# REPORT

Auckland Council

Geotechnical Desk Study
South Auckland Rural Urban Boundary Project

## Report prepared for:

Auckland Council

## Report prepared by:

Tonkin & Taylor Ltd

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# 1 Introduction

## 1.1 General

Tonkin & Taylor Ltd was engaged by Auckland Council (AC) to undertake a concept level geotechnical desk study assessment for the Rural Urban Boundary Project (RUB) in South Auckland. The scope and extent of our engagement is outlined in the T&T proposal dated 26 February 2013[1].

The objective of the desk study assessment was to evaluate the suitability of rural/greenfield land in South Auckland for future urban development and to identify possible geotechnical constraints that could impact on the viability of development. Specifically the report is intended to provide the following:

i. A summary of the typical subsurface conditions (site stratigraphy) likely to be encountered at each development area;

ii. An overview assessment of site stability;

iii. Preliminary recommendations of geotechnical risks/constraints relating to earthworks, foundations and infrastructure at each development area;

iv. Preliminary assessment of liquefaction potential (under seismic conditions) for each area; and

v. Concept level advice on the geotechnical suitability of each area for future urban development including an appraisal on the relative viability of development between the different areas.

The conclusions and recommendations presented in this report are a guide only based on published geological maps, our past experience on projects in the region and limited historical geotechnical investigations undertaken within each of the proposed development areas. Site specific geotechnical investigations comprising machine boreholes, cone penetrometer tests and laboratory testing will be required to refine and confirm the conclusions presented in this report and for detailed planning and consenting purposes.

It is understood that Auckland Council have undertaken a separate study assessing possible ground contamination related issues. This document therefore excludes reference to ground and groundwater contamination.

The development area boundaries discussed in this report and presented in associated figures were provided by Auckland Council. This study focuses exclusively on the land defined within these boundaries. We understand that the boundaries could change as the RUB is further developed, in which case further assessment of areas not covered in this study may be required.

## 1.2 Project background

The RUB project has been set up to identify suitable rural/greenfield areas for future urban development. It is expected that up to 55,000 new dwellings will be required in the South Auckland cluster to accommodate the projected population growth of Auckland City over the next 30 years. The RUB is defined in the Auckland Plan as "a Rural Urban Boundary that will define the

[1] Tonkin & Taylor Ltd Proposal: *Proposal to Provide Geotechnical Consultancy Services: Rural Urban Boundary Project*, Ref 29129, dated 26 February 2013.

maximum extent of urban development to 2040 in the form of a permanent rural-urban interface".

The challenge identified by AC is to determine a robust RUB that provides the required space for growth whilst upholding other desired outcomes – environment, community, heritage etc. It is intended that the final RUB will be incorporated into Auckland Council's Unitary Plan (the plan which determines how Auckland will develop over the next 30 years). Three main scenarios have been identified for the South Auckland 'cluster' areas. These are as follows:

i. **Corridor Focus:** Including the 'Core' areas around Drury (Core D), Karaka (Core K) and Pukekohe (Core P) and the areas defined as Whangapouri, Paerata North, Pukekohe North-East and Pukekohe South-East.

i. **West-East Focus**: Including all 'Core' areas around Drury (Core D), Karaka (Core K) and Pukekohe (Core P) and the areas defined as Karaka North and Karaka West.

ii. **Pukekohe Focus:** Including all 'Core' areas around Drury (Core D), Karaka (Core K) and Pukekohe (Core P) and the areas defined as Pukekohe North-East, Pukekohe South-East and Pukekohe West.

As defined above, each scenario will include the 'Core' development areas as well as three separately identified areas defined as 'Ramarama South', 'Alternative Business' and 'Area subject to a separate Plan Change Process' all located south east of Drury.

A detailed description of each development area is provided in Section 2.2 and the extents of the development areas are presented on Figure 1 in Appendix A. The three development scenarios (outlined above) are summarised in Figures A to D.

## 1.3 Scope

The scope of works for this desk study assessment has included the following in accordance with our proposal dated 26 February 2013 (ref 1):

- Review of published geological maps for the area;
- Review of T&T's geotechnical database and publically available geotechnical information of the area and generic appraisal of previous geotechnical investigation data;
- Review of published reports including the GNS slope stability report and the Auckland Engineering Lifelines Report, both prepared for Auckland Council;
- Review of available LiDAR elevation data, to assess potential for general landform instability;
- Assessment of typical geotechnical development constraints for the various proposed development sites and suitability of each area for future development;
- A preliminary assessment of the liquefaction hazard for the areas based on geological maps and Cone Penetrometer Tests (CPT's) performed on other South Auckland sites with similar soil conditions to those present within the development areas; and
- Preparation of this report

The locations of all relevant geotechnical projects used to prepare this desk study assessment are presented on Figure 1 in Appendix A. Approval to proceed with the scope of works outlined above was provided by Auckland Council by Email on 13 March 2013[2].

[2] Email from Ian Bayliss (AC) to Nick Speight dated 15 March, 2013: 08:26am

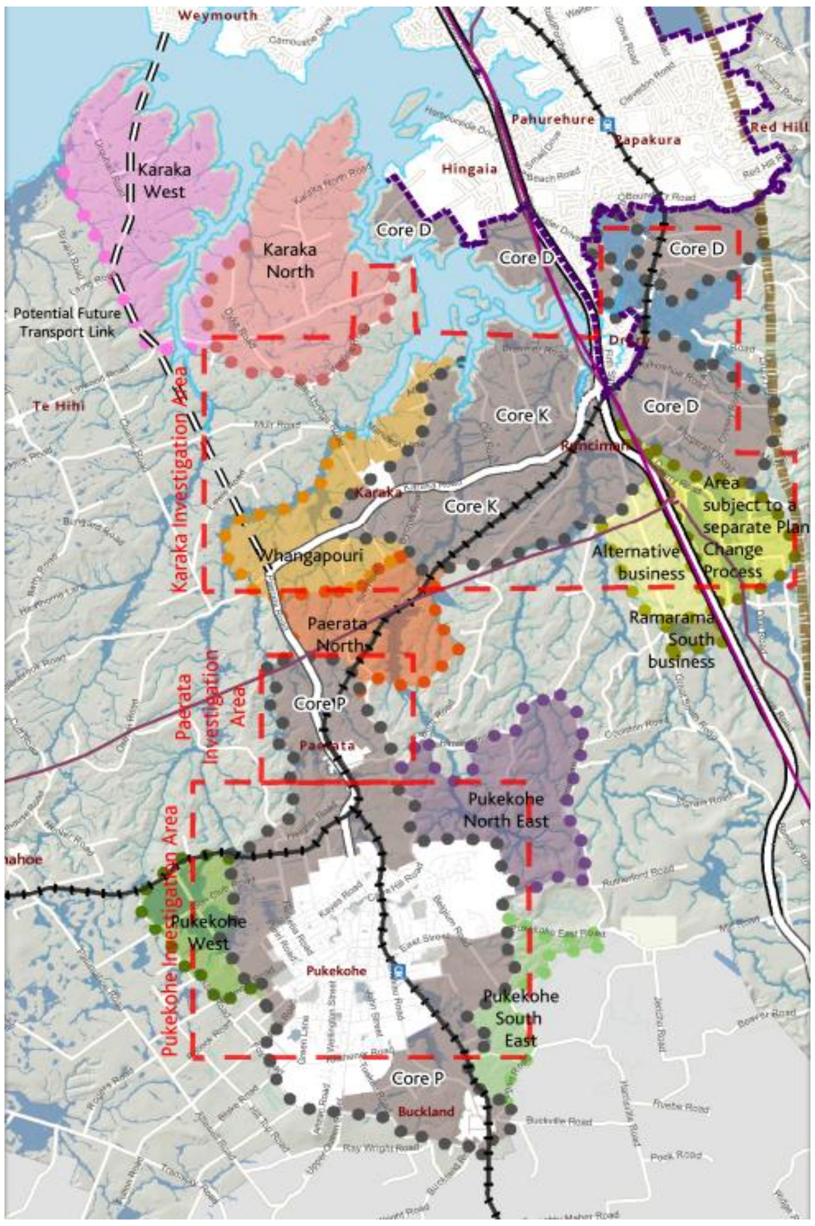


Figure A: Southern 'cluster' development areas identified for the RUB[3]

