REPORT

Geotechnical Assessment - Wellsford North Fast Track Referral Application

Prepared for

Wellsford Welding Club Ltd

Prepared by

Tonkin & Taylor Ltd

Date

February 2022

Job Number

1018519.v1.1

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Document Control

Title: Geotechnical Assessment - Wellsford North Fast Track Referral Application					
Date	Version	Description	Prepared by:	Reviewed by:	Authorised by:
28/01/2022	V1	Draft for client comment	J. Lawrie	M. Child	M. Thomas
11/02/2022	V1.1	Updated following client review	J. Lawrie	M. Child	M. Thomas

Distribution:

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1 Introduction

Wellsford Welding Club Limited ("the applicant") propose to lodge an application for a referred project under the Covid-19 Recovery (Fast-track Consenting) Act 2020 (the "Act") to utilise the fast-track consenting process via an expert consenting panel. This application relates to the development of two separate areas; the first area is at the end of Monowai Street (Pt Lot 4 DP 9919) and the second area is part of the site at 338 Rodney Street which is accessed off SH1 ("the site") which are all owned and controlled by the applicant. This landholding forms part of a larger land area within Wellsford that is currently zoned Future Urban Zone under the Auckland Unitary Plan ("AUP") and will soon form part of a private plan change process to rezone the land from Future Urban to various live residential zones under the AUP. This will enable quality urban development and well-functioning urban environments and will also generate affordable housing north of Auckland. This proposal for a referred project will give effect to the purpose of the Act to promote employment and New Zealand's recovery to the economic and social impacts of Covid-19 through the enabled constructed and delivery of a comprehensive development that offers employment opportunities and an accelerated supply of quality housing choice and diversity.

To support the application for a referred project, this memo provides a high-level review of the geotechnical aspects of the proposal, including:

- Summary of Proposal and site description;
- Summary of work completed to date;
- High level geotechnical assessment of proposal; and
- Geotechnical recommendations for the proposed plan change.

2 Site Description

2.1 Site Description

The applicant owns 12.5ha of land in two areas at the end of Monowai Street and adjacent to State Highway 1 (SH1) which is currently zoned Future Urban ("FUZ"), Single House zone and Rural – Countryside Living zone under the AUP.

The site, shown in Figure 2.1 and Figure 2.2 below, is legally described as Lot 4 DP 9919 and PT Allot SE118 Psh of Oruawharo and is located approximately 0.5 km north of Wellsford town centre, 3 km south-east of Te Hana, and 15 km south-east of Kaiwaka.

The first proposal area of the site (Area 1) is bordered by residential houses to the north, the North Auckland Line (NAL) to the east, Armitage Road to the west, and Monowai Street to the south. Area1 generally comprises undulating pastural land with a moderate slope near the eastern end of the proposed development which steepens when falling towards an existing gully. A prominent watercourse forms the existing gully and flows from the south-east to north-west.

The second area of the site (Area 2) is bordered by 374 Rodney Street to the north. SH1 to the west, and farmland to the south and east. Area 2 generally comprises gently to moderately sloping hummocky and undulating topography leading from SH1 down towards a central drainage gully near the eastern boundary of the development area. An existing farm shed, and residential dwelling are located within this area of the site.

Figure 2.1: Location plan (scale 1 in 100,000)

Figure 2.2: Location of proposal areas (scale 1 in 7,500)

As shown in Figure 2.3 below, the applicant is proposing staged development of this land for residential use, with the inclusion of a small neighbourhood centre. Approximately 2,700 m² GFA of retail is proposed centrally on the site. Residential development and associated roading is proposed and will comprise of a mixture of terraced housing, duplex and standalone dwellings.

There are 84 lots, and two additional superlots proposed as part of this application, with approximately 570 additional dwellings enabled through the Private Plan Change application, which will be lodged late this year.

Planting of a large green reserve running through the centre of the site is also proposed.

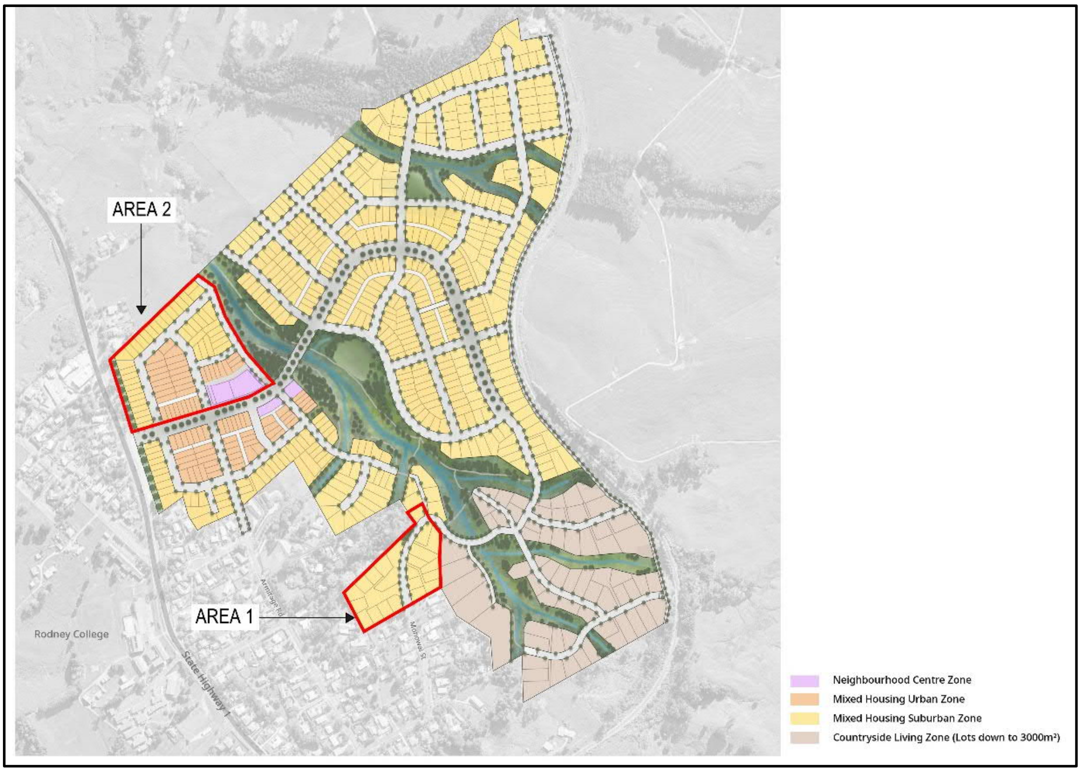

Figure 2.3: Plan of proposed development

2.2 General

Tonkin & Taylor (T+T) have previously been engaged by Wellsford Welding Club Ltd to provide specialist geotechnical services to assess a proposed plan change (PPC) for the larger land area owned by Wellsford Welding Club Ltd (of which Area 1 and Area 2 are located within) that is currently zoned Future Urban Zone under the Auckland Unitary Plan ("AUP"). This assessment is included in the report titled Wellsford Residential Development Plan Change – Geotechnical Assessment Report[1] (included in Appendix A).

A summary of the work undertaken in relation to the proposal areas (Area 1 and Area 2) is included below.

[1] Tonkin & Taylor Ltd. Wellsford Residential Development Plan Change – Geotechnical Assessment Report. 1018519.V2. Dated December 2021.

2.3 Existing Geotechnical Information

2.3.1 Published geology

The GNS Science 1:250,000 geological map of the Auckland area[2] provides compilation of existing data at a large scale. An annotated extract of the geological map showing the site location and development areas is presented in Figure 2.4.

The geological map shows Mahurangi Limestone (Omm) of the Northland Allochthon is likely to be present across the entirety of Area 1. Our investigations within Area 1 encountered brittle sandstones, siltstones and limestone which generally correspond to this mapped geology (discussed further in section 2.6 of this report).

Within Area 2, Mahurangi Limestone (Omm) is mapped through the eastern part of the development area, and Mangakahia Complex (Kk) of the Northland Allochthon along the western part. Mahurangi Limestone is described as a series of pale grey to white, laminated muddy limestones, commonly interbedded with graded sandstone beds. Mangakahia Complex is described as closely fractured to sheared, light or dark coloured, siliceous, and locally calcareous mudstone. Our investigations within Area 2 encountered soil and rock which correspond to Mahurangi Limestone, although it seems likely that the Mangakahia Complex materials will be present within zones of active movement in this area (discussed further in section 2.6 of this report).

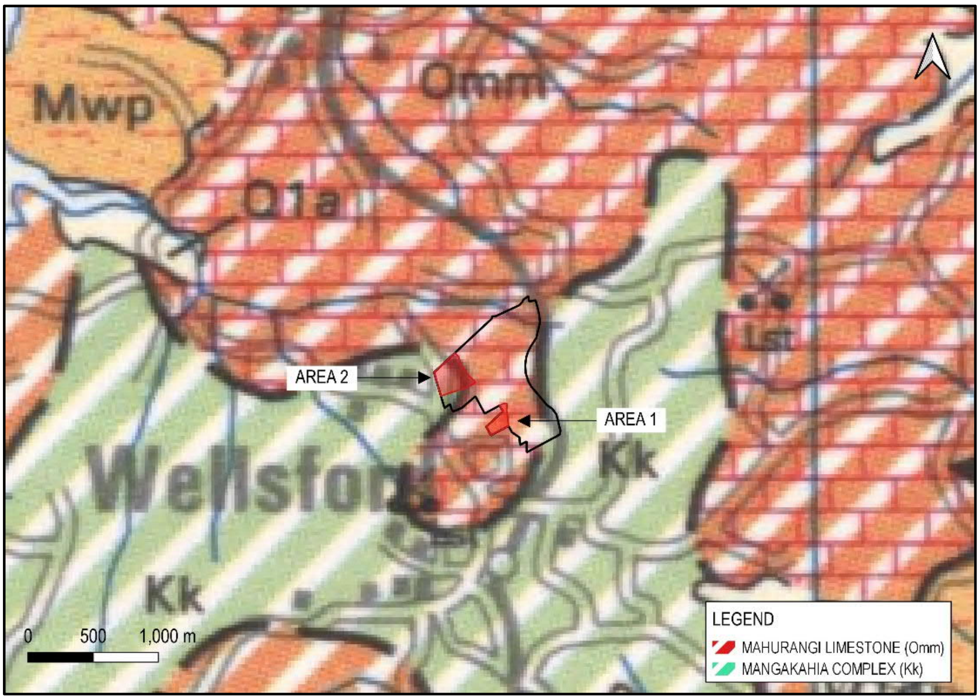

Figure 2.4: Extract of the 1:250,000 geological map of the Auckland area

2.3.2 Review of aerial photographs

A review of historical and recent aerial photography has been undertaken to understand whether any land-use or obvious topographical changes have occurred within the available record.

[2] Edbrooke, S.W (compiler) 2001. Geology of the Auckland area. Institute of Geological & Nuclear Sciences 1:250 000 geological map 3. 1 sheet + 74p. Lower Hutt, New Zealand. Institute of Geological and Nuclear Sciences Limited.

Historic aerial photographs have been sourced from Retrolens[3], Google Earth[4], and Land Information New Zealand (LINZ)[5] for the purpose of this assessment. A schedule presenting the aerial images described below is included in the Geotechnical Assessment Report[1].

In the timeframe available (1961 to 2017) the following notable features and changes to the site were observed:

1 Based on the aerial photography from 1961 (sourced from Retrolens), both areas of the site appear to be primarily used as farmland. Within Area 2, the existing dwelling at 338 Rodney Road is constructed, and part of the existing farm tracks are present near the eastern boundary. Numerous slope deformation features can be observed including hummocky ground and small landslips across both areas;

2 From the 1976 and 1982 aerial photography (sourced from Retrolens), the now existing farm track which accesses the site from Rodney Road has been constructed adjacent to Area 2;

3 No notable changes are observed between 1982 and 1992 aerial photography. Construction had begun on the development at Kelgary Place, north-west of Area 1; and

4 From 1992 to 2017, the site appears visually to be largely the same. Changes to SH1 near the western boundary of Area 2 are observed which we infer to have occurred prior to 2006, based on Google Earth imagery. These changes appear to be associated with earthworks stabilisation of SH1 and may also comprise installation of subsoil drainage and relief wells.

2.4 Geotechnical investigations and site walkover

2.4.1 Geotechnical investigations

A suite of intrusive investigations was carried out to investigate the general ground conditions of the site during the assessment of the larger land area. These included:

1 26 test pit (TP) excavations; and

2 11 hand auger (HA) boreholes

Further details on the investigations including locations and geotechnical logs are included in the Geotechnical Assessment Report. A summary of the investigations and encountered geology in each area is included in Section 2.6.

2.4.2 Site walkover

A site walkover was carried out by a Senior Engineering Geologist from T+T to undertake geological and geomorphological mapping of the larger land area. Key points for the two proposal areas are included below.

Area 1

Area 1 is defined by a broad ridge crest situated near the eastern end of the development which trends south to north. The ridge has gently to moderately inclined side slopes which fall 20° to the east and 15° to the west, to local drainage gullies. Hummocky ground and terracettes were observed along the western slope consistent with active slope movement. A geomorphology map of Area 1 is presented in Figure 2.5.

