

Appendix I Geotechnical Memo

Memorandum

Subject: ARL Project – Geotechnical Memorandum
Reference No: 1101798
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Date: 28 July 2026

1 Introduction

WM New Zealand (WMNZ) has engaged Tonkin & Taylor Ltd (T+T) to prepare technical memoranda for the proposed new solid waste management and disposal facility in the Wayby Valley, north of Auckland ('ARL' or 'Project').

The Project will involve constructing, operating, closing and providing aftercare for a new 24 Mm³ landfill facility and associated infrastructure at Wayby Valley, Wellsford. Ngāti Manuhiri are Project partners and will work with WMNZ on the proposed management and mitigation measures. Once landfilling ceases, the land will be returned to Ngāti Manuhiri as tāngata whenua.

The new landfill will be a Class 1 landfill, as defined in the Technical Guidelines for Disposal to Land (WasteMINZ Technical Guidelines)¹, accepting municipal solid waste. This includes residential and commercial waste, construction and demolition waste, some industrial wastes that meet acceptance criteria, and contaminated soils. Following waste settlement, the landfill cap surface will have a maximum height of 205 m RL.

WMNZ landholdings in the Wayby Valley area comprise a total area of 1020 ha, with the landfill footprint being approximately 60 ha. The WMNZ landholdings have been divided into five general areas; the Eastern Block, the Western Block, the Southern Block, the Waiwhiu Tributary Block and the Waiteraire Tributary Block. The proposed works will involve the following:

- **Site access and operation:** Construction of site access roads, weighbridges, and a vehicle wheel wash.
- **Landfill development:** Major earthworks and the installation of environmental management systems, including a landfill lining system and collection networks for leachate, stormwater, and landfill gas (LFG).
- **Leachate and landfill gas management:** A dedicated leachate management system and a LFG treatment facility, including a LFG flare and a LFG waste-to-energy plant.
- **Support infrastructure:** Facilities for site staff, plant maintenance, and water supply.
- **Terrestrial, freshwater and wetland biodiversity measures:** This includes native revegetation, and a weed and animal pest management programme to offset or compensate for residual adverse effects on terrestrial, freshwater and wetland ecology.

This memorandum provides an outline of the initial findings of the geotechnical assessment and has been prepared for inclusion in an application for Ministerial referral of the Project under the Fast-track Approvals Act 2024 ('FTAA'). Specifically, this memorandum responds to the requirements under section 3.4 of the Fast-track Approvals Referral Application Form and section 13(4)(h) of the

¹ Technical Guidelines for Disposal to Land, WasteMINZ, September 2023, Revision 3.1.

FTAA. A full description of the draft proposal is included in the accompanying information attached to the application form for the referral.

2 Summary of findings

Comprehensive geotechnical investigations have been undertaken for the Project from 2018 through to 2024, comprising 35+ machine boreholes, over 100 hand augers, 35 test pits, and 6 CPT soundings, supplemented by extensive laboratory testing and geophysical surveys.

The site is underlain primarily by Pakiri Formation (interbedded sandstone and siltstone) and Northland Allochthon sediments. The key geotechnical hazards and risks identified for the Project include slope instability, low-lying weak ground, settlement, groundwater seepage, subsurface 'tunnel' gully erosion (locally referred to as 'tornos') and seismic ground shaking. These hazards are well understood and can be appropriately managed through conventional geotechnical engineering techniques that are industry-standard in New Zealand.

Slope stability analyses demonstrate that the proposed landfill design achieves appropriate factors of safety above minimum acceptance thresholds, providing substantial confidence in the design. Under seismic loading conditions (0.25g PGA for 2500-year return period), calculated displacements are minimal (4mm for maximum credible earthquake) and would have negligible impact on landfill integrity.

The geotechnical design for various landfill components (slopes, dams, roads, stockpiles), has been developed in accordance with industry-standard codes including the NZ Geotechnical Society Slope Stability Guidance, Auckland Council Code of Practice for Land Development and Subdivision, Chapter 2, Earthworks & Geotechnical (2023), and NZTA Bridge Manual (SP/M/022 Third Edition, Amendment 4², effective May 2022). Geotechnical stabilisation measures and hazards mitigation measures include earthworks and drainage ground improvement works that will be implemented where required to ensure stability.

