REPORT

Tonkin+Taylor

Te Kuiti Landslide Susceptibility

Prepared for
Waitomo District Council

Prepared by
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Table of Contents

1 Introduction

Tonkin & Taylor Ltd (T+T) was engaged by Waitomo District Council (WDC) to review the existing hazard areas for Te Kuiti that relate to land instability (landslides). Following this, extend the hazard areas to include the proposed future urban and rural residential zones, referred to as "Dream Zones". This work has been undertaken in accordance with our Letter of Engagement dated 1 August 2018.

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

<u>Review existing landslide hazard areas – Phase 1</u>:

- Review the suitability of the existing methodology of determining landslide hazard areas in the study area of Te Kuiti as determined by the Urban Land Use Capability Report (Waikato Valley Authority, 1979) and supplemented by the Waikato Region Landslides Report (Smith, 1999).
- Provide advice on what other geological and 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.
- Review the current district plan rules regarding the hazard areas. Provide advice on data gaps to Council that are a priority to fill.
- Provide a report summarising the review.

<u>Future re-zone landslide hazard assessment – Phase 2:</u>

- Extend the landslide hazard assessment to previously unmapped areas of Te Kuiti, based on the Dream Zones provided by WDC.
- Provide a written methodology for the updated hazard assessment, a series of figures to show the spatial distribution of the geological units and slopes, and proposed updated susceptibility areas to cover the Dream Zones.

This report outlines the results of Phase 1 and Phase 2 of this work.

1.1 Study Areas

For the purposes of Phase 1, the study area is the area previously assessed as either Hazard Area A or Hazard Area B on the District Plan planning map 39 (Waitomo District Council (WDC), 2009).

WDC defined the Phase 2 study area as the proposed Dream Zones, as supplied via email on the 4 April 2019. Figure A1.1 in Appendix A shows the location of the Phase 1 (existing hazard areas) and Phase 2 (Dream Zones) study areas in relation to the existing Te Kuiti Township. A description of the Dream Zones is given in Section 5.1.

1.2 Information used in the assessment

In order to undertake the work required, information has been used from various sources. Table 1.1 below summarises these.

Table 1.1: Information sources used on the project

File	File type	Information source	Comment
LiDAR	GIS Shapefile	WDC	LiDAR coverage of Te Kuiti in 1m and 5m contours
Te Kuiti Unstable Land Area	GIS Shapefile	WDC	Hazard Zone A and B from the Operative District Plan based on previous landslide hazard assessments.
Landslide locations	GIS Shapefile	GNS	Download of relevant data from the GNS Science New Zealand Landslide Database
T+T project data	GIS Shapefile	T+T database	T+T records land instability in Te Kuiti
Waikato 0.5m Rural Aerial Photos (2012-2013)	Ortho-rectified RGB GeoTIFF images	Land Information New Zealand	Orthophotography for the Waikato region
2017 Aerial Photography	Ortho-rectified RGB GeoTIFF images	WDC	Aerial photography for the region available on WDC GIS.
Te Kuiti Land Instability Report - 1979	PDF Report	WDC	1979 Waikato Valley Authority Technical Publication
Landslide Susceptibility Mapping and Risk Assessment for the Waikato Region	PDF Report	WDC	1999 report undertaken for Environment Waikato
NZGeo-50-BFF Te Kuiti	PDF Map	The University of Waikato	1:50,000 geological map of Te Kuiti
Proposed “Dream Zones”	GIS Shapefile	WDC	Identified deferred residential and rural residential zone locations in the Te Kuiti area

1.3 Context

1.3.1 Resource Management Act

The Resource Management Act (Government, 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.

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 –

a. To avoid or mitigate natural hazards or any group of hazards

1.3.2 Waikato Regional Policy Statement

With regards to natural hazards, Objective 3.24 of the Waikato RPS is as follows:

The effects of natural hazards on people, property and the environment are managed by:

d) Increasing community resilience to hazard risks;

e) Reducing the risks from hazards to acceptable or tolerable levels; and

f) Enabling the effective and efficient response and recovery from natural hazard events.

Section 13 of the Waikato RPS sets out the management of natural hazards in the Waikato Region. Policy 13.2 of the Waikato RPS sets out to "Manage activities to reduce the risks from natural hazards". In order to support the implementation of this policy, Waikato Regional Council (WRC) has provided a Risk Assessment Framework (Framework) (Waikato Regional Council, 2018) based on ISO 31000:2018 *Risk Management – Guidelines*.

This landslide susceptibility assessment work undertaken in this study is intended to demonstrate how WDC responsibilities have been fulfilled under the Waikato RPS and how they can be fulfilled for the future re-zoning work occurring within Te Kuiti.

The Framework highlights the policies within the Waikato RPS that are the responsibility of Territorial Authorities. In terms of land instability in Te Kuiti, WDC is required to implement the following methods:

13.2.1: Subdivision control in areas with intolerable risk.

13.2.2: Identify hazard zones and areas.

13.2.5: Control development and use in high risk hazard zones and areas.

1.3.3 Waitomo District Operative District Plan

The Operative Waitomo District Plan (WDP) meets these requirements through the identification and implementation of the Te Kuiti Hazard Area Map (planning map 29). This map is used to control activities within these areas by classifying activities as either non-complying or discretionary. Discretionary activities in the WDP are to be supported by specific further information in order to complete the risk assessment for the site. Further details on the relevant WDP provisions are given in Section 6 of this report.

1.4 Terminology and definitions

Preconceptions regarding the meaning of the terms susceptibility, vulnerability, 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 those adopted by the Australian Geomechanics Society (AGS, 2007) and are presented in Table 1.2. The primary distinction that needs to be made is that susceptibility relates to the <u>potential</u> for a landslide to occur whereas hazard relates to the <u>likelihood</u> of a landslide occurring. Risk relates to the <u>outcomes</u> of such an event, should it occur i.e. expected annual loss and is the product of likelihood and consequence.

Table 1.2: Definition of terms

Term	Definition in Landslide Risk Management
Susceptibility	The relative potential for a landslide event to occur *E.g. this area has a high susceptibility to landsliding because of the geology and steep terrain.*
Hazard	Probability or likelihood of a landslide occurring *E.g. this area typically experiences 5 landslides/km^2/annum, therefore warranting a high landslide hazard rating.*
Risk	Hazard x consequence *E.g. the annual loss of life risk for the person most at risk in this area is 1x10^{-4} or in other words 1 chance in 10,000 per year.*
Vulnerability	The degree of loss to a given element or set of elements within the area affected by the landslide hazard expressed on a scale of 0 (no loss) to 1 (total loss) *E.g. for property, the loss will be the value of the damage relative to the value of the property. For people, vulnerability is the probability that a fatality will result should that person be directly impacted by the landslide or its debris.*

The terminology used in the Regional Policy Statement and the Operative District Plan suggests that hazard areas have been defined when in actual fact they are susceptibility zones due to the absence of a quantitative and frequency element. Further to discussions with WDC and WRC it has been agreed that a susceptibility map is the appropriate level of detail required for a District Plan. This study therefore, represents a susceptibility assessment of the Dream Zone study area in Te Kuiti.

Where reference is made in this report to “Te Kuiti Hazard Area A and B”, it should be noted that susceptibility is a more appropriate term, however, the District Plan terms have been retained. The areas are defined in Section 27 of the WDP (2009) as:

- Te Kuiti Hazard Area A relates to known areas of significant instability.
- Te Kuiti Hazard Area B relates to areas of potential suspect stability, and some limited flood prone areas.

We note that on the WDC online map ‘Intramaps’, these areas are referred to as ‘Te Kuiti Unstable Land Areas – Risk A and Risk B. For consistency with the WDP, the District Plan terms have been retained in this report and the existing hazard areas are referred to as “Te Kuiti Hazard Area A and Area B”.

2 Geological setting

The geological setting of Te Kuiti can be divided into six key geological formations. The geological history and deposition environment of these units are outlined in this section. A geological map, which also highlights the geomorphology in the area, is provided in Figure 2.1.

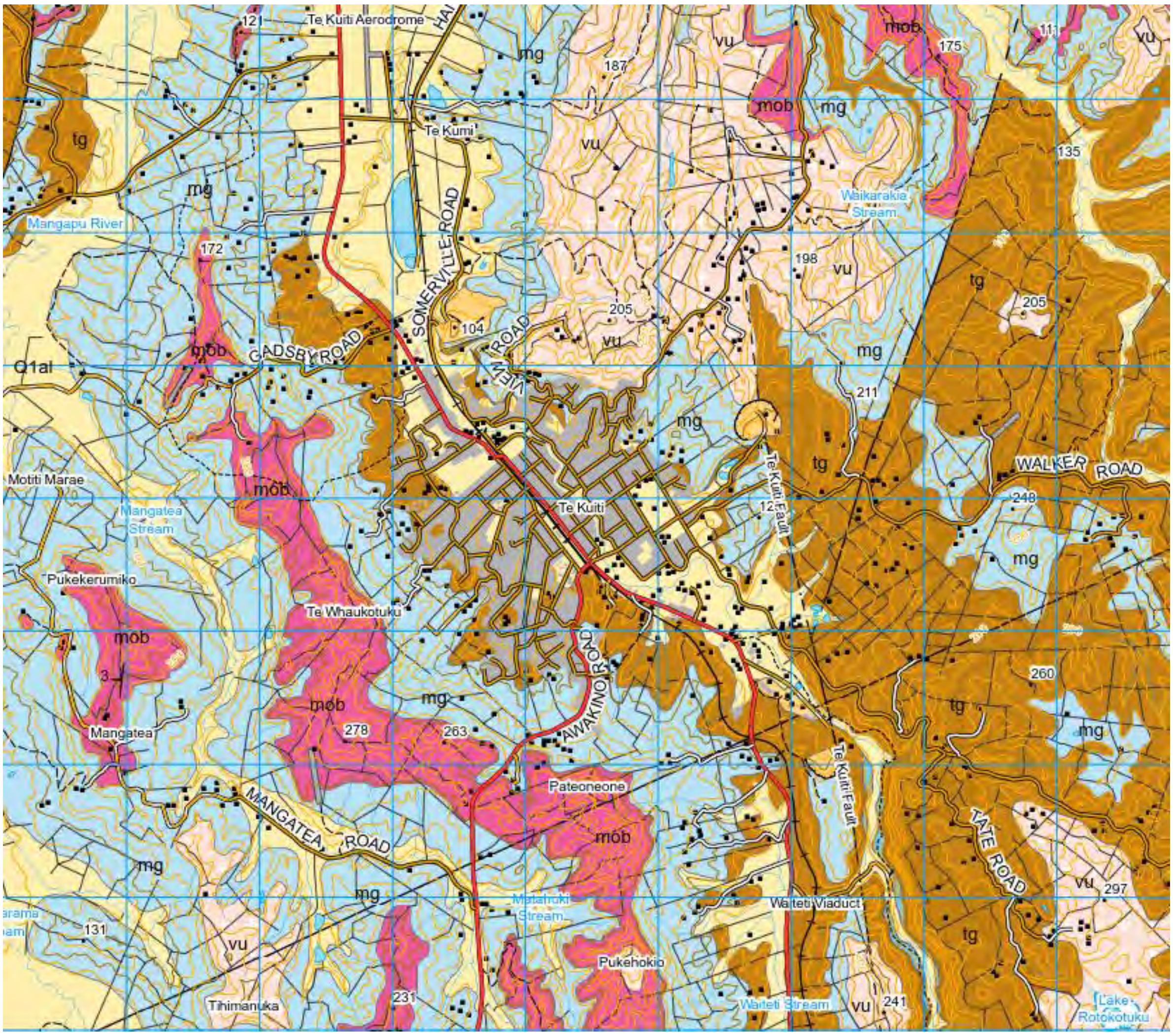


Figure 2.1: Geological map of Te Kuiti (Whiteman, 2017). Units are tg (brown) – Te Kuiti Group, mg (light blue) – Mahoenui Group, mob (dark pink) – Bexley Sandstone (Mokau Group), vu (light pink) – Raepahu Formation, Q1al (yellow) – alluvial deposits, basement rock (dark blue).