[3] Retrolens 2021, accessed 1 October 2021, https://retrolens.co.nz
[4] Google Earth 2021, accessed 15 November 2021, https://earth.google.com
[5] Land Information New Zealand 2021, accessed 1 October 2021, https://data.linz.govt.nz

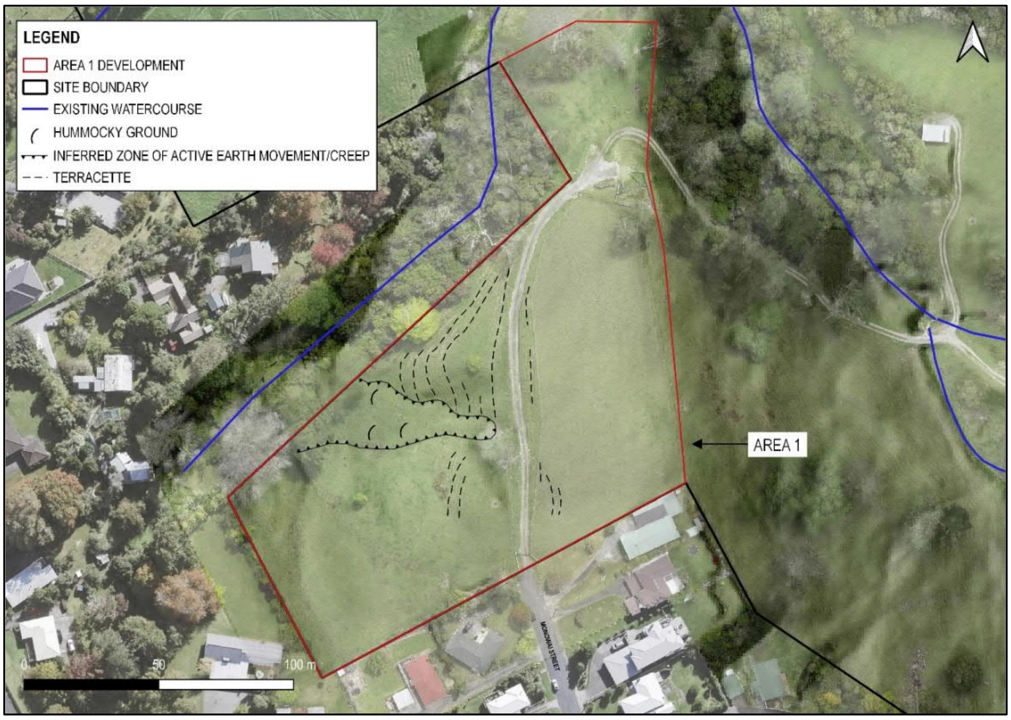

Figure 2.5: Geomorphology plan – Area 1

Area 2

Area 2 generally comprises gently sloping terrain which falls to the north-east towards an existing drainage gully adjacent to the development area. The land in this area typically comprises undulating and hummocky topography. Obvious signs of active earth movement upon the insitu bedrock were observed immediately below SH1. Shallow slope creep is also typical of this terrain on slopes exceeding about 8 degrees. A geomorphology map of Area 2 is presented in Figure 2.6.

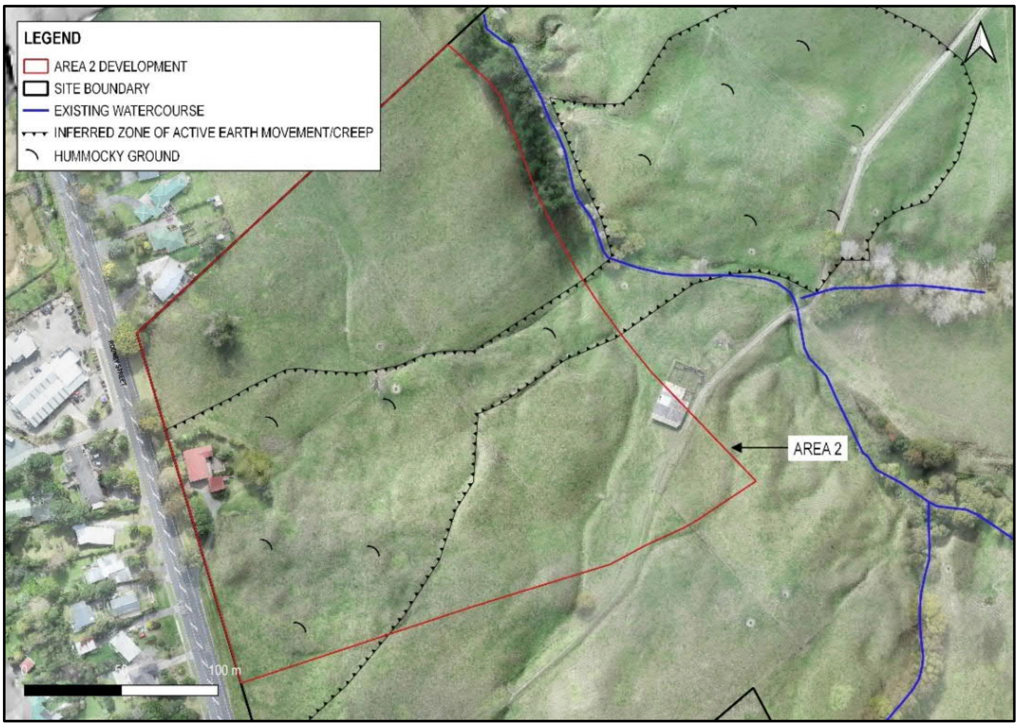

Figure 2.6: Geomorphology plan – Area 2

2.5 Geotechnical conditions and ground model

2.5.1 Overview

This section summarises the inferred ground conditions at the site based on our interpretation of the geomorphology, the material encountered, and data recovered from discrete investigation locations. The nature and continuity of subsoil away from these locations are inferred but it must be appreciated that actual conditions could vary from the assumed model. The inferred geology at the site is presented in Figure 2.7.

Across the larger land area, the subsurface investigations generally indicate pockets of alluvium, and residually weathered soils are present overlying Northland Allochthon rock at depth, which is generally consistent with the published geology described in Section 2.3.1 within the proposal areas. Northland Allochthon material described as siltstone, sandstone and limestone was encountered across most of the sites southern portion, including in both Area 1 and Area 2. Northland Allochthon derived mudstone/siltstone was encountered within the centre part of Area 2.

Northland Allochthon has an inherently variable lithology and changes may occur both laterally and vertically in the geologic profile over very short distances. It is not uncommon to have a range of Northland Allochthon lithologies over tens of meters in open excavations. As such, we expect that the geology on site will vary from that assumed.

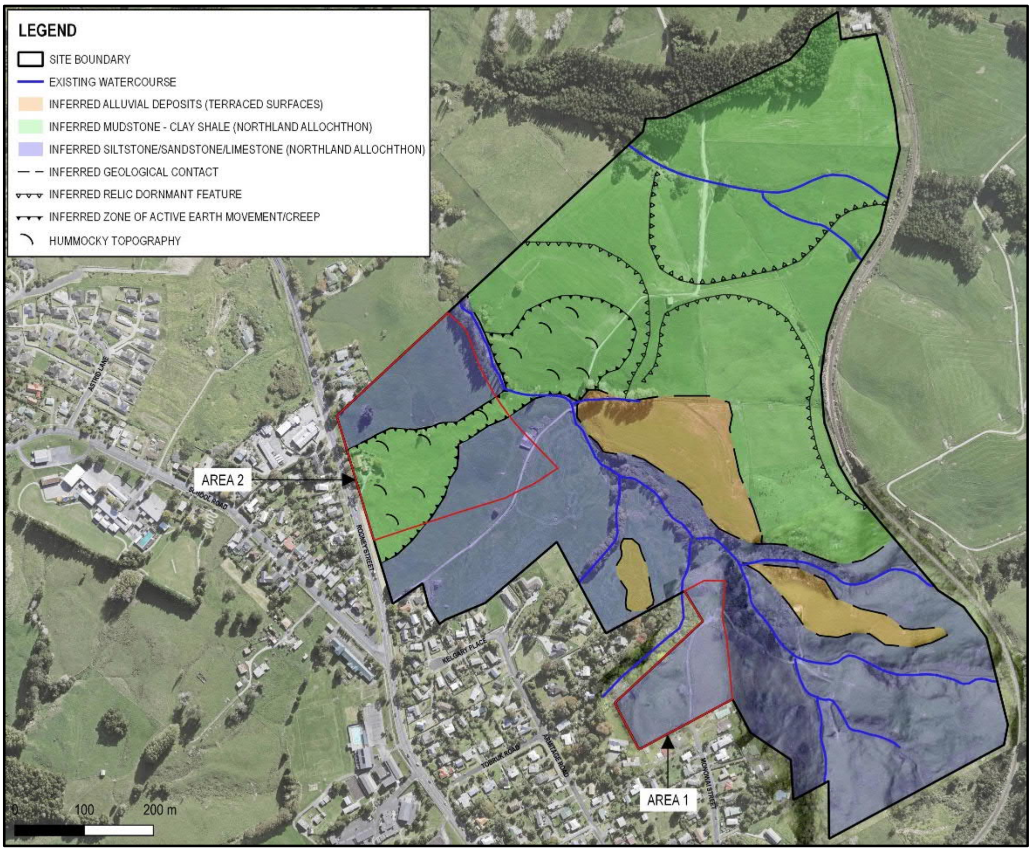

Figure 2.7: Inferred geology for the site

2.6 Site ground conditions

A summary of the inferred ground conditions in Areas 1 and 2 is included in Table 2.1.

Table 2.1: Summary of site ground conditions at each development area.

Area	Investigations	Encountered geology	Inferred ground conditions
1	2 hand auger boreholes	Northland allochthon residual soils to depths of between 2.4 m bgl and 3.4 m bgl overlying weathered siltstone / sandstone / limestone (Northland Allochthon) rock.	Our investigations indicate that near surface soils within Area 1 are underlain by variable brittle sandstones, siltstones and limestone. These materials generally correspond to the mapped geology of Mahurangi Limestone of the Northland Allochthon. Locally, pockets of recent alluvium may also be present. An area of active earth movement, inferred to comprise residual soils moving upon the insitu bedrock is present along the western slope. Due to the high variability of Northland Allochthon materials, fissile mudstone / clay shale (Mangakahia Complex) may also be present locally within this area.
2	3 test pit excavations 3 hand auger boreholes	Northland allochthon residual soils to depths of between 1.0 m bgl and 4.0 m bgl overlying weathered limestone and mudstone (Northland Allochthon) rock.	Our investigations indicate that near surface soils within Area 2 are underlain by variable brittle sandstones, siltstones and limestone. These materials generally correspond to the mapped Mahurangi Limestone geology of the Northland Allochthon. Fissile mudstone and clay shale may also be present, and it is likely that this material is present within the zone of active movement in the centre of the development area. These materials generally correspond to the mapped Mangakahia Complex geology of the Northland Allochthon.

3 The masterplan

The application is for the first stage of development of the applicant’s land that will be subject to a comprehensive structure planning and master planning process. Once fully developed the master planned area, as shown in Figure 3.1 below, will enable the delivery of between 650-800 residential dwellings, ranging from countryside living to medium density residential living. The highest site density is proposed at 338 Rodney Street, adjacent to SH1 where the main road will provide direct access to and from SH1. The lowest site density is proposed to be located in the southern portion of the master planned area, as the steep slopes and waterways allow for larger allotments consistent with a countryside living typology.

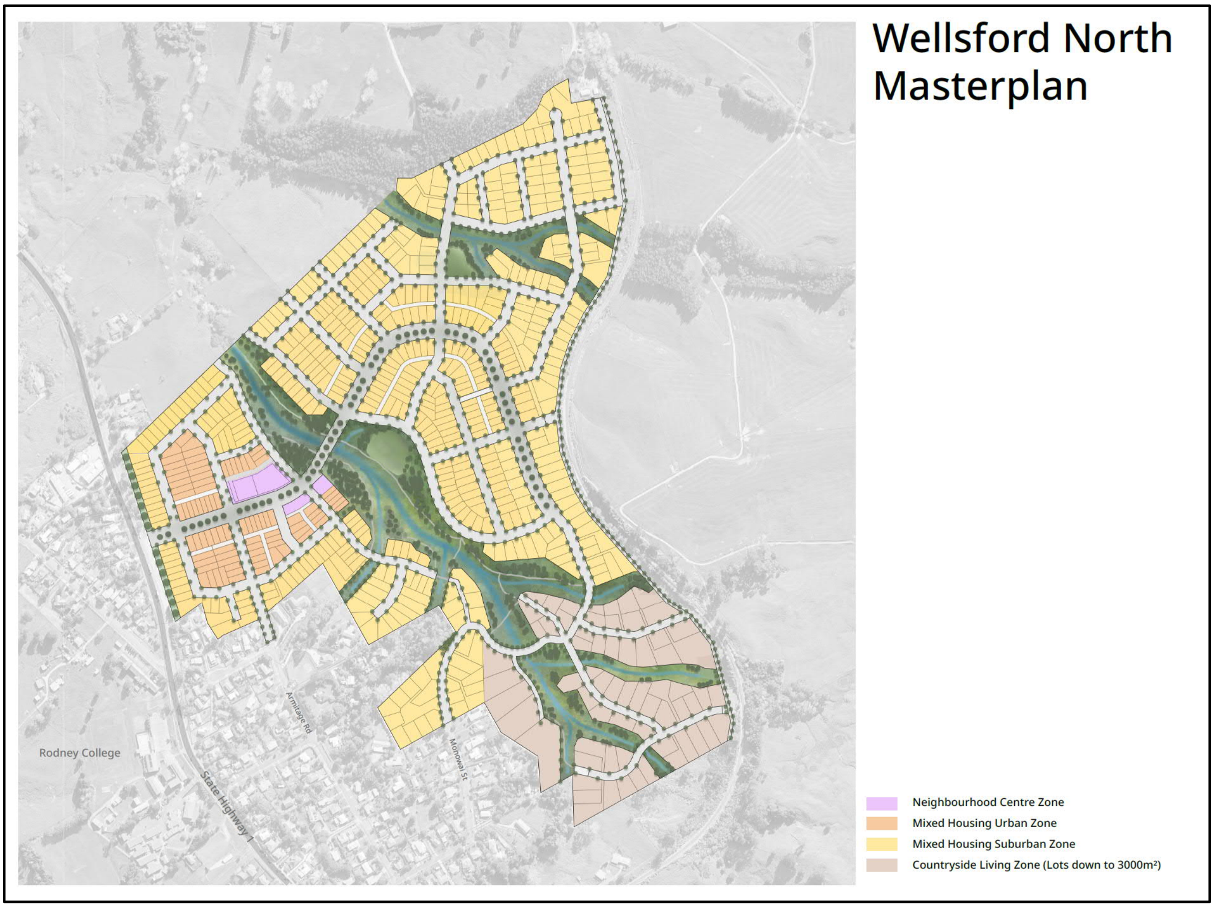

Figure 3.1: Draft Wellsford North Masterplan

The masterplan for this project has been designed to maintain and provide a suitable buffer around the natural wetland and stream network on site, to minimise ecological effects while enabling the provision of low-medium density residential development, supported by a neighbourhood centre that will provide for small scale commercial activities to meet the local community's convenience needs.