Based on the investigations and analyses undertaken to date, it is concluded that the site geotechnical conditions are suitable for the proposed landfill development, and that identified geotechnical hazards and risks can be appropriately managed to acceptable levels.

3 Assessment methodology

The geotechnical assessment has been based on both desktop studies and extensive field-based investigations conducted progressively between 2018 and 2024. Appendix A shows the extent of the geotechnical investigations undertaken to date. Intrusive geotechnical site investigations are ongoing for the main access road and landfill shell components.

3.1 Desktop assessment

Desktop-based tasks undertaken included:

- Review of published geological and geotechnical information for the region
- Review of regional seismicity and active fault databases
- Geomorphological assessment using LiDAR and aerial photography
- Review of previous geotechnical investigations in similar geological settings
- Assessment of regional groundwater conditions

² TAN#26-02, Seismic Resilience of new state highway bridges and soil structures (24 April 2026). Recent update to advise the Sector of the direction of the NZ Transport Agency Waka Kotahi (NZTA) regarding the adoption and implementation of updated seismic design standards in the design of new State Highway bridges and soil structures.

3.2 Field investigations

Field investigations that have been undertaken to date to inform this memo are included in Appendix B.

3.3 Geotechnical reporting

There is an extensive compendium of geotechnical reporting relating to the ARL. These documents describe the key geotechnical investigation, and design works that have been undertaken to date. These documents collectively underpin and validate the findings presented in this geotechnical technical memorandum for Ministerial referral under the Fast-track Approvals Act 2024.

4 Site and project context

4.1 Geological setting

The site is in a region of relatively complex geology within the North Auckland region. The key geological units relevant to the geotechnical assessment include:

- **Pakiri Formation:** The dominant bedrock unit underlying the proposed landfill footprint comprises interbedded sandstone and siltstone of Early Miocene age. The formation is characterized by:
 - Closely interbedded sequences with individual bed thicknesses ranging from centimetres to several meters.
 - Sedimentary bedding predominantly dipping gently (5° to 20°) to the east and northeast.
 - Variable weathering with residual soil to highly weathered rock extending up to 10 m below ground surface.
 - Moderately to slightly weathered rock characterized by widely spaced joints and some tectonically disturbed zones.
 - Landslide deposits comprising chaotic debris and displaced bedrock blocks up to 10 m deep - controlled by rock mass effects including bedding plane shears.
- **Northland Allochthon:** Located in the Western Block, west of the proposed main stockpile, comprising:
 - Soft to stiff clay and silt materials.
 - Variable thickness, locally exceeding 10m.
 - Potentially compressible where alluvial deposits are present.
- **Residual Soils and Colluvium:** Overlying bedrock across the site, comprising:
 - Stiff to very stiff silty clay materials derived from weathering of underlying bedrock.
 - Typically, 2-4m thick, locally up to 8m.
 - Some areas affected by shallow landslide processes.
- **Alluvium:** Present in valley floor locations, comprising:
 - Soft to firm clayey silt materials.
- Up to 11m thick in the Main Stockpile and Main Access roundabout areas.
 - Generally assessed as non-liquefiable based on CPT testing.

4.2 Hydrogeological conditions

Three groundwater systems have been identified:

- 1 **Perched groundwater:** In residual soil cover, typically responding rapidly to rainfall.
- 2 **Upper fracture aquifer:** In weathered to moderately weathered Pakiri Formation, characterized by variable permeability.
- 3 **Deep fracture aquifer:** In slightly to unweathered Pakiri Formation with variable rock mass fracture permeability.

Lugeon testing indicates highly variable bedrock permeability ranging from 0 to over 100 Lugeon units, with higher permeability associated with open fractures and broken zones.

