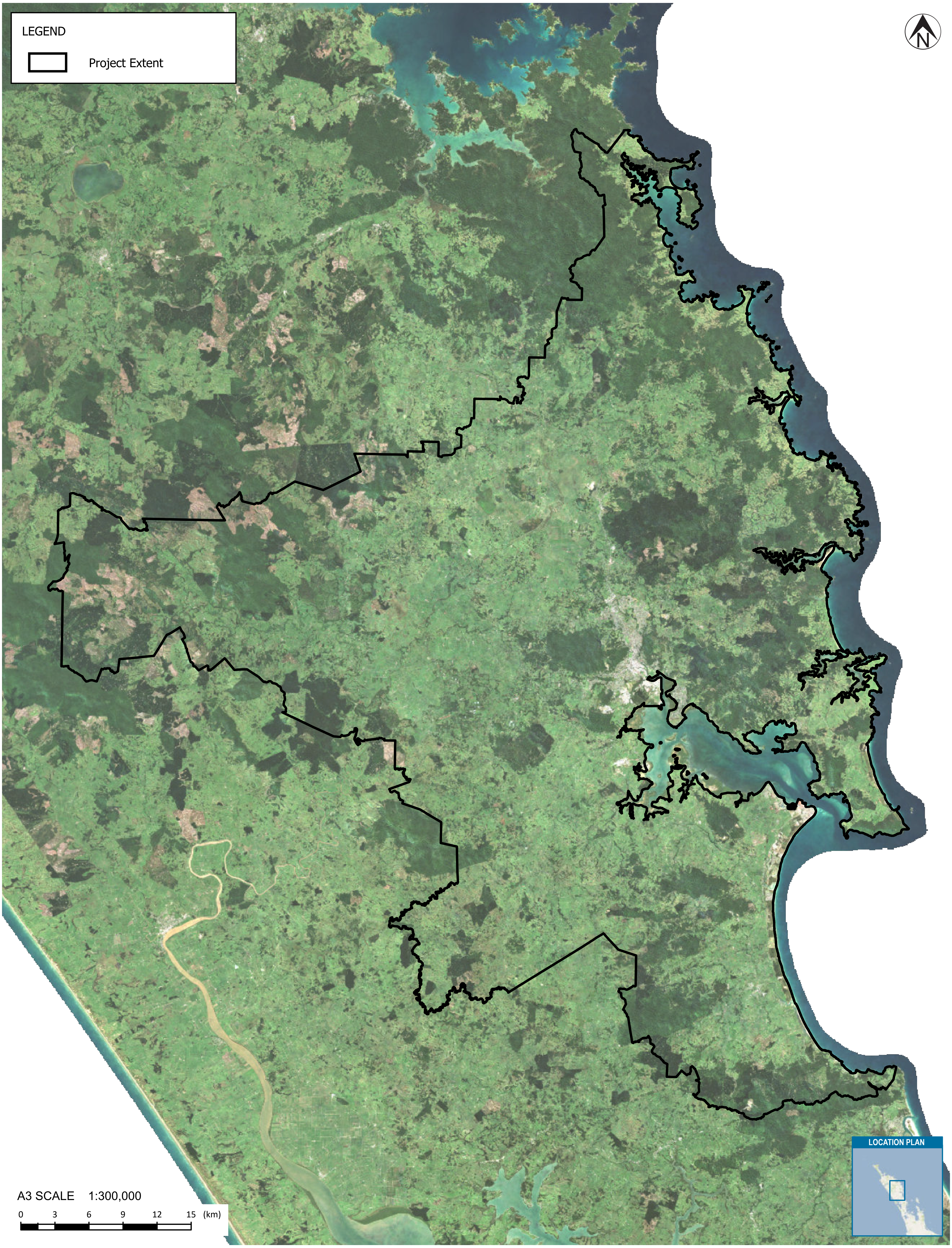
Appendix A: Figures



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DESIGNED	JORB	NOV.20
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CHECKED	MOLI	NOV.20
APPROVED	pp JKK	NOV.20 (DATE)

