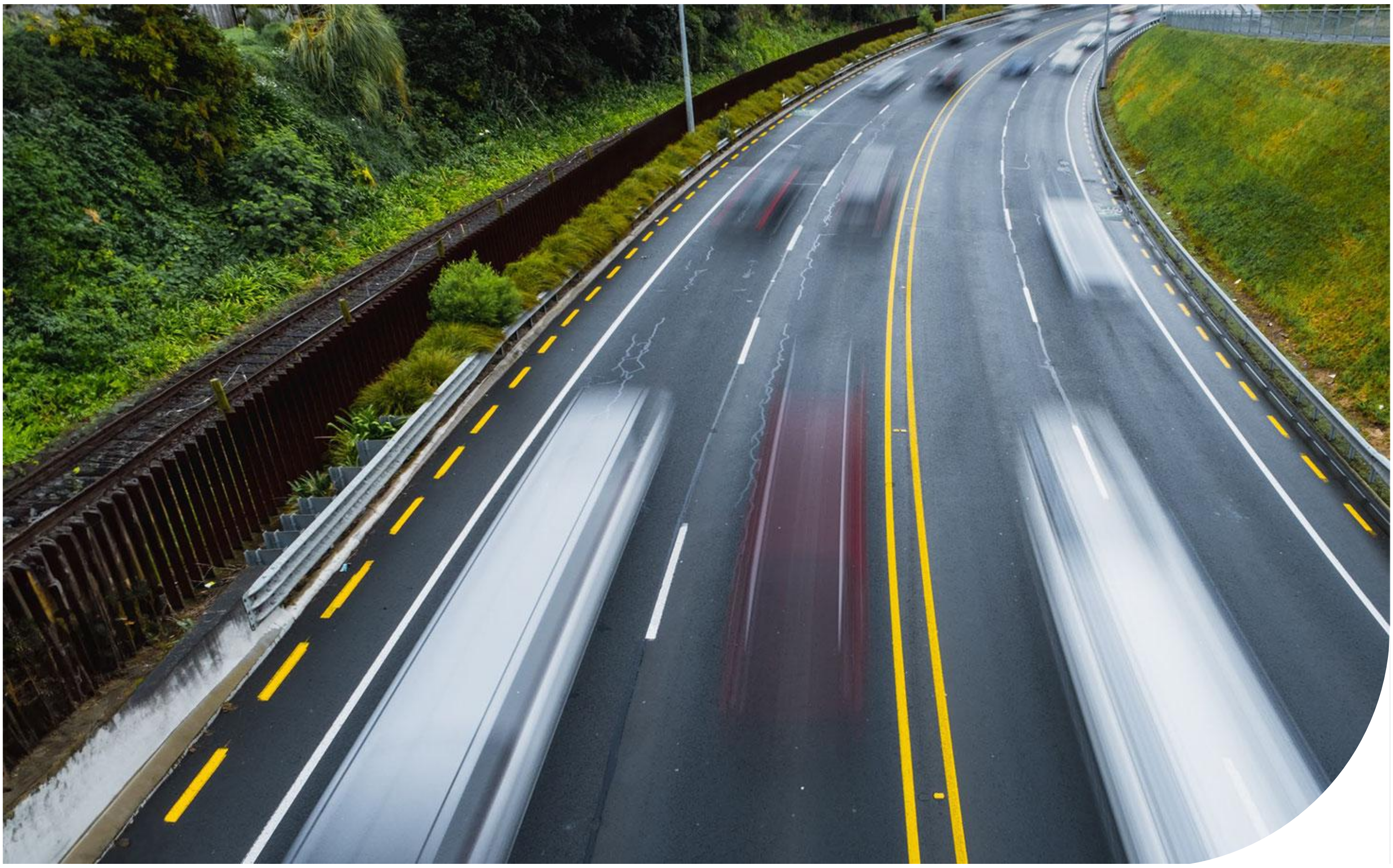

# Alternative to Brynderwyn Hills, Stage 1 Ground Investigation Report

## Northland Corridor

24 August 2026

Revision C

10722-PTA-2BO-GO-RPT-0001

Roads of National Significance

Te Kāwanatanga o Aotearoa
New Zealand Government

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# 1. Abbreviations and Report Purpose

## 1.1. Abbreviations

The terms and acronyms detailed in Table 1 are used throughout this document.

*Table 1: Acronyms and Definitions*

| Acronym | Definition |
|---|---|
| ATV | Acoustic Televiewer |
| bgl | Below ground level |
| BH | Borehole |
| CPT | Cone Penetration Test |
| CW | Completely Weathered |
| g | Gram/s |
| GNS | Institute of Geological and Nuclear Sciences (GNS Science) |
| GPS | Global Positioning System |
| HW | Highly Weathered |
| JV | Joint Venture |
| km | Kilometre/s |
| kN | Kilonewton/s |
| kPa | Kilopascal/s |
| m | Metre/s |
| $m^2$ | Squared metre/s |
| $m^3$ | Cubic metre/s |
| mg | Milligram/s |
| mm | Millimetre/s |
| MN | Meganewton/s |
| m bgl | Metre/s below ground level |
| MW | Moderately Weathered |
| NZGS | New Zealand Geotechnical Society |
| NZTA | New Zealand Transport Agency |
| NZTM | New Zealand Transverse Mercator 2000 co-ordinate system |
| OTV | Optical televiewer |
| RoNS | Road of National Significance |
| RS | Residual Soil |
| SH1 | State Highway 1 |
| SPT | Standard Penetration Test |

| Acronym | Definition |
|---|---|
| SPT ‘N’ | Standard Penetration Test, the “N” value |
| SW | Slightly Weathered |
| t | Tonnes |
| TP | Test Pit |
| UCS | Unconfined Compressive Strength |
| UW | Unweathered |

## 1.2. Report Purpose

The purpose of the Ground Investigation Report is to present the factual data obtained from the Alternative to Brynderwyn Hills Stage 1 ground investigation.