2.1 Geomorphology

Te Kuiti is situated in an alluvial basin of the Mangaokewa Stream, which flows through the centre of the township (Figure A1.1, Appendix A). The town of Te Kuiti has grown either side of the stream on the alluvial plain. Beyond this, rolling hills rise up each side of the basin.

The hillsides are predominantly comprised of mudstone rocks of the Mahoenui Group. Some areas of mudstone have short, steep benched landforms which form pronounced terraces, especially on the western slopes. Mudstone on the lower hills typically form rolling, hummocky surfaces (Waikato Valley Authority, 1979). These hummocky areas can also show slump features from deep seated creep landslides in this formation.

To the north, east and south of Te Kuiti, the hills are topped by hard limestones which form steep scarps (Te Kuiti Group). Hills to the west are capped by moderately stable sandstones (Bexley Sandstone), although these are subject to surface erosion. Hilltops to the north-east are capped by volcanic ignimbrite deposits of the Raepahu Formation. These form a rolling downward topography with bluffs which are prone to toppling (Waikato Valley Authority, 1979).

A digital elevation model (DEM) of the sloping ground in Te Kuiti, which identifies the range of slope angles identified by 5 m contours (provided by WDC) is shown in Figure A1.3, Appendix A.

2.2 Geological units

Descriptions of each of the six geological formations and their depositional environment are summarised in Table 2.1. This table also indicates typical landslide failures observed in these units around Te Kuiti. The geological map of the study areas is provided in Figure A1.2, Appendix A. The following sections describe the geological formations relevant to the Te Kuiti study areas.

2.2.1 Basement rock – Waipapa Terrane

Basement rocks in this area are made up of greywacke of the Manaia Hill Group, within the Waipapa Terrane. These rocks are dated as Jurassic age, between 201.3 to 145 Ma (million years).
A regional unconformity occurs at the top of this unit, which leaves an age gap between 145 Ma and 34.6 Ma to the Te Kuiti Group units above (Whiteman, 2017).

The greywacke is dominated by well-indurated, massive or poorly bedded volcanoclastic sandstone with some interbedded argillite (Whiteman, 2017). This unit is exposed to the south of the township.

2.2.2 Te Kuiti Group

The Te Kuiti Group generally comprises a sequence of marginal marine to outer shelf calcareous mudstones, sandstones and limestones (Edbrooke, 2005). The unit is predominantly made up of limestones with a high calcium carbonate content.

During the Late Eocene and Oligocene (34.5-25.2 Ma), this sedimentary succession is estimated to have accumulated to a thickness of several hundred meters above the basement rock, during a time of continental extension (White & Waterhouse, 1993) when the region slowly subsided and sediment inundated the basement rocks.

The Te Kuiti Group is typically observed in the field as flaggy limestone cliff outcrops and karst landscapes to the east of Te Kuiti Township, with some outcrops to the west of the township.
Figure 2.2 shows a generalised sketch of these exposures (Whiteman, 2017).

2.2.3 Mahoenui Group

Overlying the limestone is the Mahoenui Group. This is comprised of two mudstone formations which are early Miocene aged (25.2-18.7 Ma); the Taumatamaire and Taumarunui Formation (Whiteman, 2017). The exposures around Te Kuiti are dominated by the Taumatamaire Formation.

The mudstones formed from an accumulation of sediment during continued subsidence of the surface associated with ongoing continental extension. The calcareous mudstone would have accumulated by hemipelagic-pelagic suspension sedimentation at depth resulting in the massive, blue-greyish mudstones (Townsend, Vonk, & Kamp, 2008). The mudstone has a high clay content which has resulted in this unit being notoriously unstable with large creep or translational landslides observed around Te Kuiti (Waikato Valley Authority, 1979).

In the field around Te Kuiti, the mudstones usually form undulating hills that show slumping geomorphology. These areas are prone to landslides (Figure 2.2).

2.2.4 Bexley Sandstone (Mokau Group)

The Bexley Sandstone is around 60 m thick, late Miocene in age (18.7-15.9 Ma) and comprises a shallow marine sandstone with some interbedded mudstones (Whiteman, 2017). The sandstone is thought to have formed in a foreshore environment, and accumulated following inversion (uplift) of the Mahoenui basin (Kamp, 2004).

Outcrops of the Bexley Sandstone in the field are identified as rough, steep topography with some bluffs and cliff faces (Figure 2.2). The rock is typically stable but prone to surface erosion (Waikato Valley Authority, 1979). The sandstone is typically orange-brown in colour, moderately calcareous, well sorted and massive, with some mudstone beds as well as a basal conglomerate. The conglomerate likely formed from fan delta deposits from fluvial systems in the basin (Whiteman, 2017).

2.2.5 Raepahu Formation

The volcanic ignimbrites observed within the Te Kuiti area are pumice-rich pyroclastic flows from the Taupo Volcanic Zone which infilled pre-existing topography (Edbrooke, 2005). The pyroclastic flows likely comprise material sourced from the Mangakino Volcanic Centre (Brink, 2012).

The ignimbrite deposits typically form flat top hills up to 700 m high with eroding bluffs, usually observed in the field as cliff faces with fallen boulders (Whiteman, 2017).

2.2.6 Alluvial Deposits

The most recent deposit in this area comprises alluvium that has been deposited along river and stream valleys from deposition of weathered and reworked materials (Whiteman, 2017). This can also comprise colluvium, from surficial landslides in the area. Within the recent soil cover, the majority of the Te Kuiti area is mantled by volcanic ash which is observed as the yellow-brown soils in the area.

Surface erosion is likely, especially where this unit on laps other geological formations. Failures along the banks of streams are also possible.

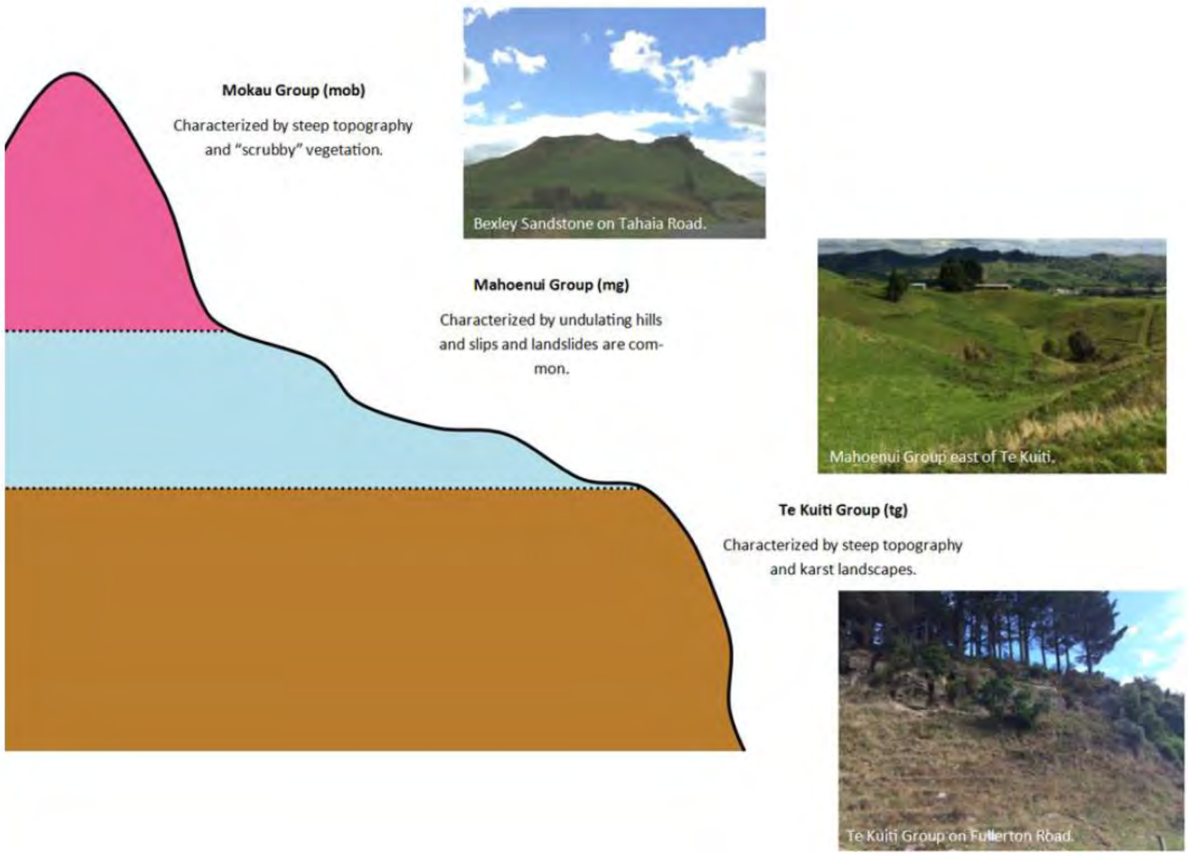


Figure 2.2: Geomorphology of some units within the Te Kuiti area, (Whiteman, 2017).

Table 2.1: Simplified geological model of Te Kuiti (compiled from Whiteman, 2017)

Geological Formation	Main rock types	Age (Ma)[1]	Geological description	Te Kuiti observations[2]	Landslide hazard risk[2]
Q1al: Alluvial Deposits	Alluvium	Quaternary Holocene 0.01 Ma to Present	Alluvium formed from weathered and reworked sediments typically within valleys or overlying other geological formations.	The majority of the hillside surfaces and the floodplain through the centre of Te Kuiti are recent soils.	Shallow surface erosion is likely, especially where overlying existing geological units.
vu: Raepahu Formation	Ignimbrite	Quaternary Pleistocene 2.6 to 0.01 Ma	Pumice-rich (rhyolitic) pyroclastic flow deposits from the Taupo Volcanic Zone.	Typically form the hilltops to the east of Te Kuiti as a flat sheet of ignimbrite.	Instability is likely as rock topple from exposed cliffs.
Unconformity					
mob: Bexley Sandstone	Sandstone and mudstone	Miocene 18.7-15.9 Ma	Massive, shallow marine sandstone with some interbedded mudstones and a basal conglomerate.	Interbedded layers of sandstone and mudstone typically form the hilltops to the west of Te Kuiti.	Shallow surface erosion is likely, landslides less likely to be deep seated.
Unconformity					
mg: Mahoenui Group	Mudstone	Miocene 25.2-18.7 Ma	The blue-grey Taumatamaire Formation mudstone, formed in a deep sea environment by suspension sedimentation.	This unit makes up the majority of slopes to the east and west of Te Kuiti. The mudstone is crumbly and unstable when exposed.	Likely risk of large, deep seated, earthflow movements.
tk: Te Kuiti Group	Limestone	Oligocene 34.5-25.2 Ma	Marginal marine limestones formed during continental extension and subsidence in the region.	Typically quarried around the town. Identified on lower slopes and within the gorge to the south of Te Kuiti.	Not likely to pose any issues with instability.
Regional Unconformity					
Waipapa Terrane	Greywacke	Jurassic 201.3-145 Ma	Basement greywacke rock in the region.	Not observed in outcrop in this area.	Not applicable.
1 Ma = Million years. 2 Waikato Valley Authority, 1979					