CLIENT WHANGAREI DISTRICT COUNCIL
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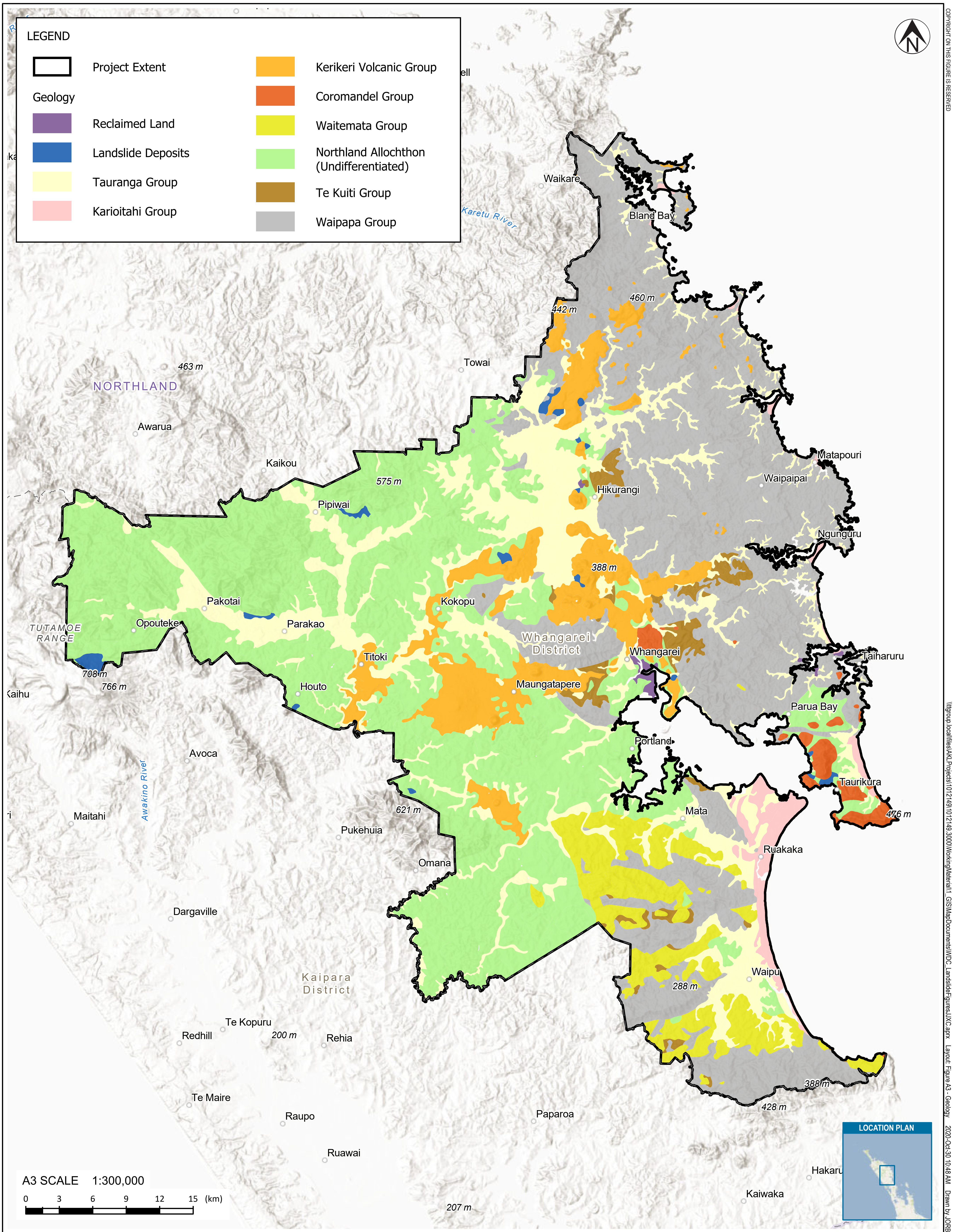

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CLIENT WHANGAREI DISTRICT COUNCIL
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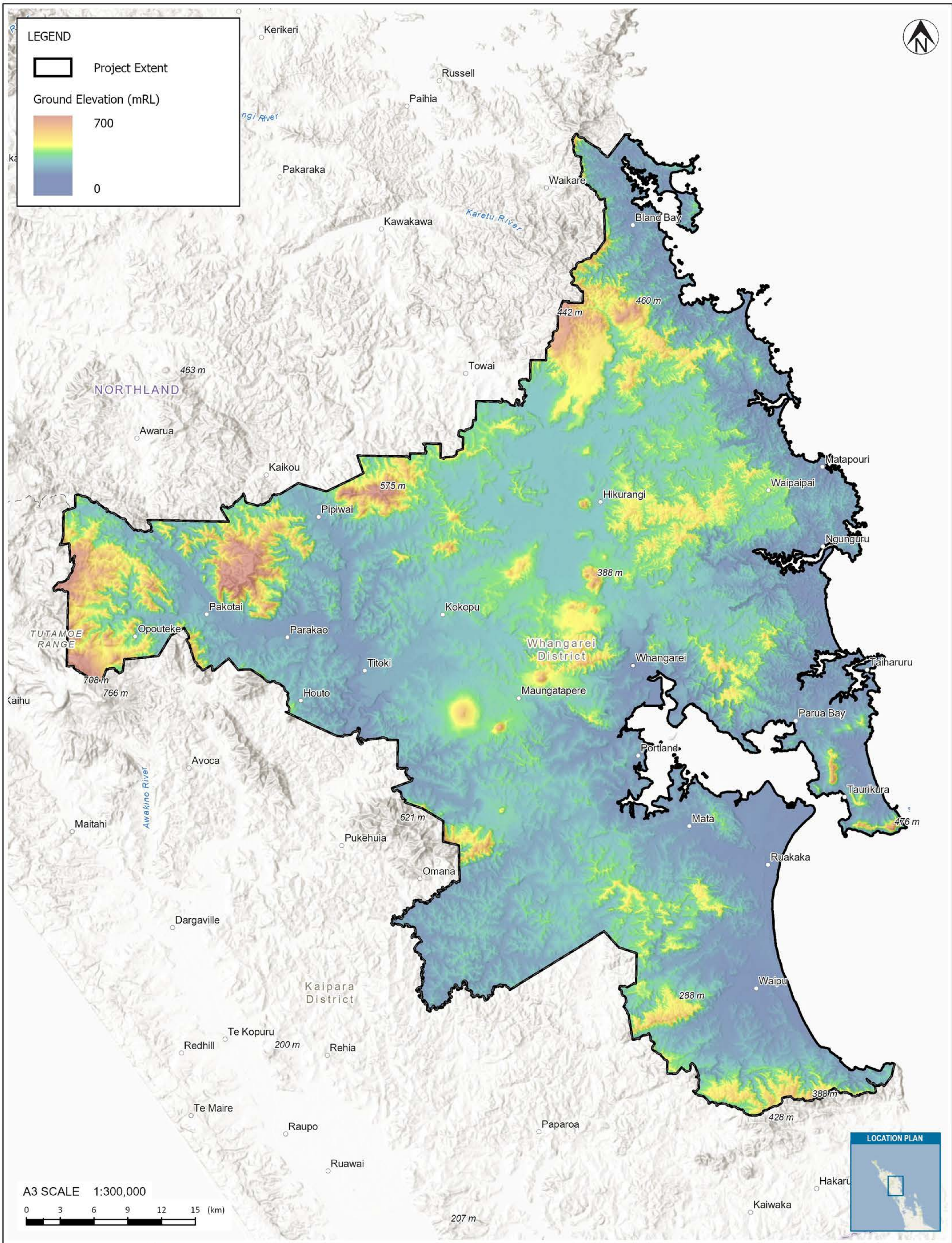