This application is for the first stage of the Masterplan, providing 84 residential lots and two additional residential superlots, as well as approximately 2,700m² GFA of retail is proposed centrally on the site.

4 Assessment

4.1 Geotechnical implications of the plan change

The geotechnical implications of the proposed plan change have been summarised below for the proposal areas based on our interpretation of geomorphology, encountered geology, and current development plans.

4.1.1 Area 1

Geotechnical Implications

Signs of active slope movement are present within the centre and western part of Area 1. Stabilisation of this land will be required in order to meet the requirements set out in the Auckland

Council Code of Practice for Land Development and Subdivision. Other parts of Area 1 may also require stabilisation in order to raise the factor of safety against instability to the required levels.

It is likely that the slope movement is occurring within the soil layers and zones of broken rock. The limited site-specific investigations generally indicate that the soil layers likely extend to approximately 2 to 4 m depth below existing ground. Moderately to highly weathered Northland Allochthon rock is expected to be encountered below the soil layers.

Area 1 is likely suitable for development using a range of geotechnical ground enhancement techniques. Such techniques may range from relatively simple measures such as installation of deep drainage to reduce ground water pressures, to more complex stability improvement through deep earthworks shear keys and drainage measures that extend through the broken zone into the top of the intact rock mass and reworking of unsuitable material. For areas of lower density housing, localised improvement measures such as palisade walls may be more cost effective; whereas wider-scale stabilisation works are likely to be more suited for higher density housing.

Shallow foundations will likely be suitable in situations or areas that have been enhanced through earthworks and/or deep drainage measures. Where near surface ground conditions are less favourable or where palisade walls are adopted to stabilise specific lots, then piled foundations may be required.

Confirmation of geotechnical assessment

Development within this area is achievable but requires confirmation of ground conditions through detailed geotechnical investigation. Depending on the chosen development density, suitable building platforms will need to be identified. This is likely to entail site specific geotechnical investigation and design to satisfy Auckland Councils minimum factor of safety for slope stability. As such, flexibility in the development layout and earthworks/topography should be afforded at this stage.

4.1.2 Area 2

Geotechnical implications

Active slope movement affects much of the southern part of Area 1, and stabilisation will be required in order to meet the requirements set out in the Auckland Council Code of Practice (as well as any other areas which require an increase in factor of safety against slope instability).

The previous investigations undertaken generally indicate that the underlying moderately weathered to highly weathered Northland Allochthon rock is located within about 4 m of the surface over most of Area 2.

The relatively shallow rock and active instability lends the site toward a conventional but relatively complex bulk earthworks mass stabilisation comprising a series of stabilised terraces or slopes. Stability improvement can be achieved through deep earthworks shear keys and drainage measures that extend through the broken zone into the top of the intact rock. This type of earthworks and retention solution is typical of the recent large-scale development surrounding the Silverdale area.

Development will need to maintain or improve the stability of adjacent properties and infrastructure such as State Highway 1 to the west.

Confirmation of geotechnical assessment

Development within this Zone is possible but requires confirmation of ground conditions through detailed geotechnical investigation, assessment of slope stability and large-scale earthworks design to satisfy Auckland Councils minimum factor of safety for slope stability. As such flexibility in the development layout and earthworks/topography should be afforded at this stage.

4.2 Slope stability

Gentle to moderately sloping ground forms the majority of the proposal areas. However, the geology in the Wellsford area is inherently unstable due to its Northland Allochthon origin and requires careful consideration and design to support development and satisfy Auckland Council development requirements.

A range of geological features were observed on site that indicate both historic and recent instability may have occurred on site. Modes of instability include:

- Active surficial creep; and
- Active movement of the soil mantle over shallow rock.

We believe that the risk of instability can be suitably mitigated through commonly used earth working and retaining systems such as embedded pile walls, mechanically stabilised earth (MSE), mass earthworks comprising shear keys, and deep drainage, along with site specific in-ground walls and foundation solutions where required. Some or all of these techniques could potentially be used to provide suitably stable building platforms (subject to the findings of site-specific geotechnical investigations). Areas where stabilisation for housing is not cost effective could be more suited for use as open / green spaces, which don't require such high factors of safety against slope instability.

4.3 Expansive soils

Expansive soils are clayey soils that undergo appreciable volume change upon changes in moisture content. This 'shrink-swell' effect results in movement of the near-surface soils over the course of seasonal moisture fluctuations and affects the design of shallow building foundations. The soils in the Wellsford area are expected to be typical of clay rich soils associated with the Northern Allochthon geological conditions and high expansivity can be expected. Locally, extremely expansive soils may exist on the site and can be treated accordingly. Commonly used design solutions such as stiffened (waffle / ribraft) slabs, or deep (~1 m) footings or piles are likely to be suitable for buildings in these ground conditions, subject to other geotechnical considerations such as laboratory testing and assessment of the performance of existing building foundations.

4.4 Liquefaction

Liquefaction is the partial or complete loss of strength of soil, usually as a result of ground shaking during an earthquake. The loss of strength causes the soil to behave more like a liquid, potentially resulting in effects such as sand boils, settlement of the ground surface, damage to buildings, buried structures and infrastructure, and lateral ground movement. To liquefy, the soil must be loose, sandy or silty and below the groundwater table.

Evidence of past liquefaction due to historical/ancient earthquakes can sometimes be seen in the sides of excavations. We did not observe any evidence of liquefaction in the test pits excavated during October 2021. Our qualitative assessment of the soils within both proposal areas is that they are unlikely to liquefy during an earthquake, as they are predominantly residually weathered cohesive soils with relic structure.

This is a preliminary assessment, and it would be prudent to confirm this conclusion for each area of the site during design development with additional site investigations and lab testing.

The design of infrastructure and buildings of any size will need to consider these hazards. Liquefaction hazard does not preclude the proposed plan changes for building development, as there are many conventional design solutions which can be used to manage and mitigate the risk of liquefaction on buildings of all sizes.

Typical measures include stiffened floor (waffle / ribraft) slabs, suspended floors, piled foundations, structural earth fill building platforms, rammed aggregate piers, and many other widely used systems which have been developed for the New Zealand housing market.

Buried pipework in land subject to liquefaction or other types of potential ground movement can utilise designs which are tolerant of movement, such as PE pipes and flexible connections. Manholes and other buried structures can be designed for buoyancy and mitigation against liquefaction ejecta, if required.

Lateral spread could potentially occur if liquefaction occurs within a continuous or largely continuous soil layer, on sloping ground or ground adjacent to a free edge such as a streambank. Based on the data presented in this report, the risk of earthquake-induced lateral spread appears to be highly unlikely, though it cannot be ruled out completely.

5 Further work

The layout of the developments will need to take account of the stabilisation works that may be required to create suitably stable building platforms. There may be some areas which are more conducive or cost effective to stabilise than others, and this information can be used to refine the development layout.

In order to carry out an assessment of what stabilisation measures may be required, an additional suite of geotechnical investigations comprising several machine boreholes, hand augers and additional test pits is likely to be required. We would then work with the project team to assess suitable stabilisation measures across both areas, and develop stability improvement measures to support detailed design of the subdivision.

6 Conclusion

The ground conditions within the proposal areas are generally suitable for residential development, subject to the following conclusions and recommendations:

1. A suite of preliminary investigations was undertaken during the PPC for the wider land area owned by Wellsford Welding Club. Information from this investigation was used to inform the development of a global ground model for the proposal areas discussed in this memo. Both proposal areas are underlain by various lithologies of the Northland Allochthon. Active slope deformation features were observed on site in both Area 1 and Area 2. Slope stability presents the biggest risk to development, and achieving Councils required factor of safety for residential development presents the main geotechnical challenge in developing the site and confirming the development plan.
2. The work carried out to date has been used to develop a global model of the ground conditions. Additional site investigations and analysis will be required to assess what actual ground stabilisation measures may be required in each Area, to support detailed design of the subdivision. The type of investigations and design outcomes that can be anticipated are discussed in Section 4 and 5 which should be read in conjunction with these conclusions.

3 The specific development layout and actual intensification should be confirmed in collaboration with the Geotechnical Engineer as understanding of the ground conditions is developed. Therefore, we recommend that the development is afforded the flexibility to increase or decrease the proposed lot intensity based on the scale and complexity of ground enhancement required to achieve the required levels of slope and geotechnical stability.

4 Ground enhancement works to achieve acceptable slope stability, and/or specific foundation design will be required over most of the proposal areas, and the type and scale of these works will need to be determined on confirmation of item 2 above.

5 The soil expansivity and potential liquefaction hazards within the site are similar to many other parts of northern Auckland. Earthquake induced liquefaction lateral spread hazards are highly unlikely but cannot be ruled out completely.

7 Applicability

This report has been prepared for the exclusive use of our client Wellsford Welding Club Ltd, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application for Fast Track approval and that Auckland Council as the consenting authority will use this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

Report prepared by:	Report reviewed by:
....	....
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Geotechnical Engineer	Engineering Geologist

Authorised for Tonkin & Taylor Ltd by:

....

Mark Thomas

Project Director

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Appendix A: T+T 2021 Geotechnical Assessment Report

REPORT

Tonkin+Taylor

Wellsford Residential Development Plan Change

Geotechnical Assessment Report

Prepared for

Wellsford Welding Club Ltd

Prepared by

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Date

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Document Control

Title: Wellsford Residential Development Plan Change					
Date	Version	Description	Prepared by:	Reviewed by:	Authorised by:
02/12/21	1	Geotechnical Assessment Report	J Lawrie / M Child	M Child / B Hegan	M Thomas
16/12/21	2	Minor updates	J Lawrie / M Child	M Child / B Hegan	M Thomas

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Table of contents

1 Introduction

Tonkin + Taylor Ltd (T+T) has been engaged by Wellsford Welding Club Ltd to provide specialist geotechnical services to assess a proposed plan change (PPC) for a residential development in Wellsford (the site). The site encompasses approximately 56 ha of land zoned as future urban and rural countryside living under the Auckland Unitary Plan (AUP).

This report outlines the findings from a geotechnical desktop study and the results of site investigations undertaken in October 2021 by T+T. This information has been used to review the suitability of the ground and groundwater conditions for the proposed new land use, and comments on the likely implications for building foundations, excavations and other geotechnical factors that may affect the development.

This report has been prepared to assist Auckland Council and decision makers in assessing this PPC in accordance with section 32 and Schedule 1 of the Resource Management Act 1991 (RMA).

We understand that investigations and reporting for contaminated land and other aspects of this development are being prepared by others.

1.1 Scope of work

The work has been undertaken based on our Letter of Engagement dated 23 July 2021[1]. The work carried out is limited to geotechnical aspects and is summarised below:

- Undertake a desktop assessment to review the historic land use and geomorphology of the site.
- Preliminary geotechnical investigations to assess the subsurface site conditions.
- Site walkover carried out by a T+T Engineering Geologist to carry out geomorphological mapping of the site.
- Preparation of this report to summarise the outcomes of the work undertaken and geotechnical recommendations for the proposed plan change.

1.2 Site description

The site, shown in Figure 1-1 and Figure 1-2 below, comprises five properties with a land area of approximately 56 ha. The legal titles of these five properties are:

- 338 Rodney Street
- PT Allot 117 SO22925
- PT Lot 4 DP 9919
- PT Lot 2 DP 26722
- PT Sec 25 DP 9682

The five properties are located approximately 0.5 km north of Wellsford town centre, 3 km south-east of Te Hana, and 15 km south-east of Kaiwaka. They are bordered by Rodney Street (State Highway 1) to the west, Worthington Road to the east, and Bosher Road to the north. The eastern border of the site is also adjacent to KiwiRail's existing North Auckland Line (NAL). The site is accessed from Monowai Road, Rodney Street, and Bosher Road.

[1] Tonkin & Taylor Letter of Engagement dated 23 July 2021. *Offer of Geotechnical Services to Support Resource Consent Application. Proposed Subdivision at 28 and 48 Old Waipu Road, Mangawhai.*

The site generally comprises undulating pastural land with moderate slopes that steepen where they fall towards existing gullies. Two prominent watercourses form the existing gullies and flow from the south-east to north-west. An existing dwelling at 228 Rodney Road is present near the western boundary of the site. Several existing farm structures including sheds and barns are located across the site.