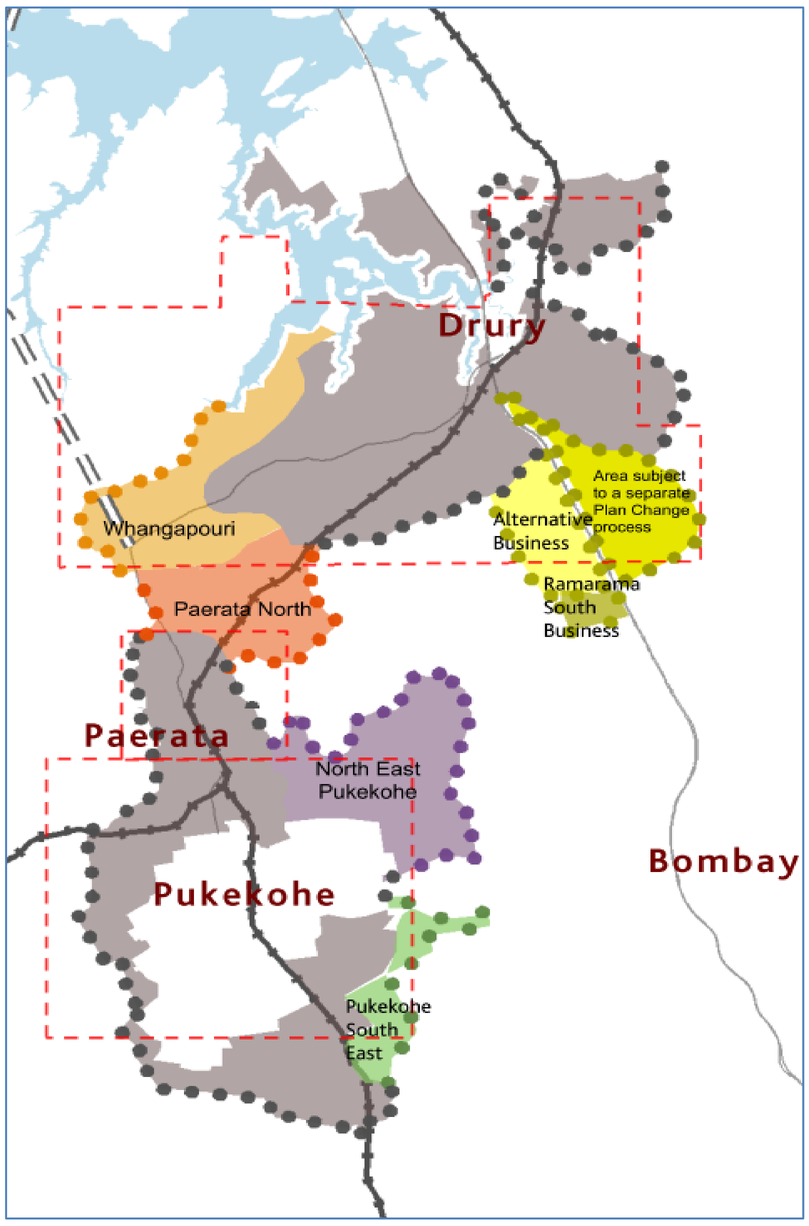


**Figure B**: Development Scenario: Corridor Focus[3]

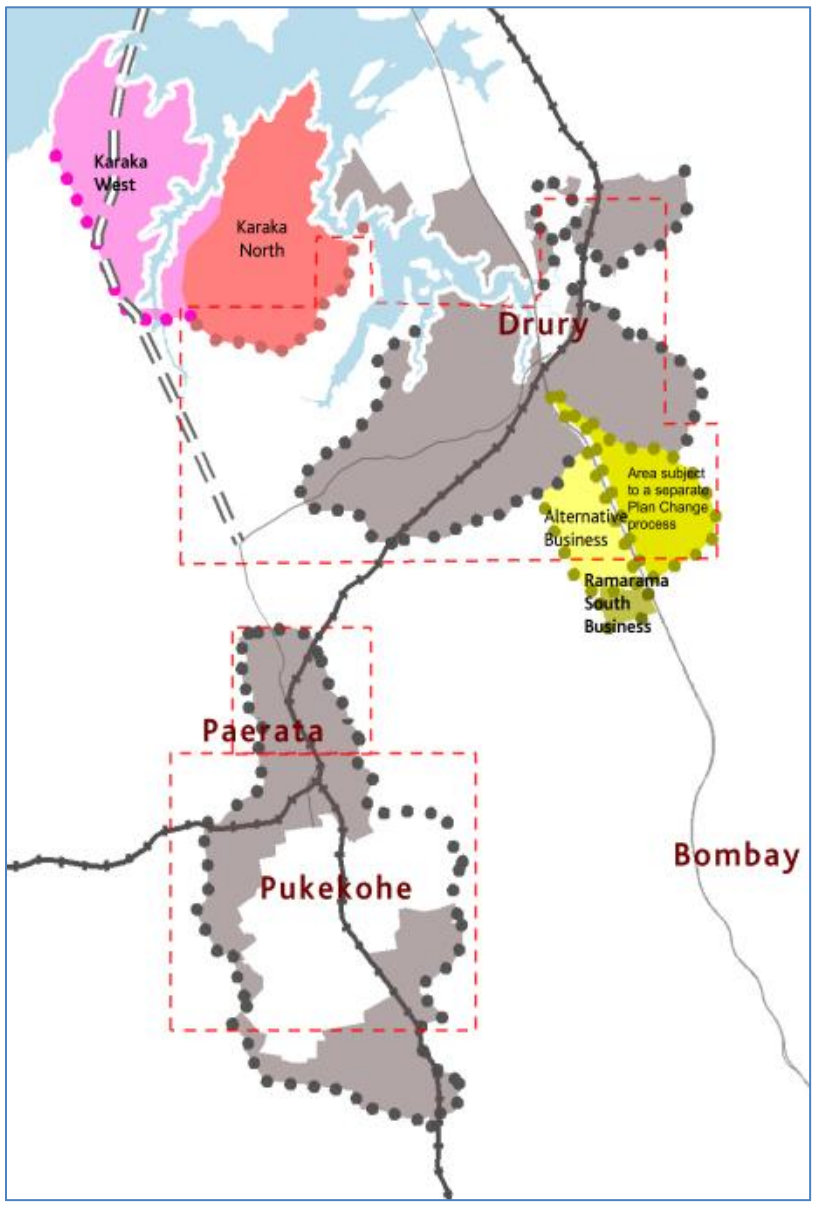


**Figure C:** Devlopment Scenario: West-East Focus[3]

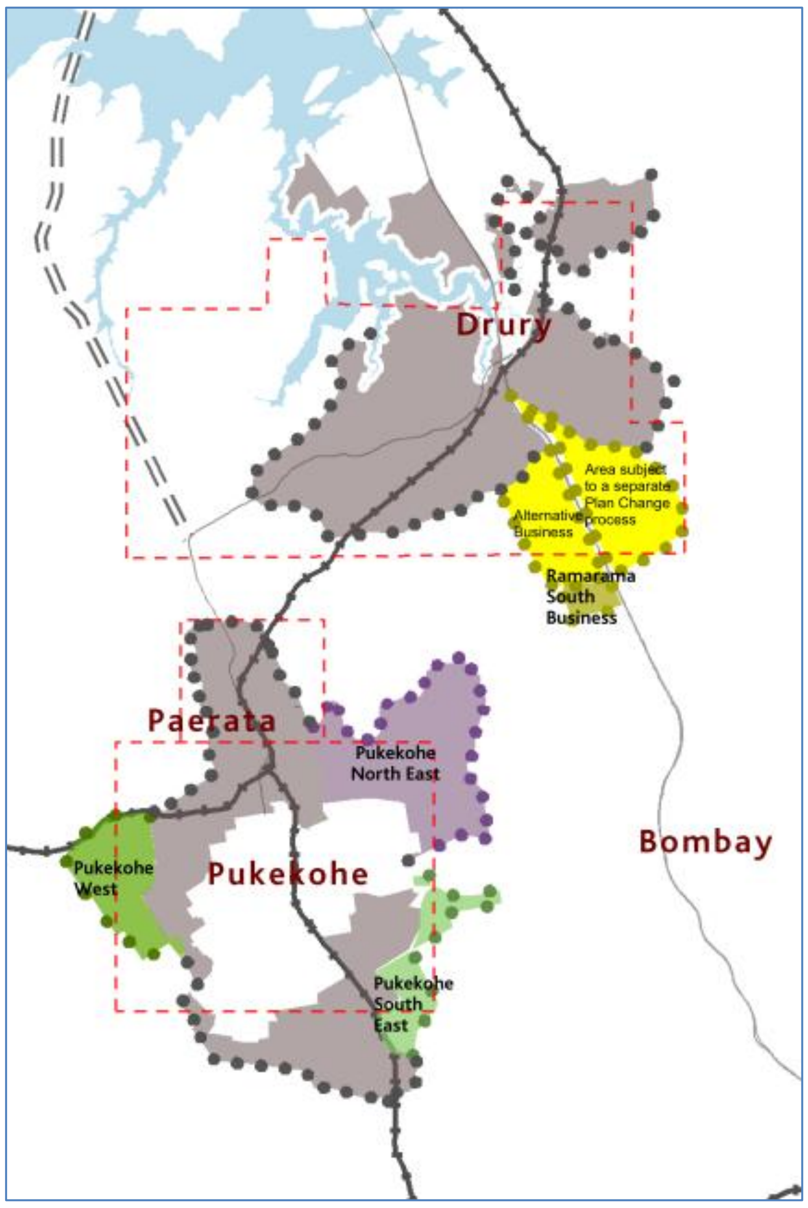


**Figure D:** Development Scenario: Pukekohe Focus[3]

[3] Auckland Council: Southern Rural Urban Boundary, Draft Unitary Plan (from Auckland Council website)

# 2 Site Descriptions

## 2.1 Core Development Areas

### 2.1.1 Drury Core Development area (Core D)

The Drury Core (Core D) development area is located around the existing suburb of Drury in South Auckland, as shown above and on Figures 1 and 3 in Appendix A. It is proposed that the development area will be centred around the Drury motorway interchange and expand on the existing boundaries of Drury and include pockets of additional land to the north around Papakura, Red Hill and on the Hingaia Peninsula. Major transport facilities including SH1, SH22 and the North Island Main Trunk (NIMT) railway line all run through this development area.

The topography of the site is variable due to the large size and extent of the development area; with typical elevations ranging between 3m RL and 5m RL, around the waterways and harbour, and up to RL 50 m in the south west of the development area, towards the stream headwaters. The Drury Core development covers an area of approximately 1,000 ha which is expected to accommodate approximately 9,000 new dwellings.

### 2.1.2 Karaka Core Development Area (Core K)

The Karaka Core area (Core K) is located within the existing rural area of Karaka and is bound by Manukau Harbour tidal inlets to the north, the Southern motorway (SH1) to the east and the Whangapouri development area to the west (refer to Figures A to D above). Major transport infrastructure includes SH22 and the NIMT railway line which both dissect the development area. The Oira Creek and Ngakoroa Stream run through the development area, both on an approximate north-south alignment, discharging into the Drury Creek.

The Karaka Core Development area (Core K) covers an area of approximately 1,300 ha. It encompasses land with variable topography with typical elevations ranging from 2 to 5 m RL in the north, around the waterways and harbour, and up to 50 m RL in the south west of the development area, towards the stream headwaters. It is expected that the Karaka Core development area will accommodate approximately 12,000 new dwellings.

### 2.1.3 Pukekohe Core Development area (Core P)

The Pukekohe Core (Core P) development area is located to the north, south and west of the existing Pukekohe Township and includes the rural centres of Buckland (to the south) and Paerata (to the north) as shown in Section 1.3. Main access to the area is via SH22 (Karaka Road) from the north and Pukekohe East Road, to the east. The NIMT Railway line also runs through the development area.

The ‘Core P’ development area covers approximately 1570 ha which is expected to accommodate approximately 14,000 new dwellings. The surface topography of the Core P development area is typically higher than the lower lying Core K and Core D areas with elevations typically ranging from 60m RL to 90 m RL. The Whangapouri Creek flows through the northern end of the development area on a north-south alignment, on a similar alignment to the railway line.

## 2.2 Corridor Focus Development Areas

### 2.2.1 Paerata North

The Paerata North development area is located between Drury and Paerata and is dissected by the existing NIMT railway line (see Figure B). This development area, combined with the Core development areas, would create a continuous rural-urban corridor along the rail line, linking Pukekohe to Drury (refer to Figure 1 in Appendix A).

The Paerata North development area occupies approximately 450 ha which is expected to yield approximately 4,500 new dwellings. Oira Creek, a tributary of Drury Creek which flows to the north, dissects the development area forming a distinctive gully feature on an approximate north-south alignment. Land rises to the east and west of Oira Creek with elevations varying from between RL 10 to 20 m within the Oira Creek valley to as high as RL 50 m outside the valley.

### 2.2.2 Whangapouri

The Whangapouri development area is located directly west of the Drury Core area (Core D) and follows the eastern edge of Whangapouri Creek as shown on Figure B and Figure 1 (Appendix A). Several small tributary creeks and streams of the Whangapouri Creek, originate from within the proposed development area. The area is accessed by SH22 (Karaka Road) which cuts through the southern third of the development area before heading south towards Pukekohe.

The Whangapouri development area typically slopes toward the Whangapouri Creek on the western side with elevations ranging from RL 5 to 10 m along the edge of the creek, to RL 20 to 30 m on the eastern side of the development area. The site rises to a maximum elevation of approximately 50m RL in the south east. It is estimated that the Whangapouri Development area could accommodate an additional 6,500 dwellings and occupy an area of 550ha.

## 2.3 West-East Focus Development Areas

### 2.3.1 Karaka North

The Karaka North area is located to the north west of the Drury Core development area on the edge of the Manukau Harbour, as illustrated on Figure C and Figure 1 (Appendix A). The area is surrounded by the Manukau Harbour to the north east and north west, with Drury Creek to the east and Whangamaire Stream to the west. The topography is typically low-lying with elevations ranging from RL 3 to 5 m close to the Harbour to RL 40 m in the centre of the development area. The site covers an area of approximately 920 ha.

It is estimated that the Karaka North area could accommodate approximately 8,500 new dwellings but will require construction of new arterial roads and services to service future development. It is anticipated that the main access to the area would be through the Hingaia Peninsula with bridges upgraded to meet increased traffic demand. The Karaka North area is currently predominantly open pasture land.

### 2.3.2 Karaka West

The Karaka West area is located to the west of the Karaka North area on the peninsula overlooking the Pahurehure Inlet and the Manukau Harbour, as shown on Figure C and Figure 1 (Appendix A). The Whangamaire Stream defines the eastern boundary of the area, running in an approximate north-south alignment. Access to Karaka West is currently limited to minor roads, with no public transport infrastructure servicing the area.

The Karaka West area occupies approximately 790 ha and in terms of topography is very similar to the Karaka North area. The topography is typically low lying around the coastal fringes and increases in elevation towards the centre with elevations typically ranging from RL 3 to 5 m near the coast up to RL 40 to 50 m further inland.

## 2.4 Pukekohe Focus

### 2.4.1 Pukekohe North East

The proposed Pukekohe North East development area is located to the north east of the existing Pukekohe Township boundary as illustrated on Figure D and Figure 1 (Appendix A). The development will utilise existing facilities and infrastructure within Pukekohe. The proposed north-east Pukekohe development area is approximately 660 ha in size and could accommodate approximately 5,500 new dwellings. Currently the development is occupied by a number of small land parcels (lifestyle blocks).

The topography of the development area is heavily influenced by the presence of two streams; Oira Creek and Ngakoroa Stream. Oira Creek runs through the development area from the south to the northwest, while Ngakoroa Stream originates around the centre of the development area and flows out through the north eastern end of the areas. Both streams flow into Drury Creek, which discharges at the Manukau Harbour, and have a number of small tributaries which extend across the development area. The surface topography of the site is typically undulating with a number of valley and gully features present. Elevations range from RL 20 to 30 m within the gullies, to as high as RL 80 to 100 m at the top of the stream catchments.

### 2.4.2 Pukekohe West

The Pukekohe West area is located to the west of the existing Pukekohe Township, but west of the Pukekohe Core (Core P) area as shown on Figure D and Figure 1 (Appendix A). The topography of the area is relatively consistent with the other Pukekohe areas with elevations ranging from RL 60 min the north to RL 80 m in the south. There is an absence of any major waterways within the development area, apart from one small creek which dissects the centre of the area on an east-west alignment.

The Pukekohe West area occupies approximately 290 ha and is currently used as open pasture land.