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CLIENT **WHANGAREI DISTRICT COUNCIL**
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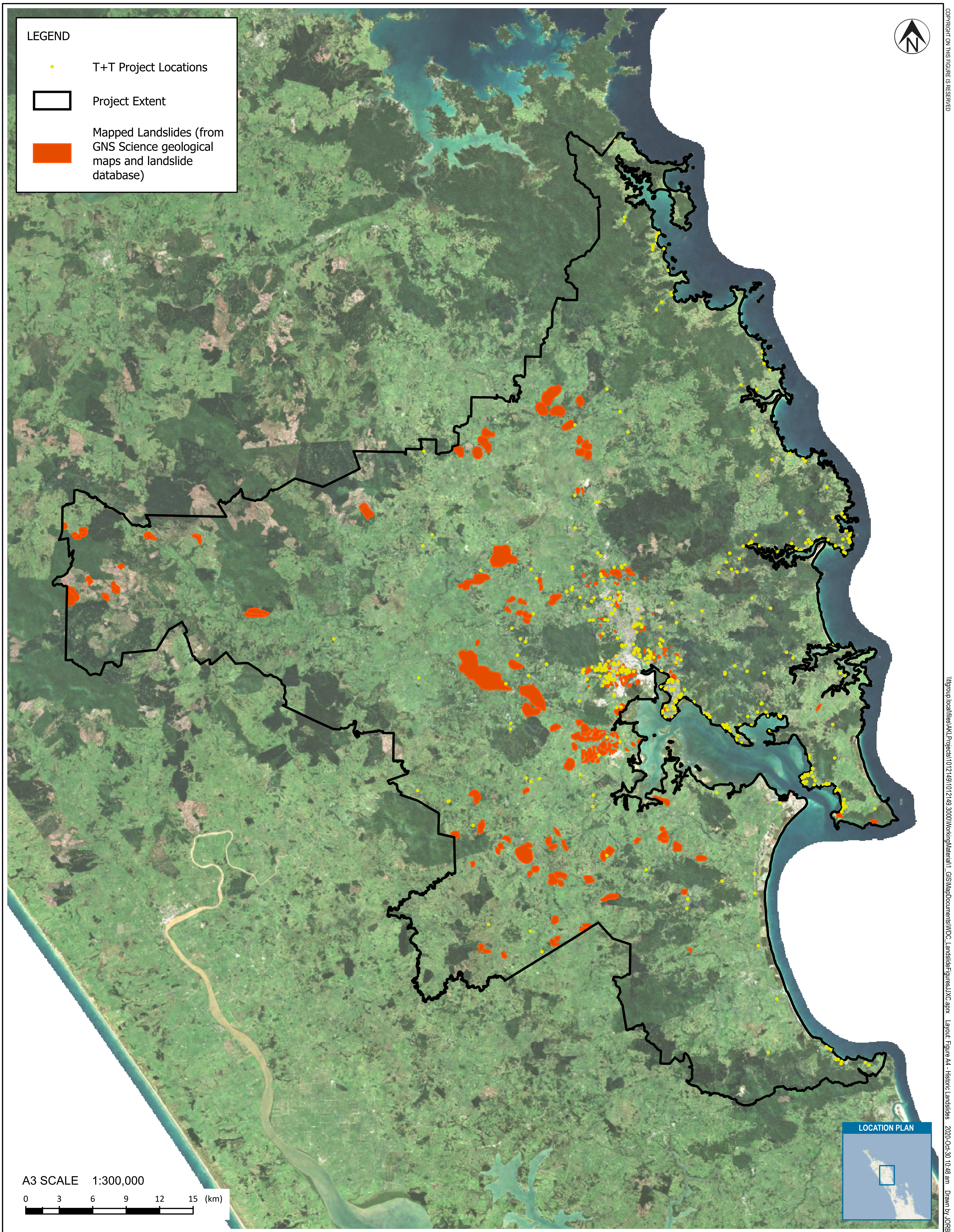

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GNS Landslide Database accessed from: https://data.gns.cri.nz/landslides/wms.html