4.3 Key project elements from a geotechnical perspective

From a geotechnical engineering perspective, the critical project elements include:

Landfill base grade preparation:

- Large-scale cut-to-fill earthworks required to create stable base grade platform
- Stabilisation and / or removal of potentially unstable soils and landslide materials
- Installation of comprehensive subsoil drainage to intercept groundwater seepage
- Achievement of design factors of safety for base grade slopes

Landfill lining system:

- Foundation on competent Pakiri Formation bedrock or engineered fill
- Protection from differential settlement, subsurface tunnel erosion and slope instability
- Interface friction design for geomembrane and geotextile components

Waste slopes and final capping:

- Stability of waste mass during filling operations and final configuration
- Design height up to 205 mRL with internal benching
- Final capping system requiring long-term stability

Access roads:

- Cuts within Pakiri Formation soil and rock requiring slope stabilisation
- Potential for rock fall hazards requiring mitigation measures
- Design slope angles to achieve design stability factors of safety

Main stockpile area:

- Foundation on potentially compressible alluvial soils up to 11m thick
- Settlement assessment and ground improvement requirements
- Stability of stockpile embankment slopes

Dam structures:

- Multiple stormwater detention dams, reservoirs and wetland area
- Slope stability and stabilisation requirements
- Foundation assessment on Pakiri Formation
- Seepage control requirements
- Note: Dam design is subject to separate assessment in accordance with NZSOLD guidelines

5 Assessment of potential effects

Based on the proposal and the information available, an assessment of potential effects has been undertaken and summarised below.

5.1 Slope stability

5.1.1 Existing conditions

The potential for slope instability has been identified as a key geotechnical consideration for the Project. The Pakiri Formation bedrock, which underlies most of the site, requires careful engineering practices to address slope instability hazards. These slope instability considerations are typical for the region and can be addressed with conventional earthworks and ground improvement techniques.

Multiple existing landslide features have been identified and investigated within the Project area, including features designated as 'Kea' and 'Moa' landslides. These features are characterized by disrupted soil profiles, sharp shear contacts, and evidence of past movement.

5.1.2 Construction phase effects

During construction, temporary slope instability effects may arise as a result of:

- Exposure of weak geological horizons during excavation
- Temporary reduction in slope stability during cut operations
- Potential for rainfall-induced shallow failures in excavated slopes
- Groundwater seepage and pore pressure increases

5.1.3 Operational and post-closure effects

During landfill operations and post-closure, potential effects may include:

- Progressive buttressing of foundation slopes as waste is placed, which progressively improves the landfill shell slope stability
- Changes to groundwater regime due to lining system installation and leachate generation
- Long-term weathering of exposed cut slopes
- Landfill settlement and slope stability considerations

5.1.4 Mitigation and management

Comprehensive slope stability analyses have been undertaken for all critical slope elements using limit equilibrium methods. Design factors of safety have been established based on industry-standard criteria, as presented in Table 5.1 below.

Table 5.1: Geotechnical design factors of safety

Design Scenario	Minimum FoS
During Construction slopes – design groundwater conditions	1.3
During Construction slopes – elevated groundwater	1.1
Final design slopes – design groundwater conditions	1.5
Final design slopes– elevated groundwater/leachate	1.3
Final design slopes – extreme groundwater/leachate	1.1

Typical slope stabilization measures to be implemented include:

- Relocation of infrastructure to avoid localised landslide areas where practicable
- Bulk earthworks to remove or buttress unstable materials
- Shear key earthworks within critical slopes
- Installation of subsoil drainage including sub-horizontal bored drains,
- Surface water cut-off drains,
- Slope strengthening measures including in-ground palisade walls, soil nailed mesh, or deep soil mixing where required
- Progressive construction staging to manage temporary stability

5.2 Tunnel gully erosion

5.2.1 Nature of hazard

Subsurface tunnel gully erosion are subsurface erosion features created by concentrated groundwater flow removing soil along geological boundaries. The process typically occurs in the upper soil profile where surface water infiltrates and concentrates along less permeable layers.

Site inspections, including a walkover with local landowners, have identified several tunnel gully erosional features in the vicinity of the site. These features manifest as lines of sinkholes connecting subsurface voids, which can pose a hazard to features built above them.