### 2.4.3 Pukekohe South East

As illustrated on Figure D and Figure 1 (Appendix A), the Pukekohe South East area is located to the south east of the existing Pukekohe Township and east of the Pukekohe Core (Core P) development area. Like the Pukekohe West and Pukekohe North East areas, this area utilises the existing facilities within the Pukekohe region whilst maintaining an independence from urban Auckland. Several small streams and creeks flow through the development area, discharging into Tutaenui Stream and away towards the south.

The Pukekohe South East area is the smallest of the proposed development areas covering approximately 220 ha. The surface topography is typically rolling to moderately sloping with elevations ranging from RL 50 m in the south to RL 120 m in the east, with local lower elevations within the stream gullies.

# 3 Geotechnical Reference Information

As noted in Section 1.1, this geotechnical desk study assessment has been undertaken based on published geological maps, limited historical geotechnical investigation data and our past experience gained on projects in the region. The following reports have also been referenced and utilised for the purposes of the study:

- Landslide Susceptibility for South Auckland Greenfield Area – Glenbrook, Karaka, Kingseat, Paerata and Pukekohe: GNS Science Consultancy Report 2012/255[4]
- Auckland Engineering Lifelines Project Study – Stage One Report for Auckland Regional Council (dated 1997)[5]

The Landslip Susceptibility study was undertaken by GNS science in August 2012 using published geological maps and LiDAR terrain data. The report provides a factual output of terrain analyses but does not provide geotechnical interpretation of the results to qualify the potential for constraints for future urban development.

The Auckland Engineering Lifeline Report was published in July 1997, and outlines the hazard vulnerability of Auckland due to various natural disaster events. Of particularly relevance is the section relating to earthquakes and earthquake induced landslips and liquefaction. The report provides a high level review of the hazards and possible issues but does not specifically focus on the South Auckland area. In addition, the report was produced in 1997, and therefore precedes the current New Zealand design standards relating to seismic hazard (NZS1170:2004). In addition, the understanding of land response to earthquake shaking (especially liquefaction potential) has evolved significantly since the Canterbury sequence of earthquakes.

[4] D.W. Heron, B Lukovic G.D. Dellow: 2012- *Landslide Susceptibility for South Auckland Greenfield Area –Glenbrook, Karaka, Kingseat, Paerata and Pukekohe* GNS Science Consultancy Report 2012/255
[5] Auckland Regional Council:1997 – *Auckland Engineering Lifelines Project – Stage One Report*

# 4 Geological Overview

## 4.1 Published geology

The surface geology of the South Auckland region is presented as Figure E below. The areas shown in an 'off-white' colour (labelled 'Q1a') are underlain by Tauranga Group Holocene Age alluvial soils and the 'peach/orange' colour (majority of the northern area – labelled 'Pup') are underlain by Tauranga Group Puketoka Formation soils (Pleistocene Age). The red and pink areas to the south represent the extent of the basalt lava flows ('Qva') and volcanic ash soils (Qvs) respectively, derived from the South Auckland volcanic field. The orange represents East Coast Bays Formation, comprising alternating sandstone and mudstone. A more comprehensive illustration of the geology of South Auckland is presented on Figures 2 (overall area) and Figures 3, 4 and 5 (proposed development areas) in Appendix A.

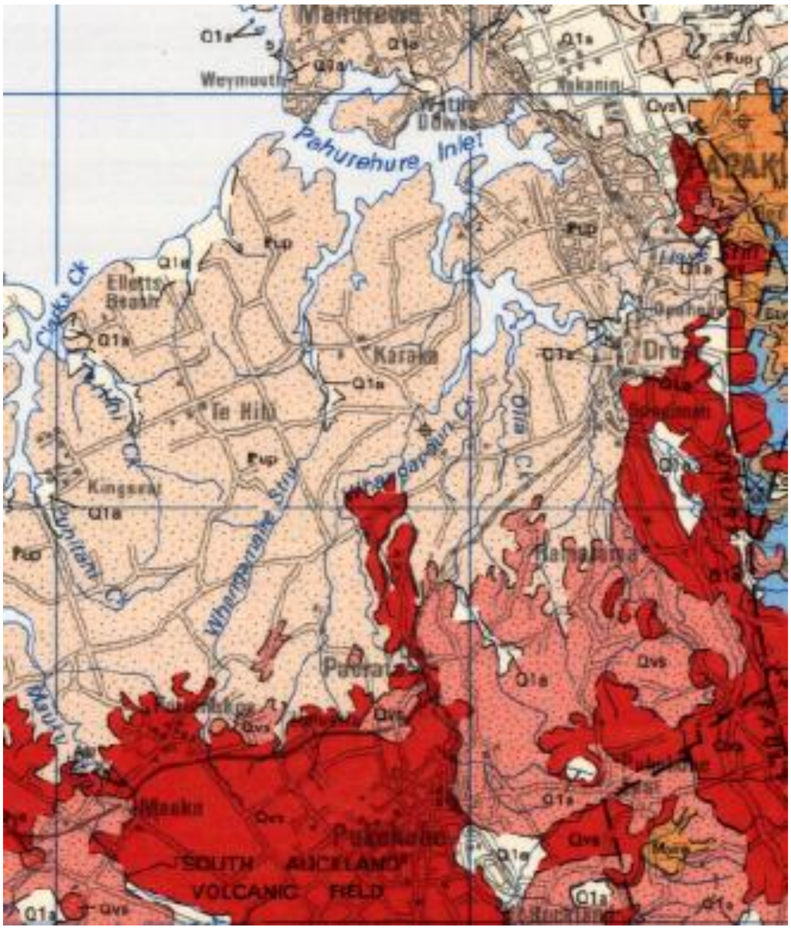


**Figure E:** Regional Geology of South Auckland[6]

A description of the different geological units and material types is presented in the following sub-sections.

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[6] Edbrooke, S.W (compiler) 2001: Geology of the Auckland Area. Institute of Geological & Nuclear Sciences 1:250,000 geological map3 1 sheet+74p Lower Hutt New Zealand, Institute of Geological & Nuclear Sciences Limited

## 4.2 Geological units

### 4.2.1 General

A summary of the various geological units present across the RUB development area, along with a description of their geotechnical behavioural characteristics, is provided below.

### 4.2.2 Holocene Alluvium

Holocene alluvium (Q1a on the geological map) typically comprises highly compressible soft to firm organic silts and clays found bordering rivers and streams, within gully features, and around low lying coastal areas. The alluvium often includes layers of peat and other low strength/compressible soils which are typically considered unsuitable or difficult to construct over. Where possible, Holocene Age alluvial soils are removed from development areas during subdivisional earthworks (e.g. “mucking-out” of stream/gully features and backfilling with engineered fill is a common component of land development). Alternatives, if not removed from site, could include re-engineering the soil or managing soil specifically during development.

### 4.2.3 Volcanic Ash & Tuff

Volcanic ash and tuff derived from the South Auckland volcanic cones underlies the south western and south eastern parts of the study area as shown on Figure E and Figures 2 and 5 (Appendix A). Volcanic airfall deposits from the Central North Island volcanic field could also be present. Based on past experience in the southern areas of the Southern ‘cluster’, the majority of the development sites are likely to have a surface capping layer of volcanic ash derived from the nearby volcanic activity. The thickness of this layer will typically be in the range of 5 to 10 m; however, erosion in coastal areas, gully features and along waterways may have significantly reduced the thickness and presence of this layer. These soils are generally very stiff, orange brown silty clays of moderate to high plasticity.

Ash may exhibit high sensitivity when disturbed but in its natural condition has relatively low compressibility and can provide a rafting action over the underlying softer sediments.

Tuff is a volcanic ash deposit made up of mostly crystalline rock fragments. The tuff present across South Auckland typically comprises an upper layer of stiff sandy silt underlain by graded beds of welded sand, silt and basalt fragments. The tuff generally becomes increasingly welded with depth with rock strengths ranging from very weak to weak (1 to 5 MPa).

### 4.2.4 Tauranga Group - Puketoka Formation (Pleistocene)

Published geological maps show that the development sites in the northern part of the study areas are located on land of low relief and predominately underlain by Puketoka Formation alluvial soils of the Tauranga Group (‘Pup’ on geological maps – Figures 2 to 4 Appendix A). The Puketoka Formation generally comprises light grey to orange brown pumiceous silt (distal ignimbrite materials), sand and gravel with lenses of muddy black compressible peat and lignite from the Pleistocene Age.

Our experience with Puketoka Formations soils indicates that the peat layers could be up to 3 m thick and are typically present within the upper 10 m. The peat is largely amorphous with minor fibrous content and has usually been subject to a degree of pre-consolidation that limits settlements under moderate loading. However if the pre-consolidation pressure is exceeded primary consolidation rates of the peat can be high. In addition peat soils can settle over a long period of time due to secondary consolidation (creep) effects.

The upper Puketoka Formation soils also comprise layers of loose to medium dense, and dense Tauranga Group sands which underlie the silty clays. These layers vary considerably in depth, density and thickness. The medium dense to dense Tauranga Group sands are typically present from a depth of approximately 10 to 20 m below ground level but are not necessarily continuous (upper layers typically being limited to 3 to 5 m in thickness). The loose sandy layers of the Puketoka Formation have been identified as being susceptible to liquefaction under seismic conditions.

### 4.2.5 Basalt

The basalt lava present across the southern part of the South Auckland 'cluster' originates from volcanoes within the South Auckland Volcanic Field, made up of approximately 97 volcanic centres. The volcanic episodes include both effusive centres, which have produced Scoria Cones and associated lava flows (source of the basalt), and explosive centres which have predominately produced tuff rings. Due to the large number of volcanic vents and the extent of the development area, specific basalt lava flows are not identified and may have been sourced from any one of a number of volcanic centres.

The South Auckland basalt tends to be fine to medium grained, vesicular and porphyritic (distinct difference in crystal sizes). Overlying the basalt rock, air-fall ash, scoria and weathered basalt rock are likely to be present. The thickness of the overlying deposits is expected to range between 5 and 20 m, based on historical investigation data.

### 4.2.6 East Coast Bays Formation (Miocene)

Although not identified within the published geological maps as being present, at the surface over any of the proposed development areas, historical geotechnical investigation results indicate that East Coast Bays Formation (ECBF) rock is likely to be present at shallow depths (underlying Puketoka Formation soils) and along the western edge of the Drury Core development area. The very weak to weak ECBF rock typically consists of interbedded layers of sandstone and mudstone. The residual ECBF soils (which overlie the rock) comprise stiff to very stiff, grey silts and clays which gradually increase in strength with depth. The weathered (residual) layer thickness can vary between 2 and 10 m.

## 4.3 Stratigraphy

### 4.3.1 General

The site stratigraphy presented in the following sections is based on limited geotechnical investigations undertaken for other purposes, within each of the proposed development sites; our experience in the region and based on available published geology. The nature and continuity of the subsoil conditions has been inferred from the available data and it must appreciated that, due to the limited data and large size of the area of interest, actual conditions will locally vary from those presented below. Site specific geotechnical investigations comprising machine boreholes, cone penetrometer tests and laboratory testing will be required to confirm and validate the findings and conclusions presented in this report.

Subsurface conditions of the development areas typically fall into one to the following site stratigraphy category:

i. Coastal development areas (northern half of the 'South Auckland cluster'): Puketoka Formation and Holocene Age alluvial deposits; and

ii. Inland development areas (southern half of the 'South Auckland cluster'): Volcanic ash/tuff soils overlying basalt rock.

In addition to the detailed description of the geological units provided in Section 4.2, the geological map identifying historic investigations sites is provided on Figures 2 (overall area) and Figures 3 to 5 (specific development areas) in Appendix A.

### 4.3.2 Coastal development areas

The coastal development areas include the Drury and Karaka Core (Core D and Core K), Karaka North, Karaka West, Whangaporui and Paerata North. These areas are predominately underlain by Puketoka Formation alluvial soils with areas of recent (Holocene Age) alluvial deposits.

Geotechnical investigations to the north, on the Hingaia Peninsula and across the centre of the Core D and Core K development areas, indicate the subsurface soils are predominantly Puketoka Formation materials comprising firm to stiff silty clay and clayey pumiceous silts with deposits of fine to medium sand throughout. Peat and organic materials were typically encountered from a depth of 5m (below ground level).

Localised areas of soft, recent alluvium (Holocene) are shown to be present around the eastern end of Drury Creek. Geotechnical investigations in this area indicate that firm to stiff clay and silty clay soils (consistent with alluvium) are present in this area. In addition, recent alluvium is likely to be present particularly around gully features and low lying coastal areas. We would also expect recent alluvial deposits around the coastal areas of the Karaka North and Karaka West areas.