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TITLE MAPPED LANDSLIDES

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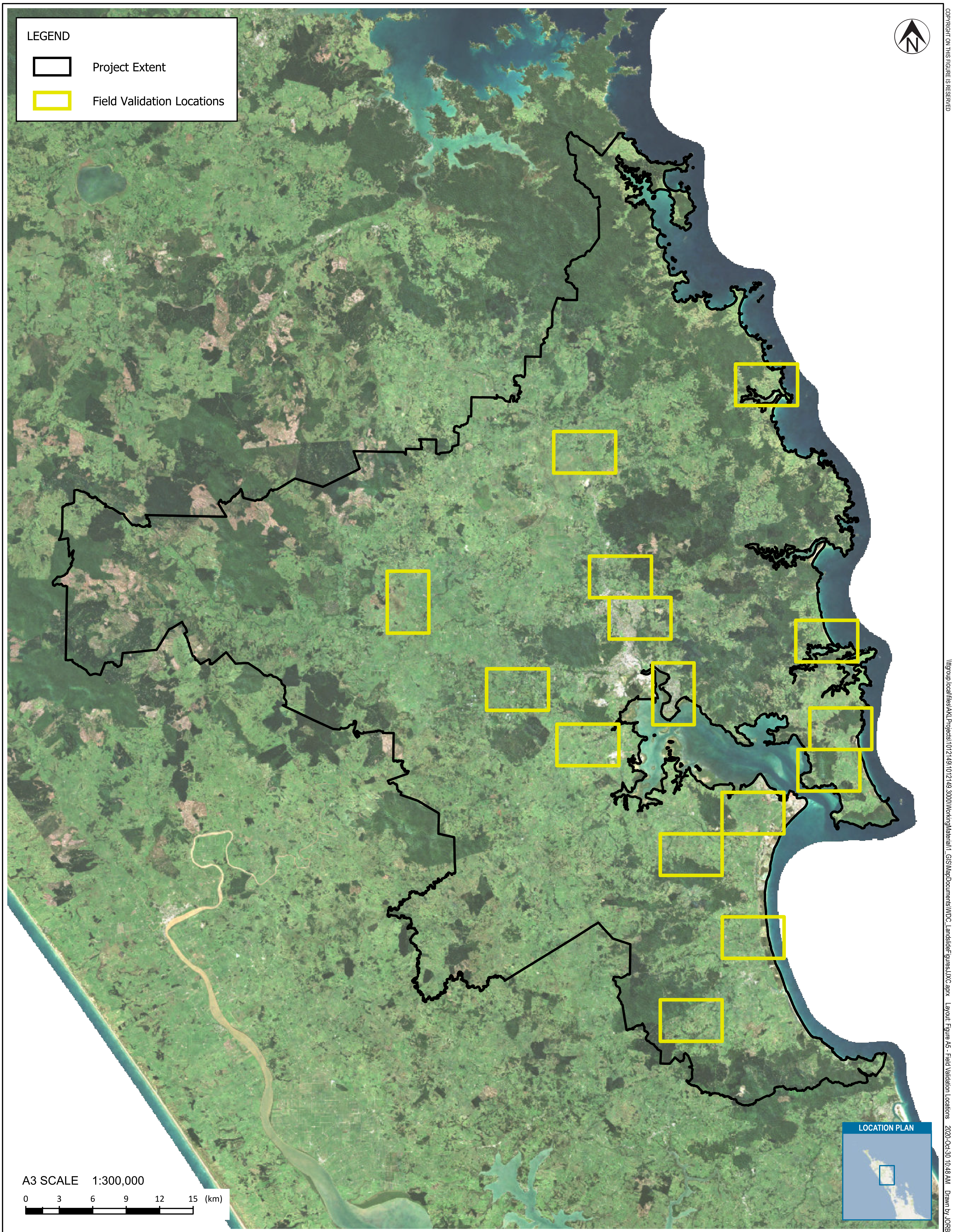

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CLIENT WHANGAREI DISTRICT COUNCIL
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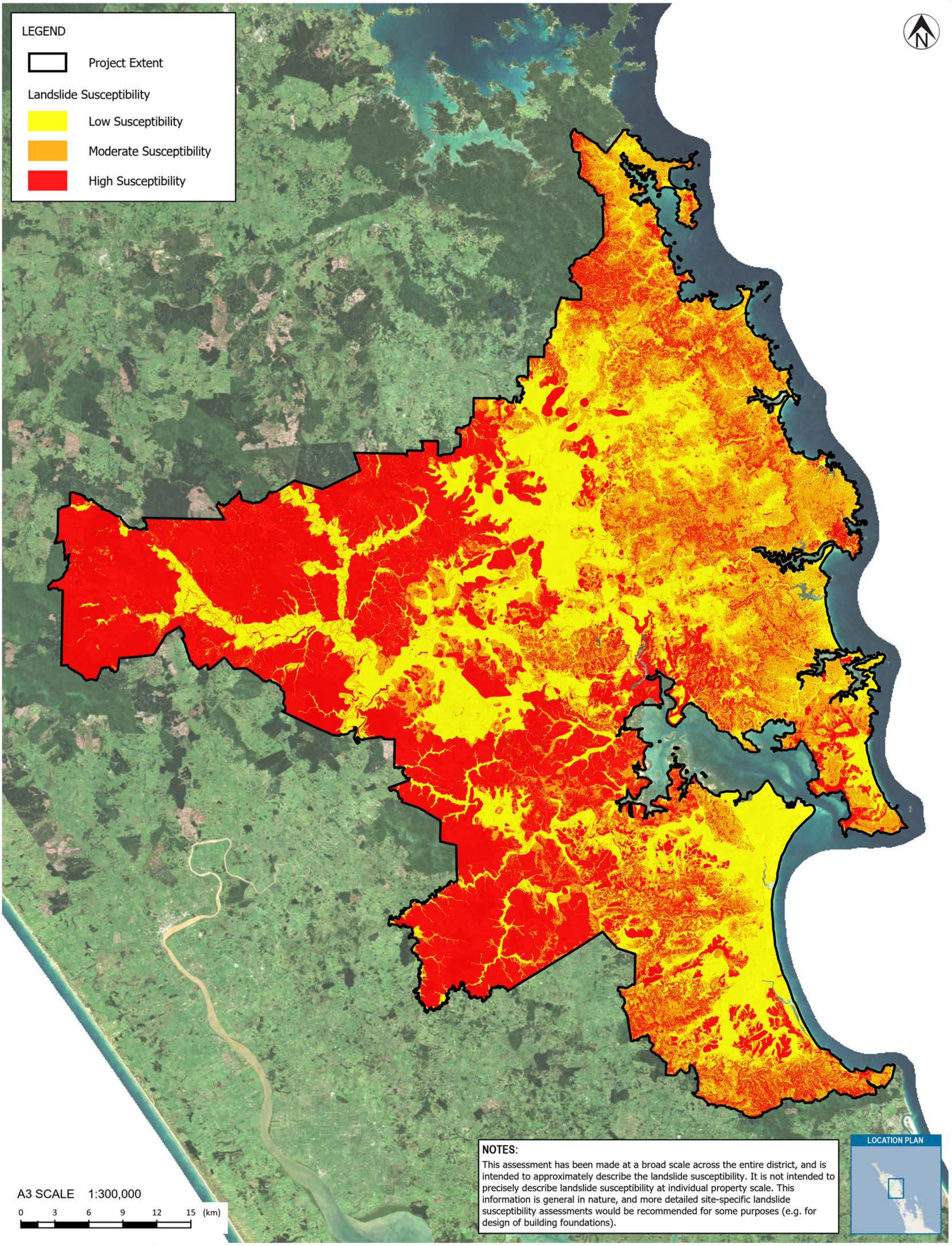