5.2.2 Assessment

The tunnel gully erosional hazard is assessed as being confined to the shallow (< 3 m) surficial soil layers overlying bedrock. Key factors in the assessment include:

- The features observed are relatively shallow in nature
- They are associated with surficial soil layers rather than deep-seated geological structures
- Similar features in the area are related to surface water concentration and infiltration.

5.2.3 Management

Tunnel gully erosional hazards will be managed through:

- Removal of potentially affected surficial soils during landfill base grade preparation
- Installation of the fully lined and sealed landfill structure which will limit surface water infiltration
- Comprehensive subsoil drainage beneath the landfill lining system to control groundwater seepage
- Surface water management to prevent concentrated infiltration
- Ongoing monitoring and maintenance of drainage systems

Based on these control measures, the development of tunnel gully erosion beneath the constructed landfill shell is assessed as unlikely.

5.3 Seismic hazards

5.3.1 Seismic setting

The Project is located in a region of relatively low seismic hazard in New Zealand terms. The nearest significant active faults are:

- Kerepehi Fault Zone: approximately 70 km southeast
- Wairoa North Fault Zone: approximately 80 km south

A site specific Probabilistic Seismic Hazard Assessment (PSHA) was undertaken in 2019. That assessment indicated a peak ground acceleration (PGA) of 0.19 g.

Since that time, the 2022 National Seismic Hazard Model (NSHM2) has been released. For seismic design purposes, a PGA of 0.25 g has been adopted, based on a 2,500-year return period earthquake with a magnitude of 6.3, as derived from the 2022 NSHM³ for a Vs30 value of 375 m/s (approximately equivalent to a Class C site).

The adoption of the higher PGA reflects the use of the most up-to-date national seismic hazard information.

5.3.2 Seismic slope displacement

Where a calculated FoS of less than 1.0 is achieved for the seismic loading conditions, the yield acceleration and slope displacement has been assessed using 50th percentile values as recommended by the Auckland Council Code of Practice for Land Development and Subdivision, Chapter 2, Earthworks & Geotechnical (2023). Seismic slope displacement analyses have been undertaken using three industry-accepted methods.

For the landfill stability analyses, under the Maximum Credible Earthquake (MCE) scenario:

- Calculated factor of safety: 0.8
- Maximum displacement: 4 mm

These minimal displacements demonstrate that seismic loading would have negligible impact on the integrity of the landfill lining system or capping systems.

5.3.3 Liquefaction

CPT-based liquefaction and lateral spreading assessments have been undertaken in low lying areas underlain by weak, saturated and potentially liquefiable alluvial soils. These assessments indicate low to moderate liquefaction susceptibility for the low-lying alluvial soils at the site, which will be managed with appropriate soil removal/replacement or ground improvement work.

5.4 Settlement and compressibility

Potentially compressible alluvial soils exceeding 10 m thickness are locally present in low lying areas. CPT and a suite of laboratory tests, including oedometer testing has been carried out.

Settlement assessments will inform foundation design and any potential ground improvement requirements. Options include preload / surcharging, staged construction, and installation of wick drains or stone columns to accelerate and manage the settlement and during construction slope stability.

5.5 Groundwater and seepage

Groundwater springs and seepage will be managed as follows:

- Interception of seepage springs during base grade excavation
- Installation and maintenance of subsoil drainage networks
- Protection of lining system from uplift pressures

³ National Seismic Hazard Model, issued by GNS Science

- Long-term monitoring of piezometric levels
- The comprehensive subsoil drainage system beneath the landfill lining will intercept and control groundwater, protecting the lining system integrity.

6 Conclusions

Comprehensive geotechnical investigations and analyses have been undertaken to support the development of the Project. The investigations have progressively advanced from the feasibility level phase (2018-2019) through to detailed design phase (2023-2024). Ground modelling and design has been based on over 35 machine boreholes, 100+ hand augers, test pits, CPTs, and extensive laboratory testing programs.