Based on the proximity of the site to the South Auckland volcanic field, we would expect a thin veneer (0.5 to 2 m thick) of ash material within the upper soil layers. This ash layer may not be continuous over the entire site as it could have been partially or fully eroded, particularly on steep slopes and in gullies.

Previous geotechnical investigations also indicate that East Coast Bays Formation rock may be present at shallow depths along the eastern edge of the Drury Core (Core D) development area.

Groundwater levels are expected to be at near surface elevations (0 to 3 m below ground level) within the coastal development areas.

### 4.3.3 Inland development areas

The inland development areas include the Pukekohe Core (Core P), Pukekohe North East, Pukekohe South East and Pukekohe West. These areas are typically underlain by volcanic soils from the South Auckland Volcanic Field. Geotechnical information sourced from approximately 15 previous geotechnical investigations in the Pukekohe area confirm the subsurface conditions are consistent with those presented on the published geological maps.

The geology of the western and southern areas of the South Auckland ‘cluster’ is identified on the geological map as being underlain by basalt lava but our experience indicates it is generally capped by a layer of ash. Geotechnical investigations in these areas encountered stiff to very stiff volcanic ash of varying thickness. Basalt rock was typically not encountered by shallow investigations which generally terminated at 5m depth.

The eastern areas, where investigated, were found to be underlain by ash and tuff which is consistent with the geological map. The deeper, underlying geology in this area is likely to consist of weathered tuff, which increases in strength with depth, becoming completely welded tuff. Investigations in this area also identified small isolated pockets of alluvium, with peat present throughout. The alluvial deposits were found within and along the alignment of streams within the development area. Paleo valleys infilled with softer (recent) alluvial soils are often present within lower lying areas.

To the south east of the Pukekohe Development Area, an area of Holocene Age alluvium is present, as identified on the geological maps. The subject area underlies the south-eastern edge of the existing Pukekohe Township, Pukekoke raceway and an area of farmland to the east. Investigations in the area indicate the geology consists of soft to stiff clayey silt soils with peat and some fine sand also encountered. The alluvial deposit extends to at least 5m depth and may extend considerably deeper than this. We expect areas of alluvial soils to be present along the alignments of the streams within the development areas including, the Ngakoroa Stream and the Oira Creek.

Previous geotechnical investigations have identified a large area in the northeast of the inland development areas where the interpreted near surface geology and the published geology differ. The area, between Whangapouri Creek and Cape Hill Road is identified on the geological map as being underlain by basalt and ash/tuff material. Whilst the presence of basalt, ash/tuff in this area cannot be fully discounted, additional investigation data indicates the presence of Tauranga Group alluvium interspersed with peat.

## 4.4 Groundwater

Subsurface groundwater conditions are an important consideration for any development, and may have a major impact on foundations, services (excavations), earthworks, slope stability and liquefaction potential (refer to Sections 5 and 6). While geotechnical investigations have been carried out within the proposed development areas, the available specific groundwater data is not considered to be reliable due to changes in groundwater regimes and climate influences. However, based on our experience working with similar areas in the South Auckland region we typically expect the following groundwater conditions:

- Groundwater levels within coastal areas, including the Drury, Karaka and Whangapouri development areas are likely to be near surface (shallow depth to groundwater) within 3m of existing ground level. The groundwater within low lying coastal areas is likely to be influenced by tidal effects. Care will need to be taken in the development of land with high groundwater levels to ensure that possible settlement related effects of groundwater drawdown are mitigated and controlled.
- Groundwater levels in development areas further inland, including the Pukekohe (Core, Southeast, West and Northeast Pukekohe) and Paerata North development areas will likely be relatively low (deeper depth to groundwater) with water likely to be present at depths of 3 m or more below ground level.
- Groundwater flow across all development areas is typically from elevated areas toward streams and creeks (river re-charge from surrounding environment), with resulting groundwater levels being closer to the surface near streams and creeks and within gullies.
- Groundwater aquicludes (interbedded less permeable materials) may exist in some areas allowing the development of perched water tables and zones of seepage where intersected by sloping ground.

We recommend groundwater monitoring instruments (piezometers) be installed during future geotechnical investigations to provide design inputs and confirm the assumed groundwater conditions outlined above.

## 4.5 Seismic Subsoil Class

The New Zealand Standard for Structural Design Actions (NZS 1170: 2004) provides guidance on the levels of ground shaking that should be considered for the design at the site.

Investigation data reviewed for the purposes of this desk study assessment was not sufficient to determine the depth to underlying rock as required to determine the site subsoil class in accordance with NZS 1170. We can therefore only make generalised comments based on our experience across the wider South Auckland area. Detailed geotechnical investigations will be required to confirm the seismic subsoil class at each site.

Generally, areas identified as being underlain by volcanically derived rock, including basalt and tuff will be classified either as Class B (rock) or Class C (shallow soil site) based on the following:

- Areas where stiff soil thickness in the area exceeds 3 m are classified as a shallow soil site;
- Areas with soil thickness less than 3m are classified as a rock site.

For the development of areas underlain by alluvial soils including Puketoka Formation soils the site seismic subsoil class will likely be either Class C – shallow soil or Class D – deep or soft soil, depending on the strength of the overlying soils and depth to underlying rock.

On the basis of the above generalisations and our expectation of the site geology, the following site subsoil classes are anticipated for each area:

- Drury Core: Class D
- Karaka Core/Karaka West/Karaka North: Class D
- Whangapouri and Paerata: Class C and Class D
- Pukekohe North East/Pukekohe West: Class B and Class C
- Pukekohe Core/ Pukekohe South East: Class B, Class C and Class D (possibly in alluvial zone)

### 4.5.1 Peak ground accelerations

Approximate peak ground acceleration magnitudes have been assessed under various seismic conditions for preliminary liquefaction analyses. The following has been assumed for calculation of peak ground accelerations in accordance with NZS1170.5 (2004)

- Building importance level: IL 2 (assuming typical residential dwelling or commercial building)
- Building design life: 50 Years
- Return period 500 Years – ULS Event (Table 3.2 NZS 1170.5)
  25 years – SLS event (Table 3.2 NZS 1170.5)
- Near Fault Factor 1.0 (distance to nearest fault > 20km)

**Table 1** – Spectral Shape Factors for seismic subsoil class

| **Site Seismic subsoil Class** | **Class B – Rock** | **Class C – Shallow Soil** | **Class D – Deep/soft Soil** |
|---|---|---|---|
| Spectral Shape Factor | 1.0 | 1.33 | 1.12 |

Assuming the above information, the peak ground accelerations presented in Table 2 have been calculated based on an earthquake with magnitude 7.5 under Ultimate Limit State (ULS) and Serviceability Limit State (SLS) seismic conditions.

Ultimate Limit State conditions are generally defined as ‘extreme’ conditions (e.g. a 1 in 500 year seismic event) that a building or structure should be designed (under NZ building code requirements) to withstand without collapse. However, under ULS conditions the building or structure does not necessarily need to be ‘serviceable’ or ‘functional’ following such an event, i.e. it is accepted that the structure may need to be repaired or demolished.

Design for Serviceability Limit State conditions is design for events with a medium to high probability of occurrence within the life time of the structure (e.g. a 1 in 25 year earthquake event). Buildings and structures should be designed and detailed to be fully serviceable during and following such an event.

**Table 2 – Assessed Peak Ground accelerations for varying Site Subsoil Class**

| **Seismic Case** | **Class B – Rock** | **Class C – Shallow Soil** | **Class D – Deep/soft Soil** |
|---|---|---|---|
| Serviceability Limit State Event (1 in 25 years) | 0.032g | 0.042g | 0.04g |
| Ultimate Limit State Event (1 in 500 years) | 0.13g | 0.17g | 0.15g |

# 5 Geotechnical Hazards

## 5.1 General

Based on the available geotechnical information and our knowledge of the likely subsurface conditions at each development area, we have identified the following key geotechnical hazards which will need to be considered for future urban development.

1. Slope instability, including coastal erosion;
2. Liquefaction: loss of strength under earthquake shaking and associated lateral spreading and settlement.
3. Settlements: compressible soils, such as peat/organic matter which are prone to degradation and long term consolidation settlement;

The preliminary recommendations and conclusions presented in Sections 5 and 6 are based on our interpretation of published geological information and limited geotechnical investigation data. The recommendations are intended to provide guidance for a feasibility assessment of the proposed development areas and should not be used for detailed design or consenting purposes. Appropriately scoped site specific geotechnical investigations will be required to confirm the subsurface conditions across the site and to validate or otherwise the conclusions and recommendations of this report. In particular, it is recommended that investigation be undertaken to assess the liquefaction and lateral spread hazard and risk in areas that have been identified as potentially susceptible to liquefaction under seismic potential, and or when additional data or information indicates additional areas may also be susceptible.

It is understood that flooding, sea level rise and other non-geotechnical hazards have been addressed in other studies. This document therefore excludes reference to these additional hazards, however, we note that sea level rise will increase the susceptibility of some land to undergo liquefaction.

## 5.2 Hazard Potential

In order to provide Auckland Council with a coarse but useable appraisal of the proposed development areas we have adopted a ‘hazard potential’ categorisation. Each of the areas within the proposed South Auckland RUB has therefore been defined as having low, medium or high “hazard potential” with regards to slope instability, liquefaction and settlement (due to compressible soils). The categorisation of each hazard is also illustrated on Figures 6 to 12 in Appendix A.

The majority of land within the South Auckland RUB is considered geotechnically suitable for development, but with various degrees of engineering control required to remedy or mitigate the risk or impact of geotechnical hazards.

## 5.3 Slope Instability Potential

### 5.3.1 General

A preliminary assessment of slope instability potential has been undertaken for the proposed South Auckland RUB; using published geological maps (for categorisation of soil types), LiDAR surface elevations sourced from AC and our experience with landslips in the Auckland region. The GNS Report Landslide Susceptibility for South Auckland Greenfield Area – Glenbrook, Karaka, Kingseat, Paerata and Pukekohe (2012) has also been referenced as part of the slope stability review.

Landforms have been categorised into three slope instability hazard vulnerability classes (low, medium and high) based on the expected geology (per the geological map) and the ground surface topography (LiDAR data). The category slope profile limits are presented on Table 3 below and discussed in more detail in the following sections. The slope profile limits have been derived based on our previous experience and knowledge of similar soils and topography within the greater Auckland region. In addition, T&T have provided geotechnical advice to the Earthquake Commission in relation to landslip disaster damage on residential properties over the last 30 years and hence, have awareness on the spatial distribution of such events within the Auckland region. We note that our current appreciation of slope instability potential is based on present prevailing weather patterns in NZ. However, it should be recognised that these conditions may be influenced by to climate change effects over the longer term.

A plan showing the slope instability hazard categories for the South Auckland RUB areas is presented as Figures 6-9 in Appendix A. The South Auckland RUB areas typically have a lower slope instability potential, especially when compared to other areas in the greater Auckland region (e.g. the former East Coast Bays and Rodney District).

In general, the northern lower lying, coastal areas (Karaka/Drury/Whangapouri) have a low slope instability potential (as shown as green on Figure 6-9). The exceptions to this are the stream/creek gully features which are represented by linear orange/red (medium/high) potential classification zones on Figures 6-9 and the coastal margins susceptible to erosion. These areas would typically be either earthworked (re-profiled to form stable slopes) or alternatively avoided for future development, or retained as reserves.

At the southern end of the South Auckland RUB (Pukekohe and Paerata North), the surface relief is typically steeper however, the soils are generally more competent (of higher strength). Therefore, the overall slope instability potential in this area is also low, with the exception of stream gullies and locally steeper relief around the northern Pukekohe Core and Pukekohe North East areas.

**Table 3 - Slope Instability Potential: Slope Profile Limits**

| Geological unit | Slope Instability Potential - Slope Profile Limits* | | |
|---|---|---|---|
| | Low | Moderate | High |
| Holocene Alluvium | 0-10$^{o}$ | 10-23$^{o}$ | >23$^{o}$ |
| Puketoka Formation | 0-10$^{o}$ | 10-23$^{o}$ | >23$^{o}$ |
| South Auckland Volcanic field ash/tuff | 0-18$^{o}$ | 18-30$^{o}$ | >30$^{o}$ |
| East Coast Bays Formation (residual soil) | 0-15$^{o}$ | 15-26$^{o}$ | >26$^{o}$ |

* Indicative only; each site should be subject to specific investigations to evaluate detailed site topography, geology and groundwater conditions.