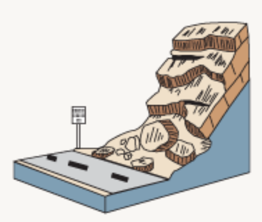
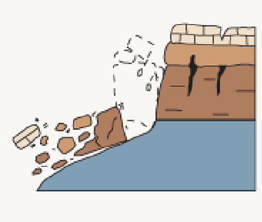
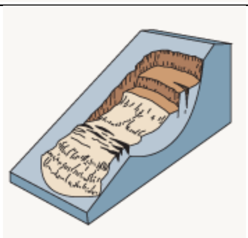
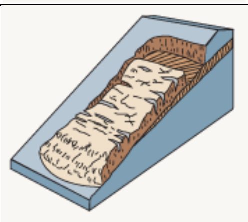
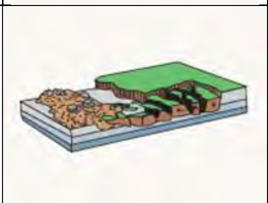
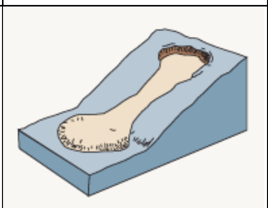
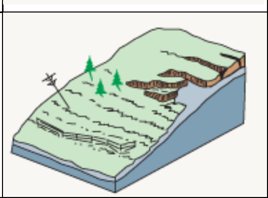
3 Landslide history in Te Kuiti

Land instability in areas of proposed development in Te Kuiti has been subject to review previously, such as in the Waikato Valley Authority (1979) report. The factors contributing to the occurrence of the land instability include weak geology and steep geomorphology, although the primary trigger for landslide occurrence is prolonged or intense periods of rainfall.

The mudstone rocks (Mahoenui Group) around Te Kuiti are the predominant materials that are affected by slope instability. These clay-rich rocks are not only weak, they are susceptible to changes in moisture content, shrink-swell processes and slaking. It is characteristic of weak mudstones to be susceptible to large-scale instability along with the shallower creep movement characteristics of the slopes as observed around Te Kuiti (Waikato Valley Authority, 1979). Deeper cracks 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 (Waikato Valley Authority, 1979).

Other land instability types that are observed around Te Kuiti include toppling of the ignimbrites, and shallow, more translational landslides, within the alluvium at the surface. Different types of landslide and their failure mechanisms have been summarised in Table 3.1.

Table 3.1: Types of landslide and relevance to Te Kuiti

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 a possibility of this failure mechanism within the gorges downstream of the Te Kuiti township.
Topples		Movement by forward rotation about a pivot point. Typically observed in the ignimbrite cliffs around Te Kuiti.
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 mudstone units around Te Kuiti.
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 Te Kuiti.
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 Te Kuiti.
Flows		Slow to rapid movements of saturated or dry materials which advance by flowing like a viscous fluid, usually following an initial sliding movement. Some flows may be bounded by basal and marginal shear surfaces but dominant movement of the displaced material is by flow. Not typically observed around Te Kuiti.
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 Te Kuiti.

1 (United States Geological Society, 2019)

3.1 Landslide inventory

To better understand the geological and topographical control of landslides around Te Kuiti, research into the location of land instability in the area was undertaken.

Landslips are typically mapped from analysis of aerial images. GNS Science (GNS) have a publically available landslide database (GNS, Accessed 2019), which has used aerial images to map identified landslides. Data used from this database has assisted in creating a landslide inventory for Te Kuiti. In addition, data has been utilised from historic T+T projects where land assessments have been undertaken, and features of instability have been identified from the study of aerial imagery supplied by WDC.

It should be noted that the two databases operate at fundamentally different scales, with the GNS data sourced primarily from large scale instability, whereas historic T+T project data is derived from relatively small scale instability affecting properties. The GNS database therefore tends to under represent the number of landslides that take place on an annual basis, and the T+T project data is strongly skewed towards urban developed areas.

For additional information, a tabulated inventory of EQC claims using T+T data can be found in Table C1, Appendix C.

The GNS and T+T data include point locations for landslides that have been observed in the field or from aerial mapping. We note that the majority of the landslides identified by GNS in this area are not dated, so accuracy of the date and location of the landslides is reduced. Whilst the return period or annual frequency of landslides serves as a necessary input into a hazard map or annualised Loss of Life or Property Loss Risk, it is not necessary to establish an area's relative landslide susceptibility.

Figure B1.1 in Appendix A shows the locations of T+T data, GNS landslides and areas of land instability features overlain on a map of Te Kuiti. T+T data locations occur on both the mudstone and limestone materials. The mudstone landslides were noted as deep creep, slow, or large scale movements, as expected for this material. Of the landslides that were mapped on areas of limestone, these occurred as surficial landslides or from retaining wall failures.

The distribution of landslides identified in the GNS data are more extensive in area but are mostly within the mudstone hills around Te Kuiti or associated with the boundary between the mudstone and other units. This reflects the larger scale of the landslides in this particular geology. Some landslides are also mapped as occurring on the ignimbrite and limestones.

4 Review of current landslide hazard area methodologies

As outlined in Section 1, Waitomo District Council has requested a review of two reports which helped form the existing methodology to determine landslide hazard areas around Te Kuiti. These reports have been used to develop the current 'Te Kuiti Unstable Land Area' hazard layer in the Waitomo District Council District Plan. The methodologies outlined in the two reports are summarised and reviewed below.

4.1 Review of 1979 Waikato Valley Authority Report

This report was written to assess land use capability around Te Kuiti for planning future housing developments. The report dissected the Te Kuiti township into five main land classes, Class A to E, as outlined in Table 4.1.

Table 4.1: Land Use Classes as described in Waikato Valley Authority (1979)

Class A	Suitable for development	Land that has few limitations to, and is very suitable for any type of urban development (alluvial deposits).
Class B	Suitable for development	Land that, while very suitable for urban land use, has some inherent properties such as being less well-drained or with slight undulations (alluvial deposits).
Class C	Suitable for development	A medial class of a variety of conditions which occurs on gently rolling slopes that could be adapted to development (alluvial deposits, ignimbrites and some well drained mudstones).
Class D	Marginally suitable for development	Development is possible with limitations such as flood risk, moderately steep rolling slopes (alluvial, sandstones, ignimbrites and some mudstones).
Class E	Unsuitable for development	Unsuitable for development including steep slopes (sandstones, ignimbrites, mudstones), unstable mudstone areas or potentially serious earthflow areas.

The allocation of these classes was based on five considerations which included the following factors:

1 Slope (angle).
2 Instability of underlying bedrock and soils (geology).
3 Wetness (flood risk or drainage issues).
4 Location (relative to sensitive areas and existing infrastructure).
5 Agricultural potential (as an alternative land use to urban development).

The main factors influencing landslide susceptibility are the underlying geology and slope angles. These factors within the land use classes, developed a classification that planners could use to base decisions on, regarding the development of the town. The report author provided a table of the characteristics of each land use class which included the geology and slope angles. A summary of these characteristics are in Table 4.2.

Table 4.2: Summarised slope characteristics for geological materials of land around Te Kuiti (Waikato Valley Authority, 1979)

Geology	Soil environment	Class A-C - suitable	Class D – marginally suitable	Class E - unsuitable
		Slope Angles		
Alluvium	Flood plain, low lying land along the river, and flat valley floors	0-3°	n/a	n/a
Ignimbrite (Raepahu Formation)	Steep, rolling slopes on the hill tops	9-20°	21-26°	>27°
Mudstone (Mahoenui Group)	Gently sloping terraces higher on the hills with improved drainage	9-15°	16-20°	>21°
Limestone (Te Kuiti Group)	Broad, gently sloping flat terraces on the hill slopes	9-15°	16-26°	>27°
Sandstone (Bexley Sandstone)	Rough, steep slopes on hillsides, prone to surface erosion	9-15°	16-26°	>27°

This report concludes that lower angle, well drained sites are suitable for development in the majority of geological units. Mudstones are less likely to be suitable, but some of the higher elevation sites with slope angles less than 20 degrees would be suitable if adequate drainage is provided.

A summary land use capability map is provided at the end of the Waikato Valley Authority (1979) report. The zones on this map are very similar to the Hazard Areas identified on planning map 39 in the District Plan. It has been inferred that Classes D and E have been used to determine the land instability zones B and A respectively, in the District Plan.

4.2 Review of 1999 Environment Waikato Report

The Environment Waikato Report (Smith, 1999) considers landslide susceptibility across the whole Waikato Region, and therefore is at a much larger scale than the Waikato Valley Authority (1979) report. The parameters considered in the susceptibility assessment are more detailed and varied, and are outlined in Table 4.3.

Table 4.3: Parameters used in the 1999 Environment Waikato Report

Parameter	Description
Geology	Simplified geology was undertaken of the Waikato region from the NZGS 1:250,000 scale map, into materials, based on age and material type: • Unconsolidated, calcareous, altered mafic, ignimbrites, fresh mafic, silicic and indurated sedimentary materials. The materials were classified on their rock compressive strength as a proxy for overall rock strength of each material. The report notes that the simplified geology is a limit on the larger scale analysis. At a smaller scale, local faulting, weathering, structure and composition will increase accuracy of this parameter.
Slope angle	The slope angle ranges used in this study were taken from bounds used on Landcare Research databases and online GIS layers: • <15°, 16-20°, 21-25°, 26-35°, >35°. The report noted that the slope height and modification of slopes are also important details to understand. They state that the accuracy is a limitation to the report results.
Annual rainfall	Normal annual rainfall data over a 30 years period prior to 1999 was used over the Waikato region, based on CliFlo data. Contours of annual rainfall was divided into the following bands: • 1000-1250, 1250-1500, 1500-1750, 1750-2000, 2000-2250, 2250-2500, >2500 mm.
Storm rainfall	Storm (high intensity) rainfall events over a 24 hour period, recorded from CliFlo, with a return period of 5 years were used for this parameter, split into the following bounds: • <100, 120, 140, 160, 200 mm in 24 hours.
PGA	Peak ground acceleration was taken from a GNS earthquake shaking map. The PGA parameter was divided into three bounds: • <0.25 g, 0.25-0.35 g, >0.35 g.
Vegetation	Vegetation cover was divided into: • Forest, scrubland/shrubs, and grassland/pasture. Other parameters were noted in the report but were simplified into the above, these included urban areas, freshwater, fresh water wetlands, tussock, and separating exotic and native forests.

The resulting map of the Waikato region (Smith, 1999) shows landslide susceptibility from very low to extremely high across the Waikato. The area of Te Kuiti is mapped with high susceptibility to landslides. Further analysis in the report states that landslides in Te Kuiti are dominated by the underlying geology.

When comparing this information to planning map 39 (WDP, 2009), this report does not appear to have modified the land instability mapped as Hazard Areas A and B for Te Kuiti but does reference that a more detailed district scale map should be developed using the parameters outlined in Table 4.3, due to the detail that is missed at the regional scale of this reported work.