Ground Investigation types include tracked boreholes (BHs), cone penetration tests (CPTs) and test pits (TPs). Naming of investigations follow the nomenclature outlined below:

- Rotary Cored Boreholes BH2B_1000
- Wash/install/additional Boreholes BH2B_1000A
- Sonic Boreholes BH2B_1000B
- Cone Penetration Tests CPT2B_1000
- Test Pits TP2B_1000

# 2. Introduction

## 2.1. Project Overview

The Alternative to Brynderwyn Hills section of the Northland Corridor Project Consent Design (Figure 1) comprises the following major elements:

- Construction of a four lane, grade separated rural motorway, each lane being 3.5m wide with 3m shoulders to wire rope safety barrier, 1.5m of which is sealed and a 3.0m median.
- A 110 km/hour speed limit in accordance with the NZTA Standardised design solutions for use on RoNS.
- An interim at-grade connection with SH1 at Pukekaroro (SH1/Baldrock Road).
- A grade separated interchange at SH12.
- A Diamond dog-bone interchange at Waipu between Millbrook Road and Shoemaker Road.


*Figure 1: Alternative to Brynderwyn Hills section of the Northland Corridor*

For the purpose of this assessment, the Alternative to Brynderwyn Hills has been separated into four zones that reflect the earthworks requirements and conditions of different areas of the Project (refer Figure 2):

**Zone 1** – The Northern Lowlands, from the Interim Waipu Interchange, extending across the alluvial plains to the foot of the northern edge of the Brynderwyn Hills.

**Zone 2** – The Brynderwyn Hills, extends from the northern edge of the Brynderwyn Hills to the bottom of the southern escarpment.

**Zone 3** – Brynderwyn Hills to SH12 extends from Piroa Stream to the proposed SH12 interchange.

**Zone 4** – SH12 to Pukekaroro, stretching from the proposed SH12 interchange to north of Pukekaroro.

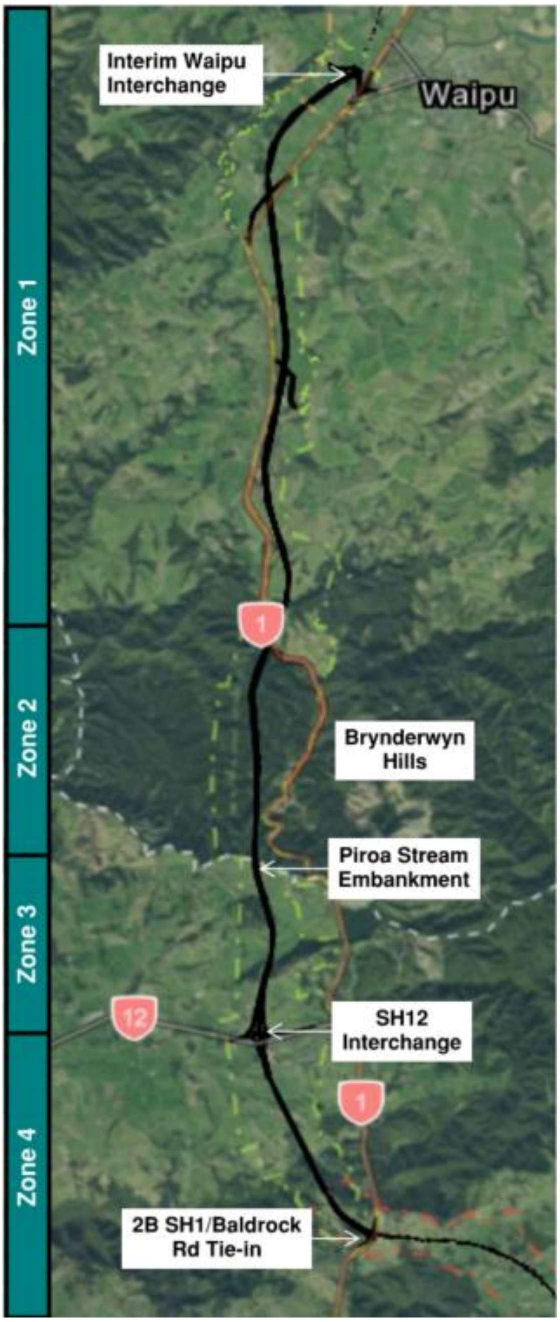


*Figure 2: Alternative to Brynderwyn Hills- Earthwork Zones*

# 3. Site Setting

## 3.1. Regional Geology

The geology encountered along the Alternative to Brynderwyn Hills preferred route represents a condensed expression of the regional stratigraphic and structural framework. The broad distribution of geological units encountered and expected within the preferred route extents are summarised below and shown in Figure 3. The indicative alignment is shown in red for reference.