Figure 1-1: Location plan (scale 1 in 100,000)

Figure 1-2: Location plan (scale 1 in 7,500)

1.3 Proposed development

An early stage concept site plan for the proposed development was provided to T+T by the project planners Barker & Associates (B&A) and is shown as Figure 1-3 below. The planned development is currently shown to comprise residential, medium density and lifestyle lots. A small suburb centre is also shown near the western end of the site. Access to the development is from the western property boundary, along Rodney Street, and from the south-western corner of the site at Monowai Street. Several open park spaces are also proposed through the centre of the site, and near the northern end, adjacent to the existing streams.

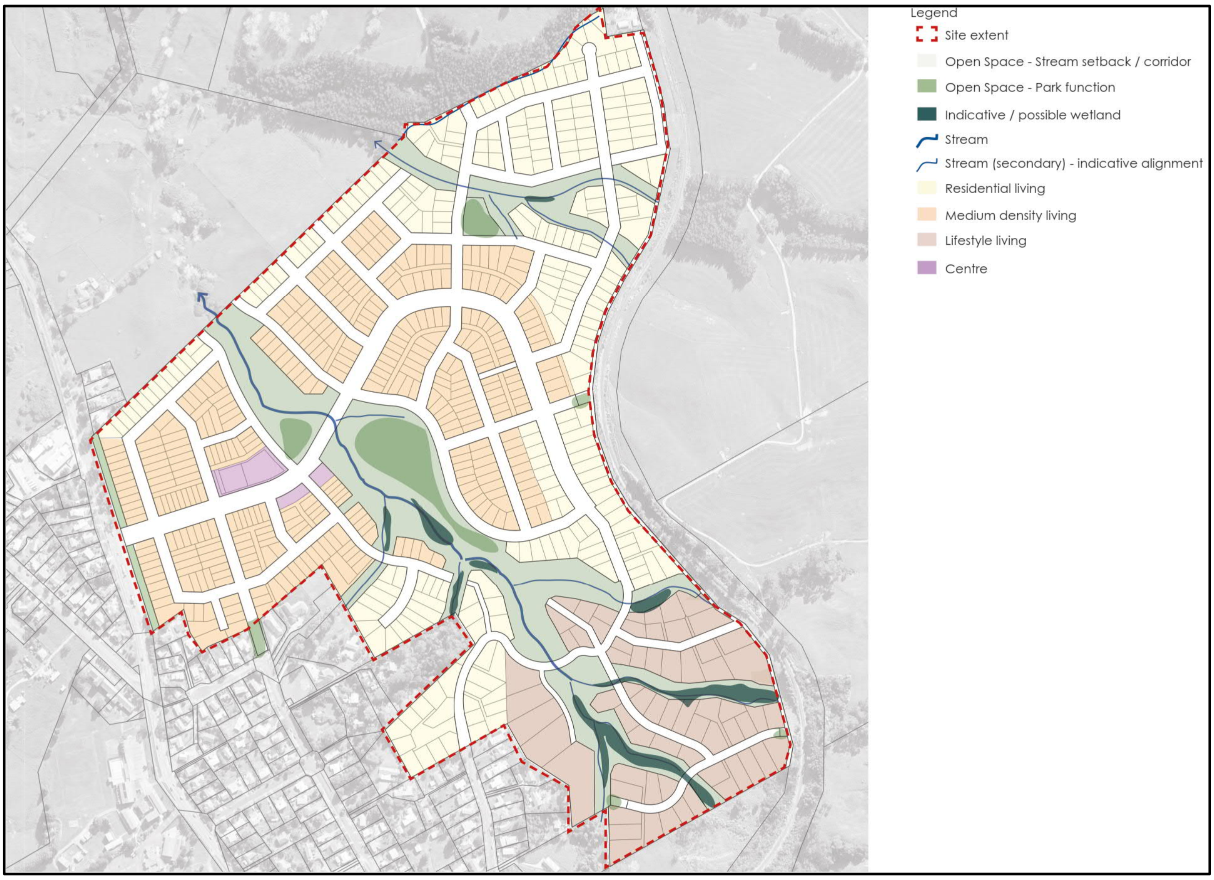


Figure 1-3: Proposed development zoning by B&A

2 Review of existing geotechnical information

2.1 Published geology

The GNS Science 1:250,000 geological map of the Auckland area[2] shows part of the site underlain by Mahurangi Limestone (Omm) of the Northland Allochthon. This material is described as a series of pale grey to white, laminated muddy limestones, commonly interbedded with graded sandstone beds. Mangakahia Complex (kk) of the Northland Allochthon is mapped to the east and west of the site. This material is described as closely fractured to sheared, light or dark coloured, siliceous, and locally calcareous mudstone. It should be noted that the GNS geological map is based on compilation of existing data at a large scale, and cannot be relied on for site specific data.

[2] Edbrooke, S.W (compiler) 2001. Geology of the Auckland area. Institute of Geological & Nuclear Sciences 1:250 000 geological map 3. 1 sheet + 74p. Lower Hutt, New Zealand. Institute of Geological and Nuclear Sciences Limited.

The 1:100,000 land inventory rock map of the Maungaturoto-Kaipara area[3] maps the site as being underlain by muddy limestone ($L5_2$) with mudstone with blocks ($M4_2$) mapped to the east and south of the site. Comparison with the 1:250,000 geological map indicates that the muddy limestone ($L5_2$) is likely equivalent to the Mahurangi Limestone (Omm) and the mudstone with blocks ($M4_2$) to the Mangakahia Complex.

Annotated extracts of the geological maps showing the site location are presented in Figure 2-1 and Figure 2-2.

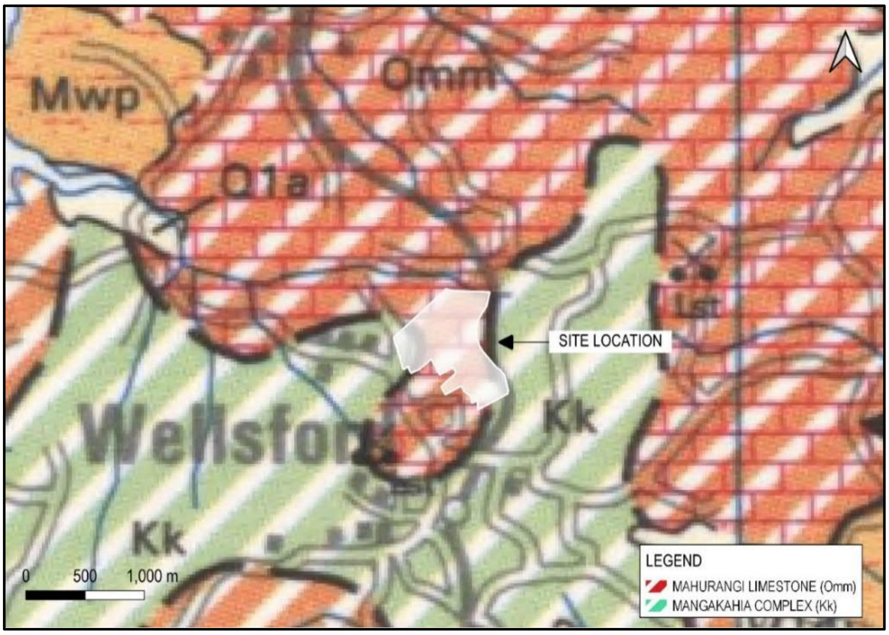


Figure 2-1: Extract of the 1:250,000 geological map of the Auckland area

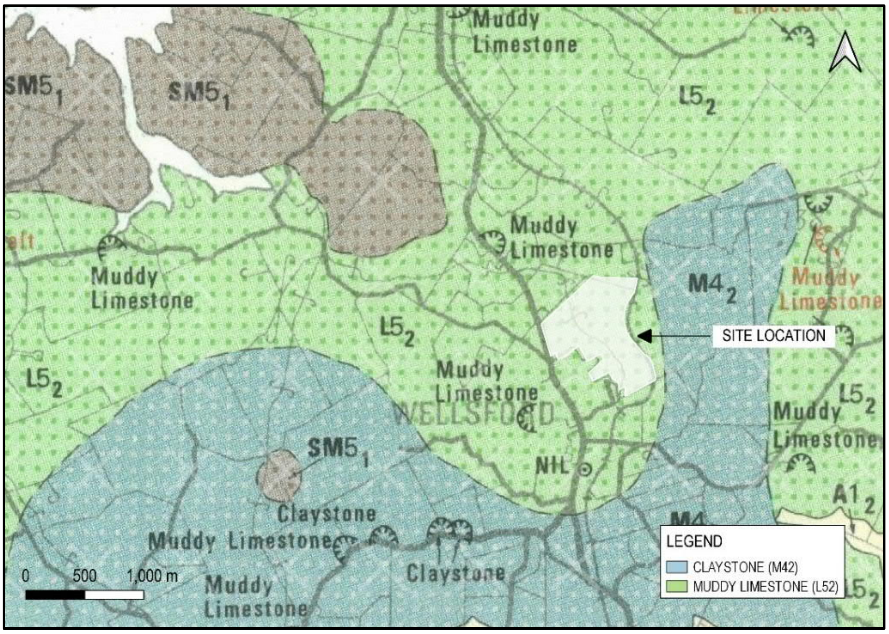


Figure 2-2: Extract of the 1:100,000 rock type map of the Maungaturoto-Kaipara area

[3] Markham, G.S and Crippen, T.F. 1981: "Maungaturoto-Kaipara" NZMS290 Sheet Q08/09, 1:100 000. New Zealand Land Inventory. Rock Types. Department of Lands and Survey, Wellington, New Zealand.

2.2 Review of aerial photographs

A review of historical and recent aerial photography has been undertaken to understand whether any land-use or obvious topographical changes have occurred within the available record. Historic aerial photographs have been sourced from Retrolens[4], Google Earth[5], and Land Information New Zealand (LINZ)[6] for the purpose of this assessment. A schedule presenting the aerial images described below is included in Appendix B.

In the timeframe available (1961 to 2017) the following notable features and changes to the site were observed:

1. Based on the aerial photography from 1961 (sourced from Retrolens), the site appears to be primarily used as farmland. The existing dwelling at 338 Rodney Road is constructed, and part of the existing farm tracks are present near the centre of the site. Numerous slope deformation features can be observed across the site including hummocky ground and small landslides including what we infer to be a recent landslide feature near south-eastern corner of the site.
2. From the 1976 and 1982 aerial photography (sourced from Retrolens), the now existing farm track which accesses the site from Rodney Road has been constructed. Several existing structures on the farm has been demolished with new farm sheds and barns constructed near the centre of the site. Large areas of bush have also been cleared near the north-western corner and south-eastern end of the site.
3. No notable changes are observed between 1982 and 1992 aerial photography. Construction had begun on the development at Kelgary Place near the south-western corner of the site, and a barn was constructed near the centre of the site.
4. From 1992 to 2017, the site appears visually to be largely the same. A new access track was constructed near the northern end of the site from Bosher Road. Changes to SH1 near the western boundary of the site are also observed which we infer to have occurred prior to 2006, based on Google Earth imagery. These changes appear to be associated with earthworks stabilisation of SH1 and may also comprise installation of subsoil drainage and relief wells.

[4] Retrolens 2021, accessed 1 October 2021, https://retrolens.co.nz
[5] Google Earth 2021, accessed 15 November 2021, https://earth.google.com
[6] Land Information New Zealand 2021, accessed 1 October 2021, https://data.linz.govt.nz

3 Geotechnical investigations

3.1 General

The scope of geotechnical investigations undertaken to assess ground conditions and aid the recommendations within this report comprised a walkover by a Senior Engineering Geologist from T+T to undertake geological and geomorphological mapping of the site, and a suite of intrusive investigations to ascertain the geology of the site comprising:

1 26 test pits (TP) excavations
2 11 hand auger (HA) boreholes

Coordinates for investigation locations are presented in terms of the New Zealand Transverse Mercator 2000 (NZTM 2000) projection. Locations were assessed using a handheld GPS (typical accuracy of ±2 m) or inferred on site. Elevations correspond to the New Zealand Vertical Datum 2016 (NZVD2016) and were assessed using a handheld GPS or from LIDAR contours (typical accuracy of ±1 m).

Materials recovered during the investigation were logged by a T+T Geotechnical Engineer and Engineering Geologist in general accordance with the Field Description of Soil and Rock guideline (NZGS, 2005)[7].

The presence of overhead and underground services was considered prior to any intrusive investigations being undertaken. Service plans were requested via the beforeUdig online service and obtained from Council GIS databases. No services were found to be in the vicinity of the works.

Investigation locations are presented on the Site Investigation Plan which is attached as Figure 1 in Appendix A.

3.2 Site walkover inspection findings

The site generally comprises grassed paddocks with small areas of bush and tree lined slopes which are predominantly confined to the steeper slopes of local drainage gullies. To the west and south the site is bordered by SH1 and private properties that form part of Wellsford township. The eastern site boundary is shared with KiwiRail's North Auckland Line (NAL), and the northern boundary borders open farmland.

Based on the topography and geomorphology observed on site we have broadly categorised it into four typical geological zones, as shown in Figure 3.1 and in Appendix A. The four zones are described below:

Geological zone A: Terraces (inferred alluvial deposits)

Three broad terrace features are located within the site. These features generally comprise gently sloping even ground with no obvious signs of recent instability observed within the terraces. These areas are denoted Zone A for discussion of the development and zoning considerations presented in Section 5.

Geological zone B: Active slope movement (Northland allochthon)

In the western corner of the site there is a narrow area of land that slopes gently down from SH1 to toward the main central drainage gully within the site. Above the gully immediately east is a small pocket of land that falls west, back toward the central drainage gully.