4.3 Discussion

It is standard practice in assessing the potential for landslide occurrence to firstly consider the underlying geology and the slope terrain, as these are the most important landslide controls in most areas. In some areas factors such as vegetation type or distance from a water course may be of significance, however these are typically secondary to geology and slope angle, or are reflections of them. Note that these "causes" are distinct from the landslide trigger.

The landslide inventory for Te Kuiti (see Section 3.1) indicates that the majority of instability features are associated with geological and topographical controls. This illustrates that this simplistic method approach to determine land use capability is appropriate. The main uncertainties relate to the scale that the work was previously undertaken at and recent updates to the geological mapping of the area along with improvements in the topographical survey through technology such as Light Detection and Ranging (LiDAR) methods.

Further work could be undertaken to determine the landslide density within these geomorphological zones and combining this with data, such as historic rainfall to derive a probabilistic landslide assessment for the region but this is not considered to be appropriate for the level of detail required in the District Plan.

Based on our review of the above reports, the methodology of the 1979 assessment can be considered suitable for determining the relative susceptibility of the areas in and around Te Kuiti to landslides. It appears that Class D areas relate to Te Kuiti Hazard Area B as marginally suitable, and Class E areas relate to Te Kuiti Hazard Area A as unsuitable for development.

It must be noted however that the 1979 assessment is considered to be landslide susceptibility and not a hazard assessment. A susceptibility map will typically present an assessment of the potential for future landsliding based on the abundance (or absence) of existing landslides, whereas a hazard map is also an assessment of likelihood of such events occurring. For example a susceptibility map may determine the various landslide susceptibility classes on a purely qualitative assessment or on the proportion of an area that has previously been affected, whereas a hazard classification would be based on (for example) the number of landslides that occur per unit area per annum.

5 Dream Zone landslide susceptibility assessment

5.1 Dream Zones description

The extents of the Dream Zones are shown in Figure A1.1, Appendix A. For the purposes of reporting, the Dream Zones have been divided into Areas 1 to 4. The two larger Areas, 1 and 2 are located to the northwest and northeast respectively, with two smaller Areas, 3 and 4 located to the east and to the south respectively.

The geomorphological characteristics of the Dream Zones have been determined through desktop assessment of aerial photographs, LiDAR data and a site walkover undertaken by an Engineering Geologist on the 4 September 2019.

A summary of the characteristics of the Dream Zones has been provided in Table 5.1.

Table 5.1: Dream Zone characteristics

Dream Zone	Size (ha)	Geology	Geomorphology	Land use	Existing mapped zones
Area 1	136.8	From west to east, the area is underlain by the Bexley sandstone, then Mahoenui Group Mudstone, followed by the Te Kuiti Group limestone and alluvial deposits.	This area is predominated by sandstone cliffs to the western side of the area, beneath which is hummocky mudstone. Towards the east of this area the slope becomes gentler towards the river. Slope instability features are common in this zone including hummocky ground, rock debris, scarps and gullies.	Multiple larger rural residential properties are located in this area, with Gadsby Road running through the centre. The rest of the area appears to be agricultural land.	This Dream Zone is ~50% covered by the existing district plan Hazard Areas A and B.
Area 2	152.5	The majority of the area is underlain by the Raepahu Formation ignimbrite. Downslope of the ignimbrite, towards the west, is Mahoenui Group Mudstone.	A flat sheet of ignimbrite on top of the hillside dominates most of this area, bluffs are evident at the edge of this outcrop, which have steep and eroded features. Downslope of this are slopes of hummocky mudstone towards the centre of the valley. The mudstone areas show signs of instability in the form of hummocky ground, rock debris and scarps.	Multiple larger rural residential properties are located in this area, with Mangarino Road running through the area. The rest of the area appears to be agricultural land.	This Dream Zone is ~30% covered by the existing district plan Hazard Areas A and B.
Area 3	22.9	From the higher elevation at the eastern part of the area to lower elevation towards the west, this area is underlain by Te Kuiti Group Limestone, Mahoenui Group Mudstone and alluvial deposits.	Steeply undulating land on the eastern hills, down into the flat alluvial plain in the centre of town. The central parts of this site show signs of instability in the form of scarps and some gully features.	Currently agricultural land. The northern block may have been used for forestry in the past. Walker Road runs through this block. Road cuttings appear to be stable.	This Dream Zone is ~90% covered by the existing district plan Hazard Areas A and B.
Area 4	9.22	Te Kuiti Group Limestone with some Mahoenui Mudstone at the southern point of the area at the highest elevation.	Gently sloping land at the base of the western hills. No signs of instability were noted in the aerial imagery although an extensive area of hummocky ground was identified immediately to the east. Some ponding water and extensive drainage swales are evident throughout this area.	Currently agricultural land, to the right of Pukenui Road (Private). A few rural residential properties are located in this area.	This Dream Zone is almost 100% covered by the existing district plan Hazard Areas A and B.

5.2 Landslide susceptibility method

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.

Following a workshop attended by Waitomo District Council, Waikato Regional Council and Tonkin + Taylor on the 14 June 2019 and subsequent email correspondence, the accepted methodology for the extension of the susceptibility assessment shall follow the (Waikato Valley Authority, 1979) qualitative study approach of geology and slope angle using updated data. Given that the distribution of landslides identified as part of the landslide inventory (see Section 3.1) showed a correlation with the underlying geology and the distribution of the existing Hazard Areas A and B, this approach is deemed to be appropriate.

Statistical validation of the assessment through a "normalised difference" approach (see section 6) was not included in the scope of this project.

In order to extend the landslide susceptibility assessment into the unmapped "Dream Zones" in Te Kuiti, the following tasks were undertaken:

- Create a geological map of Te Kuiti showing locations of Dream Zones (Figure A1.2).
- Create a slope angle map using the 5 m contour data supplied by WDC adopting slope classes from the 1979 Report (Figure A1.3).
- Interpret aerial photography and LiDAR data to identify potential areas of land instability in the vicinity of the Dream Zones (Figure B1.1).
- Re-create the 1979 geology and topography classes using the updated geology and contour data (Figure B1.2).
- Re-create the Hazard Area A and Hazard Area B map using the updated assessment for the Dream Zones (Figure C1.1).

It should be noted that a significant proportion of the Dream Zones already have the Hazard Areas A and B defined. As such, the final output for each zone consists of 1979 and 2019 assessments.

5.3 Dream Zone analysis

Figure B1.2, Appendix A shows the relationship between the existing and updated susceptibility assessments. They are broadly consistent although there are some differences likely due to the use of the updated datasets. The original areas used geological mapping from 1960 at a 1; 250,000 scale whereas the updated geological mapping from (Whiteman, 2017)has been completed at a 1:50,000 scale. The scale of the updated topographical data will also be different, although the source of the original topographical data is unclear.

These scale effects are visible in the differences between the existing and updated susceptibility assessments where a finer level of detail allows individual gullies and other breaks in slope to be differentiated.

Figures C1.1 to C1.5, Appendix A, show the proposed landslide susceptibility assessments within each Dream Zone. Where landslide susceptibility was previously mapped in a Dream Zone, these have been retained, only unmapped areas have been newly classified.

Table 5.2 summarises the results of the susceptibility mapping for each Dream Zone. The susceptibility coverage is a total of the existing Hazard Areas A and B, and the areas assessed using the updated data. The table adopts the same terminology as the (Waikato Valley Authority, 1979)study in terms of unsuitable, marginally suitable and suitable slopes as presented in Table 4.2 of this report.

The susceptibility areas shown on Figure B1.2, and C1.1 to C1.5 identifies existing Hazard Area A with stripes, and B with dots. The updated areas are identified in red for land unsuitable for development, and yellow for land marginally suitable for development. Note that green areas within the updated susceptibility assessment are showing areas suitable for development.

Table 5.2: Dream Zone landslide susceptibility summary

Dream Zone	Size (ha)	Susceptibility Coverage			Comment
		Category	**Area (ha)**	**%**	
Area 1	136.8	Unsuitable	48.0	35	The previously mapped areas to the east of this area indicate predominantly marginal to unsuitable land. The newly classified parts of the Dream Zone to the west suggest areas of unsuitable land with isolated areas of suitable land. Development of these suitable areas is likely to require construction of infrastructure across unsuitable land.
		Marginal	50.5	37	
		Suitable	38.3	28	
Area 2	152.5	Unsuitable	39.7	26	This Dream Zone has large areas of developable suitable land with unsuitable land generally confined to distinct parts of the area.
		Marginal	42.0	28	
		Suitable	70.8	46	
Area 3	22.9	Unsuitable	5.7	25	The eastern half of this dream zone is covered by the existing hazard areas with the western half likely to have been classed as suitable at the time. The updated mapping is broadly consistent with the 1979 mapping although the central section is showing a mixture of unsuitable and marginal land whereas the 1979 map indicates suitable slopes. A site walkover has confirmed that there are signs of instability in the central part of this Dream Zone.
		Marginal	7.1	31	
		Suitable	10.2	44	
Area 4	9.2	Unsuitable	0.5	6	The majority of this Dream Zone was covered by the existing 1979 hazard areas. A small area to the north was not mapped as unsuitable or marginal, it is likely that this area was classified as suitable at the time, however the updated mapping suggests that it should be reclassified as marginally suitable.
		Marginal	8.5	92	
		Suitable:	0.2	2	

6 District Plan provisions

The current District Plan Hazard Areas A and B are shown on Figure A1.1 in Appendix A.

Section 27 of the District Plan places the following status on activities in these areas:

- Hazard Area A – any building to be located within an area identified as Hazard Area A on Planning Map 39 shall be a Non-complying Activity, apart from Rule 27.5.2.3 which states that "any building which is specifically designed to be able to be readily relocated shall be a Discretionary Activity".
- Hazard Area B - any building to be located within an area identified as Hazard Area B on Planning Map 39 shall be a Discretionary Activity.

Table 6.1 shows the rules in the District Plan which request an assessment of a number of factors and provide good practice guidelines for activities within Te Kuiti Hazard Area B. It is unclear if there is a deliberate distinction made here or if discretionary activities in Hazard Area A are not obliged to follow rule 27.5.2.4 and 27.5.3. Assessment criteria are given for discretionary activities in Rule 27.5.4, as outlined below.

- The severity of the past natural hazards which have affected the site and the potential for the hazard to reoccur.
- The measures proposed to avoid, remedy or mitigate the effects of the natural hazard
- The likely risk to people and property from the natural hazard.
- The extent and nature of information available to assess risks
- The effect of the development on the natural character of the coastal environment.
- The availability of alternative siting options outside the hazard area

Table 6.1: Relevant rules regarding activities within the Te Kuiti Hazard Area

Matters to be considered for a proposed activity in Hazard Area B areas (Rule 27.5.2.4)	**Good practice in Hazard Area B areas (Rule 27.5.3)**
The slope of the land	
Any local areas of known instability	Avoid
The extent of cut earthworks and remaining unsupported cuttings	Minimise earthworks
The extent of fillings that may be placed	Minimise placement of fill
The method of undertaking earthworks	Minimise earthworks
The extent of any retaining walls	Minimise earthworks
The alteration to drainage patterns	Minimise impervious surfaces
Disposal of stormwater and sewage	Reduce the water available for uptake by the clays
Access to site	
Destruction of established vegetation	Protect existing conservation planting and native bush areas
Proposed establishment of improved drainage	Eliminate all ponding
Proposed establishment of soil conservation methods and planting	Establish new conservation planting
Where relevant, the relationship of proposed floor levels to an anticipated 50 year flood event	Improve drainage

Section 36(1) of the Building Act (1991) states that the Territorial Authority (TA) *"shall refuse to grant a building consent…if the land is subject to or is likely to be subject to …slippage…unless the TA is satisfied that adequate provision has been or will be made to protect the land…or restore damage…"* This statement reinforces the same sentiment as the Operative District Plan. However, in practice, there are difficulties in meeting the performance criteria of the Building Code when designing a building to be readily relocated following a landslide and for consent to be issued for a building to be constructed on land with a known hazard, representing a potential risk to the Council, people and property.