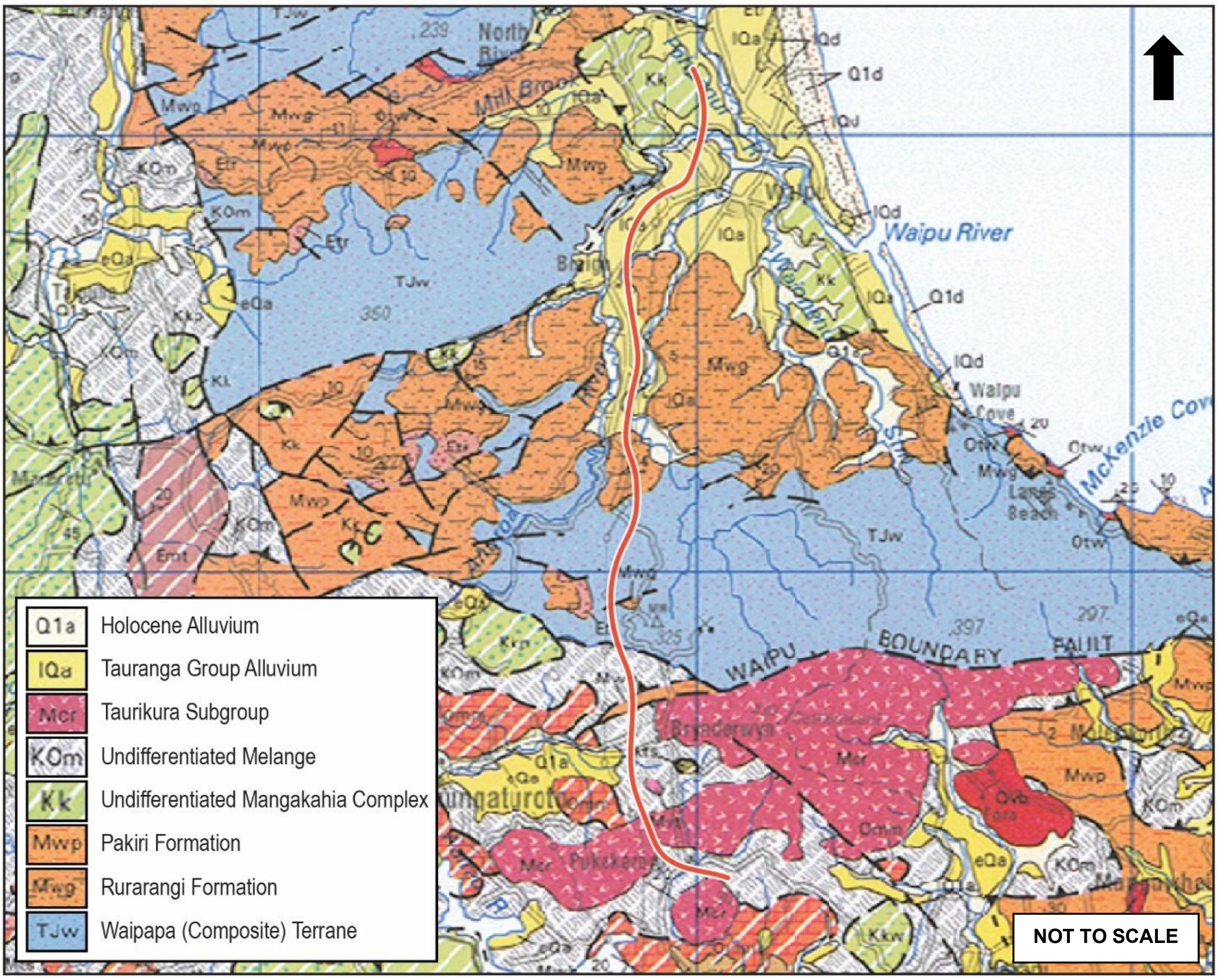


*Figure 3: Alternative to Brynderwyn Hills preferred route mapped geology. Adapted from Edbrooke & Brook (2009).*

Basement rocks of the Waipapa Composite Terrane are inferred to underlie the entire preferred route, but are exposed only within the Brynderwyn Hills, where they comprise steeply dipping and highly fractured greywacke and argillite. North of the Brynderwyn Hills, the basement is unconformably overlain by the Waitemata Group's Ruarangi Formation, comprising interbedded calcareous sandstone and siltstone. The Ruarangi Formation is mapped as isolated pockets across the ridge tops and at the foot of the Brynderwyn Hills and is inferred to be encountered beneath alluvial cover along the Ahuroa River valley (Northern Section of Alternative to Brynderwyn Hills). To the south of the Brynderwyn, Hills, a single fault-bounded occurrence of Pakiri Formation sandstone is present, possibly representing a para-autochthonous raft within the Northland Allochthon.

The Northland Allochthon is mapped both to the south of the Brynderwyn Hills, and at the very northern end of the Preferred Route. The Allochthon includes deformed 'blocks' of mudstone, calcareous siltstone, and sandy limestone of both the Motatau and Mangakahia Complexes, as well as extensive melange, often with a pervasively sheared matrix comprised of distinctive red-green Hukerenui Mudstone and hosting variously sized blocks from meters to kilometre scales. The Allochthon is generally pervasively sheared throughout, displaying disrupted bedding and brecciation consistent with its emplacement via thrusting and gravity sliding. The mapped geology indicates the Allochthon at the north end of the Preferred Route consists of structurally complex units of tectonically intercalated non-calcareous sandstone and mudstone.

Dacite intrusions and domes of the Taurikura Group are locally present to the south of the Brynderwyn Hills within the Preferred Route. The dacite domes are generally small, overlapping bodies and are inferred to have been intruded through and flowed out onto the Northland Allochthon.

Quaternary alluvial and colluvial deposits mantle low-lying areas, valley floors and slopes throughout the preferred route, with the largest accumulations of alluvium (both Pleistocene Tauranga Group and Holocene aged sediments) encountered along the Ahuroa River and its tributary valleys.

# 4. Ground Investigation

## 4.1. Investigation Scope and Workflow

For the Alternative to Brynderwyn Hills Section of the Northland Corridor Roads of National Significance Project, the ground investigation has been split into 3 stages:

- Stage 1: To inform Consent Design, including development of the geotechnical framework initial ground models and initial earthworks and risk assumptions
- Stage 2: To inform reference design, leading to further refinement of ground models, design and risk assumptions.
- Stage 3: Procurement ready Investigations. Additional investigations to inform Tender phase

The Aurecon-WSP Joint Venture (JV) has been contracted to provide site investigations for Consent Design (Stage 1) purposes for the Northland Corridor Road of National Significance, Alternative to Brynderwyn Hills Section.

The original planned intrusive scope is outlined in Table 2 below.

*Table 2: Stage 1 Planned Investigations*

| Investigation Type | Stage 1 Planned Quantity |
|---|---|
| Rotary Cored Borehole (BH) | 60 |
| Sonic Borehole (BH) | 0 |
| Washbore (WB)/iVane | 5 |
| Cone Penetration Test (CPT) | 17 |
| Test Pit (TP) | 25 |

To facilitate the ground investigations, the following workflow was completed:

### 4.1.1. Access Constraint Considerations

Ground investigations in the project corridor are constrained by land access issues, utility networks, and existing infrastructure. Investigations were positioned across:

Private Property: property parcels owned by individuals. Access to these properties required an approved LTO.

### 4.1.2. Access Development and Ecological Considerations

- Multiple locations along the alignment required development of access tracks. Within Waipu Forest, old forestry tracks were re-formed for access to borehole locations. Vegetation was cleared where required.
- When vegetation needed to be disturbed for ground investigation purposes, JV Ecologists inspected the sites and conducted onsite ecological features and risk checks. If any potential risks to ecological values were identified, the investigative locations were adjusted to avoid these areas. In some cases, borehole site access was modified from using access tracks. In other cases, passive management was employed, and small pieces of low value habitat were carefully moved outside of the disturbed areas to deter fauna using the site during works.

