Eastern Busway Geotechnical Factual Report

EB3C

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6th October 2023

Eastern Busway

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The following provides the record of authorisation and revisions made to this document.

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Contents

Abbreviations

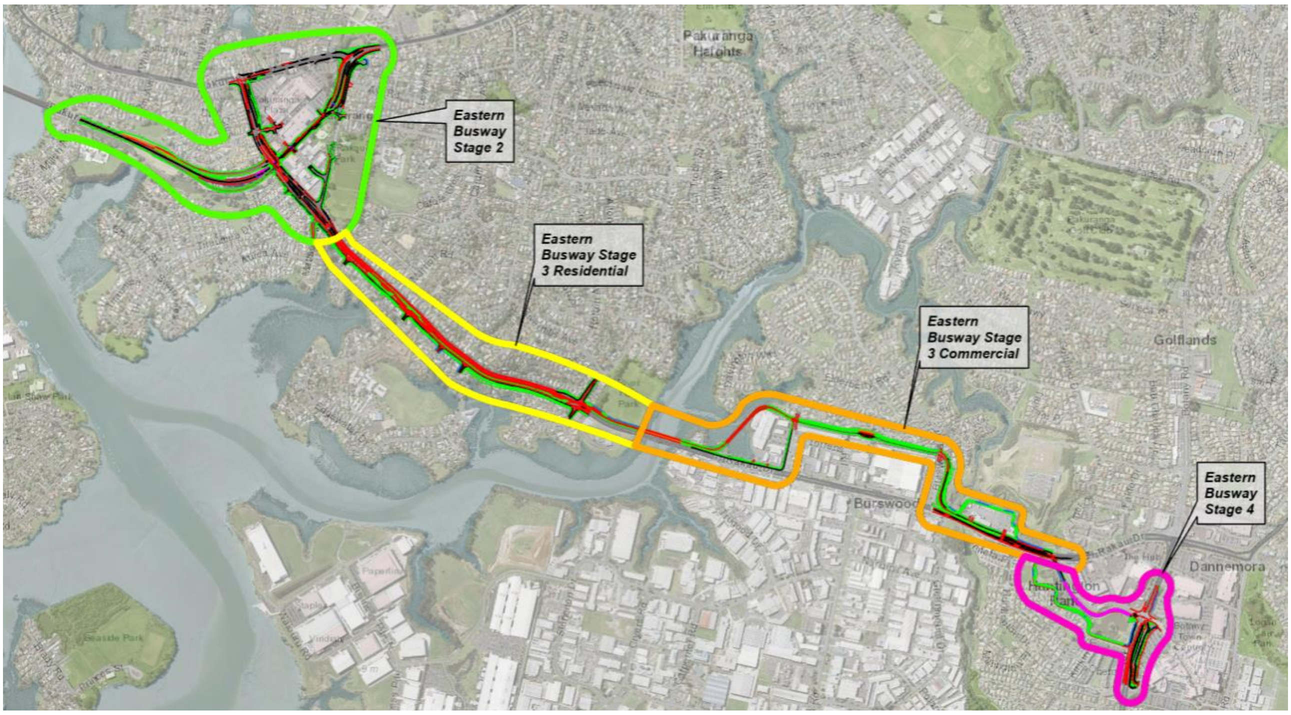
Abbreviation	Description
ASTM	International American Society for Testing and Materials International
AT	Auckland Transport
CAT	Cable Avoidance Tool
CPT	Cone Penetration Test – with pore pressure measurement
DCP	Dynamic Cone Penetrometer, may also be referred to as a Scala penetrometer
DH	Machine drillhole – using triple barrel coring techniques
EB1	Eastern Busway Stage 1
EB2	Eastern Busway Stage 2
EB3R	Eastern Busway Stage 3 Residential
ESPG	European Petroleum Survey Group – universal codes for coordinate systems
GFR	Geotechnical factual report
GPR	Ground Penetrating Radar
HA	Hand auger hole
HQ	A drillhole diameter: A 96 mm diameter hole with 63.5 mm diameter core
HSV	Handheld shear vane test
HVSR	Horizontal to Vertical Spectral Ratio Analysis
IANZ	International Accreditation New Zealand
ID	Inside Diameter
iVane	Icone Vane testing
m BGL	Metres Below Ground Level
NZGD2000	New Zealand Geodetic Datum 2000
NZGS	New Zealand Geotechnical Society
NZS	New Zealand Standards
NZVD2016	New Zealand Vertical Datum 2016
OD	Outside Diameter
PVC	Polyvinyl Chloride
sCPT	Seismic Cone Penetration Test
SIC	Service Identification and Clearance
SPT	Standard Penetration Test
T50	Time to 50% dissipation
TP	Test Pit
VW	Vibrating wire piezometer
WB	Machine drillhole – using wash drilling techniques