[7] New Zealand Geotechnical Society (2005). Field description of soil and rock. Guideline for the field classification and description of soil and rock for engineering purposes. New Zealand Geotechnical Society inc.

The land in this area typically comprises undulating and hummocky topography, and obvious signs of active earth movement upon the insitu bedrock were observed immediately below SH1. Shallow slope creep is also typical of this terrain on slopes exceeding about 8 degrees. This area is denoted Zone B for discussion of the development and zoning considerations presented in Section 5.

Geological zone C: Steeper terrain (Northland allochthon: Siltstone / Sandstone / Limestone)

The remaining southwest portion of the site comprises undulating terrain formed of several broad ridge crests with gently to moderately inclined side slopes leading down to a series of local drainage gullies. Many of these gullies are tree lined, indicating land that is less favourable to farming compared to the gently sloping land in the north. The steeper side slopes show signs of shallow near surface creep, and some possible signs of instability. This area is denoted Zone C for discussion of the development and zoning considerations presented in Section 5.

Geological zone D: Gentler terrain (Northland allochthon: Mudstone / Clay Shale)

The northeast half of the site generally comprises gently to moderately inclined undulating terrain with less obvious surface drainage features and incised gullies. The land in this area has what is inferred to be relic dormant features indicating inactive[8] slope movement in the form of scallop shaped arc features below the main ridge crests, above undulating terrain below. This area is denoted Zone D for discussion of the development and zoning considerations presented in Section 5.

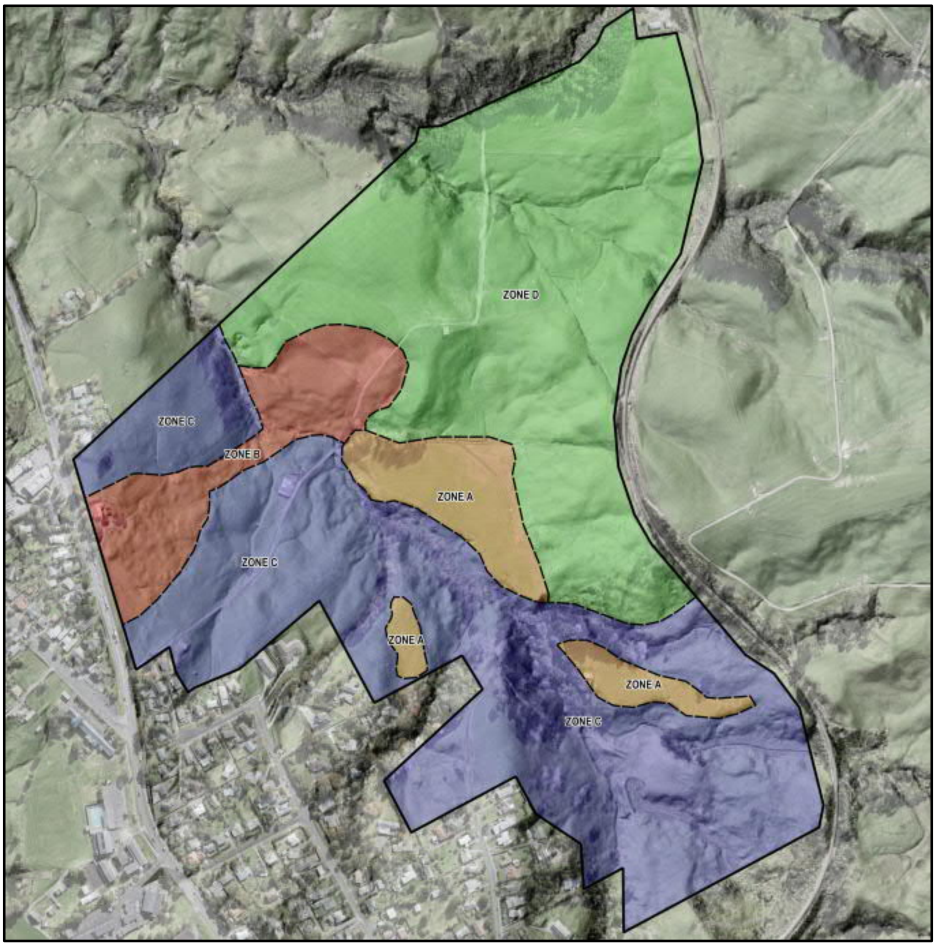


Figure 3.1: Geological zones

[8] Paper from Utah State University "Preliminary Age Classification of Landslides for Inventory Mapping" J.P. McCalpin 1984

3.3 Test pit excavations

Excavation of 28 test pits was undertaken by Masons Contractors Limited from the 12 October 2021 to 14 October 2021. The test pits were excavated using a 16-tonne excavator, which was able to excavate to a maximum depth of 3 to 5 metres depending on the terrain. Several of the test pits did not reach maximum depth due to "refusal" on hard rock, as noted in Table 3.2 below. Handheld shear vanes were undertaken on selected spoil samples, and in the floor and wall of test pits where possible.

A summary of the completed test pit excavations is presented in Table 3.2, with geotechnical logs and photographs included in Appendix C.

Table 3.1: Summary of test pit excavations

Hand auger ID	Location (NZTM 2000)		Ground surface elevation (NZVD2016) [m RL]	Termination depth [m bgl]	Termination reason
	Easting [m]	Northing [m]			
TP01_2021	1736665	5983629	31	1.5	Encountered rock.
TP02_2021	1736581	5983454	47	4.6	Encountered rock.
TP03_2021	1736633	5983316	56	2.6	Encountered rock.
TP04_2021	1736893	5983346	43	4.0	Encountered rock.
TP05_2021	1736771	5983405	41	2.7	Encountered rock.
TP06_2021	1736790	5983507	28	3.7	Encountered rock.
TP07_2021	1736702	5983737	25	4.4	Unable to excavate further
TP08_2021	1736844	5983674	33	4.8	Unable to excavate further
TP09_2021	1736957	5983515	30	4.7	Unable to excavate further
TP10_2021	1737247	5983029	47	3.6	Encountered rock.
TP11_2021	1737134	5983438	47	4.6	Unable to excavate further
TP12_2021	1737220	5983472	53	4.3	Unable to excavate further
TP13_2021	1737164	5983660	50	3.4	Encountered rock.
TP14_2021	1737291	5983963	42	3.0	Unable to excavate further
TP15_2021	1737278	5984071	45	3.8	Unable to excavate further

Hand auger ID	Location (NZTM 2000)		Ground surface elevation (NZVD2016) [m RL]	Termination depth [m bgl]	Termination reason
	Easting [m]	Northing [m]			
TP16_2021	1737003	5983981	30	3.8	Unable to excavate further
TP17_2021	1736849	5983852	40	3.7	Unable to excavate further
TP18_2021	1737003	5983821	36	3.7	Unable to excavate further
TP19_2021	1737118	5983752	42	3.0	Encountered rock.
TP20_2021	1737065	5983685	38	3.0	Encountered rock.
TP21_2021	1736952	5983732	41	5.0	Unable to excavate further
TP22_2021	1737002	5983549	30	4.6	Unable to excavate further
TP23_2021	1737223	5983260	46	4.4	Unable to excavate further
TP24_2021	1737379	5983251	50	4.5	Encountered rock.
TP25_2021	1737269	5983155	47	4.3	Encountered rock.
TP26_2021	1737412	5983111	54	2.9	Unable to excavate further

3.4 Hand auger boreholes

A total of 11 hand auger boreholes were completed by T+T between the 13 and 14 of October 2021. Nine of the eleven hand augers did not reach the target depth of 5.0 m bgl as they were unable to be advanced or reached refusal within hard ground. Handheld shear vanes were undertaken downhole in cohesive soil at 0.3 m intervals. Where encountered, groundwater measurements were recording using an electronic dip meter.

A summary of the hand auger boreholes is presented in Table 3.2. The full logs are presented in Appendix C.

Table 3.2: Summary of hand auger boreholes

Hand auger ID	Location (NZTM 2000)		Ground surface elevation (NZVD2016) [m RL]	Termination depth [m bgl]	Groundwater level [m bgl]	Termination reason
	Easting [m]	Northing [m]				
HA01_2021	1736784	5983570	24	4.7	2.12	Too difficult to auger
HA02_2021	1736676	5983527	31	3.0	Dry	Too difficult to auger

Hand auger ID	Location (NZTM 2000)		Ground surface elevation (NZVD2016) [m RL]	Termination depth [m bgl]	Groundwater level [m bgl]	Termination reason
	Easting [m]	Northing [m]				
HA03_2021	1736942	5983445	26	3.1	1.51	Squeezing
HA04_2021	1736577	5983560	40	1.8	Dry	Too difficult to auger
HA05_2021	1736648	5983412	43	2.2	Dry	Too difficult to auger
HA06_2021	1736945	5983142	48	2.4	Dry	Too difficult to auger
HA07_2021	1737085	5983127	58	3.4	1.12	Squeezing
HA08_2021	1737298	5983288	45	3.6	2.95	Too difficult to auger
HA09_2021	1736894	5983676	34	5.0	Dry	Target depth
HA10_2021	1736832	5983560	22	3.2	3.40	Too difficult to auger
HA11_2021	1737025	5983460	31	5.0	2.58	Target depth

4 Geotechnical conditions and ground model

4.1 Overview

This section summarises the inferred ground conditions at the site based on our interpretation of the geomorphology, the material encountered, and data recovered from discrete investigation locations. The nature and continuity of subsoil away from these locations are inferred but it must be appreciated that actual conditions could vary from the assumed model.

Across the site, the subsurface investigations generally indicate alluvium and residually weathered soils are present overlying Northland Allochthon rock at depth, which is generally consistent with the published geology described in Section 2. Northland Allochthon derived mudstone/siltstone was encountered at the northern portion of the site and in a small area which extends to the south-western boundary. Northland Allochthon material described as siltstone, sandstone and limestone were also encountered across most of the sites southern portion, particularly in the moderately inclined areas of the site.

Northland Allochthon has an inherently variable lithology and changes may occur both laterally and vertically in the geologic profile over very short distances. It is not uncommon to have a range of Northland Allochthon lithologies over tens of meters in open excavations. As such, we expect that the geology on site will vary from that assumed.

A plan showing the approximate extent of the inferred geological units is presented as Figure 2 in Appendix A, an excerpt of this map is presented as Figure 4-1 below.

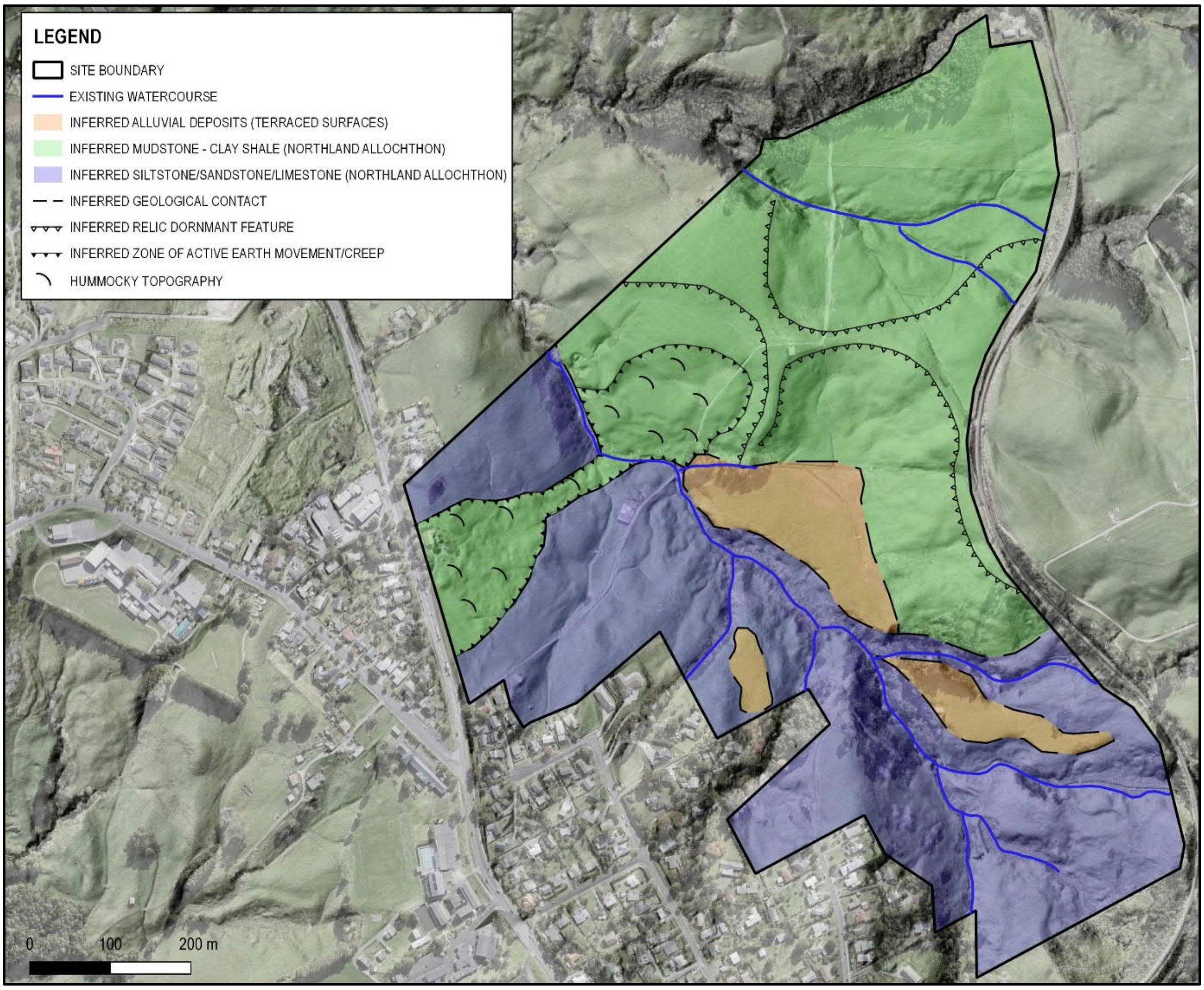


Figure 4-1: Inferred geology of the site

4.2 Site ground conditions

The recent site investigations have been used to inform the extent and development implications of each identified Zone (shown in Figure 3.1). A summary of the encountered geology in each zone is included in Table 4.1.