- Terrain evaluation and mapping, including desktop mapping and associated field observations, was also undertaken and have been reported on separately in the Geology and Geotechnical Assessment Report.

### 4.1.3. Utilities Avoidance

- A utilities avoidance workflow, designed to reduce risk of working proximal to buried and overhead services was implemented for the GI programme. Desktop service location enquiries on the BeforeUDig platform were followed by service location undertaken by LocatorMan alongside representatives from the JV, the drilling and/or test pit partner, and Mana Whenua (Te Uri o Hau, Patuharakeke and/or Te Parawhau).
- In locations where gas or fuel utility setback distances had to be confirmed, written approval from First Gas (First Gas' Maungaturoto transmission pipeline) was obtained for the following Investigation IDs: BH2B_1157, BH2B_1160, TP2B_1126, TP2B_1130, CPT2B_1116.

### 4.1.4. Cultural and Heritage Considerations

- Oversight of test pit excavation was undertaken by Mana Whenua (Te Uri o Hau, Patuharakeke and Te Parawhau) following Archaeological desktop assessment (*Alternative to Brynderwyn Hills, geotechnical investigation: archaeological desktop assessment,* CFG Heritage 2024). Where sites of interest were identified, a CFG Heritage Archaeologist reviewed the material excavated during test pitting and confirmed no artifacts had been disrupted.
- Prior to borehole drilling, Mana Whenua completed inspection of hand auger excavated material to 1.5m depth to evaluate potential cultural interest in near surface soils. Mana Whenua were also present for all test pitting. Cultural oversight requirements were completed in line with cultural monitoring protocol.

### 4.1.5. Core Storage

During the ground investigation programme, temporary and long-term core storage facilities were established at three locations:

- Wharehine Contractors, 1650 State Highway 1, Wellsford 0900 (Subsequent to the completion of earlier stages, temporary storage at Wharehine Contractors has since been discontinued).
- Old Swinging Cow Café, Corner State Highway 1 and State Highway 12, Brynderwyn 0587.
- Te Hana long term storage yard, 558 State Highway 1, Wellsford 0975

The storage facilities include an indoor core processing facility and core storage within weatherproof shipping containers. The containers have been fitted out with heavy duty shelving. A dedicated team manages the storage, recording, and sampling of all core boxes in accordance with design team requirements.

## 4.2. Summary of Completed Intrusive Works

Stage 1 investigations were undertaken between 18 August 2025 and 15 December 2025. The total quantities of each intrusive investigative type undertaken to date as part of Stage 1 are summarised in Table 3 with the Ground Investigation Location Plans included in Appendix A.

*Table 3: Alternative to Brynderwyn Hills Investigations Completed during Stage 1.*

| Investigation Type | Stage 1 |
|---|---|
| Rotary Cored Borehole (BH) | 53 |
| Sonic Borehole (BH) | 2 |

| | |
|---|---|
| Washbore/iVane | 4 |
| Cone Penetration Test (CPT) | 13 |
| Test Pit (TP) | 18 |

A number of Stage 1 Investigation locations could not be completed as part of the Stage 1 Investigation programme, and these are summarised in Table 4. As of 23 January 2026, 21 No. Stage 1 GI locations (9 No. BHs, 7 No. TPs and 5 No. CPTs) were rescheduled to be completed as part of the Stage 2 Investigations or cancelled.

*Table 4: Delayed or Cancelled Investigations*

| Reason for Delay or Cancellation | Investigation Locations BH | Investigation Locations TP | Investigation locations CPT |
|---|---|---|---|
| Property access denied / License to Occupy (LTO) not executed - To be completed with Stage 2 Investigations | BH2B_1102, BH2B_1103, BH2B_1123, BH2B_1123A, BH2B_1138, BH2B_1141, BH2B_1158, BH2B_1163 | TP2B_1122, TP2B_1123, | CPT2B-1101, CPT2B-1104, CPT2B-1116, CPT2B-1117 |
| Property access restrictions/on-hold - To be completed with Stage 2 Investigations. | | | CPT2B_1115 |
| Northern Alignment change (cancelled) | | TP2B_1117, TP2B_1118, | |
| Site constraints / License to Occupy (LTO) not executed (cancelled) | | TP2B_1126, TP2B_1127 | |
| No TMP approval (cancelled) | | TP2B_1105 | |
| Site constraints- position not practicable (cancelled) | BH2B_1112 | | |

## 4.3. Methodology

### 4.3.1. Borehole and Test Pit Logging/Field Test Guidelines

All soils and rocks on the project were logged and sampled in general accordance with *NZGS Guidelines Field Description of Soil and Rock, Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes (2005).*

SPT's were undertaken in accordance with *NZS 4402:1988 – Test 6.5.1* at 1.5m intervals. SPT samples were double bagged in order to maintain moisture content and placed in the core box at the relevant depth.

Hand-held shear vanes testing was undertaken in accordance with the *NZGS Guidelines for the Hand Held Shear Vane Test, 2001.* Calibration certificates for all handheld shear vanes are available in Appendix B2.

### 4.3.2. Surveying of Investigation Locations

Investigation locations were set out on-site relative to the planned investigation locations. Each investigation location was located according to site-specific conditions to avoid tree driplines, utilities, existing structures/infrastructure, and steep terrain. As built coordinates were captured using a Trimble R12i Receiver and TSC5 Controller. Vertical and horizontal accuracies for each location are shown on the individual borehole logs because each location position had different accuracies due to the survey method.

Borehole locations were recorded at surface level at the centre of the flush toby or backfilled hole or at surface level alongside an upstand. For holes measured during drilling, the measurement was taken either as close as possible to the hole (in the drilling pit the collar/lip surrounding the hole) or at an even offset on two opposite sides, with the average of both measurements used.

Test pit locations were recorded at ground surface level at the approximate centre of the backfilled pit. Vertical and horizontal accuracies for each location are shown on the individual borehole logs because each location position had different accuracies due to the survey method.

CPT and Dissipation test locations, completed by the WSP Laboratory, were recorded directly by the rig operator using a Garmin eTrex 20 with a maximum +/-3m horizontal accuracy.

The Site Investigation Location Plans are presented in Appendix A.