1. Introduction

1.1 Appointment

Auckland Transport (AT) have established an Alliance to deliver the Eastern Busway Stages 2, 3 & 4 (refer to Figure 1 below) as a part of a programme of works consisting of multiple transportation projects that will deliver a multi-modal transport corridor for the Eastern suburbs of Auckland. The non-owner participants of the Alliance are Fletcher Construction, Acciona, Jacobs and AECOM. Together, Jacobs and AECOM are responsible for delivering a scheme design, reference design and business case that meet the project requirements and deliver a cost-effective solution within the affordability threshold.

Figure 1: Project Site Overview



1.2 Overview

1.2.1 Project purpose

AT's overarching project aim for Eastern Busway is to provide a reliable, frequent and comfortable bus-based mass transit service for East Auckland that safely and efficiently connects customers from Botany and beyond to the Auckland CBD, via Pakuranga and Panmure, in under 40 minutes. The segregated busway will enable growth and investment in the community, while maintaining or improving safety and accessibility for all modes of transport, including freight, cyclists and pedestrians.

1.2.2 Summary of project elements

The Eastern Busway Stages 2, 3 & 4 project conceptually consists of the design and construction of:

- Approximately 5km of segregated, at-grade urban busway between Pakuranga Town Centre and Botany Town Centre, which extends the Eastern Busway Stage 1 link (EB1) built as Stage 1 and provides for the anticipated future Airport to Botany public transport system on Te Irirangi Drive
- Major interchange stations to be provided at Pakuranga and Botany town centres
- A maximum of four intermediate stations

- Improved active modes (walking and cycling) throughout, including physically separated and/or protected cycle facilities for the length of the busway or as agreed with AT
- Provision of direct access between Pakuranga Road and Pakuranga Highway (Reeves Road Flyover) to reduce general traffic loads through and about the Pakuranga town centre
- Maintained or improved access to the town centres and local points of interest for all modes
- New physical and operational transport infrastructure, which does not preclude land use development and plans by private and public-sector third-party developers
- A grade-separated Busway/Ti Rakau Dr & Reeves Road intersection (currently assumed to be the Reeves Road Flyover)
- Two new bridges across Pakuranga Creek tidal areas for the Busway, one of which will also include the cycleway
- Major utility works (including Watercare and Transpower)
- Fully operational mass transit service to be complete no later than the end of FY 2025.

1.2.3 Extent of works

Eastern Busway Stage 3 commercial (EB3C) comprises:

- Two bridges that cross tidal areas associated with Pakuranga Creek at two locations: next to the existing Pakuranga Creek bridge (a.k.a. the Ti Rakau Drive Bridge) and across the estuarine inlet behind Chinatown. Roading improvements at the Mobil fuel station and Pet shop retail outlet that serves as a connector between the two bridges, with a new cycleway being built along Ti Rakau Drive and Burswood Drive before connecting with the Busway behind Chinatown.
- A new busway and cycleway that traverses the Burswood residential area with an intermediate Burswood bus station. The busway and cycleway then follow Burswood Reserve's western and southern perimeter before the cycleway separates from the busway to cross the reserve behind the existing bus depot. The busway and cycleway merge again before crossing Ti Rakau Drive into Eastern Busway Stage 4.

1.3 Purpose of investigations

The purpose of the ground investigation was to assess ground conditions along the proposed new alignment. The investigations also provide subsurface information at locations where unfavourable conditions could have a significant impact on the design. Investigation locations were selected to:

1) Determine geology, geotechnical conditions and infill gaps in the geotechnical data particularly where key design elements are required (such as piers, retaining walls etc.), and,

2) Provide the necessary ground and groundwater information to adequately support resource consent requirements including groundwater effects, extent of works and effect on existing structures.