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CHECKED	JKK	NOV.20

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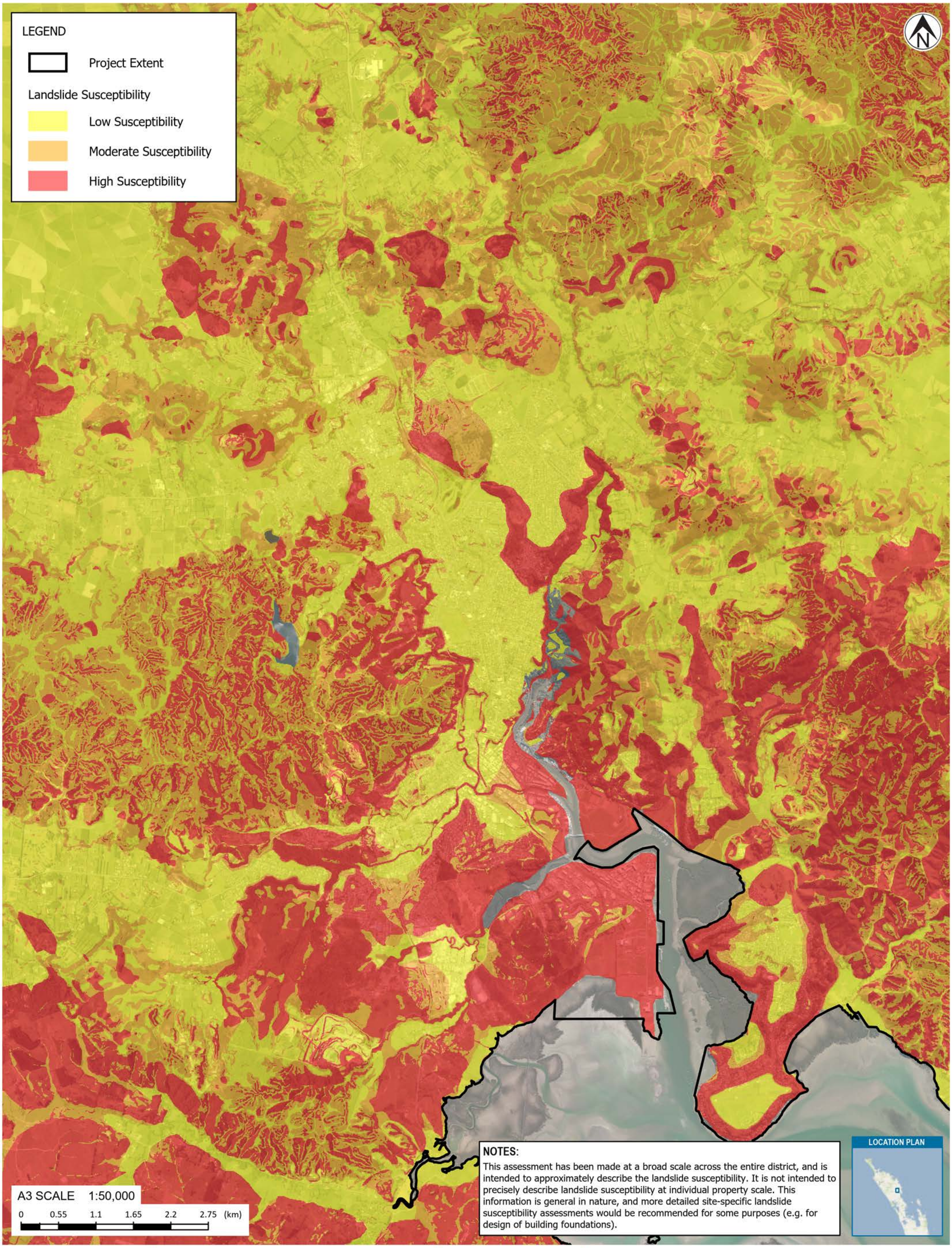

NOTES:
This assessment has been made at a broad scale across the entire district, and is intended to approximately describe the landslide susceptibility. It is not intended to precisely describe landslide susceptibility at individual property scale. This information is general in nature, and more detailed site-specific landslide susceptibility assessments would be recommended for some purposes (e.g. for design of building foundations).