### 4.3.3. Rotary Cored Boreholes

Boreholes were undertaken by Drill Force NZ Limited, McMillan Drilling (N I) Limited, and Pro-Drill (Auck) Limited using both track and tractor mounted rotary core drilling equipment. A borehole summary table is presented in Appendix C1. A nomenclature guide for each logging system used (OpenGround and CoreGS) is available in Appendix C2. All borehole logs and photographs are presented in Appendix C3 and associated drilled depth vs. groundwater depth (DVD) plots are presented in Appendix C4.

The Stage 1 borehole investigations were undertaken between 18 August 2025 and 27 November 2025. The drilling rigs and Standard Penetration Test (SPT) hammers used are outlined in Table 5 and SPT hammer efficiencies are available in Appendix B1.

*Table 5: Drilling Rigs and SPT Hammers Utilised in Stage 1 Investigations*

| Company | Rig ID | Rig Make/Model | SPT Hammer |
|---|---|---|---|
| Drill Force NZ Limited | DF05 | Coretech YDX1800 | DF009 |
| Drill Force NZ Limited | DF99 | Tech Drill 250 HD | DF099 |
| McMillan Drilling (N I) Limited | MD1 | Hanjin/D&B 10 | N102 |
| McMillan Drilling (N I) Limited | MD2 | Hanjin/D&B 10 | N103 |
| Pro-Drill (Auck) Limited | ML02 | Fraste SRS | SRS ML 02 |
| Pro-Drill (Auck) Limited | CAT308 | CAT308 on Digger Rig | Cat308 |

Vertical boreholes were drilled using wireline triple tube coring methods using HQ or PQ core barrels.. All boreholes were logged, sampled and photographed by an Aurecon-WSP JV Engineering Geologist. Water level measurements were taken at the start and end of each shift (where possible) and recorded in DVD plots (Appendix C4).

In-Situ handheld shear vanes were undertaken where appropriate, within boreholes using a Pilcon Shear Vane with extension rods, to a maximum depth of 3m below ground level (bgl). Below 3m bgl, hand-held shear vanes were undertaken in the end of the core barrel. Results are presented on the relevant borehole logs (Appendix C3).

Thin wall 54mm diameter Push Tube samples (U54) were completed at a range of locations and depths in the soft and/or alluvial soils. The undisturbed samples were sealed onsite to maintain moisture content prior to transport. Where U54 samples were taken, they are recorded on the borehole logs in Appendix C3.

Following completion of the drilling operations, each borehole was flushed with clean water to remove drilling fluids and cuttings in preparation for downhole geophysical surveys and/or groundwater monitoring instrumentation installation. Where no groundwater instrumentation was installed, the borehole was backfilled with a cement/bentonite grout. Where shallow standpipe piezometer installations were required, these were installed in wash drilled boreholes, offset by a minimum of 1m from the adjacent cored borehole.

#### 4.3.4. Sonic Boreholes

A departure (10722-PTA-2B0-GL-DEP-0001) from *Technical Advice Note 20-09: Use of sonic drilling in ground investigations* was endorsed on the 28th November 2025 for the use of sonic drilling on Northland Corridor in specific ground conditions. In particular, sonic drilling was used to advance the borehole through dense alluvial gravels to allow recovery of the fine-grained matrix. Subsequently, two sonic boreholes were completed to address data gaps identified within rotary cored boreholes progressed through soft/ loose alluvial deposits where significant core loss was recorded. Sonic boreholes were undertaken by Pro-Drill (Auck) Limited using track mounted drilling equipment.

Sonic boreholes were drilled using wireline methods producing 83mm core.

All borehole logs and photography are presented in Appendix C3, and associated drilled depth vs. groundwater depth (DVD) plots are presented in Appendix C4.

#### 4.3.5. Cone Penetration Testing (CPT)

13 No. Cone Penetration Tests (CPT) were undertaken by WSP Laboratories using a Geomil Panther 100 rig with a dead weight reaction force of 13.1 tonnes and using a 10cm$^2$ cone.

Testing was focussed on the Northland Allochthon and alluvial materials. Stage 1 CPT's, completed to date, were undertaken between 29 September 2025 and 11 December 2025 and measured pore pressure, sleeve friction and cone resistance. CPT's were terminated at effective refusal or due to inclination variance.

Following a review of the CPT data, 5 No. CPTu tests (CPT2B-1102, CPT2B-1106, CPT2B-1107, CPT2B-1108, CPT2B-1114) have been noted to have unreliable pore pressure data, mainly caused by incomplete saturation of the pore pressure transducer

Testing locations are presented within Appendix A, and cone calibration certificates are in Appendix B4. A summary table can be found in Appendix D1, and the CPT logs are presented in Appendix D2.

#### 4.3.6. CPT Dissipation Tests

A total of 13 No. pore water pressure dissipation tests were undertaken alongside 9 No. CPT locations.

Stage 1 dissipation testing was undertaken between 29 September 2025 and 11 December 2025 and terminated at target depths. Test locations are presented within Appendix A. CPT logs and summary tables of CPT testing are included in Appendix D3.

#### 4.3.7. Machine Excavated Test Pits

A total of 18 No. test pits were excavated as part of the Stage 1 Ground Investigation and were completed between 15 September 2025 and 15 December 2025. The purpose of the test pits was to obtain bulk disturbed samples for earthworks re-usability assessment and to confirm the near-surface geology. All test pits were completed in accordance with *Northland Corridor Geotechnical Investigation Field Manual Appendix G: Test Pitting Procedure*.

Investigation locations are shown in Appendix A and summarised in Appendix E1. Test pits were excavated to depths between 1.8 m and 5 m bgl using a 16T excavator provided and operated by

Wharehine Construction Limited. Flat bladed and toothed buckets were utilised to achieve required depths, depending on the soils encountered.

Soil recovered from test pit were logged and sampled by an Aurecon-WSP JV Engineering Geologist. Photographs of the spoil and pit sides and base were taken. Upon completion, each pit backfilled with arisings compacted by the excavator. Test pit logs and photographs are presented in Appendix E2.