### 5.3.2 Low Slope Instability Potential

As outlined on Table 3 and presented on Figures 6 to 9, land typically considered to be flat (those with slope angles less than 10 to 18$^{o}$ depending on geology) is likely to have a low slope instability potential. Some minor slope re-grading works may be required to form the desired finished landform but these works are unlikely to require significant engineering design and/or construction control to address the potential for slope instability. As can be seen from Figures 6 to 9, the majority of the areas within the South Auckland RUB have 'Low Slope Instability Potential'.

### 5.3.3 Moderate Slope Instability Potential

Land classified as having 'Moderate Slope Instability Potential' is typically identified as being moderately sloping with surface relief ranging between 10 to 23 $^{o}$ (for the lower strength alluvial soils) and 15 to 30 $^{o}$ (for more competent, volcanic and ECBF soil types). Although these areas are identified as having medium slope instability potential, the hazard does not preclude future development occurring.

Within the 'Medium Slope Instability Hazard' areas, developers will likely need to consider a number of additional factors, not required for development of generally flat (low premium) land including:

- Additional earthworks to form stable slopes and building platforms;
- Possible low to medium sized retaining structures to support excavations ( both temporary and permanent);
- Possible control of groundwater, where deep cuts may be required;
- Increased design input from engineering professionals.

Specific (lot by lot) engineering design is unlikely to be required for construction on land classified as 'Moderate Slope Instability Potential' provided that subdivisional earthworks have been undertaken to address global stability issues and provide stable finished landforms.

### 5.3.4 High Slope Instability Potential

Land classified as having 'High Slope Instability Potential' is identified as being moderately to steeply sloping with ground profiles exceeding 23 to 30$^{o}$ (depending on the geology and groundwater conditions). However, as with areas that are classified with a Moderate Slope Instability Potential; the land is not precluded from future development, although additional factors will likely need to be considered. These factors may include:

- Global earthworks/re-profiling to achieve stable slope angles and suitable finished landform to support development;
- Installation of structural retention, e.g. retaining walls, shear keys, stabilised earth slopes, to terrace or support sloping ground. Such works need to consider both local and global stability;
- Possible deep (pile) foundations for dwellings/buildings positioned close to steep slopes;
- Control of groundwater (e.g. installation of subsoil drainage – horizontal drains, buttress drains etc.).
- Possible specific engineering design and construction control to address stability issues on a 'lot by lot' basis;
- Intensive engineering design and construction control by consulting engineers and Council.

Land which falls within the 'High Slope Instability Potential' category should, where possible, be developed using a global earthworks approach to provide stable landforms.

## 5.4 Liquefaction Potential

### 5.4.1 General

Liquefaction occurs when excess groundwater pressures are generated within loose, saturated and generally cohesionless soils (typically sands and silty sands) during earthquake shaking. The resulting high groundwater pressures can cause the soils to undergo a partial to complete loss of strength which can result in settlement and/or horizontal movement (lateral spread) of the soil mass. The occurrence of liquefaction is dependent on several factors including:

- the intensity and duration of ground shaking;
- soil density;
- particle size and distribution; and
- the groundwater elevation.

Liquefaction could affect the future development in the following ways:

- Deformation and rupture of road pavements;
- Flotation of manhole risers and sagging/hogging of services;
- Differential settlement of services resulting in rupture or reversal of grade;
- Total and differential settlement of building floor slabs (on grade) which could also result in structural failure and where severe, increased post-seismic flooding hazard;
- Differential settlement of building foundations resulting in deformation or possible structural failure;
- Lateral spreading of ground within 100 to 200m[7] of unsupported faces (e.g. streams, harbour); and
- Ejection of sand/silt on to the ground surface.

The extent by which liquefaction can effect urban development can be coarsely assessed with knowledge of the "crust thickness" overlying a liquefiable soil, i.e. the thickness of the surface soils (non-liquefiable cohesive soils and/or above groundwater level) which 'raft' over the liquefied soils. Based on experience gained from the Christchurch sequence of earthquakes and published empirically based information (Ishihara, 1985) it is anticipated that where the "crust thickness" exceeds a minimum of 3 m, the effects of liquefaction can generally be mitigated without significant damage to structures at ground surface. This assumes that the "crust" is of sufficient capacity/strength to 'raft' over the liquefiable layers, though this does not preclude global settlement and deep-seated lateral spreading.

The liquefaction potential over the South Auckland RUB areas has been categorised as low, medium or high based on our present knowledge of the geology and anticipated groundwater levels. The assessed liquefaction 'trigger' hazard (i.e. the hazard of liquefaction occurring under given seismic conditions) for each area is presented on Figure 10 in Appendix A and is summarised further below. It should be noted that the information presented on Figure 10 does not provide quantitative assessment/categorisation of the potential effects of liquefaction (as outlined in the bullet points above).

Table 4 below summaries the typical Liquefaction Potential within each development area

[7] Youd,T.L, Hansen, C.M, Bartlett, S.F. (2002) *Revised Multilinear Regression Equations for prediction of lateral Spread Displacement*, Journal of Geotechnical and Geoenvironmental Engineering, December 2002

### 5.4.2 Preliminary Liquefaction Analysis

Preliminary liquefaction analyses have been undertaken to evaluate the potential of typical South Auckland soils to liquefy under seismic conditions. The analyses have been undertaken using geotechnical data sourced from geotechnical investigations undertaken in the Mangere region. The ground conditions in Mangere are considered to be comparable to the ground conditions at Karaka North, Karaka West and most of the Karaka Core (i.e. a thin veneer of volcanic soils overlying Puketoka Formation soils with a relatively high groundwater level). Analyses were undertaken for both serviceability limit state (SLS) and ultimate limit state (ULS) seismic events with peak ground accelerations as outlined in Table 2 in Section 5.4.1.

The Cone Penetrometer Tests (CPT's) results from the Mangere investigations yielded the following ground profile:

- 1 to 2 m of Volcanic ash: very stiff to hard highly plastic silty clay overlying;
- 10 to 15 m of Puketoka Formation - stiff to very stiff clayey silt and silty clay, including firm organic silty clay, loose silty sands and firm sandy silts, overlying;
- Puketoka Formation Medium dense to dense silty sands
- Groundwater at depths of between 1 and 4 m below ground level

The CPT data from the above tests were run through a liquefaction calculator which assess the probability of liquefaction occurring based on the Idriss & Boulanger liquefaction trigging method (2008)[8] with an assumed near-surface groundwater elevation. The analyses indicate that the 'typical South Auckland soil profile' is unlikely to liquefy under a serviceability limit state event (PGA = 0.042g for an assumed 25 year return period) seismic event. However, under a ULS earthquake event (PGA = 0.15g for a 500 year return period) the preliminary analyses indicate that liquefaction of the saturated loose silty sand and sandy silt layers could theoretically occur. The theoretically liquefiable soils typically lie at a depth of between 3 and 6 m below ground level and the thickness of the liquefiable soils is between 1 and 5 m. Such an event could result in ground surface settlements of between approximately 50 and 200 mm.

The above results have been used to support the 'liquefaction hazard potential' categorisation of the various South Auckland RUB areas. These are discussed in detail in the following Sections.

### 5.4.3 Low Liquefaction Potential

As noted above, two of the principal factors which can result in liquefaction occurring under seismic conditions is the presence of sands/sandy silts and groundwater. The volcanic ash materials which are present around the southern areas of the South Auckland RUB areas are typically cohesive (clays and clayey silts). In addition groundwater levels are typically lower in these areas; probably present within the basalt rock aquifer (8 to 10 m deep). Therefore, the Pukekohe Core, Pukekohe West, Pukekohe South East, the eastern Drury Core and parts of Whangapouri and Paerata North areas are considered to have a low liquefaction potential. Some localised pockets of alluvial soils are known to be present in Pukekohe South East and in the northern Pukekohe Core. These areas are assessed as having a medium liquefaction potential (as below).

[8] Idriss, I.M. & Boulanger, R.W. (2008). *Soil liquefaction during earthquakes*, MNO–12, Earthquake Engineering Research Institute, 242p

### 5.4.4 Moderate Liquefaction Potential

Areas which have been identified as having a moderate potential of liquefaction are those areas which, based on our understanding of the subsurface conditions (soils and groundwater levels) have the potential to liquefy under an ULS seismic event (as defined by NZS1170.5 – refer to Section 4.5). Preliminary analyses have been undertaken to validate this using the results of historical geotechnical tests (CPTs) completed in areas with comparable geology (Mangere, South Auckland). These preliminary analyses are discussed above in Section 5.4.2.

The medium liquefaction potential areas are those which are known to be underlain by alluvial soils (both Puketoka Formation and Holocene Age alluvium) which include layers of loose sand or sandy silts present below groundwater levels. These areas include the Karaka Core, Karaka West, Karaka North, Drury Core, and parts of Whangapouri and Paerata North. These areas are considered likely to experience some form of liquefaction under peak ground accelerations consistent with a 1 in 500 year return period seismic event.

Moderate potential liquefaction areas may not necessarily require specific engineering design for residential type construction (excluding multi-storey buildings). However, the following will likely be required for urban development extending into these areas:

- Site specific geotechnical investigations including; CPT and machine boreholes to determine whether loose sands/silts are present with in the upper materials, groundwater levels and the "crust thickness". These investigations should be undertaken as part of the subdivision stage of development
- Site specific lateral spread assessment. As a general guide a minimum 'set-back' distance (e.g. 25 m) of all building platforms from unsupported soil faces (i.e. slopes, embankments, creeks, streams, harbours) to minimise the risk of being affected by 'lateral spreading'. Buildings located within 100 m of unsupported soil faces may also be subject to specific analyses and design. For 'life-line' and important structures, lateral spreading effects may need to be considered at greater distances from unsupported faces.
- Design of commercial retail and multi storey residential tower building foundations to tolerate large magnitude total differential settlements and lateral kinematic loadings under ULS seismic conditions.
- Possible earthwork controls to ensure that the "crust thickness" over development areas is maintained to at least 3 m in thickness to mitigate the surface effects of below ground liquefaction (as listed in the bullet points in Section 5.4.1).
- Detailing of services to maintain falls and resist flotation.

### 5.4.5 High Liquefaction Potential

Areas identified as having a high risk of liquefaction are defined in this report as sites having the potential for liquefaction to occur under SLS (1 in 25 year return period) seismic conditions. No specific areas have been identified within the South Auckland RUB as meeting this classification. However, this does not preclude the possibility of these areas being present in localised/discrete zones.

Areas which could liquefy under SLS seismic conditions would theoretically be underlain by very loose sand/silts and with high groundwater levels. In the South Auckland region, these conditions could be present around the coastal fringes of the Karaka and Drury areas and potentially close to streams and creeks.

For future construction within these areas the following options may need to be considered in addition to those outlines in Section 5.4.4 (medium):

- Add fill material across the construction site to increase the "crust thickness". Fill material would need to be cohesive to prevent silt ejection and to be compacted to an engineered standard. The effect of fill placement would need to be assessed in relation to the risk of consolidation settlement (refer to Section 6.3 - Earthworks), and aggravation of lateral spread risk.
- Piled foundations to support building structures. Negative skin friction effects would need to be considered for pile foundations extending above and through the liquefiable soil layers and lateral loads applied by any lateral spreading.

**Table 4 – Development Areas: Summary of Liquefaction Potential Hazard**

| Area | Drury Core | Karaka Core | Karaka North | Karaka West | Whangapouri | Pukekohe Core | Pukekohe Southwest | Pukekohe Northwest | Pukekohe West | Paerata North |
|---|---|---|---|---|---|---|---|---|---|---|
| Low | | | | | | X | | X | X | |
| Medium | X | X | X | X | X | | X | | | X |
| High | | | | | | | | | | |

### 5.4.6 Liquefaction Investigations

It is recommended that detailed geotechnical investigations, comprising site specific Cone Penetrometer Tests, be undertaken in the areas identified as having a 'Medium' Liquefaction potential. These areas are:

- Drury Core
- Karaka Core
- Karaka North
- Karaka West
- Whangapouri
- Pukekohe Southwest
- Paerata North

Using the results of the Cone Penetrometer Tests, an assessment of the liquefaction trigger potential of each area can be undertaken to confirm and validate the preliminary information presented on Figure 10. In addition, analysis of CPT data would enable assessment/qualification of possible liquefaction effects (e.g. ground settlement, ejection of sand/silt or lateral spreading). Tonkin & Taylor have recently completed a similar study in Christchurch utilising the results of thousands of CPTs to map liquefaction hazard zones. Using this data, T&T have developed an engineering tool, the Liquefaction Severity Number (LSN)[9] which can be used to evaluate the potential effects of liquefaction and risk of damage to structures at the ground surface, i.e. to measure what effects liquefaction would have at a site, and consequently the level of design and construction effort required to develop robust foundation solutions. It is recommended that a

[9] Tonkin and Taylor (2013) *Liquefaction vulnerability study*, Tonkin and Taylor Report 52020.0200/v1.0. February 2013. 52 pages and 14 appendices.

preliminary study, focused on the most at-risk areas, be undertaken for the South Auckland RUB project using the results of CPT investigations.