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APPROVED	pp JKK	NOV.20

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PROJECT **WDC LANDSLIDE SUSCEPTIBILITY ASSESSMENT**
TITLE LANDSLIDE SUSCEPTIBILITY MAP

SCALE (A3) 1:50,000 FIG No. FIGURE A7 REV 0

Appendix B: Geological summary

Appendix B Table 8.1: Waipapa Group

Geological unit	Waipapa Group
Age	Permian to Late Jurassic 299.0 – 145.5 Ma (million years)
Depositional environment	Basement rocks that amalgamated on the ocean floor along the eastern margin of Gondwanaland. Predominantly igneous derived, low grade metamorphosed sedimentary sequences are inferred to represent arc-trench complexes.
Main rocks	Predominantly thin bedded, alternating fine-grained sandstone and argillite, massive poorly bedded argillite, and massive jointed greywacke sandstone. Some basaltic volcanic rocks (pillow lavas and volcanic breccias).
Rock strength	Typically, hard to very hard and can be closely fractured, strength reduces with weathering. Veins are common. Overall high shear strengths.
Weathering	Coastal outcrops are typically fresh, however inland they can be deeply weathered to 20 m deep on more gentle westerly dipping slopes.
Soils	Residual soils from weathering are typically stiff, white to yellow-brown clays and silts and are typically present as surficial soils.
Typical extent in Whangarei	These rocks form most of the rocky, indented coastline north of Ocean Beach, and the hills to the east of the District. Slopes are typically moderately to steeply sided (15-30°).
Indicators of landslides	Wedge/slab failures if in a shear zone or closely spaced joints. Surficial failures occur as shallow slides, debris flows or creep on steep slopes.
Other information	A regional unconformity is identified at the top of this unit, indicating a period of erosion prior to deposition of the Te Kuiti Group.

Appendix B Table 8.2: Te Kuiti Group

Geological unit	Te Kuiti Group
Age	Eocene to Oligocene 55.5-23.8 Ma
Depositional environment	Started as terrestrial unit with coal forming from swamps (Kamo Coal Measures). Sea level rose during continental extension, forming marine sands (Ruatangata Sandstone). Further marine encroachment left more marine organisms in the sediments forming the Whangarei Limestone.
Main rocks	Predominantly mudstone, sandstone and limestones. Ruatangara Sandstone is typically greenish-grey, fine-drained, and the Whangarei Limestone is typically white to pink and bioclastic.
Rock strength	Sandstones and limestones are strong and are observed to stand in near vertical bluffs. Limestone can show widely spaced subvertical joints.
Weathering	Sandstones becomes moderately weak to very weak when weathered. Limestones can form pinnacles when weathered.
Soils	Residual soils from weathering are typically clay dominated.
Typical extent in Whangarei	These rocks are observed to the west of the Waipapa Group rocks, in the centre of the District.
Indicators of landslides	Weaker units have minor landslides, typically failing by creep movement. Harder limestones have been observed to raft downslope when underlain by a softer sandstone. Some slab failures can occur on the bluffs.
Other information	Deposition of this unit stopped due to emplacement of Northland Allochthon units.

Appendix B Table 8.3: Northland Allochthon

Geological unit	Northland Allochthon (complete)
Age	Cretaceous to Oligocene 145.5-23.8 Ma
Depositional environment	Most of the Northland Allochthon units were originally deposited in deep sea environments to the north-east of the area (Mangakahia Complex). The Tangihua Complex comprises ocean floor pillow basalts, argillites and ophiolites. They were emplaced in thrust slices over the District.
Main rocks	Predominantly mudstone, sandstone and limestones with older basalts.
Rock strength	Rocks are typically highly sheared (mudstones) and faulted (sandstones). Volcanic rocks of the Tangihua Complex are typically strong in comparison.
Weathering	Weathering can occur at depth along rock mass defects but is typically a shallow profile.
Soils	Residual soils are typically soft, wet, highly plastic yellow-white clays.
Typical extent in Whangarei	These units cover the majority of the western part of the District, with some traces of these units to the east and along the coastline. They are typically hummocky and undulating.
Indicators of landslides	Shallow failures are typically controlled by thickness of weathered material, shear strength and water content. Deeper failures relating to rock mass defects can form large areas of low, rolling, hummocky topography. Shear surfaces are typically highly polished and coated in clay.
Other information	Multiple complexes have been identified within the Northland Allochthon, as well as a melange unit of undifferentiated Northland Allochthon soils.

Appendix B Table 8.4: Waitemata Group

Geological unit	Waitemata Group
Age	Early to Late Miocene 23.8-11.2 Ma
Depositional environment	This unit is typically made up of deep marine sediments. These are predominantly made up of the Ruarangi Formation (brownish yellow siltstone); the Ngatoka Sandstone (calcareous); and the Pakiri Formation flysch (sandstone and siltstone).
Main rocks	Predominantly mudstone and sandstones.
Rock strength	Very weak to strong across the different units.
Weathering	Weathering can occur along bedding planes or surface rocks. Ruarangi Formation can be deeply weathered along widely spaced joints.
Soils	Residual soils tend to be thin and are typically clayey silts with gravels.
Typical extent in Whangarei	This unit is typically located to the south of the District, adjacent to Te Kuiti Group and Waipapa Group rocks.
Indicators of landslides	The ground surface tends to be at least slightly hummocky, with shallow failures including soil creep forming larger areas of low, rolling, hummocky topography. Some bedding plane failures have also been observed.
Other information	This unit has been found to overlie, underlie and be incorporated within the Northland Allochthon units in the area. The majority of this unit is found overlying Waipapa Group in a series of NNW-NNE tilted half grabens in the southern part of the District.