Table 4.1: Summary of site ground conditions at each development zone

Zone	Investigations	Encountered geology
A	4 test pit excavations 1 hand auger borehole	Alluvial deposits to depths of 1.3 m bgl to greater than 5 m bgl, overlying residual and weathered Northland Allochthon rock.
B	2 test pit excavations 1 hand auger borehole	Northland Allochthon residual soils and active earth movement to depths of between 1.4 m bgl to greater than 5 m bgl overlying weathered siltstone and mudstone rock.
C	8 test pit excavations 9 hand auger boreholes	Northland Allochthon residual soils and areas of local instability to depths of between 0.5 m bgl to 4.1 m bgl overlying weathered siltstone / sandstone / limestone rock.

Zone	Investigations	Encountered geology
D	12 test pit excavations	Northland Allochthon residual soils to depths of 2.7 m bgl to greater than 5.0 m bgl overlying and inferred to be overlying mudstone and siltstone rock. Inferred relic dormant features, possibly related to higher sea levels are also observed.

4.3 Typical mode of slope deformation within Northland Allochthon materials on low angle slopes

Northland Allochthon geology comprises a complex assemblage of different geologies that were formed over tens of millions of years from the late Cretaceous to the early Miocene. These materials were transported as sub-marine landslides some 100 km to 200 km, forming highly sheared rock of various lithologies.

These sheared rocks are readily weathered into low strength soils and are prone to deformation of slopes as shallow as 7 or 8 degrees when groundwater becomes trapped within a “broken zone” causing sub-artesian ground water pressures. This ground profile, as shown on Figure 4-2, typically comprises:

- Fully softened near surface clayey soils overlying;
- A broken zone of sheared material, overlying;
- A basal sheared zone, overlying;
- An un-softened rock mass

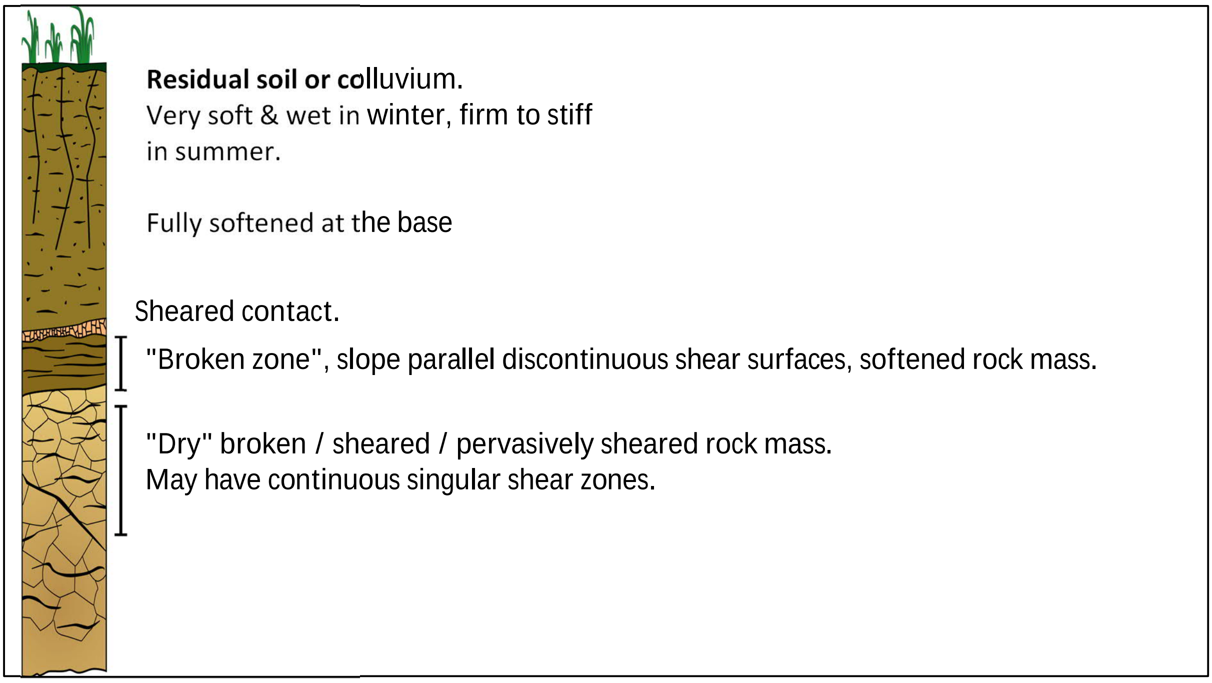


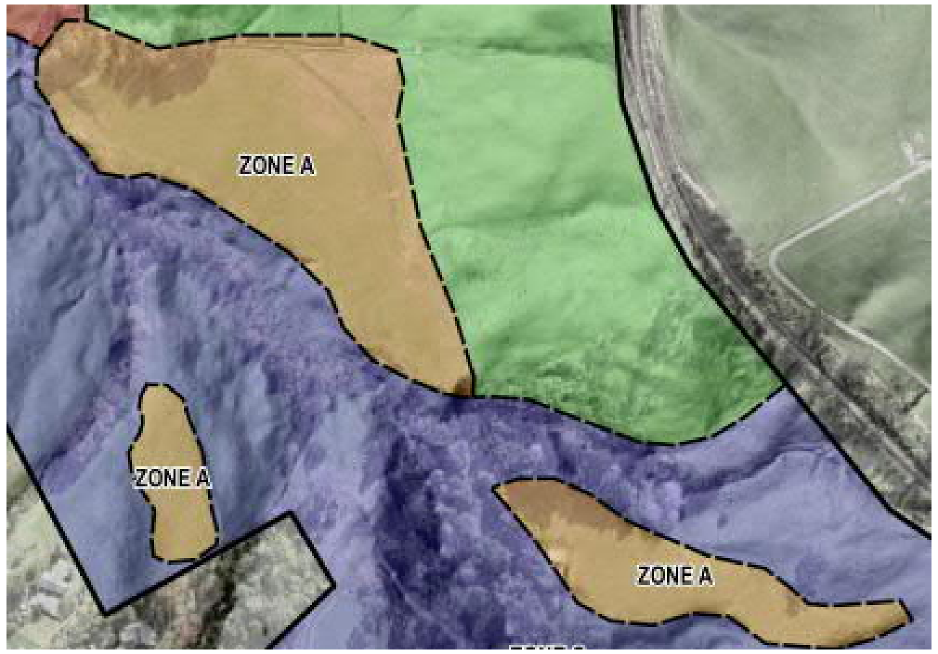
Figure 4-2: Annotated sketch of typical soil and rock profile within Northland Allochthon geology

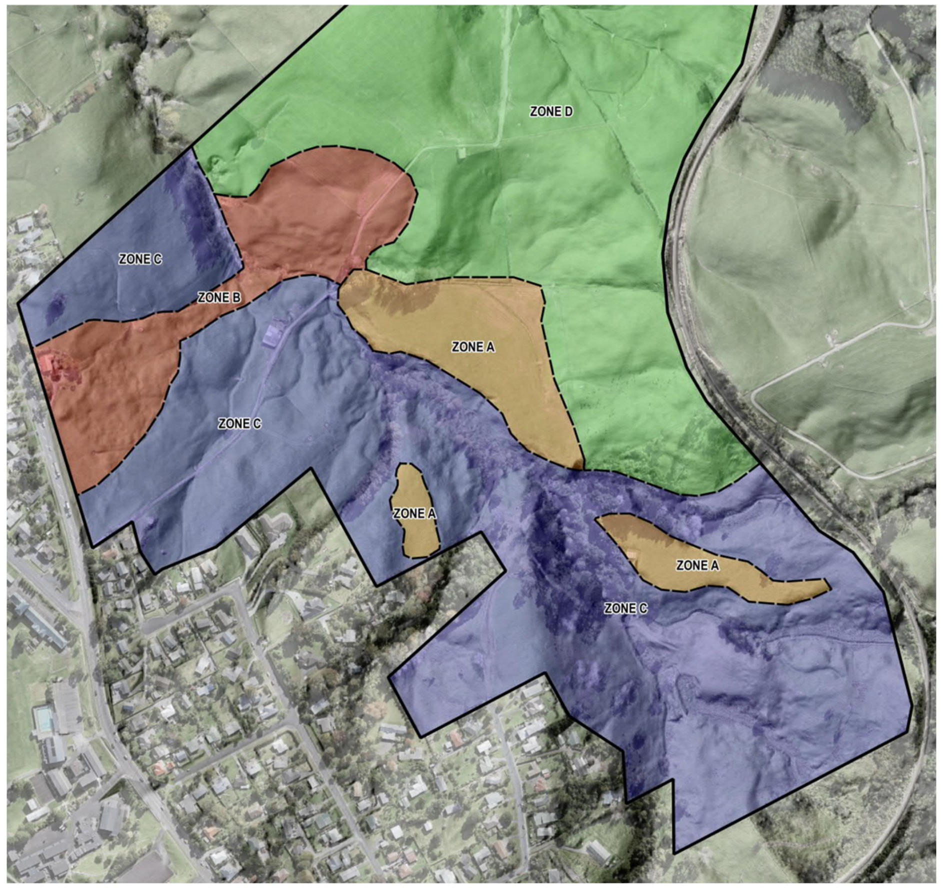
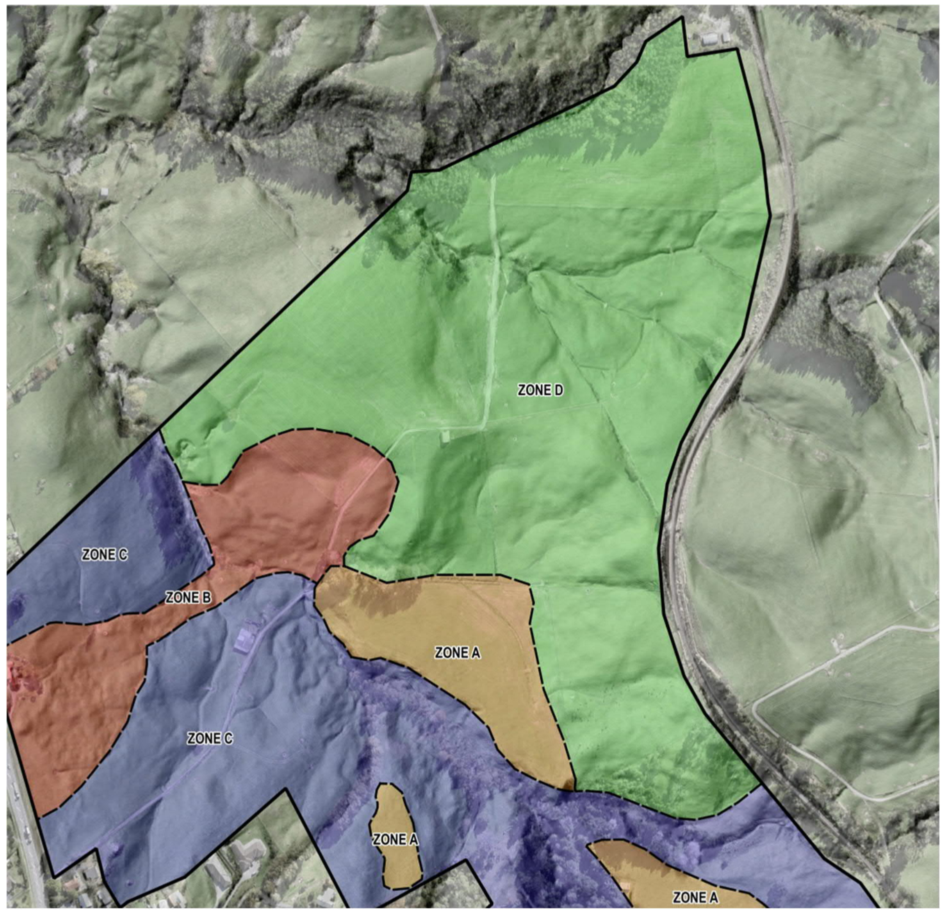
5 Geotechnical implications of the plan change

5.1 Development zones and general geotechnical implications of the plan change

The geotechnical implications of the proposed plan change can be described across four main areas (Zone A to Zone D). The preliminary location of the Zones overlain on a digital elevation model (DEM) is presented as Figure 3, attached in Appendix A. Excerpts of this figure are included in Table 5.1 below.