## 5.5 Soil Compressibility and Building Settlements

### 5.5.1 General

Foundations for future dwellings and buildings are likely to vary across the South Auckland RUB areas. The following main factors will need to be considered in relation to foundation design and construction for future development in the South Auckland RUB.

In general, foundation design and construction will be principally governed by the geology/subsurface conditions and the size of the buildings proposed. Slope stability hazards are discussed in Section 5.3 and liquefaction issues are presented in Section 5.4.

The hazard potential associated with constructing new buildings on land which may be underlain by moderately to highly compressible soils has been assessed in comparison to a theoretical baseline site underlain by very stiff/dense, low-compressibility soils overlying rock at a relatively shallow depth. Development of land which is underlain by moderately to highly compressible soils would have high settlement potential in comparison with the baseline site. Figure 11 in Appendix A illustrates the assessed hazard potential associated with soil compressibility and building settlements within the South Auckland RUB.

A summary of the 'Soil Compressibility and Building Settlement Potential' categorisation of each of the development areas is provided in Table 5.

### 5.5.2 Low Settlement Potential

The volcanic soils present over much the southern areas of the South Auckland RUB are typically competent, with relatively high shear strengths and low compressibility characteristics (refer Section 4.3). These soils are therefore considered to have relatively good bearing capacities (for shallow foundations) and a low risk of consolidation settlement. The areas underlain by volcanic soils (ash/tuff) include the majority of the Pukekohe region, i.e. Pukekohe Core, Pukekohe West, Pukekohe North East, Pukekohe South East (excluding a zone around the Pukekohe racetrack and within the Core, north of Pukekohe Township), the eastern Drury Core and parts of Whangapouri and Paerata North.

These areas are expected to be suitable for construction of one to four storey buildings (dwellings and commercial structures) supported on shallow foundations. Pile foundations may be required for structures four or more storeys high or for highly loaded structures and/or where isolated areas of peat and alluvial soils are present (e.g. South East Pukekohe). The majority of the Pukekohe region and the eastern Drury Core are expected to have a low hazard potential associated with the design and construction of foundations. Some localised areas of softer soils have been identified within Pukekohe (see Figure 11) and therefore detailed geotechnical investigations will be required to determine whether such conditions are present within any specific development area.

### 5.5.3 Moderate Settlement Potential

The northern areas (Karaka Core, Drury Core, Karaka North, Karaka West and most of Whangapouri and Paerata North) are typically underlain by Puketoka Formation soils which are considered to be of modest strength and of moderate compressibility (refer to Section 4.3). As noted in Section 4.2, layers of highly compressible soils, such as peat and organic clays/silts, are present within the Puketoka Formation unit, however, these soils are typically in discrete layers of limited thickness and are unlikely to preclude future urban development.

Based on our experience with similar conditions in the Auckland region, it is likely that land underlain by Puketoka Formation soils will be suitable for construction of one to two storey timber framed residential dwellings and light commercial buildings (retail, supermarkets etc) founded on shallow footings. Larger buildings, e.g. residential towers or commercial buildings of three storeys or more in height are likely to require pile foundations for support. Alternatively, areas with less competent/moderately compressible soils could be either excavated and replaced with engineered fill, pre-loaded/surcharged or excluded from future development areas. Raft type foundations can also provide an economic option to mitigate risk of soil variability and settlement. Where infilled gullies and soft ground are encountered, these zones can be locally excavated and replaced during subdivisional earthworks.

Commercial and light industrial buildings with low evenly distributed floor slab loads (10-20kPa) are likely to be suitable for construction in the 'Medium Settlement Potential' areas. However building floor slabs with loads greater than 20kPa will have higher potential settlement issues and will require specific geotechnical design input.

### 5.5.4 High Settlement Potential

In the limited number of South Auckland areas which have to date been identified as being underlain by highly compressible soils (Holocene Age alluvium), future building development is constrained by the risk of consolidation settlement (total and differential) occurring under foundations and floor slabs. These soils are likely to be present around the coastal fringe of the Karaka, Drury and Whangapouri areas, within gullies and around watercourses, and in south East Pukekohe (see Figure 11). Construction of most new buildings within areas underlain by Holocene Alluvium will likely necessitate either the removal of 'unsuitable' soils during the subdivisional earthworks (see Section 6.3 above) or installation of deep, piled foundations extending through the alluvium to a hard bearing stratum for support. Raft foundations could also be considered as an alternative foundation option. Raft foundations would enable the distribution of structural loads over a larger bearing area and therefore limit settlement effects.

Floor slab loads associated with large commercial and light industrial buildings would generally need to be limited to 10kPa in high settlement potential areas to mitigate settlement related issues.

**Table 5 - Development Areas: Summary of Soil Compressibility and Building Settlement Potential Hazard**

| Area | Drury Core | Karaka Core | Karaka North | Karaka West | Whangapouri | Pukekohe Core | Pukekohe Southwest | Pukekohe Northwest | Pukekohe West | Paerata North |
|---|---|---|---|---|---|---|---|---|---|---|
| Low | | | | | | X | | X | X | |
| Medium | X | X | X | X | X | | X | | | X |
| High | X | | | | | | X | | | |

# 6 Development Constraints

## 6.1 General

In addition to the specific geotechnical hazards identified in Section 5, there are other development considerations and issues which can constrain development of land for urban use. These include:

1. Earthworks, i.e. modification of land forms to achieve global development solutions;
2. Civil infrastructure, (installation of services, construction of new roads etc)
3. Individual property development (specific engineering design)

In general, we note that the majority of the land identified within the proposed South Auckland RUB is likely to be geotechnically suitable for future urban development, assuming appropriate engineering control and design is undertaken. However, some areas are likely to be more easily developed, having few if any constraints, whilst other areas may be more difficult to develop because of multiple constraints. We have categorised land as having one or more of these constraints as land that may be suitable for urban use, but at an associated 'Development Premium'.

## 6.2 Development Premium

In order to provide Auckland Council with a coarse but useable appraisal of the various South Auckland RUB areas we have adopted a land development premium categorisation. In order to mitigate one or more of the above mentioned development constraints, there would be an associated 'premium' for developing the land over and above land which is not constrained by the same issue, e.g. land which is underlain by soft low strength soils may require a higher degree of earthworking and engineering to increase the soil bearing capacity and thus would be developed at a 'high premium' compared to land which is underlain by stiff high strength soils ('low premium'). We have therefore adopted a low, medium and high "development premium" categorisation to contrast the geotechnical suitability of the various areas.

## 6.3 Earthworks

### 6.3.1 General

For future development of greenfields/rural land, we would expect earthworks to comprise the modification of the landform to provide globally suitable and stable building platforms for construction of new dwelling and buildings.

The extent and type of earthworks required will be largely dependent on the natural profile of the land (topography and relief), the inherent stability of the soil types (geology), the volume of unsuitable soils present (peat/organics/stream alluvium), groundwater levels, and the engineering characteristics of the soils (i.e. how readily they can be earthworked, their susceptibility to consolidation settlement after placement of new fill etc.). Other factors which could impact on the extent/nature of earthworks required include; the type of development proposed, the presence of rock at near surface levels and the economical re-use of natural resources (e.g. aggregates).

At this early stage, the proposed extent of earthworks for the various areas is not detailed. However, in general, the majority of the South Auckland region is gently sloping with some limited areas of moderately sloping topography. We would expect gully infilling to be limited to a small scale and overall the regional topography will remain generally unchanged.

The premium for development in relation to earthworks has been assessed relative to a baseline 'flat' site (requiring only limited re-profiling to support development) with 'stable' soils of high strength that can be readily earthworked and handled.

In general, the volcanically derived soils present over the southern areas of the South Auckland RUB are of relatively high strength and on the whole would be considered as generally 'stable'. However, the topography of the south is typically steeper than the northern Karaka and Drury areas, likely necessitating greater volumes of earthworks to provide level landforms.

Earthworks in the south should be at a 'low premium' provided that there is sufficient depth to the underlying basalt rock (expected at 5 to 8 m depth). The northern/coastal areas (Drury/Karaka) are typically gently sloping but the Holocene alluvium, and Puketoka Formation soils are less 'stable' by comparison with the volcanic soils.

Within the South Auckland RUB, we have identified all areas as having either a low or medium development premium in regards to earthworks, i.e. none of the South Auckland RUB areas are assessed as having a 'High Development Premium'.

A summary of the typical development premium associated with Earthworks within each development area is provided in Table 6

### 6.3.2 Low 'Development Premium' Areas

The areas over the southern half of the South Auckland RUB (Pukekohe and Paraeta North) as well as the eastern extent of the Drury Core and parts of Whangapouri are expected to be underlain by relatively 'stable' volcanically derived soils. Earthworks within these materials should be relatively straight forward provided that excavations do not extend into underlying basalt rock or welded tuff (likely present between 5 and 10 m deep). Excavations into basalt would require specialist rock excavation equipment and would be both time consuming and expensive. Planning constraints on both noise and vibration levels would also need to be considered. Geotechnical investigations are recommended to determine the depth to the top of the rock layers.

In general, the volcanic ash/tuff soils around South Auckland respond well to excavation and re-compaction but it will be important for earthworks in these materials to be conducted during dry periods. Volcanic ash/tuff materials can be highly sensitive when disturbed (e.g. when they are heavily trafficked) and can lose significant strength when disturbed.

### 6.3.3 Medium 'Development Premium' Areas

Based on our experience with earthworks projects around South Auckland, we consider that the areas dominated by alluvial soils (both Holocene alluvium and Puketoka Formation deposits) are likely to have a medium 'premium' for future urban development. The northern, low lying, areas (Karaka West, Karaka North, Karaka Core, Drury Core and Whangapouri) are likely to have a higher proportion of unsuitable soils (e.g. soft stream alluvium, coastal estuarine deposits, peat and other organic soils) which are typically moderately to highly compressible and may require either a high level of conditioning or excavation and removal from future building platforms. In addition, the placement of new fill over compressible soils (peat and soft alluvium) may initiate consolidation settlement that will require periods of 12 months or more to occur before construction can commence on site, or works such as wick drains and pre-loading are carried pout to accelerate such settlement.  The time period required to allow for settlements prior to construction of dwellings and infrastructure would depend on the thickness of fill placed, depth of alluvial soils present and the presence of peat. This would all need to be confirmed during geotechnical investigation and design of individual sites.

Ignimbritic silts are present within Puketoka Formation deposits and these materials are both highly sensitive and difficult to work, owing to their narrow optimum moisture content range, i.e. the soils can be difficult to handle/earthwork when they are either too dry or too wet. Appropriate conditioning and management of the soils is therefore required for earthworking of these materials.

Where possible, the surface layers of weathered volcanic ash (airfall deposit often mantling the Puketoka Formation soils) and the upper stiff/dessicated soils (where present) should be retained across the development areas (i.e. earthworks cut depths should be limited). The upper layer provides a competent bearing stratum for support of new lightweight structures (such as housing) and a sound subgrade for construction of roads and building floor slabs on grade.

Although not identified on Figures 2 to 5 in Appendix A, areas of alluvium and peat are likely to be present along the margins of bodies of water (streams, creeks and coastal fringes).

### 6.3.4 High 'Development Premium' Areas

As outlined in Section 6.2.1 above we do not consider any of the proposed development areas to have a high premium for development with respect to earthworks.

**Table 6 - Development Areas: Earthworks Development Premium**

| Area | Drury Core | Karaka Core | Karaka North | Karaka West | Whangapouri | Pukekohe Core | Pukekohe Southwest | Pukekohe Northwest | Pukekohe West | Paerata North |
|---|---|---|---|---|---|---|---|---|---|---|
| Low | | | | | | X | | X | X | |
| Medium | X | X | X | X | X | | X | | | X |
| High | | | | | | | | | | |

## 6.4 Civil Infrastructure

### 6.4.1 General

As part of the future development of the identified greenfield sites, new civil infrastructure comprising roads and the installation of stormwater, wastewater and water supply services will be required.

The development of civil infrastructure and earthworks (discussed in Section 6.3) are closely linked. Therefore the areas identified as low development premium areas with respect to earthworks are typically those areas which will also have a low civil infrastructure development premium. Geotechnical risks, such as compressible soils and slope instability areas (as identified in Section 5), will also influence the ease at which civil infrastructure can be developed.