#### 4.3.8. In-situ Shear Vane (iVane)

4 No. in-situ shear vane (iVane) tests were undertaken by McMillan Drilling (N I) Limited using a Comacchio Geo 305 crawler mounted drilling rig. Separate wash boreholes were drilled to undertake testing at the locations outlined in Table 6, with further details provided in Appendix C5. Testing data from each iVane is available in Appendix C5 and calibration certificates are in Appendix B3.

*Table 6: I-Vane test depths*

| BH_ID | I-vane test depth (bgl) |
|---|---|
| BH2B_1104A | 1.7m, 4.8m, 7.8m, 10.8m |
| BH2B_1105A | 3.2m, 4.8m, 6.2m, 7.7m, 9.2m, 10.7m, 12.22m |
| BH2B_1122A | 3.0m, 5.0m, 7.0m, 9.0m |
| BH2B_1140A | 3.2m, 4.7m, 6.2m, 7.7m, 9.2m, 10.7m, 12.2m, 13.7m |

#### 4.3.9. Downhole Geophysics

Optical and Acoustic Televiewer Survey

Downhole optical and acoustic televiewer were completed by Resource Development Consultants Limited (RDCL) in 15 No. of the 55 No. boreholes using Acoustic Borehole Imager QL40/ABI40 GR, and Optical Borehole Imager QL40 OBI/OBI40 GR.

Optical and Acoustic televiewer logs are presented in Appendix C6.

Vertical Seismic Profiling (VSP)

Downhole seismic testing (vertical seismic profiling; VSP) was undertaken in one borehole (BH2B_1122A); see Appendix A for location details. The VSP testing was undertaken to develop models of seismic velocity with depth.

The VSP method uses seismic energy generated at the ground surface and recorded by geophones in a nearby borehole. The time for the seismic energy to travel from the source to the receiver provides a measurement of the seismic velocity in the material between the source and the receiver. Data obtained by different geophone depths were used to estimate a detailed vertical seismic velocity profile of the subsurface. These velocity models were then used to derive an estimate of $V_{S30}$ (time averaged shear-wave velocity for the upper 30m of the subsurface) at the surveyed borehole location.

A detailed description of the approach to VSP surveying including methodology, approach to analysis and the resulting velocity models and $V_{S30}$ values will be presented within a separate report alongside the Stage 2 data.

#### 4.3.10. Surface Geophysics

MASW

A Multichannel Analysis of Surface Waves (MASW) survey was conducted over eight days between 28 October and 28 November 2025, comprising seven survey lines, at locations shown on the Ground Investigation Plans (Appendix A).

The MASW technique is a surface seismic method which utilises the dispersive properties of surface waves to derive shear-wave velocity ($V_S$) profiles. The completed lines cover a total distance of 3200m. MASW measures variations in surface wave velocity with increasing distance and wavelength and can be used to infer variations in ground conditions.

A detailed description of the MASW surveys including acquisition methodology, approach to analysis and the resulting velocity profile models is presented in the *Northland Corridor Alternative to Brynderwyn Hills Section Surface Geophysics (Seismic Refraction and Multi-channel Analysis of Surface Waves) Methodology and Results* Memo (10722-PTA-2BO-GO-MEM-0003).

Seismic Refraction

A seismic refraction (SR) survey was performed on site between 30 October 2025 and 27 November 2025, over a total of four days, comprising of three survey lines, as shown in Appendix A. The completed SR lines cover a total distance of 780 m and were generally targeted to assess the depth to rock in areas of interest.

The SR technique uses the arrival times of refracted compressional waves to derive compressional-wave velocity ($V_P$) profiles and identify depths of high impedance contrasts such as the soil-rock interface. SR can be used to model the structural characteristics of the rock mass, evaluate bedrock excavatability, and provide and input parameters for geotechnical design.

A detailed description of the approach to SR surveying including acquisition methodology, approach to analysis and the resulting velocity profile models is presented in the *Northland Corridor Alternative to Brynderwyn Hills Section Surface Geophysics (Seismic Refraction and Multi-channel Analysis of Surface Waves) Methodology and Results* Memo (10722-PTA-2BO-GO-MEM-0003).

#### 4.3.11. Instrumentation and Monitoring

Vibrating Wire Piezometers

A total of 62 No. Vibrating Wire Piezometers (VWP) were installed across 41 No. boreholes, at the depths specified in Appendix C7.

The VWPs were installed using the fully-grouted method. The installation procedure involved the VWPs being taped tip up to the outside of a 25-40 mm ID uPVC sacrificial tremie pipe, through which a cement:bentonite grout mix was pumped to backfill the borehole. The cement:bentonite grout mix was varied on site, depending on the ground conditions encountered in each borehole.

Where the permeability of the ground was too high to use the fully-grouted installation method, VWPs were installed in a sand filter pack, with bentonite seals above and below the filter pack to isolate the response zone. R30 slow-swell bentonite pellets were used to ensure that the bentonite created an effective seal at the required depth. Further details of piezometer construction details are contained in Appendix C8.

During installation of the VWPs, a series of pre- and post-installation calibration readings were taken as part of the QA process to confirm functionality of the installed instruments. Calibration certificates and data are provided in Appendix B5.

Standpipe Piezometers and VWPs

As a part of the Stage 1 ground investigation, 11 No. open standpipe piezometers were installed and were constructed of plain and slotted 50 mm internal diameter uPVC piping with threaded environmental connections. Flush and steel upstand Toby boxes were installed across the project and fencing constructed around monitoring equipment that may be affected by stock. VWPs have been installed at the depths specified in the standpipes, and a summary of standpipe piezometers and equipment installs is shown in Appendix C7. Calibration details of installed VWPs are available in Appendix B5 and C7.

All water levels in the open standpipes have been corrected for barometric pressure, using site-specific data from a weather station installed at Pilbrow Hill.

At the time of writing, a single VWP installation in standpipe BH2B_1160 is outstanding due to property access restrictions.

<u>Pilbrow Hill Weather Station</u>

During the Stage 1 investigations a weather station was installed in Zone 2 at the top Pilbrow Hill in a temporary laydown area adjacent to the existing radio transmitter. The weather station was installed to record the following data:

- Rainfall
- Air pressure
- Air Temperature
- Wind speed and direction
- Humidity

Rainfall data beginning October 2025 is shown in Appendix G.