Appendix B Table 8.5: Volcanic Groups

Geological unit	Kerikeri and Coromandel Volcanic Groups
Age	Miocene to Quaternary 23.8-1.8 Ma (million years)
Depositional environment	The volcanic groups in the District typically resulted from subduction related volcanism. Lava flows and scoria cones overlie the older geological units, as they overlaid the existing surfaces
Main rocks	Coromandel Group typically represented with rhyolite domes Kerikeri Volcanic Group is typically basaltic lava flows and scoria cones
Rock strength	Typically, stable and hard
Weathering	Weathering to clays at the surface
Soils	Alter to clayey minerals, typically represented by white clay rich soils
Typical extent in Whangarei	Coromandel Group is typically located around Whangarei Heads Kerikeri Volcanic Group is typically located in the central parts of the District
Indicators of landslides	Coromandel Group instability is typically observed as rock topple or block sliding landslide features, due to the steeper intrusive nature of the unit. Kerikeri Volcanic Group has exposed bluffs forming due to strength of lava flow units. These can result in rock topple or slab failures where weathered or undercut. Where these lava flow units overlie softer rocks, these have been observed to creep downslope, rafting on the softer rock beneath.
Other information	Downslope of lava flows is typically a bouldery colluvium due to topple failures from undercutting resulting in debris downslope of the main units. Rock fall risks is also likely near to these units.

Appendix B Table 8.6: Karioitahi Formation

Geological unit	Karioitahi Group
Age	Early Pleistocene to Holocene 1.8 to 0.1 Ma
Depositional environment	Recent coastal processes have formed sand dunes along the coast. Some are fixed, older dunes inland of the coastline, whereas some are active sand dunes along the coastline. Sandy beach deposits are also found along the current coastline and in bays between headlands of greywacke rocks.
Main rocks	Typically, quartz rich, dune-bedded sands
Rock strength	Weakly cemented to uncemented
Weathering	Can be subject to weathering and erosional processes where exposed
Soils	Sand and gravels with some local peats
Typical extent in Whangarei	These units are typically observed along the eastern coastline and within the harbour.
Indicators of landslides	Shallow failures are likely to be observed but more likely relate to erosional processes.
Other information	N/A

Appendix B Table 8.7: Tauranga Group

Geological unit	Tauranga Group
Age	Early Pleistocene to Holocene 1.8 to 0.1 Ma
Depositional environment	Recent alluvial deposits have formed on high-level erosion surfaces, within valleys and along coastal inlets and harbours. Flood plains and river/stream channels are typically observed through the District.
Main rocks	Mainly muds, sands, gravels and peats
Rock strength	Soft to firm muds and weak sands
Weathering	Can be subject to weathering and erosional processes where exposed
Soils	Typically muds, sands and gravels. Peats and swamp deposits are also included in this group.
Typical extent in Whangarei	These units are found across the majority of the District in flood plains, alluvial channels, gullies in the hills and alluvial terraces. The older alluvial terraces occur between 3 to 30 m above the present floodplains. Holocene alluvial deposits commonly underlie the present day floodplains and harbours.
Indicators of landslides	Shallow failures are likely to be observed along stream edges or terrace edges.
Other information	N/A

Appendix B Table 8.8: Reclamation Fill

Geological unit	Reclamation Fill
Age	Recent
Depositional environment	Construction fill or land reclamation in areas typically around the harbour at the Port, but also formed in dams or landfills.
Main rocks	Predominantly recompacted clays to gravels from various sources.
Rock strength	Typically, soft to moderately hard
Weathering	Can be subject to weathering processes where exposed in the harbour
Soils	Typically, sands, gravels and clays however the sources of materials could vary greatly.
Typical extent in Whangarei	The main area where this is located is at the Port in Whangarei. Other areas have been identified at dams and landfills.
Indicators of landslides	Shallow failures would be more typically identified along the edges of this unit.
Other information	Dredging of the harbour assisted in forming the reclaimed land at the port and reserves near the Whangarei city centre.

Appendix C: Photographs

Photograph Appendix C.1: Moderate to steep slopes of Waipapa Group greywacke rocks.

Photograph Appendix C.2: Multiple shallow landslides scarps over the hillslopes.

Photograph Appendix C.3: Predominantly stable hillslopes of Te Kuiti Group in the distance.

Photograph Appendix C.4: Multiple slump movements observed on very hummocky surface.

Photograph Appendix C.5: Gentle undulations in Northland Allochthon soils.

Photograph Appendix C.6: Steep hillsides of Tangihua Complex (Northland Allochthon) with shallow surficial erosion observed.

Photograph Appendix C.7: Rotational landslides within Waitemata Group soils, similar features are observed in translational movement also.

Photograph Appendix C.8: Linear features evident of translational sliding on gentle slopes.

Photograph Appendix C.9: Steep hills with pinnacles of volcanic rock exposed at the surface.

Photograph Appendix C.10: Volcanic rocks exposed on a steep hillslope posing possible rock fall issues.

Photograph Appendix C.11: Undeveloped piece of land showing hummocky allochthon beneath volcanics.

Photograph Appendix C.12: Gently undulating landforms of relict sand dunes with areas of ponding water.

Photograph Appendix C.13: Flat to gently sloping land typical of recent alluvial deposits.

Photograph Appendix C.14: Area of fill observed as flat land surrounded by hills.

Photograph Appendix C.15: Mapped landslide on a slope underlain by Northland Allochthon soils.

Appendix D: Legislative/regulatory context

The following documents provide a brief summary of the regulatory context with regards to the identification and management of landslide hazards in Whangarei.

Resource Management Act 1991

The Resource Management Act (RMA, 1991) is the primary legislation that sets out the functions and responsibilities of a territorial authority (i.e. Waitomo District Council) in terms of the management of natural hazards. Section 6 of the RMA sets out the matters of national importance and states that *In achieving the purpose of this Act, all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall recognise and provide for the following matters of national importance:*

(h) The management of significant risks from natural hazards.