Table 5.1: Geotechnical assessment for the plan change

Geological Zone	Proposed Plan Change	Ground Conditions	Implications for change of Zoning
A		Terrain: Zone A typically comprises terrace features which slope at between about 2 and 3 degrees to the northwest. Data confidence: Published maps of the area indicate that these areas are underlain by Mahurangi Limestone of the Northland Allochthon. Our site observations indicate that these terraces comprising alluvial soils overlie the Allochthon (as described below). No other historical supporting information is readily available for this zone. Inferred ground conditions: Our preliminary investigations indicate that the ground conditions within the areas denoted Zone A are likely to comprise alluvial deposits. Alluvial deposits can be highly variable and may comprise soft compressible, or liquefiable granular materials. We infer that these terrace deposits were deposited during a period of elevated sea level, indicating that they are in the order of 100,000 to 150,000 years old.	Geotechnical Implications: The inferred ground conditions within these zones are anticipated to be favourable for light weight residential development on shallow or raft type foundations. Where adverse ground conditions are encountered, local ground improvement measures could be incorporated into the earthworks development of these sites. Development will need to be set back from steeper slopes to satisfy Auckland Councils minimum factor of safety for slope stability. Confirmation of Geotechnical Assessment: Development within this Zone is achievable but requires confirmation of ground conditions and may require assessment of liquefaction vulnerability and slope stability where development near steep slopes is proposed.
B		Terrain: Zone B typically comprises gently to moderately sloping hummocky and undulating topography leading from SH1 down toward the central drainage gully. Above the gully immediately east is a small pocket of land that falls west, back toward the central drainage gully. The hummocky terrain located centrally within this zone displays obvious signs of active earth movement within the upper soils and broken zone of upper rock. It appears that a series of manholes and relief wells are located on the site below SH1 that may be associated with stabilisation of the road. Moderately sloping ground either side of this is potentially subject to shallow surface creep. Data confidence: Published maps of the area indicate that these areas are underlain by Mahurangi Limestone and Mangakahia Complex of the Northland Allochthon. Our site observations also indicate the presence of Mangakahia Complex. No other historic supporting information is readily available for this zone. Inferred ground conditions: Our preliminary investigations indicate that near surface soils within this Zone are underlain by fissile mudstone. Clay shale may also be present, and it is likely that this material is present within the zone of active movement. These materials generally correspond to the mapped geology of and Mangakahia Complex mudstone of the Northland Allochthon.	Geotechnical Implications: The investigations undertaken for this report generally indicate that the underlying moderately weathered rock is located within about 5 m of the surface over most of Zone B. The relatively shallow rock and active instability lends the site toward a conventional but relatively complex bulk earthworks mass stabilisation comprising a series of stabilised terraces or slopes. Stability improvement can be achieved through deep earthworks shear keys and drainage measures that extend through the broken zone into the top of the intact rock. This type of earthworks and retention solution is typical of the large scale recent development surrounding the Silverdale area. Development will need to maintain or improve the stability of adjacent properties and infrastructure such as State Highway 1 to the west. Confirmation of Geotechnical Assessment: Development within this Zone is possible but requires confirmation of ground conditions, slope stability assessment and large scale earthworks design.

C		Terrain: Zone C typically comprises a series of ridge crests and drainage gullies with gently to moderately inclined side slopes up to about 20 degrees (locally steeper), falling toward watercourses at the base of the slopes. This zone is considered susceptible to primarily shallow surface creep and local instability within the upper 3 m to 4 m on slopes steeper than about 14 degrees. Deeper seated instability or instability on slopes as gentle as 7 degrees is less likely, but cannot be ruled out at this stage. Data confidence: Published maps of the area indicate that these areas are underlain by Mahurangi Limestone and Mangakahia Complex of the Northland Allochthon. This is supported by our site observations and investigations. No other historic supporting information is readily available for this zone. Inferred ground conditions: Our preliminary investigations indicate that near surface soils within this Zone are underlain by variable brittle sandstones, siltstones and limestone. These materials generally correspond to the mapped geology of Mahurangi Limestone of the Northland Allochthon. Due to the high variability of Northland Allochthon materials, fissile mudstone / clay shale (Mangakahia Complex) may also be present locally within this zone.	Geotechnical Implications: The investigations undertaken for this report generally indicate that the underlying moderately to highly weathered rock is located within about 3 m to 4 m of the surface over most of Zone C. Some areas within Zone C may be suitable for development with relatively simple stability improvement measures such as deep drainage to lower ground water pressures. The feasibility of mass earthworks stabilisation should be considered against the achievable lot density in Zone C. Some areas within this zone may lend themselves to specific mass earthworks stability enhancement where greater lot densities can be achieved, if economically feasible. This may be the case in the western corner of the site. Where stabilisation of large land areas to enable density is not economically feasible, then stabilisation of selected building platforms within larger lot sizes may be more suitable to this Zone. Building platforms in some areas may not be economically feasible to develop in this zone and may be better suited to green spaces within larger lots. Typically, building or site-specific engineering design in Zone C may comprise solutions such as piled foundations designed to resist soil creep, local earthworks stabilisation, drainage, and in-ground reinforced concrete palisade walls. Shallow foundations may be suitable in some situations or areas that have been enhanced through earthworks and/or deep drainage measures. Confirmation of Geotechnical Assessment: Development within this Zone is possible but requires confirmation of ground conditions. Depending on the chosen development density, suitable building platforms will need to be identified. This is likely to entail site specific geotechnical investigation and design.
D		Terrain: Zone D typically comprises gently to moderately inclined undulating terrain with some hummocky areas, and less obvious surface drainage features and incised gullies. The land in this area shows what appear to be relic dormant features associated with inactive slope movement. These features appear in the form of scallop shaped arcs within the landscape below the main ridge crests, above undulating terrain below. Localised areas within the Zone appear free of obvious signs of recent instability, and generally present less onerous development opportunities than Zones B and C. Data confidence: Published maps of the area indicate that these areas are underlain by Mahurangi Limestone of the Northland Allochthon. No other historic supporting information is readily available for this zone. Inferred ground conditions: Our preliminary investigations indicate that near surface soils within this Zone are typically underlain by fissile mudstone / clay shale of the Mangakahia Complex of the Northland Allochthon. Due to the high variability of Northland Allochthon materials brittle sandstone, siltstone and limestone may also be present locally within this zone. Based on the geomorphology and our understanding of the age of the terrace surfaces, we infer that the relic dormant features are in the order of 50,000 to 200,000 years old.	Geotechnical Implications: The investigations undertaken for this report generally indicate that the underlying moderately to highly weathered rock is located greater than 3 m depth below the existing ground surface. In areas where large relic dormant features with deep landslip surfaces are confirmed, it will be important to assess whether stabilisation is required to achieve the full factor of safety required by Auckland Council for residential development. Stabilisation of very deep slip surfaces may be uneconomical, and housing would need to be located in areas which can developed more economically. Conversely, some localised areas within these dormant features and areas that have not been subject to ancient instability may be suitable for residential development with much less onerous design requirements. In these areas conventional raft type foundations may be feasible (possibly coupled with drainage measures) subject to site specific testing and stability assessment. The land within Zone D may also comprise a “middle ground” where stability enhancement can be achieved through bulk earthworks and drainage or retention to promote local areas of higher density. Confirmation of Geotechnical Assessment: Development within this Zone is achievable but requires confirmation of ground conditions and a better understanding of the inferred dormant features to confirm the most suitable method of development. This is likely to entail site specific geotechnical investigation, monitoring and design. Flexibility to reduce the proposed lot densities within some areas of this zone is considered prudent at this stage.

Notes: Zoning taken from B&A Masterplan, Indicative Lot / Landuse Layout, Dated 12/07/2021 – Draft in progress

5.2 Slope stability

Gentle to moderately sloping ground forms the majority of the proposed development area. However, the geology in the Wellsford area is inherently unstable due to its Northland Allochthon origin and requires careful consideration and design to support development.

A range of geological features were observed on site that indicate both historic and recent instability may have occurred on site. The modes of instability we infer to include:

- Active surficial near surface creep
- Active earth movement of the soil mantle over shallow rock
- Possible relic dormant features associated with inactive (ancient) earth movement

We believe that the risk of instability can be suitably mitigated through commonly used earth working and retaining systems such as embedded pile walls, mechanically stabilised earth (MSE), mass earthworks comprising shear keys, and deep drainage, along with site specific in-ground walls and foundation solutions where required. All are likely to be suitable options in this geology to provide suitably stable building platforms and have been used successfully elsewhere. However, there are likely to be parts of the site which are not economically viable to stabilise for housing, and these areas could be more suited for use as open / green spaces.

5.3 Expansive soils

Expansive soils are clayey soils that undergo appreciable volume change upon changes in moisture content. This 'shrink-swell' effect results in movement of the near-surface soils over the course of seasonal moisture fluctuations and affects the design of shallow building foundations. The soils in the Wellsford area are expected to be typical of clay rich soils associated with the Northern Allochthon geological conditions and high expansivity can be expected. Locally, extremely expansive soils may exist on the site and can be treated accordingly. Commonly used design solutions such as stiffened (waffle / ribraft) slabs, or deep (~1 m) footings or piles are likely to be suitable for buildings in these ground conditions, subject to other geotechnical considerations such as laboratory testing and assessment of the performance of existing building foundations.

5.4 Liquefaction

Liquefaction is the partial or complete loss of strength of soil, usually as a result of ground shaking during an earthquake. The loss of strength causes the soil to behave more like a liquid, potentially resulting in effects such as sand boils, settlement of the ground surface, damage to buildings and buried structures, infrastructure and lateral ground movement. To liquefy, the soil must be loose, sandy or silty and below the groundwater table.

Evidence of past liquefaction due to historical/ancient earthquakes can sometimes be seen in the sides of excavations. We did not observe any evidence of liquefaction in the test pits excavated during October 2021. Our qualitative assessment of the soils within Zones A to D is that they are unlikely to liquefy during an earthquake, as they are predominantly residually weathered cohesive soils with relic structure, or alluvial deposits with high clay content. This is a preliminary assessment, and it would be prudent to confirm this conclusion for each area of the site during design development with additional site investigations and lab testing.

The design of infrastructure and buildings of any size will need to consider these hazards. Liquefaction hazard does not preclude the proposed plan changes for building development, as there are many conventional design solutions which can be used to manage and mitigate the risk of liquefaction on buildings of all sizes. Typical measures include stiffened floor (waffle / ribraft) slabs, suspended floors, piled foundations, structural earth fill building platforms, rammed aggregate piers and many other widely used systems which have been developed for the New Zealand housing market. Buried pipework in land subject to liquefaction or other types of potential ground movement can utilise designs which are tolerant of movement, such as PE pipes and flexible connections. Manholes and other buried structures can be designed for buoyancy and mitigation against liquefaction ejecta, if required.

Lateral spread could potentially occur if liquefaction occurs within a continuous or largely continuous soil layer, on sloping ground or ground adjacent to a free edge such as a streambank. Based on the data presented in this report, the risk of earthquake-induced lateral spread appears to be highly unlikely, though it cannot be ruled out completely.

5.5 Existing residential and infrastructure development considerations

Adjacent residential dwellings and public infrastructure (State Highway 1 and the North Auckland railway line) should be suitably considered when developing the scheme plan and in the ensuing project stages. Conventional geotechnical assessment and design methods can be used to manage geotechnical effects upon these assets.

6 Conclusion

The ground conditions within the PPC area are generally suitable for residential development, subject to the following conclusions and recommendations:

1. A suite of preliminary investigations have been undertaken to inform development of a global ground model for the site. The site is underlain by various lithologies of the Northland Allochthon, with some surficial alluvial deposits also present. Both relic dormant features and active slope deformation features were observed on site. Slope stability presents the biggest risk to development, and achieving Councils required factor of safety for residential development presents the main geotechnical challenge in developing the site and confirming the development plan.
2. Whilst we have confidence in the global model (in general), additional site-specific geotechnical investigation and design will be required to better understand local ground conditions and confirm our geotechnical assessment and development recommendations for Resource Consent application and subdivision design. The type of investigations and design outcomes that can be anticipated are discussed in Table 5.1 which should be read in conjunction with these conclusions.
3. The specific zoning and actual intensification should be confirmed in collaboration with the Geotechnical Engineer as understanding of the ground conditions is developed. Therefore, we recommend that the development is afforded the flexibility to increase or decrease the proposed lot intensity based on the scale and complexity of ground enhancement required to achieve the required levels of slope and geotechnical stability.
4. Ground enhancement works to achieve acceptable slope stability, and/or specific foundation design will be required over most of the site and the type and scale of these works will need to be determined on confirmation on item 3 above.
5. The soil expansivity and potential liquefaction hazards within the site are similar to many other parts of northern Auckland. Conventional and/or commonly used design solutions are available to manage and mitigate these hazards, such as stiffened floor (waffle / rib-raft) slabs, suspended floors, piled foundations, structural earth fill building platforms, rammed aggregate piers. Earthquake induced liquefaction lateral spread hazards are highly unlikely but cannot be ruled out completely.
6. The proposed development and associated ground enhancement works should give due consideration to existing residential development and public infrastructure (e.g. State Highway 1 and the North Auckland rail line).

7 Applicability

This report has been prepared for the exclusive use of our client Wellsford Welding Club Ltd, with respect to the particular brief given to us to support the proposed plan change and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Recommendations and opinions in this report are based on data from discrete investigation locations. The nature and continuity of subsoil away from these locations are inferred but it must be appreciated that actual conditions could vary from the assumed model.