Drawings showing the as-built investigation locations are presented in Appendix 1.

The purpose of this Geotechnical Factual Report (GFR) is to present all EB3C factual information obtained between October 2021 and April 2023. Investigations for other stages of the project, ie Stage 2 and Stage 3 residential are reported separately.

2. Field investigations

2.1 General

Intrusive geotechnical investigations for EB3C were undertaken by the Alliance. Investigations were undertaken between October 2021 and April 2023, with data collection for long-term groundwater monitoring still ongoing. Most investigations were completed between June 2022 and April 2023. During this time period rainfall was consistently higher than average and the region experienced flooding during January 2023 and February 2023. Despite the rainfall, the sites remained generally in good order and firm underfoot, although it locally required track mats during wetter periods to track plant and vehicles to exploratory hole locations. In the heat of summer care was taken to prevent the exposure and 'drying out' of cores and samples. These investigations were supplemented by geophysical survey work as reported in Section 4.

Completed intrusive investigations comprised:

- 29 machine drillholes (DH)
- 16 Cone Penetration Tests with pore pressure measurement (CPTu) including 7 seismic CPTs (sCPT)
- 4 hand augerholes (HA) with adjacent Dynamic Cone Penetrometer (DCP) tests

All drillholes, hand augerholes and CPTs were supervised by Alliance Geologists/Geotechnical Engineers.

Upon completion, all investigation locations were surveyed by Active Survey Surveyors to 50 mm accuracy in the X and Y (horizontal) directions and 25 mm accuracy in the Z (vertical) direction or better. Coordinates are presented on the investigation logs in terms of:

- Horizontal Datum: NZGD2000 - New Zealand Transverse Mercator 2000 (EPSG Code 2193)
- Vertical Datum: Auckland 2016 (EPSG Code 1169)
- Origin of coordinates is Mt Eden Circuit

The investigations were undertaken in accordance with the standards in Section 5.

2.2 Service clearance

Prior to intrusive works taking place all locations were scanned using a Cable Avoidance Tool (CAT) and Ground Penetrating Radar (GPR). A Service Identification and Clearance (SIC) checklist was then completed and verified by a SIC Approver. A variation to the SIC procedure was approved where investigations were permitted to be drilled/pushed/excavated from the surface. Where there was a risk to nearby services hand auger or vacuum excavated starter holes were undertaken (nominally to 1.5m depth).

2.3 Intrusive investigations

2.3.1 Machine drillholes

A total of 29 machine drillholes were drilled by McMillan Drilling NI Ltd. (McMillan's) using triple-tube coring and wash bore drilling techniques with track mounted drill rigs. Drillholes were fully supervised by Alliance Engineering Geologists/Geotechnical Engineers. Cored drillholes were HQ diameter.

Standard Penetration Tests (SPTs) were generally completed at 1.5 m depth intervals with a split spoon sampler. Solid cone SPT's were completed at the driller's discretion to avoid damaging the split spoon and are noted on the drillhole logs. The blow counts for the initial two 75 mm seating drives and each of the four 75 mm increments of the test drive are recorded on the drillhole logs. Where the resistance was too much for the SPTs to be driven to the full 450 mm penetration, both the number of blows of the last increment and the penetration achieved are recorded (NZS4402 Test 6.5.1, 1988). A summary of the approach adopted for recording SPTs is provided on the key sheet in Appendix B. The SPT 'N' values provided on the drillhole logs are those measured in the field and have not been corrected for hammer efficiency, depth, etc.

Hand-held shear vane tests (HSV) were undertaken within applicable cohesive soils in starter holes and in the end of each core run, while the core was still in the barrel and the nozzle and catcher was still attached (NZGS, 2001). Where the core moved within the barrel during attempted HSV tests, no result was recorded.

Push tube samples (U54, 54 mm inside diameter [ID] and 57 mm outside diameter [OD]) were taken at intervals when advancing the drillholes by triple tube coring. Sample tubes are made from stainless steel. Samples were waxed and sealed to await their opening for testing in the laboratory.