Section 30 of the RMA sets out the functions of a regional council. Section 30(1) states that *every regional council shall have the following functions for the purpose of giving effect to this Act in its region:*

(c) The control of the use of land for the purpose of –

(iv) The avoidance or mitigation of natural hazards

Section 31 of the RMA sets out the functions of a territorial authority (i.e. Waitomo District Council). Section 31(1) states that *every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:*

(b) The control of any actual or potential effects of the use, development, or protection of land, including for the purpose of –

(i) The avoidance or mitigation of natural hazards

Under Section 60 of the RMA, each region is required to develop a Regional Policy Statement (i.e. the Waikato Regional Policy Statement (RPS) (Waikato Regional Council, 2016). The Waikato Regional Plan and any District plans (Waitomo District Plan) in the Waikato Region must give effect to the Waikato RPS (Sections 67 and 75 of the RMA).

Section 62 of the RMA sets out the contents of a regional policy statement. Section 62(1) states that *a regional policy statement must state –*

(ii) The local authority responsible in the whole or any part of the region for specifying objectives, policies, and methods for the control of the use of the land –

To avoid or mitigate natural hazards or any group of hazards

Section 106 of the RMA states that:

A consent authority may refuse to grant a subdivision consent, or may grant a subdivision consent subject to conditions, if it considers that:

There is a significant risk from natural hazards

(1A) For the purpose of subsection (1) (a), an assessment of the risk from natural hazards requires a combined assessment of -

The likelihood of natural hazards occurring (whether individually or in combination); and

The material damage to land in respect of which the consent is sought, other land, or structures that would result from natural hazards; and

Any likely subsequent use of the land in respect of which the consent is sought that would accelerate, worsen, or result in material damage of the kind referred to in paragraph (b).

Building Act 2004/Building Code

The purpose of the Building Act 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 Building Act 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 waiver 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.

Regional Policy Statement for Northland

With regards to natural hazards, Objective 3.13 of the Northland RPS is as follows:

The risks and impacts of natural hazard events (including the influence of climate change) on people, communities, property, natural systems, infrastructure and our regional economy are minimised by:

(a) Increasing our understanding of natural hazards, including the potential influence of climate change on natural hazard events;

(b) Becoming better prepared for the consequences of natural hazard events;

(c) Avoiding inappropriate new development in 10 and 100 year flood hazard areas and coastal hazard areas;

(d) Not compromising the effectiveness of existing defences (natural and man-made);

(e) Enabling appropriate hazard mitigation measures to be created to protect existing vulnerable development; and

(f) Promoting long-term strategies that reduce the risk of natural hazards impacting on people and communities.

(g) Recognising that in justified circumstances, critical infrastructure may have to be located in natural hazard-prone areas.

Risk reduction measures may include:

(a) Encouraging a change in land use to less vulnerable activities;

(b) Considering the benefits of managed retreat, particularly where the costs of protection works exceed the benefits (primarily as a response to coastal erosion but also relevant to properties that are repeatedly inundated by floods);

(c) Enhancing natural or artificial protection measures (for example, dunes and stopbanks);

(d) Increasing river channel capacity to reduce flood risk; and

(e) Not developing hazard-prone areas.

Section 7.1 of the Northland RPS sets out policies and methods for development in natural hazard-prone areas in the Northland Region. Policy 7.1.1 is intended to "enable the regional and district councils to deal with all natural hazards", and outlines general risk management guidance:

Subdivision, use and development of land will be managed to minimise the risks from natural hazards by:

(a) Seeking to use the best available information, including formal risk management techniques in areas potentially affected by natural hazards;

(b) Minimising any increase in vulnerability due to residual risk;

(c) Aligning with emergency management approaches (especially risk reduction);

(d) Ensuring that natural hazard risk to vehicular access routes and building platforms for proposed new lots is considered when assessing subdivision proposals; and

(e) Exercising a degree of caution that reflects the level of uncertainty as to the likelihood or consequences of a natural hazard event.

The Northland RPS states that this policy will *"enable development to be considered on a site-specific or development-specific, case-by-case basis using standard engineering practices and risk management techniques. These may include:*

ISO 31000: 2009 (Risk Management Standard)

NZS 9401: 2008 (Managing Flood Risk – A Process Standard)

NZS 4404: 2010 (Land Development and Subdivision Infrastructure)."

Existing additional guidance is provided in the RPS for land within the 10 and 100 year flood hazard areas, as well as areas susceptible to coastal hazards.

The Northland RSP does not specifically address landslides, or land stability, as a hazard in the Region. However, Section 7.1.8 regarding monitoring and information gathering states that:

(2) The district councils, when undertaking their functions under section 31 of the Resource Management Act 1991, will co-ordinate the gathering and collating of research on natural hazards and their risks and impacts at a district scale. This shall include landslides, stormwater management and rural fire risk.

(3) The regional council and district councils should work together to collaboratively establish and maintain an integrated natural hazards database for the region.

<u>Whangarei District Operative District Plan</u>

The Whangarei ODP doesn't specifically address landslide susceptibility as a hazard in the region. However, Part C, Section 19 (Policies – Natural Hazards) in the current ODP for Whangarei does state that:

"Generally, where there are steep slopes, little vegetation and high rainfall, land is likely to be subject to erosion and movement. Some land formations, including caves and sinkholes, are inherently unstable and constitute a major hazard. Land instability issues also arise from inappropriate earthwork activities and the removal of vegetative cover. Control of land use and development, in relation to areas of unstable land, has been left to the statutory controls within the Resource Management Act 1991 and the Building Act 2004."

Therefore, any development of land at this time only needs to meet the requirements of the RMA and the Building Act.

<u>Environmental Engineering Standards (EES)</u>

The Whangarei District Council Environmental Engineering Standards (EES) set out the minimum acceptable levels for engineering design and construction in the Whangarei District. Section 2 (Site Suitability and Earthworks) contains specific requirements for proposals that fall within the Low, Moderate and High land stability areas defined by the earlier T+T land stability assessments.

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