The key geotechnical hazards and risks identified for the Project include slope instability, low-lying weak ground, groundwater seepage, subsurface tunnel gully erosion, settlement and seismic ground shaking. These hazards are well understood and can be appropriately managed through conventional geotechnical engineering techniques that are industry-standard in New Zealand.

The geotechnical design input to date has been developed in accordance with relevant industry standards including the NZ Geotechnical Society Slope Stability Guidance, Auckland Council Code of Practice for Land Development and Subdivision, Chapter 2, Earthworks & Geotechnical (2023), and NZTA Bridge Manual (SP/M/022 Third Edition, Amendment 4, effective May 2022). The design incorporates appropriate factors of safety and has been subjected to sensitivity analyses to confirm robustness.

Based on the comprehensive investigations and analyses undertaken, it is concluded that the site is geotechnically suitable for the proposed landfill development. The identified geotechnical constraints and effects can be appropriately avoided, remedied, or mitigated through:

- Implementation of comprehensive slope stabilization measures including ground improvement shear keys, slope buttresses, soil nail and in-ground palisade walls
- Installation of extensive subsoil drainage and surface horizontal drain clusters to control groundwater
- Progressive construction staging with monitoring to manage temporary works
- Design in accordance with industry-standard codes and peer-reviewed methodologies
- Ongoing geotechnical monitoring during construction and operations

The geotechnical design provides for a landfill structure that will be stable during construction, operation, and post-closure phases, with appropriate margins of safety to account for uncertainties and extreme loading conditions.

7 Applicability

This technical memorandum has been prepared for the exclusive use of our client WMNZ, 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 WMNZ will submit this report to the Environmental Protection Authority in support of a referral application under the Fast-track Approvals Act 2024 for the works described herein, and that the Environmental Protection Authority will rely on this report for the purpose of assessing that application.

Tonkin & Taylor Ltd

Lead Author:

Authorised for Tonkin & Taylor Ltd by:

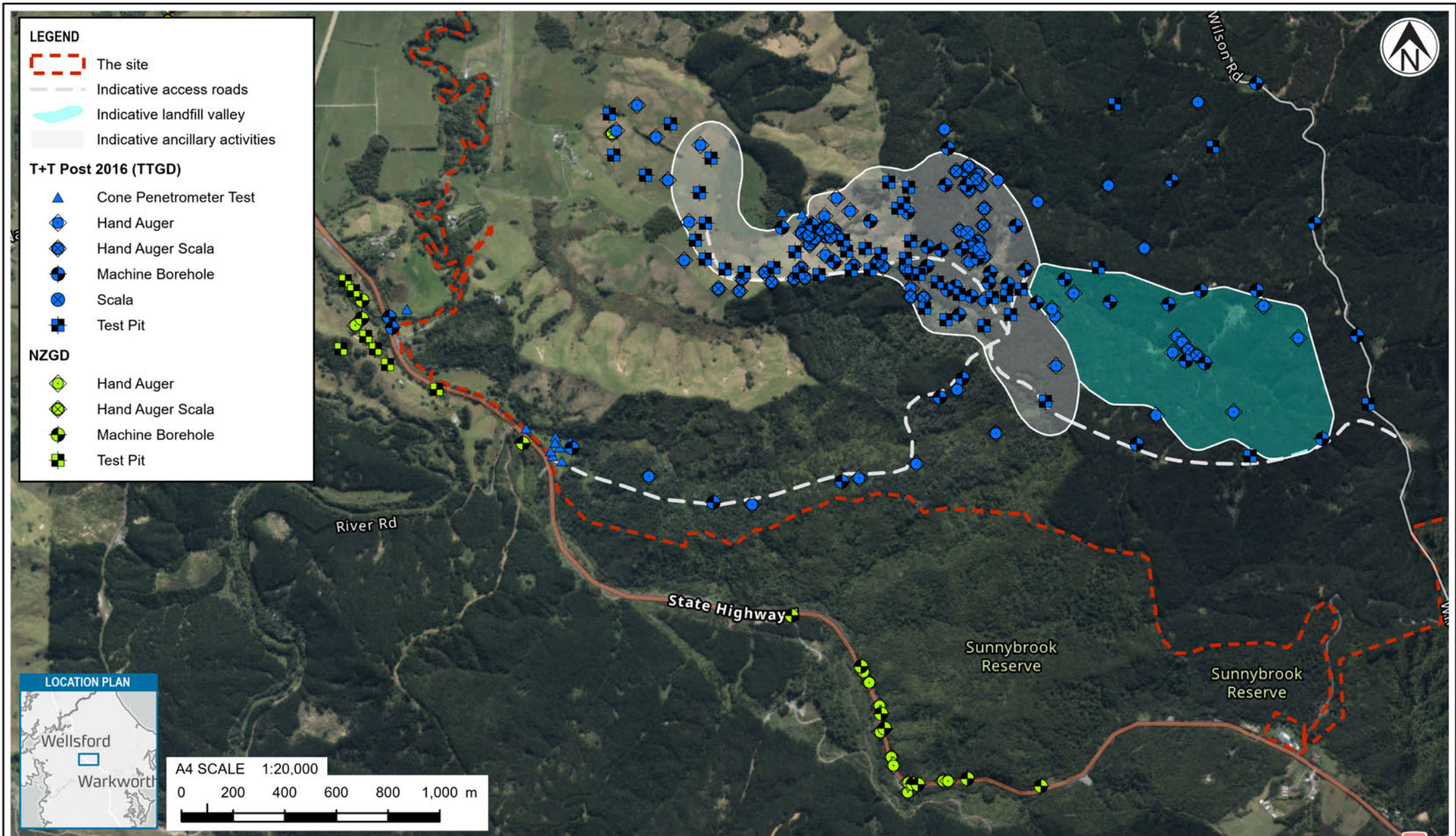


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Appendix A Figures

**NOTES:**

1. TTG/Geotechnical Investigations: Tonkin & Taylor Group, NZ Hybrid Reference (Vector): Eagle Technology, LINZ, StateNZ, NIWA, Natural Earth, © OpenStreetMap contributors. The site: NZ Imagery: Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors. TTNZ Canvas - NZ Places + Boundary Labels: QSM, State NZ, LINZ, Aotearoa New Zealand Hillshade: Eagle, LINZ, NZ Light Grey Canvas - Basemap Only.

REVISIONS

First version
31/07/26

NO.

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PROJECT ARL FAST TRACK

TITLE GEOTECHNICAL INVESTIGATIONS

SCALE (A4) 1:20,000

FIG No. FIGURE 1.

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Appendix B Field investigations

Field investigations have been comprehensive and staged to support concept and detailed design phases:

B1.1 Initial investigations 2018 to 2019

- 14 machine boreholes (BH1-BH14) up to 50m depth
- 40 Hand auger boreholes
- 10 machine excavated Test pits
- Lugeon (packer) permeability testing in all machine boreholes
- Geophysical investigations including downhole shear wave velocity testing and Multi-channel Analysis of Surface Waves (MASW)
- Installation and monitoring of 14 groundwater piezometers

B1.2 Addendum investigations 2020

- Additional deep borehole BH15 (130.5m depth) with downhole geophysical survey
- 3D geological modelling using Leapfrog software
- Enhanced Lugeon testing program

B1.3 Additional investigations 2023 to 2024

- 15 additional machine boreholes (BH101-129)
- 41 Hand auger boreholes
- 35 machine excavated Test pits
- Cone Penetration Tests (CPTs)
- Targeted investigations of identified landslide areas

B1.4 Laboratory testing

Extensive laboratory testing programs were undertaken including:

- Atterberg limits and moisture content testing
- Particle size distribution analyses
- Heavy compaction testing (Standard and Modified Proctor)
- Consolidated-undrained (CU) triaxial testing
- Unconfined compressive strength (UCS) testing of rock
- Point load testing
- Slake durability testing
- Triaxial permeability testing
- Pinhole dispersivity testing
- Allophane content testing
- 1D consolidation (oedometer) testing
- Ring shear testing