Tonkin & Taylor Ltd

Report prepared by:	Report prepared / reviewed by:
....	....
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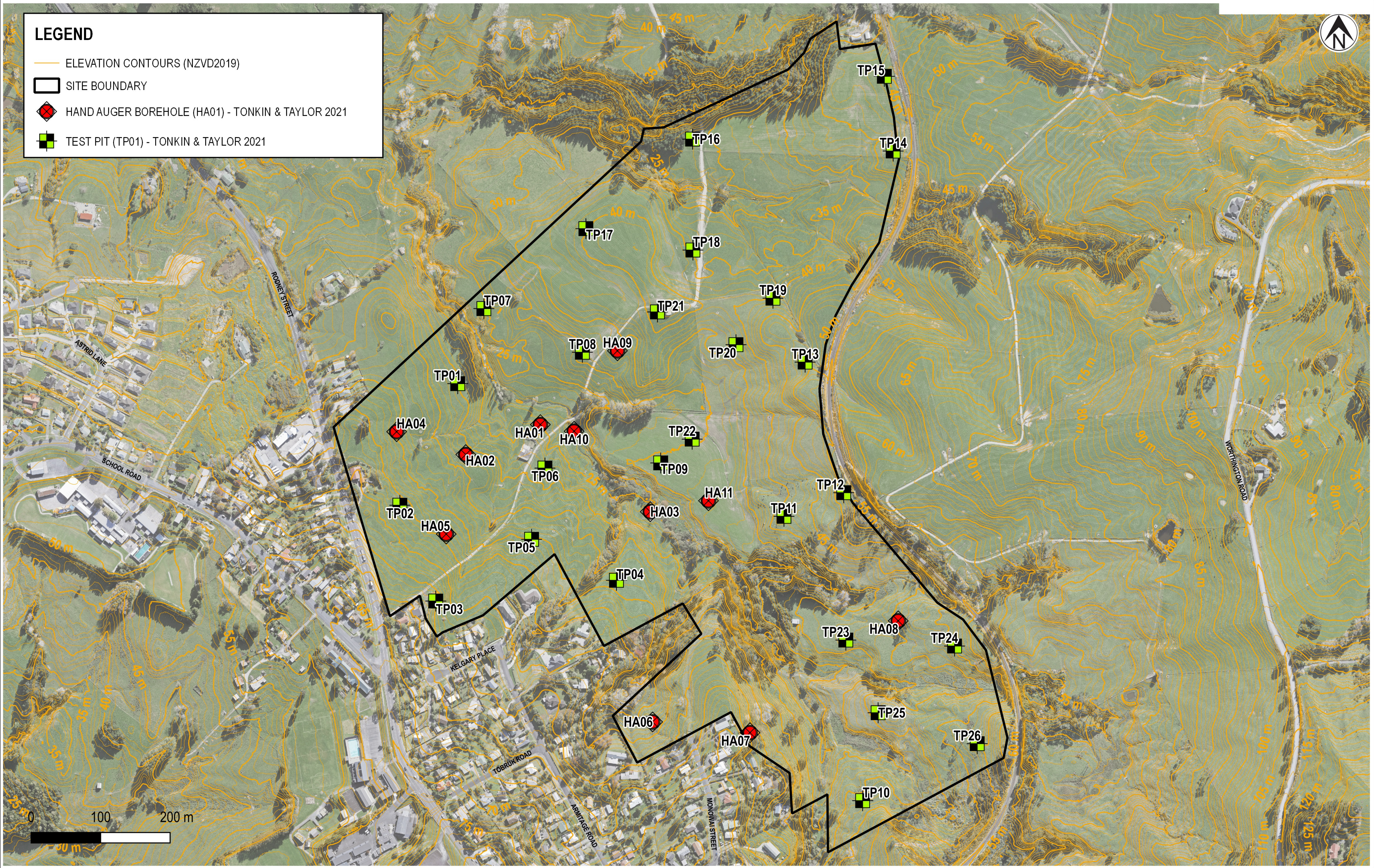
Appendix A: Figures

C:\Users\jala\Documents\QGIS\Projects\Wellsford Residential Development\Maps\Wellsford Residential Development.qgz Layout: Site Plan Drawn by JALA



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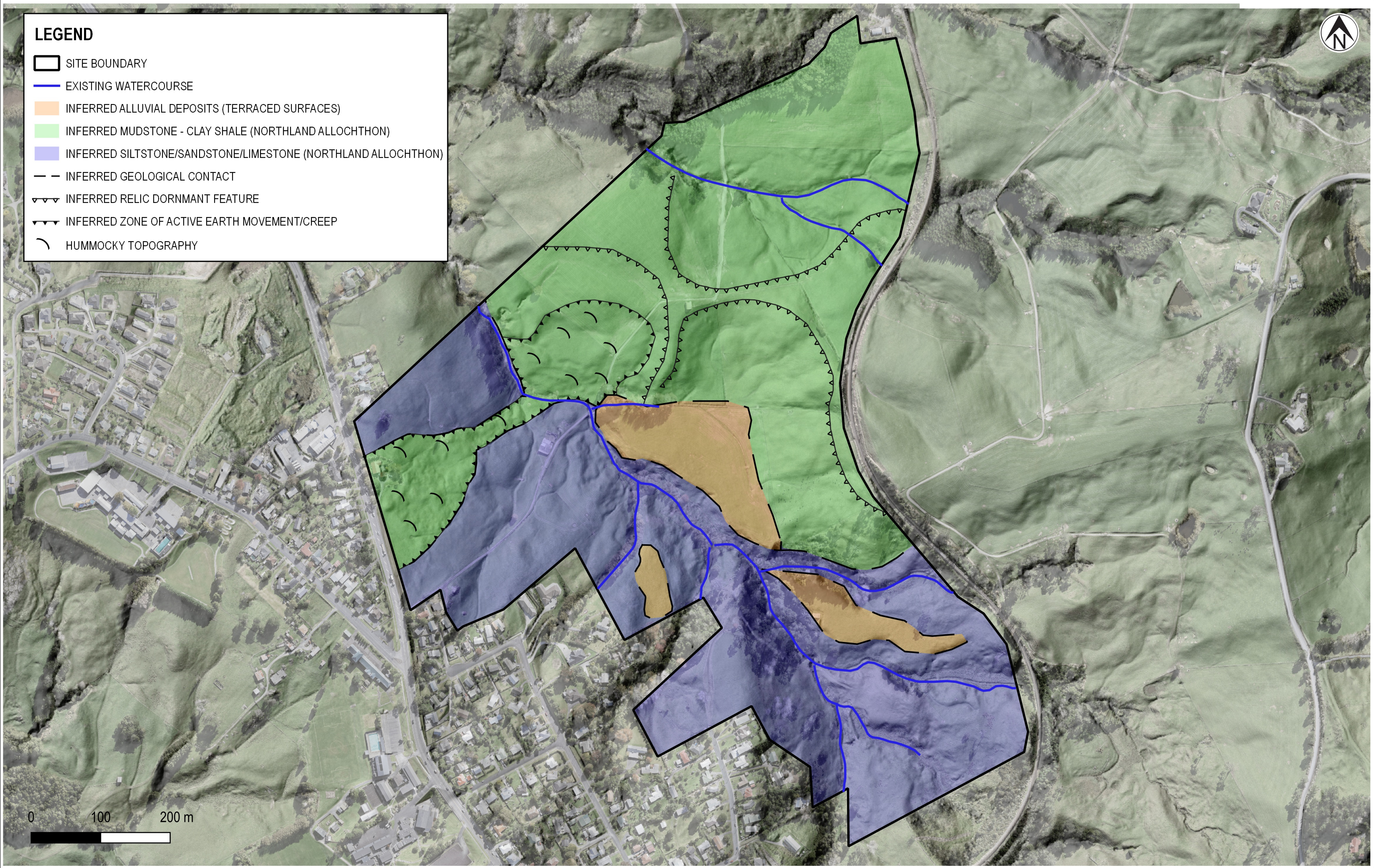
REV	DESCRIPTION	GIS	CHK	DATE
0	First version	JALA	MCHI	17/11/21

LOCATION PLAN

PROJECT No.	1018519	
DESIGNED	JALA	DEC.21
DRAWN	JALA	DEC.21
CHECKED	MCHI	DEC.21
APPROVED	MRT	DEC.21

CLIENT: WELLSFORD WELDING CLUB LTD
PROJECT: WELLSFORD RESIDENTIAL DEVELOPMENT
TITLE: INVESTIGATION LOCATION PLAN
SCALE (A3): 1:5,000 FIG No. FIGURE 1. REV 0

C:\Users\jala\Documents\QGIS\Projects\Wellsford Residential Development\Maps\Wellsford Residential Development.qgz Layout: Geology Map Drawn by JALA



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REV	DESCRIPTION	GIS	CHK	DATE
0	First version	JALA	MCHI	08/10/21

LOCATION PLAN

PROJECT No. 1018519

DESIGNED	JALA	DEC.21
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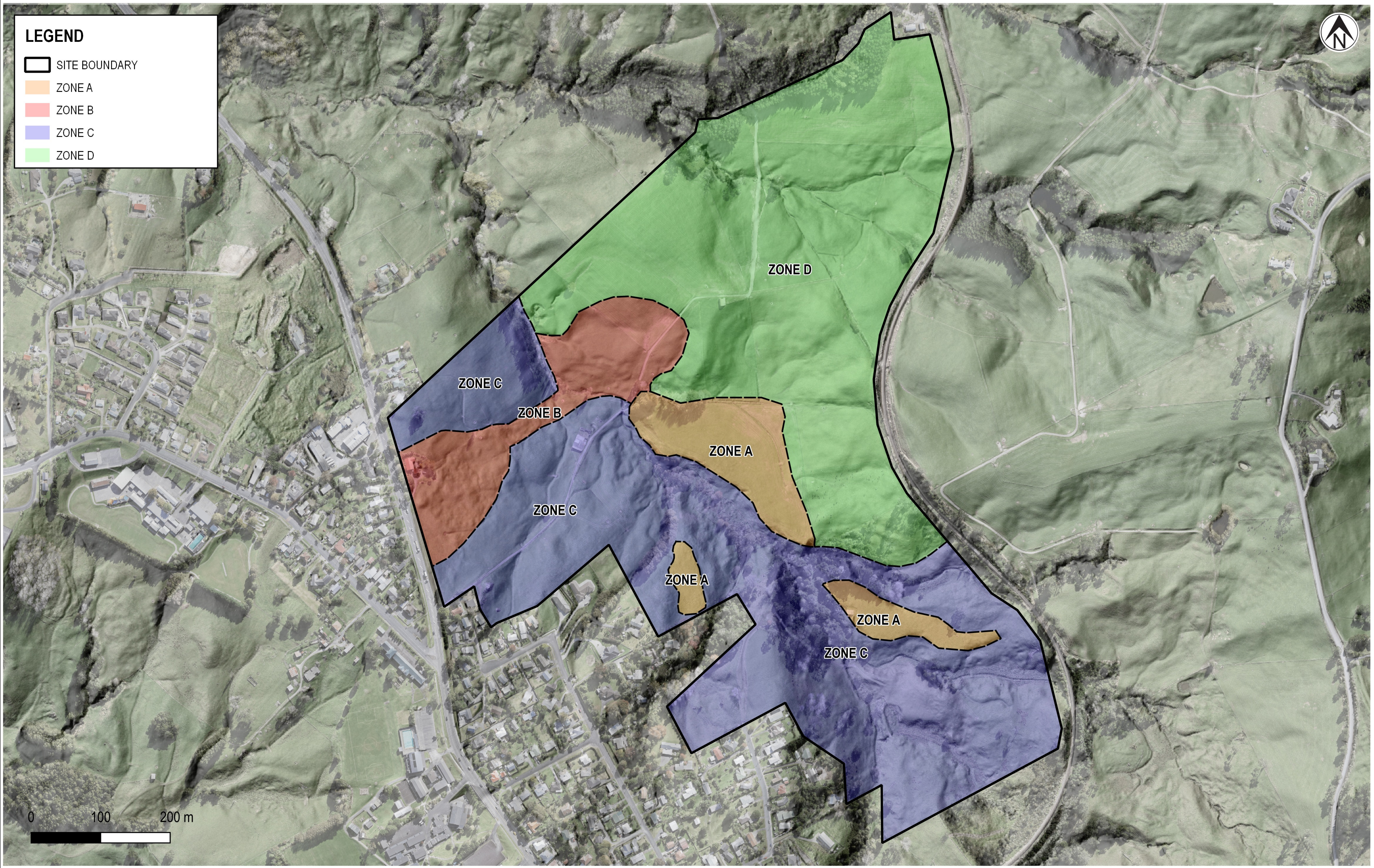
CHECKED	MCHI	DEC.21
APPROVED	MRT	DEC.21

CLIENT WELLSFORD WELDING CLUB LTD
PROJECT WELLSFORD RESIDENTIAL DEVELOPMENT
TITLE GEOLOGY AND GEOMORPHOLOGY PLAN

SCALE (A3) 1:5,000 FIG No. FIGURE 2. REV 0

C:\Users\jala\Documents\QGIS\Projects\Wellsford Residential Development\Maps\Wellsford Residential Development.qgz Layout: ZONE MAP Drawn by JALA



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REV	DESCRIPTION	GIS	CHK	DATE
0	First version	JALA	MCHI	08/10/21

LOCATION PLAN

PROJECT No.	1018519	
DESIGNED	JALA	DEC.21
DRAWN	JALA	DEC.21
CHECKED	MCHI	DEC.21
APPROVED	MRT	DEC.21

CLIENT **WELLSFORD WELDING CLUB LTD**
PROJECT **WELLSFORD RESIDENTIAL DEVELOPMENT**
TITLE ZONE MAP

SCALE (A3) 1:5,000 FIG No. FIGURE 3. REV 0

Appendix B: Aerial photographs

Figure B-1: 1961 Aerial photograph (Retrolens)

Figure B-2: 1966 Aerial photograph (Retrolens)

Figure B-3: 1973 Aerial photograph (Retrolens)

Figure B-4: 1982 Aerial photograph (Retrolens)

Figure B-5: 1992 Aerial photograph (Retrolens)

Figure B-6: 2006 Aerial photography (Google Earth)

Figure B-7: 2010 Aerial Photograph (LINZ)

Figure B-8: 2014 Aerial Photograph (LINZ)

Figure B-9: 2017 Aerial Photograph (LINZ)