# 5. Groundwater Levels During Drilling

## 5.1. Groundwater Measurements

Groundwater depths were recorded during the progression of each borehole, typically at the start and end of each shift, during drilling and immediately following completion of each borehole. Associated drilled depth vs. groundwater depth (DVD) plots are available in Appendix C4. It should be noted that drilling introduces water into the ground as drilling fluid, therefore, use of groundwater levels recorded during and immediately following completion of drilling should be assessed accordingly.

## 5.2. Artesian Pressures

Artesian groundwater conditions were encountered in four bores during drilling, as summarised in Table 7. These groundwater levels were measured in the morning before drilling began, at which time the levels were assumed to have partially stabilised overnight. However, weak artesian pressures (<0.5 m) observed in bores BH2B_1135 and BH2B_1142 likely resulted from a combination of drilling influence and the low hydraulic conductivity of the formation. The groundwater level had probably not fully equilibrated overnight. This is supported by the changes in artesian head measured in BH2B_1113. The groundwater head was increased to conduct a falling head test (see Section 6.2) overnight. The groundwater level decreased by only 0.4 m overnight but decreased to below ground level over the subsequent weekend.

A VWP was installed at 16.5 m to attempt monitoring of the artesian conditions encountered at BH2B_1155, however, monitored groundwater levels are below ground level. None of the other weakly artesian groundwater levels were targeted for monitoring.

*Table 7: Artesian conditions measured during drilling*

| BH_ID | Drill depth (m) | Groundwater level (m agl) | Flow rate |
|---|---|---|---|
| BH2B_1113 | 22.6 | 0.3 – Artificial head from falling head test | Not measured – no overflow from casing |
| BH2B_1135 | 19.88 | 0.3 | Not measured – no overflow from casing |
| BH2B_1142 | 22.3 | 0.5 | Not measured – no overflow from casing |
| BH2B_1155 | 16.5 | 2.2 | Flow 16 mins for 14.8 L (0.02 L/s) |

# 6. In-situ Permeability Testing

## 6.1. Packer Testing

Packer (Lugeon) testing was undertaken in select boreholes during drilling.

A terminal (single) packer assembly was used for most of the bores, with testing conducted as drilling was progressed. The top of the test section is sealed off using a packer and the bottom of the drill hole is the bottom of the test section.

A straddle (double) packer assembly was used for BH1157, with testing completed after drilling was complete. The test section is sealed off with a packer above and below the test section.

Five pressure stages (three increasing and two decreasing) were typically specified using a maximum test pressure (Pmax) for the specified test interval. Pmax was calculated based on the depth interval being tested and the groundwater level at the start of the test. The pressure stages are typically defined as:

- Stage 1 – 25% Pmax
- Stage 2 – 50% Pmax
- Stage 3 – 75% Pmax
- Stage 4 – 50% Pmax
- Stage 5 – 25% Pmax

An additional pressure stage of 100% Pmax was added for the testing of BH2B_1144, 40.5-53 m, because no flow occurred at low pressure. This resulted in dilation of the defects in the rock mass.

Packer test results are summarised in Appendix F1, and the actual test data are contained in Appendix F2.

## 6.2. Falling Head Test

Falling head tests were undertaken during drilling where packer testing could not be conducted due to site conditions e.g., where the risk of collapse during packer testing is high due to increased fracturing/brecciation in the formation. Falling head tests during drilling was adopted as the norm due to the efficiency of operation.

29 No. falling head tests were conducted during drilling in specified bores and completed test results are summarised in Appendix F3, and the actual test data are contained in Appendix F4. Falling head tests were typically conducted overnight, where the target formation was exposed by lifting the drilling rods to above the target formation. The bore was then flushed to clear drilling mud from the formation in the test section. The water added to the bore during flushing creates an increase in head in the bore and the recession of the groundwater level overnight is measured using an automated pressure transducer (Solinst Levelogger) set at 1-2 second intervals. Note that only relative changes in the groundwater level are measured and static groundwater levels are not available at the start of the test. In addition, the formation above the test section is not completely sealed off by the drilling rods and water could dissipate through some of the formation above the test section. Hence, the hydraulic conductivities estimated from the falling head tests during drilling are considered an estimation of bulk hydraulic conductivity of the exposed formation.

## 6.3. Slug Testing – Standpipe Piezometers

Slug tests (including falling and rising head tests in this case) were undertaken by Aurecon WSP JV hydrogeologists within nine of the eleven constructed standpipe piezometers as of 22nd January 2026. The slug tests on the remaining two standpipe piezometers (BH2B_1146 and BH2B_1161) will be reported as part of Stage 2.Completed test results are summarised in Appendix F5, and the actual test data are contained in Appendix F6. A conventional, cylindrical plastic slug was sunk below the groundwater level to induce a near-instantaneous change in hydraulic head, following which, the rate of groundwater level recovery back to the initial level prior to the testing was measured. The slug is removed when the water level has recovered to near static (typically next day) to induce a near instantaneous drop in groundwater level. The rate of groundwater level recovery was measured, similar to the falling head test. The water level changes during each test were recorded automatically using an automated pressure transducer (Solinst Levelogger) set to record at one second intervals. Slug tests were conducted in the boreholes listed in Appendix F5.

The test data was analysed using AQTESOLV® from HydroSOLVE Inc. Version 4.50 (2017). Hydraulic conductivity values were derived from the slug test data using Bouwer-Rice (1976) analysis methods and the maximum and minimum values from each test  are presented. Completed test results are summarised in Appendix F5, and the actual test data are contained in Appendix F6.

# 7. Groundwater Monitoring

A fully telemetered groundwater monitoring network has been established as part of the Stage 1 ground investigations.  The groundwater monitoring network is operated and maintained by Sixense Oceana.

Telemetry was generally installed within 7 days of the borehole completion / instrumentation installation.  Groundwater monitoring periods vary, depending on when the borehole and instrumentation installation was completed.

Errors that occur, for example where measured groundwater levels are significantly different from average levels (outliers), are shown as journal events and corrected where possible. These are indicated as flags on the data set, for the above example as “mRL limits exceeded”. Other error codes include where sensors were damaged and data is missing for that reason. In addition, the early data from some of the standpipe piezometers have not been corrected because the barometric data was not available at the time. The data is shown with a journal event denoting “Barometric Compensation not applied”.