In general, the construction of roads and services should be relatively straight forward in the South Auckland region. However, there are likely to be some areas where roads pass through soils of relatively low strength (Holocene alluvium and Puketoka Formation) soils necessitating some form of limited ground improvement, additional earthworks, subsoil drainage (for control of groundwater), robust pavement construction and differential settlement considerations relating to gravity fed services. Likewise, areas of moderate to steep topography may restrict road infrastructure construction in areas and may result in additional earthworks, ground retention, alternative road and service alignments and increased road and service network distances.

Groundwater is expected to be a factor in the development of civil infrastructure particularly in coastal areas where the groundwater level is near surface. Groundwater inflows and induced settlements related to groundwater drawdown may need to be considered when undertaking excavation and trenching for buried services. Although not precluding development, high groundwater levels may result in an increased development premium. Sea level rise should also been taken into account, estimated by government agencies to be 1m higher by the year 2115.

As with the earthworks development premium, the civil infrastructure development premium has been assessed relative to a baseline 'flat' site with stable soil of high strength and a low groundwater level.

In general the southern development areas which surround Pukekohe and are typically underlain by volcanically derived soils are considered to have a 'low' civil infrastructure development premium due to the high strength soils and low groundwater level. While the northern/ coastal areas have typically been identified as having gentler topography the presence of the less stable alluvial soils in combination with high (near surface) groundwater levels has resulted in these areas being considered to have a medium development premium.

Table 7 outlines the typical development premium associated with civil infrastructure within each of the proposed development areas.

### 6.4.2 Low 'Development Premium' Areas

The areas over the southern half of the South Auckland RUB (Pukekohe and Paraeta North) as well as the eastern extent of the Drury Core and parts of Whangapouri are expected to be underlain by relatively 'stable' volcanically derived soils and typically have low groundwater levels. Earthworks associated with construction of roads and service trenches and likely to be relatively straight forward providing excavations, particularly those for service trenches, do not extend into underlying rock (refer to Section 6.3).

### 6.4.3 Medium 'Development Premium' Areas

Based on our experience with civil infrastructure projects, we expect that the areas predominately underlain by alluvial soils are likely to have a medium 'premium' for future urban development. These areas are predominately the northern low lying coastal areas which surround Drury and Karaka.

The less stable alluvial soils which are likely present within these development areas typically have lower strength than volcanically derived soils and therefore may fail under moderate loading. The result is less favourable bearing stratum in terms of road infrastructure. Ground improvement comprising lime stabilisation or sub-excavation and replacement of soft soil with hardfill may be required to improve the ground conditions.

Differential settlement rates of alluvial soils; particularly where peat and other organics are present will need to be considered for both road construction and service infrastructure. Differing settlement rates along lengths of pipes can affect the grade and performance of pipes while differential settlement in roads can cause ponding and water infiltration into pavement layers, compromising the overall performance of the road.

Due to the relatively high groundwater levels present in coastal and low lying areas, groundwater inflow and drawdown should be considered when undertaking excavations for services installation. Lowering local groundwater levels can result consolidation settlements in neighbouring structures and infrastructure.

### 6.4.4 High 'Development Premium' Areas

We have not identified any areas within the Southern RUB development which we consider to have a high development premium in terms of civil infrastructure development.

**Table 7 - Development Areas: Civil Infrastructure Development Premium**

| Areas | Drury Core | Karaka Core | Karaka North | Karaka West | Whangapouri | Pukekohe Core | Pukekohe Southwest | Pukekohe Northwest | Pukekohe West | Paerata North |
|---|---|---|---|---|---|---|---|---|---|---|
| Low | | | | | | X | | X | X | |
| Medium | X | X | X | X | X | | X | | | X |
| High | | | | | | | | | | |

## 6.5 Individual Property Development

### 6.5.1 General

Based on our experience with subdivision development projects, we expect that shrink/swell effects, excavation stability and groundwater levels will influence the development of building foundations.

Clay soils typically exhibit shrink/swell characteristics during extended wet and dry periods, e.g. over prolonged periods of summer the soils dry out and shrink, likewise over prolonged wet periods, soils can swell with excess water. Shrink/swell can result in cracking at the ground surface and cause cracking and distortion of adjacent structures (windows/ doors no longer open/ close) and induce settlements. Shrink/swell effects can be mitigated by ensuring earthworks fill material (refer to Section 6.3) are placed at the optimum moisture content and building footings are set a minimum 600mm below ground level. In some cases 900mm or even 1200mm embedment may be required.

The ease at which excavations are carried out to allow for the construction and installation of foundations is influenced by the stability of the subsurface materials. Typically the presence of lower strength, less stable soils will reduce the allowable height of un-retained excavations, result in larger excavations to ensure stability and can result in increased construction timeframes.

Our experience suggests that the presence of groundwater above founding levels will affect the construction of building foundations. Water can lower the strength of soils and compromise the stability of excavations. Water inflows into foundation excavations will require pumping out and could induce groundwater drawdowns. Service installation may require sheet piling or well pointing.

The foundation construction development premium has been assessed relative to a baseline 'flat' site with stable soil of high strength and a low groundwater level. A summary of typical development premiums associated with design and construction of individual property foundations is outlined in Table 8.

### 6.5.2 Low 'Development Premium' Areas

It is expected that, generally the proposed southern RUB development areas will have clayey soils at or near ground surface. Thus shrink/swell of the surface soils will be an issue across all development sites. However as shrink/swell related issues can be mitigated relatively easily through the embedment of foundations to a minimum 600 mm depth, we consider all development areas to have a 'low' development premium relative to each other in terms of shrink/swell.

Development areas over the southern half of the Southern RUB (Pukekohe and Pareta North), as well as isolated areas in eastern Drury and Whangapouri, are expected to be underlain by relatively stable volcanic soils. This coupled with relatively low groundwater levels means that that foundation excavations are likely to remain stable and unlikely to collapse during construction. We expect the construction of foundations in these areas to be relatively straight forward, providing excavations do not extend into underlying rock (refer to Section 6.3) and therefore consider these areas to have a low development premium.

### 6.5.3 Medium 'Development Premium' Areas

Based on the likely presence of alluvial soils across the northern development areas which surround Drury and Karaka we consider these development areas to have a medium development premium in terms of foundation construction. We also expect groundwater to be encountered within 3 m of the ground surface within the coastal areas (refer to Section 4.4). There is potential for groundwater to be present within foundation excavations which will influence construction by lowering stability and requiring dewatering which could induce drawdown and result in settlements. Deeper foundations particularly cast *in-situ* concrete piles may also require casing over the upper saturated soils.

### 6.5.4 High 'Development Premium' Areas

We have not identified any areas within the Southern RUB development which we consider to have a high development premium specifically relating to foundation development.

**Table 8 - Development Areas: Individual Property Development Premium**

| Area | Drury Core | Karaka Core | Karaka North | Karaka West | Whangapouri | Pukekohe Core | Pukekohe Southwest | Pukekohe Northwest | Pukekohe West | Paerata North |
|---|---|---|---|---|---|---|---|---|---|---|
| Low | | | | | | X | | X | X | |
| Medium | X | X | X | X | X | | X | | | X |
| High | | | | | | | | | | |

# 7 Summary

Figure 11 in Appendix A presents a combined summary of our assessed premium for developing land with the various geotechnical hazards and constraints outlined in Sections 5 and 6. In general, the South Auckland RUB areas have been categorised as having either a low or medium development premium. However isolated parcels of land within the South Auckland RUB are susceptible to one or more geotechnical hazard and/or development constraint, e.g. slope instability, lateral spreading and /or settlements from liquefaction, seasonal shrink/ swell, coastal erosion or consolidation settlement. This land is categorised as having a High Development Premium. It is land that is not necessarily geotechnically unsuitable for development but it is likely to require significant engineering oversight to support typical urban development, e.g. major earthworks, ground improvements, deep foundations, retaining structures and groundwater control. Land categorised as having a High Development Premium could therefore be expected to be developable at a significant cost premium and with some residual risk of future geotechnical issues.

A summary of the information outlined in the above sections is presented on Figures 2 to 12 and on Tables 9 and 10 below. It is noted that this information is provided for high level planning purposes and should not be used for detailed planning, consenting or engineering design. Geotechnical investigations are recommended as part of any future planning assessment to confirm and validate the preliminary conclusions and recommendations presented in this document and in associated appendices.

If, during development of areas covered within this report, ground conditions are identified as being different to those documented, the conclusions, findings and hazard maps contained should be reviewed where appropriate and refined.

**Table 9: Summary of Geotechnical Hazards and Considerations for Future Urban Development in Coastal Development Areas**

| Geotechnical Consideration/Issue | Assessed Hazard Potential/Development Premium for Urban Land Development | | | | |
|---|---|---|---|---|---|
| | **Drury Core (excluding south eastern Core area)** | **Karaka Core** | **Karaka North** | **Karaka West** | **Whangaporui** |
| **Slope Instability Potential** | Low<br>Low to moderate surface relief.<br>Risk or erosion/foreshore retreat around coastal fringe.<br>Medium slope stability hazard around watercourse and gullies. Additional earthworks may be required to form stable slopes and building platforms. | Low<br>Low to moderate surface relief.<br>Risk or erosion/foreshore retreat around coastal fringe<br>Medium slope stability hazard around watercourse and gullies. Additional earthworks may be required to form stable slopes and building platforms. | Low<br>Low to moderate surface relief.<br>Risk or erosion/foreshore retreat around coastal fringe.<br>Medium slope stability hazard around watercourse and gullies. Additional earthworks may be required to form stable slopes and building platforms. | Low<br>Low to moderate surface relief.<br>Risk or erosion/foreshore retreat around coastal fringe<br>Medium slope stability hazard around watercourse and gullies. Additional earthworks may be required to form stable slopes and building platforms. | Low<br>Low to moderate surface relief.<br>Risk or erosion/foreshore retreat around coastal fringe<br>Medium slope stability hazard around watercourse and gullies. Additional earthworks may be required to form stable slopes and building platforms. |
| **Liquefaction Potential** | Medium:<br>High groundwater levels and presence of loose sand/silt lenses. Possible liquefaction trigger under ULS events.<br>Lateral spread risk around open faces (e.g. coastline/foreshore) and slopes.<br>Detailed investigations recommended to qualify/quantify possible liquefaction effects. | Medium:<br>High groundwater levels and presence of loose sand/silt lenses. Possible liquefaction trigger under ULS events.<br>Lateral spread risk around open faces (e.g. coastline/foreshore) and slopes.<br>Detailed investigations recommended to qualify/quantify possible liquefaction effects. | Medium:<br>High groundwater levels and presence of loose sand/silt lenses. Possible liquefaction trigger under ULS events.<br>Lateral spread risk around open faces (e.g. coastline/foreshore) and slopes.<br>Detailed investigations recommended to qualify/quantify possible liquefaction effects. | Medium:<br>High groundwater levels and presence of loose sand/silt lenses. Possible liquefaction trigger under ULS events.<br>Lateral spread risk around open faces (e.g. coastline/foreshore) and slopes.<br>Detailed investigations recommended to qualify/quantify possible liquefaction effects. | Medium:<br>High groundwater levels and presence of loose sand/silt lenses. Possible liquefaction trigger under ULS events.<br>Lateral spread risk around open faces (e.g. coastline/foreshore) and slopes.<br>Detailed investigations recommended to qualify/quantify possible liquefaction effects. |
| **Soil Compressibility and Building Settlement Potential** | Medium to High<br>Presence of moderately compressible Puketoka Formation soils likely to be suitable for 1 to 3 level residential dwellings. Deep foundations may be required for residential/commercial buildings exceeding 3 storeys.<br>Highly compressible soils around coastal fringe may necessitate deep foundations or additional earthwork requirements | Medium:<br>Presence of moderately compressible Puketoka Formation soils likely to be suitable for 1 to 3 level residential dwellings. Deep foundations may be required for residential/commercial buildings exceeding 3 storeys. | Medium:<br>Presence of moderately compressible Puketoka Formation soils likely to be suitable for 1 to 3 level residential dwellings. Deep foundations may be required for residential/commercial buildings exceeding 3 storeys | Medium:<br>Presence of moderately compressible Puketoka Formation soils likely to be suitable for 1 to 3 level residential dwellings. Deep foundations may be required for residential/commercial buildings exceeding 3 storeys | Medium:<br>Presence of moderately compressible Puketoka Formation soils likely to be suitable for 1 to 3 level residential dwellings. Deep foundations may be required for residential/commercial buildings exceeding 3 storeys |
| **Earthworks Development Premium** | Medium<br>High groundwater levels. Possible drainage requirements<br>Moderately compressible soils (settlement under new fill).<br>Ignimbritic silts present – may be difficult to earthwork/handle<br>Possible 'unsuitable' soils (peat/organic clays) may require removal from site. | Medium<br>High groundwater levels. Possible drainage requirements<br>Moderately compressible soils (settlement under new fill).<br>Ignimbritic silts present – may be difficult to earthwork/handle<br>Possible 'unsuitable' soils (peat/organic clays) may require removal from site. | Medium<br>High groundwater levels. Possible drainage requirements<br>Compressible soils (possible settlement under new fill).<br>Ignimbritic silts present – may be difficult to earthwork/handle<br>Possible 'unsuitable' soils (peat/organic clays) may require removal from site. | Medium<br>High groundwater levels. Possible drainage requirements<br>Compressible soils (settlement under new fill).<br>Ignimbritic silts present – may be difficult to earthwork/handle<br>Possible 'unsuitable' soils (peat/organic clays) may require removal from site. | Medium<br>High groundwater levels. Possible drainage requirements<br>Compressible soils (settlement under new fill).<br>Ignimbritic silts present – may be difficult to earthwork/handle<br>Possible 'unsuitable' soils (peat/organic clays) may require removal from site. |
| **Civil Infrastructure Development Premium** | Medium<br>High groundwater levels. Possible drainage requirements<br>Possible requirement for road subgrade stabilisation/ground improvements | Medium<br>High groundwater levels. Possible drainage requirements<br>Possible requirement for road subgrade stabilisation/ground improvements | Medium<br>High groundwater levels. Possible drainage requirements<br>Possible requirement for road subgrade stabilisation/ground improvements | Medium<br>High groundwater levels. Possible drainage requirements<br>Possible requirement for road subgrade stabilisation/ground improvements | Medium<br>High groundwater levels. Possible drainage requirements<br>Possible requirement for road subgrade stabilisation/ground improvements |
| **Individual Property Foundations Development Premium** | Medium<br>High groundwater levels<br>Clayey soils present at ground surface<br>Presence of firm to stiff Puketoka Formation soils | Medium<br>High groundwater levels<br>Clayey soils present at ground surface<br>Presence of firm to stiff Puketoka Formation soils | Medium<br>High groundwater levels<br>Clayey soils present at ground surface<br>Presence of firm to stiff Puketoka Formation soils | Medium<br>High groundwater levels<br>Clayey soils present at ground surface<br>Presence of firm to stiff Puketoka Formation soils | Medium<br>High groundwater levels<br>Clayey soils present at ground surface<br>Presence of firm to stiff Puketoka Formation soils |
| **Overall Assessed Development Premium** | Medium | Medium | Medium | Medium | Medium |
| **Suitable Urban Development Type** | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 2 storeys)<br>Retail/Commercial buildings (> 2 storeys) and residential towers supported on pile foundations. | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 2 storeys)<br>Retail/Commercial buildings (> 2 storeys) and residential towers supported on pile foundations. | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 2 storeys)<br>Retail/Commercial buildings (> 2 storeys) and residential towers supported on pile foundations. | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 2 storeys)<br>Retail/Commercial buildings (> 2 storeys) and residential towers supported on pile foundations. | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 2 storeys)<br>Retail/Commercial buildings (> 2 storeys) and residential towers supported on pile footings. |