Cores were logged and photographed by the supervising Engineering Geologist or Geotechnical Engineer, wrapped in plastic to limit moisture loss, and placed in core boxes. Core boxes were then transported by the civil crew and placed in storage at the Site Office.

Drillholes were backfilled predominantly with bentonite grout with small amounts of gravel used to top up some holes. The holes were concreted to surface level or reinstated with the original sod depending on location. Drillholes with piezometer installations had mixed backfill according to the piezometer design. Drillholes with piezometers installed are numbered with a 'P' suffix. Instrument installation details are discussed in Section 2.4. Drillhole details are summarised in Table 1. Drillhole logs and core photographs are presented in Appendix 2. A key sheet summarising the logging terms and abbreviations is presented at the front of Appendix 2. SPT and HSV calibration certificates are presented in Appendix 4.

Table 1 Machine Drillhole Summary

Drillhole ID	Easting (m NZGD2000)	Northing (m NZGD2000)	Surface Elevation (m RL, Auckland 2016)	Total Depth (m BGL)	Piezometer
DH301_P	411206.87	794935.26	7.50	30.00	Yes
DH302	411306.87	794902.42	6.29	18.00	No
DH303_P	411333.65	794920.83	6.68	18.00	Yes
DH304	411362.72	794914.79	6.53	24.00	No
DH305_P	411473.30	795010.20	8.74	30.00	Yes
DH306	411487.71	795041.15	8.71	25.50	No
DH307	411494.80	795054.36	8.86	22.50	No
DH308_P	411516.90	795070.30	8.88	27.00	Yes
DH309_P	411582.06	795072.05	8.20	30.00	Yes
DH310	411618.48	795052.84	8.50	25.00	No
DH311_P	411671.96	795021.63	9.17	25.50	Yes
DH312	412241.58	794690.24	12.74	25.93	No
DH313	Cancelled due to access constraints				
DH314	411928.48	794998.65	11.91	27.00	No
DH315_P	412014.97	794968.94	11.32	31.50	Yes
DH316	412143.54	794924.72	11.52	28.50	No
DH317_P	Cancelled due to access constraints				
DH318_P	412237.66	794896.328	10.82	24.29	Yes
DH319_P	412275.59	794685.54	6.67	28.50	Yes
DH320	412354.13	794688.02	4.19	25.81	No

Drillhole ID	Easting (m NZGD2000)	Northing (m NZGD2000)	Surface Elevation (m RL, Auckland 2016)	Total Depth (m BGL)	Piezometer
DH321	411731.67	795021.63	10.99	24.00	No
DH322_P	412397.38	794694.60	6.44	27.00	Yes
DH323_P	412455.00	794672.00	6.81	25.50	Yes
DH324	412529.92	794646.59	7.73	22.50	No
DH325	412548.34	794609.81	8.64	28.50	No
DH326_P	412270.62	794791.97	10.02	24.80	Yes
DH327	412274.22	794839.80	9.08	25.50	No
DH328_P	411888.60	794974.06	11.56	28.50	Yes
DH329	412311.74	794652.50	8.38	36.00	No
DH330	412454.56	794583.17	9.66	24.00	No
DH331	Moved to EB4 scope				
DH332	411399.546	795077.193	6.746	33.00	No

2.3.2 Hand augerholes

A total of 4 hand augerholes were undertaken by Alliance Engineering Geologists or Geotechnical Engineers to target depths of 5 m. HSV's were undertaken at the base of the hole as the hand augerholes advanced through cohesive soils. DCP Tests were generally undertaken adjacent to the hand augerholes to target depth of 5 m, or refusal in accordance with NZS4402 Test 6.5.2:1988. A maximum 1.5 m length was adopted for DCP tests. Where deeper testing was required a hand auger was used to excavate a starter hole to the top of the test level or testing was undertaken at the base of completed auger holes. Hand augerholes were backfilled with recovered cuttings upon completion.

Hand augerhole details are summarised in Table 2. Hand augerhole logs and photographs are presented in Appendix 3. A key sheet summarising the logging terms and abbreviations is presented at the front of Appendix 3.