Groundwater level data were exported from the monitoring portal on 27th January 2026 and are presented in Appendix G. The graphs in Appendix G show groundwater levels from the time of commencement up to the date of export, with the exception of BH2B_1146 which includes groundwater level and rainfall data up to 10th February 2026, and BH2B_1110 and BH2B_1157 which includes groundwater level and rainfall data up to 12th February 2026.

# 8. Laboratory Testing

## 8.1. Geotechnical Laboratory Testing

Laboratory testing was undertaken by 5 laboratories; New Zealand Based and IANZ accredited WSP laboratories, Geotechnics and Central Testing Services and Australian based NATA accredited (ISO 17025 equivalent) WSP laboratory and Panda Geoscience. Testing was completed to the following standards:

*Table 8: Laboratory Tests and Testing Standards*

| Test Method | Testing Standard |
|---|---|
| Atterberg Limits | NZS 4402:1986 Test 2.1/2.2/2.3/2.4 |
| Water Content | NZS 4402:1986 Test 2.1 |
| Plasticity Index for Aggregates | NZS 4407:2015 Test 3.1/3.2/3.3/3.4 |
| Particle Density | NZS 4402:1986 Test 2.7.2 |
| Particle Size Analysis (hydrometer) | NZS 4402:1986 Test 2.8.4 |
| Particle Size Analysis (wet sieve): | NZS 4407:2015 Test 3.8.1 |
| Linear Shrinkage | NZS 4402:1986 Test 2.6 |
| Shrink Swell | Shrink-swell Index: AS 1289.7.1.1 – 2003 |
| Ring Shear | ISO 17892:2018 Part 10 – Direct shear tests (Ring Shear). |
| One Dimensional Consolidation | NZS 4402:1986 Test 7.1 |
| Consolidated Undrained (CU) Triaxial: | BS EN ISO17892-9:2018 |
| Unconsolidated Undrained (UU) Triaxial: | BS EN ISO: 17892-8:2018 |
| Uniaxial Compressive Strength (UCS): | NZS 4402:1986 Test 6.3.1.<br>The methodology of estimating the young's modulus was done based on the displacement of the platen on the test apparatus. |
| Point Load Strength | ASTM D5731-16 |
| In-situ Density | NZS 4402: 1986 Test 5.1.3 |
| Dry Density/Water Content Relationship Standard Compaction | NZS4402:1986 Test 4.1.1 |
| Dry Density/Water Content Relationship Heavy Compaction | NZS4402:1986 Test 4.1.2 |
| Soaked and Unsoaked California Bearing Ratio (CBR): | NZS 4402:1986 Test 6.1.1 |
| Shear Strength using a Hand-Held Shear Vane | NZ Geotechnical Society Inc 8/2001 |
| Los Angeles Abrasion | NZS 4407: 2015 Test 3.12 |

| Test Method | Testing Standard |
|---|---|
| Slake Durability | ASTM D4644 - 16 |
| Weathering Quality Index | NZS 4407:2015 Test 3.11 |
| Bulk and Dry Density | NZS 4402:1986 Test 6.3.1, NZS 4402: 1986, Test 5.1.3, NZS 4402: 1986 Test 4.1.2 (Heavy), ASTM D5731-16 |

A summary of all laboratory test results is provided in Appendix H1, while full laboratory results according to test type are in Appendix H02-H28.

## 8.2. Contamination Testing

Opportunistic soil sampling for contaminated land purposes was undertaken at sites of interest during the geotechnical investigation including Glenmohr Road (BH2B_1140, BH2B_1104 and BH2B_1105) and Mayflower Farms (BH2B_1149). Additional soil samples were collected at BH2B_1160 following olfactory evidence of potential contamination identified during drilling.

# Appendix A: Ground Investigation Location Plans

# Appendix B: Calibration Certificates

# B1: SPT Hammer Calibration Certificates

# B2: Hand-held Shear Vane Calibration Certificates

# B3: I-Vane Calibration Certificates

# B4; CPT and SCPT Cone Calibration Certificates

# B5: Vibrating Wire Piezometer Calibration Certificates

# Appendix C: Borehole Data

# C1: Borehole Details Table

# C2: Logging and Nomenclature

# C3: Borehole Logs and Photographs

# C4: DVD Plots

# C5: I-Vane Results

# C6: OTV/ATV Data

# C7: Standpipe and VWP Details Table

# C8: Standpipe and VWP Design

# Appendix D: CPT, Dissipation Test Data

# D1: CPT Test Details Table

# D2: CPT Logs

# D3: Dissipation Test Details Table and Logs

# Appendix E: Machine Excavated Test Pit Data

# E1: Test Pit Details Table

# E2: Test Pit Logs and Photos

# Appendix F: In-situ Permeability Testing

# F1: Packer Test Summary Table

# F2: Packer Test Data

# F3: Falling Head Test Summary Table

# F4: Falling Head Test Data

# F5: Slug Test Summary Table

# F6: Slug Test Data

# Appendix G: Groundwater Monitoring and Rainfall Data

# Appendix H: Laboratory Testing Results

# H1: Laboratory Testing Details Table

# H2: Atterberg Limits

# H3: Particle Density

# H4: PSD Wet Sieve

# H5: PSD- Wet Sieve + Hydrometer

# H6: Linear Shrinkage

# H7: Shrink-Swell

# H8: Ring Shear

# H9: One Dimensional Consolidation- multi stage (t50)

# H10: One Dimensional Consolidation- multi stage (t90)

# H11: Triaxial- CUP 3 stage

# H12: Triaxial- UU 1 stage

# H13: Unconfined Compressive Strength (Simple)

# H14: Point Load (Axial)

# H15: Point Load (Axial and Diametrical)

# H16: Rock Moisture Content

# H17: Bulk Density

# H18: Dry Density

# H19: Petrography

# H20: XRD (Quantitative)

# H21: Heavy Compaction

# H22: MDD (Heavy)

# H23: Soaked CBR

# H24: Unsoaked CBR

# H25: Los Angeles Abrasion

# H26: Slake Durability

# H27: Weathering Quality Index

# H28: Plasticity Index for Aggregates