While the rules do provide some guidance to practitioners on what factors need to be considered for a proposed activity in Hazard Area B, the district plan does not state who should be undertaking such assessments. It is recommended that the rule 27.5.2.4 is amended as follows:

> *27.5.2.4* *Any application for a proposed development within the Te Kuiti Hazard Area B in accordance with Rule 27.5.2.1(e) shall include an assessment* ***<u>undertaken by a suitably qualified and experienced geoprofessional</u>*** *of the following matters and shall take into account the matters set out in Rule 27.5.3, Good Practice Guide for Development in Te Kuiti Hazard Area B.*

The assessment factors, good practice guidelines and assessment criteria provide a sound basis for completing a landslide risk assessment for a given site however, WDC could consider adopting a checklist-type approach for stability assessments as proposed by Crawford and Miller (1998). Practitioners could be directed to a checklist of information to be provided for landslide risk assessment required as part of a consent application for any proposal in a mapped discretionary area. An extract of the checklist is provided in Appendix C. In addition to this the existing guidance should be extended to cover lateral spreading risk, seismic slope stability and issues caused by seasonal variation in groundwater levels.

7 Recommendations for future work

Whereas the original susceptibility assessment undertaken in 1979 and updated as part of this scope of works assigned susceptibility classes to various combinations of geology and slope angle based on judgement, it is possible to determine the importance of these (and other factors) mathematically.

A powerful GIS tool that can be used to achieve this is the concept of Normalised Difference (ND).

$ND = (A_L - A_T)/A_T$

Where:

A_L = Percentage of the landslide population associated with a given combination of geological unit and slope class.

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

For instance, if a particular geological unit accounts for only 15% of a district's surface area but contains 40% of the landslides, it is clear that this geology has a higher susceptibility to landslides. ND can demonstrate this quantitatively. The same process can be undertaken with slope angle or any other GIS layer. By comparing the ND value for various combinations of factors it is possible to mathematically determine the combination of factors that are demonstrably associated with land instability.

8 Summary

Tonkin and Taylor have been engaged by Waitomo District Council to review the methodology that underlies the Planning Map 39 and rules contained in the District Plan on the subject of landslide hazards in the Town of Te Kuiti. The purpose for the review is to facilitate the extension of the assessment into the future urban and rural residential zones, known as “Dream Zones” being incorporated in to the township.

The methodology for identifying landslide hazard areas used in the Waikato Valley Authority 1979 report focused on slope angles, geology and the effect water has on the soils, which forms a suitable basis for determining landslide “hazard” (susceptibility) areas. It appears that the Planning Map 39 in the WDC district plan is based on the map included in this report.

The methodology used in the 1999 Environment Waikato report on regional landslide susceptibility focussed on these factors along with annual rainfall, storm rainfall events and earthquake shaking and therefore is likely to provide a more detailed method to determine landslide hazard areas in Te Kuiti. However, due to the larger scale and less local detail in this report, it is unknown if the results of this assessment impacted any detail shown on Planning Map 39 itself, although it appears that the report had some impact on the rules in terms of the matters to be considered, good practice guides and assessment criteria.

This project has produced a re-creation of the geological and slope classes used in the 1979 report with updated geological mapping and topographical data. The map produced gives a good correlation with Planning Map 39. Differences in the results can mostly be attributed to scale issues and updated geological boundaries.

An updated overall landslide susceptibility map has been produced as a part this work which includes the previous mapped Hazard Areas A and B along with the additional information from assessment of the unmapped parts of the Dream Zone areas.

Aerial photograph interpretation and a site walkover have confirmed that the proposed susceptibility areas are reasonable based on the observed presence of indications of instability.

The landslide hazard map (Planning Map 39) and relevant rules in the District Plan fulfil the responsibilities of Waitomo District Council required under the Regional Policy Statement. The current susceptibility maps could be significantly enhanced by an expansion of the landslide inventory through detailed mapping from updated LiDAR due to be commissioned in 2019 and the undertaking of a normalised difference analysis.

Some changes to the District Plan rules could be considered to include a rule on who should complete a landslide risk assessment in support of a consent for a discretionary activity. The adoption of a checklist approach to landslide risk assessments could provide some consistency in the quality of proposals received by the Council and aid practitioners in this process.

It is unlikely that a meaningful assessment of landslide frequency or annual occurrence can be made with the current available data. As such we do not believe that it is possible to develop the susceptibility maps into hazard maps. With the common misuse of the terms “susceptibility” and “hazard”, it is important that going forward, the correct use of this language is taken forward into future documentation.

9 References

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10 Applicability

This report has been prepared for the exclusive use of our client Waitomo 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.

Tonkin & Taylor Ltd

Report prepared by: Authorised for Tonkin & Taylor Ltd by:

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Hannah Udell — Kevin Hind

Engineering Geologist — Senior Engineering Geologist

Report prepared by:

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John Brzeski

Engineering Geologist

Report reviewed by Kate Williams (Senior Engineering Geologist)

HU/JJBR
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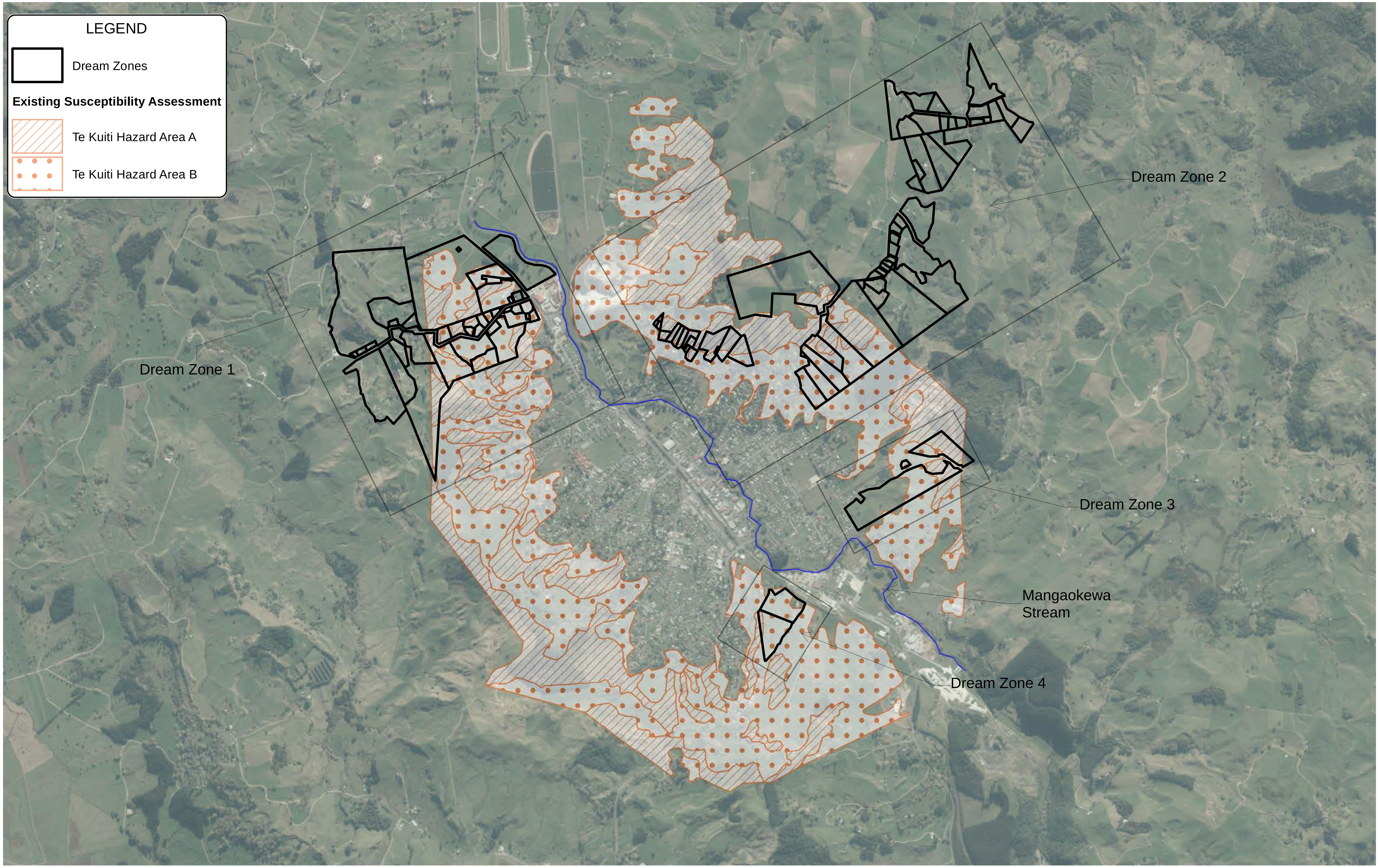
Appendix A: Figures

- **Figure A1.1**
- **Figure A1.2**
- **Figure A1.3**
- **Figure B1.1**
- **Figure B1.2**
- **Figure C1.1**
- **Figure C1.2**
- **Figure C1.3**
- **Figure C1.4**
- **Figure C1.5**



Notes:
Waikato 0.5m Rural Aerial Photos (2012-2013) sourced from Waikato Regional Aerial Photography Service (WRAPS) 2012, re-use under Creative Commons.
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A3 SCALE 1:25,000

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APPROVED	KJH	Sep.19
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TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT
Study Area - Site Plan