Table 2 Hand Augerhole Summary

Hand Augerhole ID	Easting (m NZGD2000)	Northing (m NZGD2000)	Surface Elevation (m RL, Auckland 2016)	Total Depth (m BGL)	Termination
HA301	412291.83	794837.51	9.33	5.0	Target Depth
HA302	412271.65	794732.14	12.55	0.4	Unable to penetrate further
HA303	Removed from scope after alignment change				
HA304	Removed from scope after alignment change				
HA305	411862.065	794978.60	11.45	5.0	Target Depth
HA306	411772.95	794996.61	11.15	5.0	Target Depth

2.4 Instrumentation

2.4.1 Standpipe piezometers

Standpipe piezometers were installed in 15 drillholes at 12 discrete locations to monitor groundwater and to provide a means of undertaking falling and rising head permeability testing (slug testing). Where nested piezometers were requested a separate wash drill hole was drilled adjacent to the original hole, to allow space for both installations. To accommodate the slugs, 50 mm PVC was used. All piezometers were developed post-installation using compressed air to flush out any fines. Piezometers were finished at ground surface using flush mounted tobies. An Allen key is required to undo the bolts that secure the toby cover.

As-built piezometer details are summarised in Table 3 and presented on the drillhole logs in Appendix 2.

Table 3 Standpipe Piezometer Summary

Drillhole ID	Top of Slotted Screen (m BGL)	Base of Slotted Screen (m BGL)	Base of Piezometer[A] (m BGL)	Response Zone[B] (m BGL)
DH301_P	4.00	7.10	7.20	3.40 to 7.80
DH303_P	6.00	8.00	8.25	5.60 to 8.40
DH305_P	5.40	7.40	7.00	4.90 to 7.90
DH308_P	13.00	15.50	15.55	12.30 to 16.00
DH308A_P	5.50	7.50	7.41	5.00 to 8.00
DH308B_P	2.00	4.50	4.47	1.70 to 5.00
DH309_P	2.00	6.00	6.14	1.80 to 6.30
DH311_P	6.90	9.90	10.07	6.50 to 10.20
DH315_P	7.50	10.50	10.60	6.90 to 11.00
DH318_P	4.80	7.80	7.90	4.20 to 8.30
DH319_P	5.40	6.40	6.55	4.90 to 6.90
DH322_P	6.00	7.50	7.36	5.60 to 7.70
DH326_P	4.30	6.80	6.86	3.90 to 7.30
DH328_P	9.20	10.70	10.62	9.00 to 10.90
DH328A_P	3.00	5.50	5.64	2.80 to 5.60

[A] Manual measurement of piezometer base using dip meter in piezometer post toby installation

[B] Filter/sand material between bentonite seals.

LevelSCOUT transducers have been deployed in all standpipe piezometers. A recording interval of five seconds was used during slug testing (Section 2.5.4) and 15 minutes for long term monitoring. A separate LevelSCOUT transducer used as a barometer was installed at the Site Office to monitor barometric pressure. The full data from the transducers is only stored in digital form and is available on request.

Barometric data was also obtained from the NIWA National Climate Database (Clifo Database https://cliflo.niwa.co.nz/), specifically the Mangere 2 electronic weather station (EWS). Direct comparison of barometric pressure data found insignificant differences between the NIWA data and the site barologgers. Although the NIWA data is only available at hourly recording intervals, it is continuously available throughout the whole project period, unlike the site barologgers. Furthermore, a correction needs to be applied to the recording times of the site-specific data. For the initial illustration of groundwater fluctuation over time, it was simplest to correct the transducer data relative to the NIWA barometric pressure data.