**Table 10: Summary of Geotechnical Hazards and Considerations for Future Urban Development for Inland Development Areas**

| Geotechnical Consideration/Issue | Assessed Hazard Potential/Development Premium for Urban Land Development | | | | |
|---|---|---|---|---|---|
| | **Pukekohe Core (excluding south eastern corner – refer Pukekohe South East)** | **Pukekohe South East** | **Pukekohe North East** | **Pukekohe West** | **Paerata North** |
| **Slope Instability Potential** | Low<br>Gentle to moderately sloping surface relief but typically competent volcanic soils and low regional ground groundwater levels.<br>Some areas with localised concentrations of gully features that may require additional engineering and mitigation. | Low<br>Gentle to moderately sloping surface relief but typically competent volcanic soils and low regional ground groundwater levels.. | Medium<br>Moderately sloping relief with typically competent volcanic soils, but with a concentration of gully features which may require additional engineering control and mitigation for development. | Low<br>Gentle to moderately sloping surface relief but typically competent volcanic soils and low regional ground groundwater levels. | Low<br>Gentle to moderately sloping surface relief but typically competent volcanic soils and low regional ground groundwater levels. |
| **Liquefaction Potential** | Low<br>Low regional groundwater levels.<br>Predominantly cohesive (clayey) soils overlying basalt - negligible liquefaction hazard.<br>May be some localised areas of medium liquefaction hazard – south east and north of Pukekohe Township. | Medium<br>Low regional groundwater level but possible presence of loose sand/silt present within Holocene alluvium materials.<br>Detailed investigations recommended to qualify/quantify possible liquefaction related effects. | Low<br>Low regional groundwater levels.<br>Predominantly cohesive (clayey) soils overlying basalt - negligible liquefaction hazard. | Low<br>Low regional groundwater levels.<br>Predominantly cohesive (clayey) soils overlying basalt - negligible liquefaction hazard. | Medium:<br>Possible presence of loose sand/silt lenses. Possible liquefaction trigger under ULS events.<br>Detailed investigations recommended to qualify/quantify possible liquefaction related effects. |
| **Soil Compressibility and Building Settlement Potential** | Low<br>Presence of very stiff volcanic ash soils, suitable for construction of most buildings on shallow foundations.<br>Some localised areas of highly compressible soils which may necessitate either ground improvement or deep foundations. | Medium and High<br>Presence of very stiff volcanic ash soils in some areas but highly compressible soils in others.<br>Deep foundations or ground improvement may be required for residential/commercial buildings exceeding 3 storeys (where high compressible soils are present). | Low<br>Presence of very stiff volcanic ash soils, suitable for construction of most buildings on shallow foundations. | Low<br>Presence of very stiff volcanic ash soils, suitable for construction of most buildings on shallow foundations. | Medium<br>Presence of moderately compressible Puketoka Formation soils likely to be suitable for 1 to 3 level residential dwellings. Deep foundations may be required for residential/commercial buildings exceeding 3 storeys |
| **Earthworks Development Premium** | Low<br>Potential to encounter basalt rock within upper 5 to 10 m.<br>Volcanic soils are sensitive to disturbance (trafficking under high moisture contents) | Medium<br>Potential to encounter basalt rock within upper 5 m.<br>Soft/compressible soils south east of present Pukekohe Township – Possible settlement issues under new fill and may require excavation and removal of organic soils from beneath future building platforms. | Low<br>Potential to encounter basalt rock within upper 5 to 10 m.<br>Volcanic soils are sensitive to disturbance (trafficking under high moisture contents). | Low<br>Potential to encounter basalt rock within upper 5 to 10 m.<br>Volcanic soils are sensitive to disturbance (trafficking under high moisture contents). | Medium<br>Compressible soils (settlement under new fill).<br>Ignimbritic silts present – may be difficult to earthwork/handle<br>Possible 'unsuitable' soils (peat/organic clays) may require removal from site. |
| **Civil Infrastructure Development Premium** | Low<br>Potential to encounter basalt rock within upper 5 to 10 m.<br>Service trench excavations should be limited to 5 m depth (to avoid basalt rock) | Medium<br>Potential to encounter basalt rock within upper 5 m.<br>Service trench excavations should be limited to 5 m depth (to avoid basalt rock) | Low<br>Potential to encounter basalt rock within upper 5 to 10 m.<br>Service trench excavations should be limited to 5 m depth (to avoid basalt rock) | Low<br>Potential to encounter basalt rock within upper 5 to 10 m.<br>Service trench excavations should be limited to 5 m depth (to avoid basalt rock) | Medium<br>Compressible soils (settlement under new fill).<br>Possible requirement for road subgrade stabilisation/ground improvements |
| **Individual Property Foundations Development Premium** | Low<br>Low regional groundwater levels<br>Clayey soils present at ground surface | Medium<br>Low regional groundwater levels<br>Possible presence of soft Holocene Age alluvial soils<br>Clayey soils present at ground surface | Low<br>Low regional groundwater levels<br>Clayey soils present at ground surface | Low<br>Low regional groundwater levels<br>Clayey soils present at ground surface | Medium<br>Presence of firm to stiff Puketoka Formation soils<br>Clayey soils present at ground surface |
| **Overall Assessed Development Premium** | Low | Medium | Low | Low | Medium |
| **Suitable Urban Development Type** | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 3 storeys)<br>Retail/Commercial buildings (> 3 storeys) and residential towers supported on pile foundations. | **Areas Underlain by Holocene Alluvium**<br>Residential dwellings (single storey only)<br>All other buildings on pile foundations<br>**Areas Underlain by Volcanic Ash**<br>Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 3 storeys)<br>Retail/Commercial buildings (> 3 storeys) and residential towers supported on pile foundations. | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 3 storeys)<br>Retail/Commercial buildings (> 3 storeys) and residential towers supported on pile foundations. | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 3 storeys)<br>Retail/Commercial buildings (> 3 storeys) and residential towers supported on pile foundations. | Residential dwellings (1 to 3 storeys)<br>Retail & commercial buildings (1 to 2 storeys)<br>Retail/Commercial buildings (> 2 storeys) and residential towers supported on pile foundations. |

# 8 Conclusions

Tonkin & Taylor has undertaken a geotechnical desk top study to assess the suitability of greenfield sites in South Auckland for future urban development as part of the Rural Urban Boundary Project. The RUB project has been set up to define the rural-urban of Auckland through to 2040 and to provide sufficient land for development to meet the expected growth of Auckland over the next 30 years. Auckland Council has identified ten land packages around Drury, Karaka and Pukekohe (refer to Figure 1, Appendix A) for possible future urban development. Three different combinations of these land parcels have been proposed for development and assessed by T&T. The conclusions of our assessment are provided below.

The proposed development areas are generally underlain by one of two distinct geological units. The northern development areas (coastal areas) are typically underlain by Holocene Age (recent alluvium) and Pleistocene Age (Puketoka Formation) alluvial soils. The inland development areas which surround Pukekohe are typically underlain by volcanically derived soils (ash and tuff) originating from the South Auckland Volcanic Field. The typical geological conditions are presented on Figures 2 to 5 (Appendix A). Localised areas where geology differs to the conditions outlined are expected across South Auckland, however, these areas have not been identified.

Groundwater is expected to be present between 0 and 3 m below ground level within low lying and coastal areas, while groundwater is likely to be encountered below 3m depth in inland areas.

As part of our desk study assessment we have identified the following key geotechnical hazards and potential constraints for urban development which will affect the development of each land package to some extent.

**Geotechnical Hazards**

- Slope Instability
- Liquefaction
- Soil Compressibility

**Development Constraints**

- Earthworks
- Civil infrastructure
- Individual property development

In general none of the geotechnical hazards or development constraints outlined above would prevent future urban development; however each hazard and/or development constraint will have an associated premium for development. Tables 9 and 10 (Section 7) identify the key hazards and constraints for each development area and outline how susceptible each area is to the specific hazard and/or development constraint. Suitable development types within each area are also identified with respect to the various geotechnical conditions.

Areas which we consider to have a high premium associated with future development are presented on Figure 12 (Appendix A). These areas have been identified as being susceptible to one or more geotechnical hazards and/or development constraints. The identified land is not necessarily unsuitable for development, but it is likely that significant engineering oversight will be required to support development and will likely result in a high development premium compared with low development premium areas.

Land within the following areas have been identified as having a ‘High Development Premium’:

- The coastal fringes of the **Drury Core**, **Karaka Core, Karaka North** and **Karaka West;**
- Isolated areas in the south of the **Karaka Core** and **Drury Core** areas;
- North-western and south eastern areas of the **Pukekohe Core** development area;
- South-eastern region of the **Pukekohe South East** development area; and
- Various isolated areas across the **Pukekohe North East** development area.

In conclusion, and with respect to the various geotechnical hazards and development constraints outlined in this report, we consider that the **Pukekohe Focus** Development Scenario would likely be suitable for future urban development at a lower premium relative to the other three scenarios. However, there are local zones within the Pukekohe Focus that have a high development premium (specifically within Pukekohe North East and the south eastern corner of Core P). Geotechnical investigations would be required to more accurately delineate these zones and to ensure that future urban development is not concentrated within these areas.

# 9 Applicability

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

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

| | |
|---|---|
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## Appendix A: Figures