FIGURE No. Figure A1.1

Rev. 0

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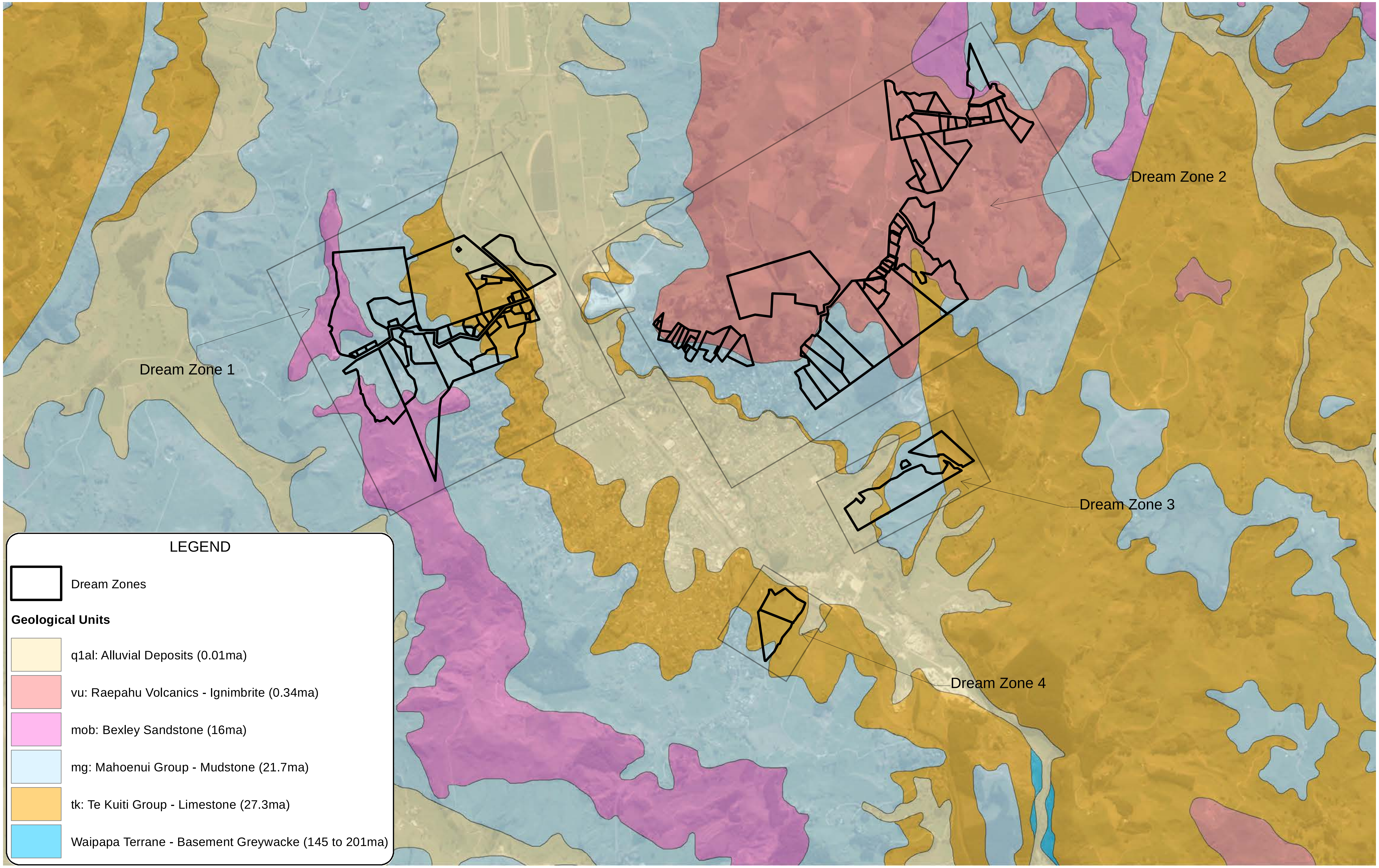

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Figure to be read in conjunction with T+T report reference 1004962.0010
Geological map sourced from Whiteman (2017)

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TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT
Geological Map

FIGURE No. Figure A1.2
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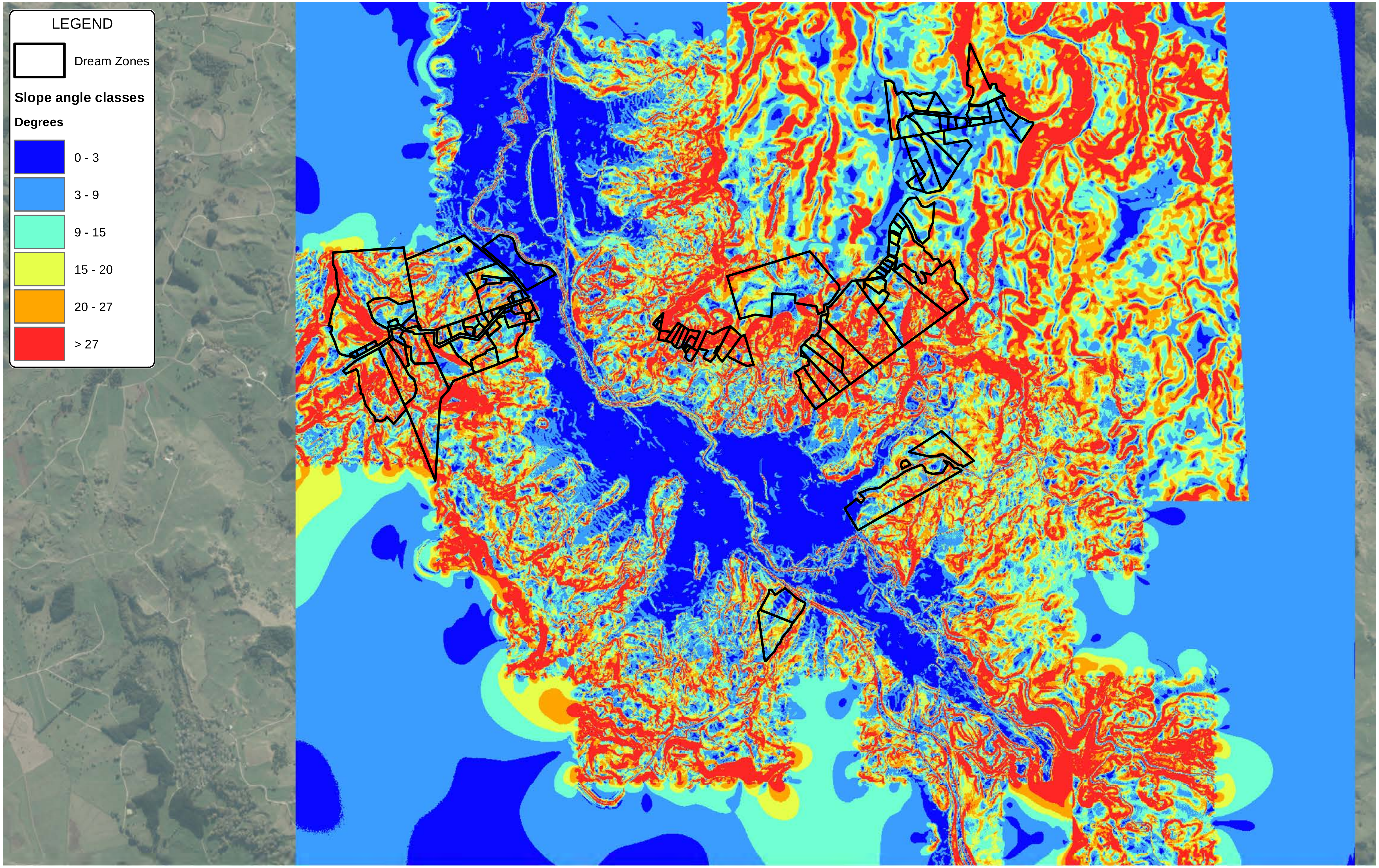

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TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT

Slope Angle DEM

FIGURE No. Figure A1.3

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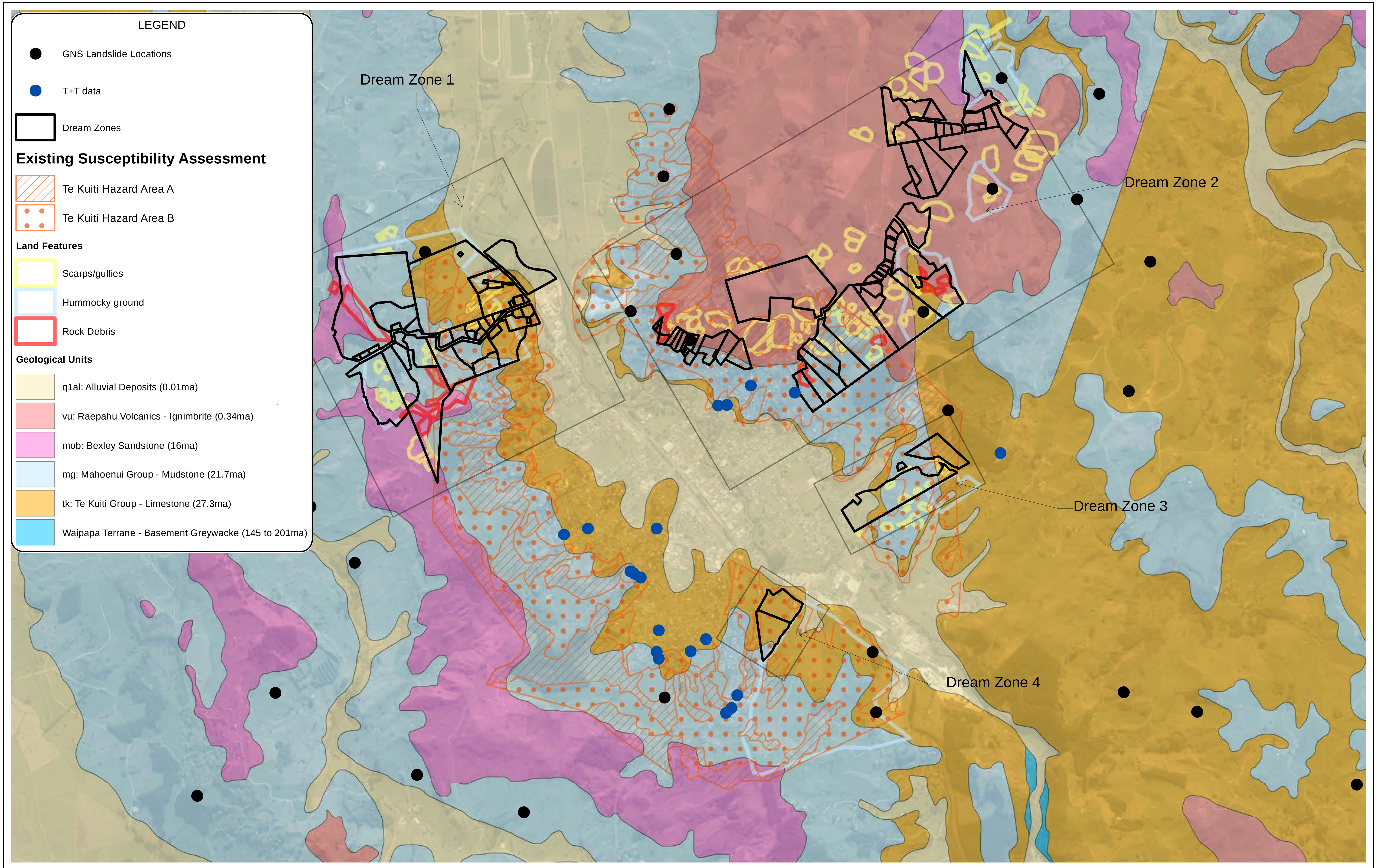

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TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT
Feature Mapping around Dream Zones

FIGURE No. Figure B1.1
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Susceptibility Assessment

FIGURE No. Figure B1.2

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WAITOMO DISTRICT COUNCIL

TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT

Dream Zones Overview

FIGURE No. Figure C1.1

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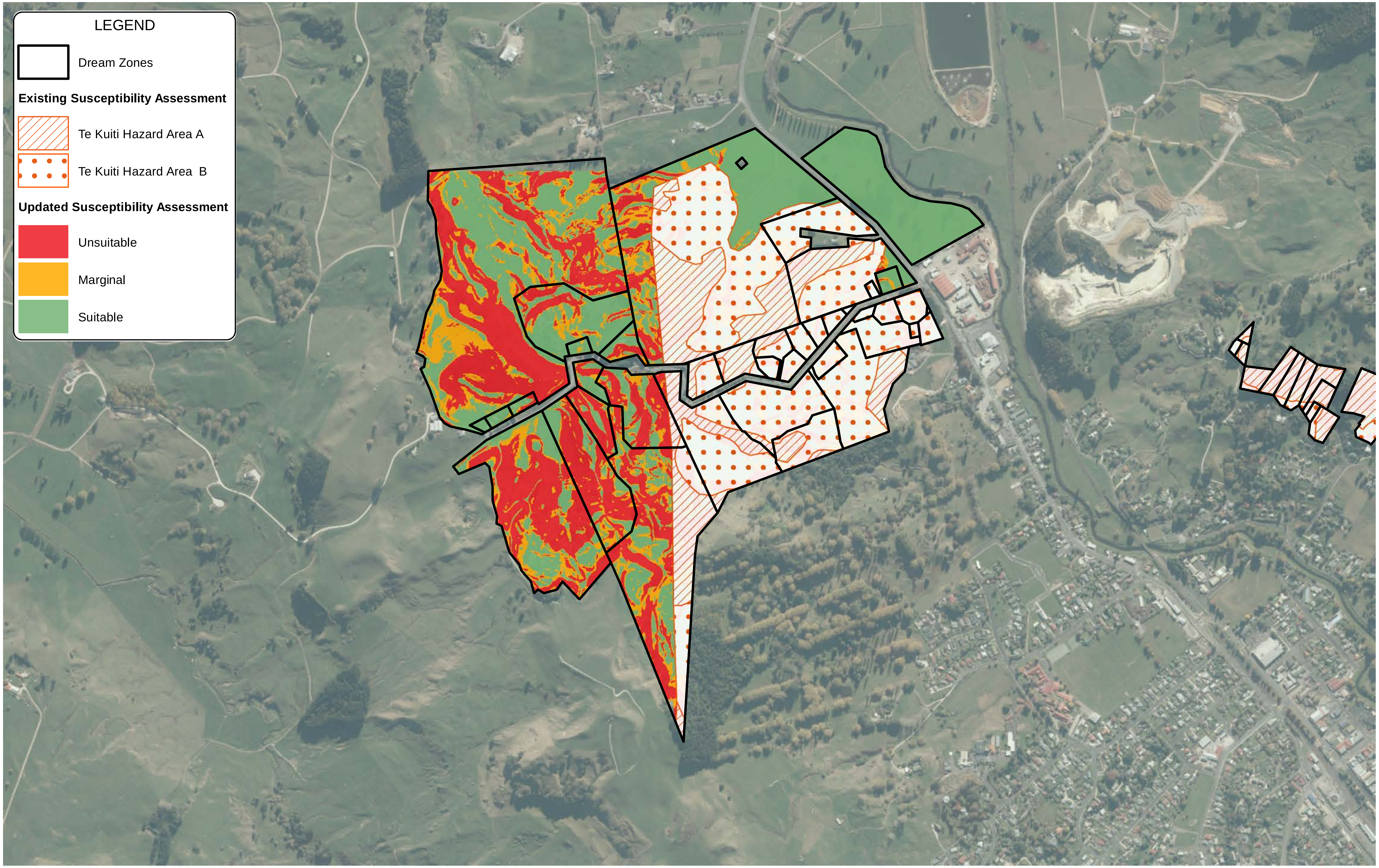

Notes:
Waikato 0.5m Rural Aerial Photos (2012-2013) sourced from Waikato Regional Aerial Photography Service (WRAPS) 2012, re-use under Creative Commons.
Figure to be read in conjunction with T+T report reference 1004962.0010

A3 SCALE 1:10,000
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WAITOMO DISTRICT COUNCIL
TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT
Area 1 landslide susceptibility

FIGURE No.
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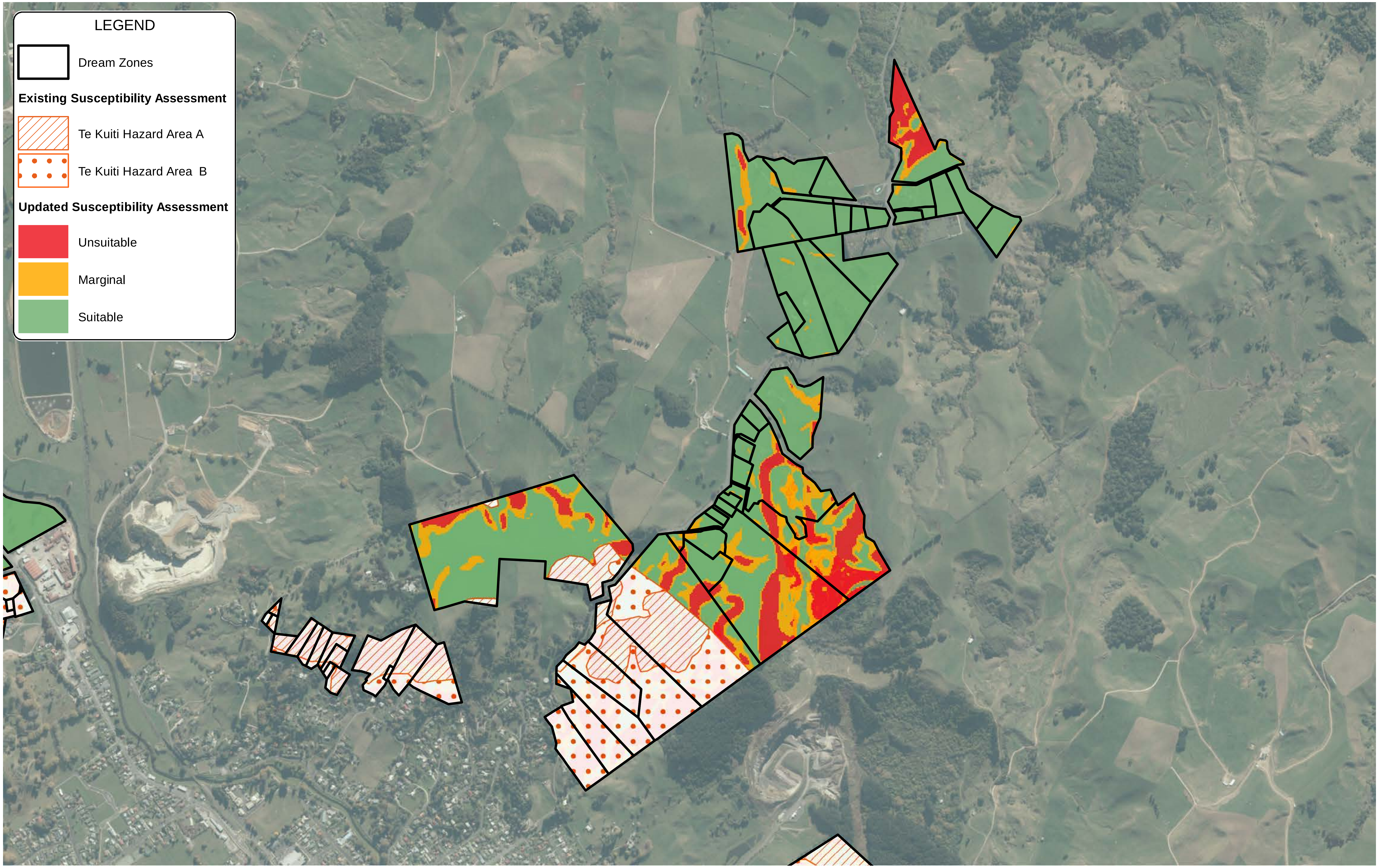

Notes:

Waikato 0.5m Rural Aerial Photos (2012-2013) sourced from Waikato Regional Aerial Photography Service (WRAPS) 2012, re-use under Creative Commons.

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A3 SCALE 1:12,500

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TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT
Area 2 landslide susceptibility

FIGURE No.

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Notes:

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A3 SCALE 1:5,000

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TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT
Area 3 landslide susceptibility

FIGURE No.

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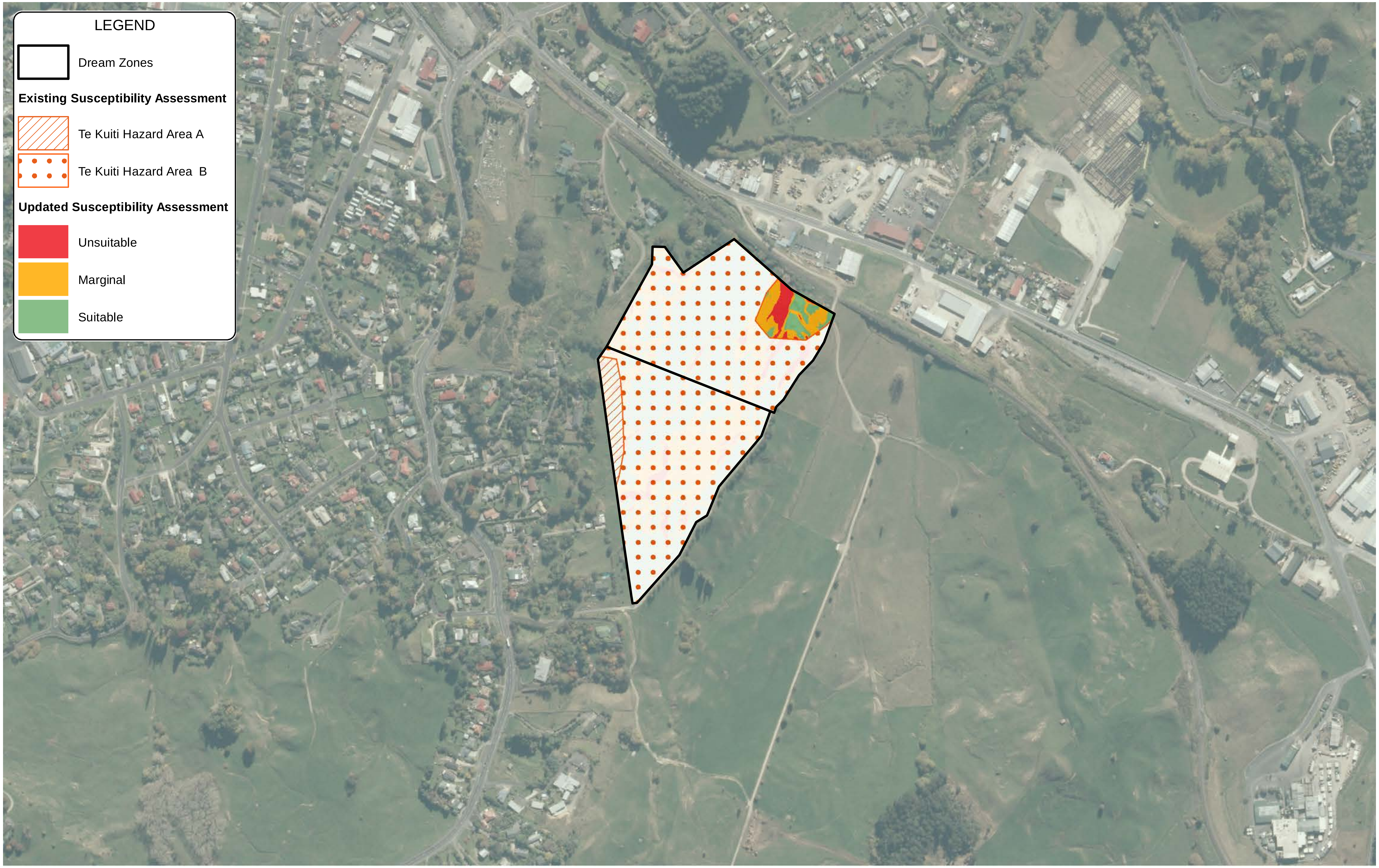

Notes:
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WAITOMO DISTRICT COUNCIL
TE KUITI LANDSLIDE SUSCEPTIBILITY ASSESSMENT
Area 4 landslide susceptibility

FIGURE No.
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Appendix B: Policy Context

Resource Management Act

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 –

a. To avoid or mitigate natural hazards or any group of hazards

Section 106 of the RMA states that:

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

(a) 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 -

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

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

(c) 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).

Waikato Regional Policy Statement

With regards to natural hazards, Objective 3.24 of the Waikato RPS is as follows:

The effects of natural hazards on people, property and the environment are managed by:

d) *Increasing community resilience to hazard risks;*

e) *Reducing the risks from hazards to acceptable or tolerable levels; and*

f) *Enabling the effective and efficient response and recovery from natural hazard events.*

In Part B of the Waikato RPS, Section 4 (Integrated Management), Policy 4.2 (Collaborative Approach) (a) states that Waikato Regional Council will recognise and provide for the unique role that territorial authorities have in the implementation of the provisions of the Waikato RPS. The implementation of the Waikato RPS, in regards to avoiding or mitigating natural hazards, is set out in Policy 4.2 part 4.2.10 (Natural Hazards):

For the purposes of avoiding or mitigating natural hazards, territorial authorities shall be responsible for the control of the use of land except for the following, which shall be the responsibility of the Waikato Regional Council:

a) *The control of the use of land in the coastal marine area and the beds of lakes and rivers; and*

b) *The control of structures in primary hazard zones.*

Section 6 of the Waikato RPS (Built Environment), Policy 6.1: Planned and co-ordinated subdivision, use and development, refers to part 6.1.5 which states that *'Rural-residential development should be directed to areas identified in the district plan for rural-residential development. District plans shall ensure that rural-residential development is directed away from natural hazard areas….'*

Section 13 (Natural Hazards) of the Waikato RPS sets out the management of natural hazards in the Waikato Region. Policy 13.2 of the Waikato RPS sets out to "Manage activities to reduce the risks from natural hazards". In order to support the implementation of this policy, WRC has provided a Risk Assessment Framework (Framework) (Waikato Regional Council, 2018) based on ISO 31000:2018 *Risk Management – Guidelines*.

This landslide susceptibility assessment work undertaken in this study is intended to demonstrate how WDC responsibilities have been fulfilled under the Waikato RPS and how they can be fulfilled for the future re-zoning work occurring within Te Kuiti.

The Framework highlights the policies within the Waikato RPS that are the responsibility of Territorial Authorities. In terms of land instability in Te Kuiti, WDC is required to implement the following methods:

13.2.1: Subdivision control in areas with intolerable risk.

13.2.2: Identify hazard zones and areas.

13.2.5: Control development and use in high risk hazard zones and areas.

Appendix C: Landslide Inventory

Appendix C Table 1: Landslide Inventory from historic T+T project data.

	Landslide Type	Geological unit	Typical reason for failure
1	Shallow landslide upslope of a stream with uncontrolled fill	Mahoenui Group	Rainfall induced
2	Ongoing creep – large area	Mahoenui Group	Rainfall induced
3	Shallow surficial landslide	Mahoenui Group	Rainfall induced
4	Large landslide - bedding shear plane above mudstone	Mahoenui Group	Rainfall induced
5	Remobilised bedding plane failure	Mahoenui Group	Rainfall induced
6	Ongoing creep of fill	Mahoenui Group	Rainfall induced
7	Ongoing creep – large area	Mahoenui Group	Rainfall induced
8	Large landslide	Mahoenui Group	Rainfall induced
9	Large landslide	Mahoenui Group	Rainfall induced
10	Large landslide	Mahoenui Group	Rainfall induced
11	Poor retaining wall design related failure	Te Kuiti Group	Rainfall induced
12	Failed retaining wall - large area upslope with tension cracks	Te Kuiti Group	Rainfall induced
13	Shallow - rock veneer failed – tree roots	Te Kuiti Group	Rainfall induced
14	Shallow - rock veneer failed – tree roots	Te Kuiti Group	Rainfall induced
15	Failed retaining wall	Te Kuiti Group	Rainfall induced
16	Failed retaining wall	Te Kuiti Group	Rainfall induced
17	Slumping piles on soft silts	Te Kuiti Group/Alluvium	Rainfall induced
18	Ongoing creep – large area	Te Kuiti Group/Alluvium	Rainfall induced
19	Ongoing creep – large area	Te Kuiti Group/Alluvium	Rainfall induced
20	Shallow - rock veneer failed – tree roots	Te Kuiti Group	Rainfall induced
21	Ground shrinkage causing movement	Te Kuiti Group/Mahoenui Group	Rainfall induced
22	Ongoing creep of fill	Te Kuiti Group	Rainfall induced
23	Ongoing creep – large area	Boundary between Te Kuiti Group and alluvium	Rainfall induced
24	Ongoing creep and failed retaining wall – large area	Boundary between Te Kuiti Group and Mahoenui Group	Rainfall induced
25	Shallow landslide upslope of a stream with uncontrolled fill	Boundary between Te Kuiti Group and Mahoenui Group	Rainfall induced
26	Hummocky uncontrolled fill and springs in the area	Boundary between Te Kuiti Group and Mahoenui Group	Rainfall induced

Appendix D: Landslide Assessment Checklist

CHECKLIST FOR STABILITY ASSESSMENTS

FACTUAL INFORMATION

1. **INTRODUCTION**
   - ☐ Report prepared for who?
   - ☐ Site Location
   - ☐ Outline of proposed development[(b)]
   - ☐ Comment on need for earthquake assessment
2. **TOPOGRAPHY**
   - ☐ Outline current landform (slope shape, height gradient, irregularities, erosion, soil creep/terracettes)
   - ☐ Outline surface drainage patterns[(b)]
   - ☐ Review aerial photos
   - ☐ Comment on any previous earthworks
   - ☐ Comment on any existing instability[(c)]
   - ☐ Additional site features (e.g. vegetation/trees structures[(b)] retaining walls, roads/driveways, services)
3. **SITE HISTORY**
   - ☐ Outline current/previous landuse
   - ☐ Comment on previous siteworks[(b)]
   - ☐ Reference "District Hazard Map"/GIS
   - ☐ Comment on previous instability[(c)]
   - ☐ Performance of existing structures
   - ☐ Review aerial photos
   - ☐ Comment on previous contamination[(c)]
4. **GEOLOGY**
   - ☐ Describe geological setting
   - ☐ Refer to relevant maps
   - ☐ Geological influences on stability (e.g. bedding, weak materials, faults)
   - ☐ Describe seismic setting
5. **INVESTIGATIONS**
   - ▸ FIELD
     - ☐ Inspection by geotechnical specialist
     - ☐ Descriptions of soils/rock in borelogs (Ref.1)
     - ☐ Outcrop/cutting descriptions[(c)]
     - ☐ Record Extent of any cracking[(c)]
     - ☐ Other field tests (e.g. CPT, etc.)
     - ☐ Monitoring of ground movements[(c)]
     - ☐ Groundwater measurements and observations (seepage, subsurface erosion)[(c)]
   - ▸ LABORATORY
     - ☐ Outline tests undertaken
     - ☐ Summarise results
     - ☐ Previous testing in local area
6. **SUBSURFACE CONDITIONS**
   - ☐ Geological interpretation[(c)]
   - ☐ Summarise subsoil conditions, e.g. extent of fill[(c)] topsoil, nature and distribution of soils/rock
   - ☐ Describe soil strengths/density, likely behaviour - refer to tests and logs
   - ☐ Highlight weak/sensitive/loose soils or rock defects
   - ☐ Describe groundwater conditions, subsurface drainage, expected seasonal fluctuations

APPENDICES
- ☐ Borelogs, Testpit Logs, Logs of Exposures (Ref.1)
- ☐ Laboratory Results
- ☐ Specifications for Remedial Works/Fills
- ☐ Site Photos

INTERPRETATION/DISCUSSION

7. **SLOPE STABILITY (Ref. 2,3,4)**
   - ▸ ENGINEERING GEOLOGICAL ASSESSMENT:
     - ☐ Discuss site features
     - ☐ Discuss geological setting/influences[(e)]
     - ☐ Influence of rainfall/groundwater
     - ☐ Reasons for landform (local, regional)
     - ☐ Likely slope failure mechanisms
     - ☐ Potential for Instability
     - ☐ Effects of the development on slopes[(f)]
     - ☐ Consequence of instability
     - ☐ Empirical assessment (qualitative)
     - ☐ Risk rating applied[(g)]
     - ☐ State whether stability analyses are required
   - ▸ GEOTECHNICAL ENGINEERING ANALYSES
     - ☐ Geotechnical slope model correct?
     - ☐ Analytical method stated
     - ☐ Determination of critical section of slope
     - ☐ Assessment of strength parameters
     - ☐ Assessment of groundwater profile/rainfall
     - ☐ Back analysis of any existing failures
     - ☐ External loads due to the development
     - ☐ State need for seismic analysis
     - ☐ Normal FOS requirements:
       - – Static (Design gwt) FOS ≥ 1.5
       - – Static (Extreme gwt) FOS ≥ 1.2
       - – Seismic (150 year EQ) FOS ≥ 1.2
     - ☐ Sensitive analyses for parameters required?
     - ☐ Results and comments
8. **GEOTECHNICAL EFFECTS OF DEVELOPMENT**
   - ☐ Slope stability risk increased or reduced?
   - ☐ Is the development feasible?
   - ☐ Need to drain slopes (surface/subsurface)?
   - ☐ Need to remove/upgrade fill?
   - ☐ Subsurface drainage beneath fills?
   - ☐ Need to retain slopes/secure rock faces?
   - ☐ Foundation conditions/requirements
   - ☐ Effect of stormwater/effluent disposal
   - ☐ Effect of service lines rupture (e.g. SW, sewer)
   - ☐ Effect of river/coastal erosion
   - ☐ Seismic effects on development and slope
   - ☐ Maintenance requirements for life of the development
9. **CONCLUSIONS AND RECOMMENDATIONS**
10. **STATEMENT BY GEOTECHNICAL ASSESSOR AS TO THEIR ABILITY & QUALIFICATIONS TO PREPARE THIS GEOTECHNICAL ASSESSMENT**

DRAWINGS/FIGURES
- ☐ Site Plan[(d)]: ☐ Borehole/Testpit Locations
  - ☐ Outline of Proposed Development
- ☐ Site Engineering Geological Maps[(d)]
- ☐ Site Contours Maps[(d)] } Cuts and fills
- ☐ Cross Sections } indicated
- ☐ Geotechnical Model
- ☐ Stability Analyses Results

REFERENCES

1. Guidelines for the Description of Soils & Rock, NZ Geomechanics Society (1985)
2. Assessment of Slope Stability at Building Sites, BRANZ Study SR4, (1987)
3. Slope Stability in Urban Development, DSIR Series 122 (1981)
4. Stability of House Sites & Foundations, Earthquake & War Damages Commission, NZ Geomechanics Society (1980)
5. Land Assessment for Development Suitability, Burns & Farquhar, NZ Geotechnical Symposium (1996)

NOTES

(a) This checklist is intended as a guide for typical stability investigation & assessments for residential developments. There may be additional requirements for specifically difficult sites, large scale developments and regional hazards
(b) Indicate on site plan
(c) Indicate on site engineering geological map
(d) These plans/maps are best combined if possible
(e) Ref.3 provides a valuable outline of stability problems peculiar to selected areas of NZ
(f) Refer BRANZ document Fig 3 (ref.2 above), Stability House Sites and Foundations (ref. 4 above)
(g) See 6.6 -"Risk Rating", Design of Permanent Slopes for Residential Development, Crawford & Millar for EQC (1998)

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