Charts illustrating the long-term groundwater monitoring have been produced from the data collected to date from the LevelSCOUT transducers installed. Data from the 'Mangere 2 EWS' monitoring station was first used to correct for variations in atmospheric pressure to determine a head of groundwater acting on the transducer. Then, by knowing the installed depth below the ground surface of the transducer, the depth of the groundwater was calculated. These calculated groundwater levels were compared with the manual readings taken at isolated intervals. Although there is usually a good correlation, in a few cases the groundwater depths derived from the transducer data were not sufficiently in agreement with manual readings and it was necessary to provide a further correction; this was applied as a change to the depth below ground of the transducer. Charts of long-term groundwater monitoring results are presented in Appendix 7 and are superimposed with daily rainfall records from NIWA's Mangere 2 EWS monitoring station. Most of the piezometer installations have not gone through a full-year monitoring cycle; groundwater levels will continue to be monitored and the graphs will be updated over the coming months. The new data will be captured in further revisions of this report.

2.4.2 Vibrating wire piezometers

Where artesian groundwater was encountered, vibrating wire (VW) piezometers were installed to monitor the water pressure. Two VWs were installed within DH323_P with tip depths of 5.60 and 12.10mBGL. The VWs were attached to 30mm PVC with the tips inverted and lowered downhole. A VW readout unit was used to record initial frequency readings pre-installation, down hole during installation, and post installation after grouting. After installation, an instrumentation and monitoring technician from Geotechnics Ltd installed telemetry equipment and commissioned the install. Data readings were set to record every 15minutes and transmit data daily to Geotechnics where the readings were converted to groundwater levels. Charts of long-term groundwater monitoring results are presented in Appendix 7 and are superimposed with daily rainfall records from NIWA's Mangere 2 EWS monitoring station.

2.5 In situ testing

2.5.1 Cone penetration tests (CPT)

A total of 16 Cone Penetration Tests were carried out by Ground Investigation Limited using a combination of Pagani track mounted anchor and truck rigs in accordance with (ASTM D5778-20, 2020). Standard 10 cm^2 compression cones with a 60° cone apex angle were used.

Within the Burswood Residential and Chinatown carpark areas, a starter hole was drilled by the drilling rig to advance the hole to the base of the basalt. The starter holes were left with PVC in them to allow the CPT rods to reach the base of basalt unobstructed. Before the test commenced, the space between the rods and PVC wall was filled with sand and gravel to prevent buckling. The test then commenced from base of basalt until refusal depth. Starter holes within the Chinatown carpark were drilled at HQ size and the rest were done as PQ size. Most starter holes were cored and the core was boxed and logged; these logs have been added to Appendix 2.

CPT's were supervised by Alliance Engineering Geologists or Geotechnical Engineers. All CPT's were pushed to refusal. Select locations were probed again for the purpose of undertaking seismic measurements or pore pressure dissipation tests (Section 2.5.2). CPT details are summarised in Table 4 and test reports are presented in Appendix 5. Calibration certificates are presented in Appendix 4.

Table 4 CPT Summary

CPT ID	Easting (m NZGD2000)	Northing (m NZGD2000)	Surface Elevation (m RL, Auckland 2016)	Total Depth (m BGL)	Refusal Comment
CPT301	411206.76	794933.90	7.43	17.22	High total load
CPT302	411307.57	794900.37	6.36	5.53	High cone end resistance
CPT303	411332.87	794920.07	6.59	12.61	High friction resistance

CPT ID	Easting (m NZGD2000)	Northing (m NZGD2000)	Surface Elevation (m RL, Auckland 2016)	Total Depth (m BGL)	Refusal Comment
CPT304	411362.04	794914.85	6.67	13.12	High cone end resistance
CPT305	411477.08	795012.75	8.82	14.43	High pore water pressure
CPT306	411489.26	795041.78	8.78	17.95	High pore water pressure
CPT307	411494.73	795052.72	8.87	17.71	High pore water pressure
CPT308	411510.88	795064.00	8.81	16.10	Inclination high or rapid increase
CPT309	411580.74	795080.35	8.01	12.88	High pore water pressure
CPT310	411619.93	795052.27	8.50	14.6	High total load
CPT311	Cancelled due to access constraints				
CPT314	411927.08	794997.17	11.90	22.03	Danger of buckling rods
CPT315	412015.64	794969.47	11.26	22.56	High pore water pressure
CPT316	412149.39	794924.59	11.67	27.24	Danger of buckling rods
CPT317	Cancelled due to access constraints				
CPT319	Cancelled. Test moved to 329				
CPT320	412354.51	794689.87	4.11	15.44	High total load
CPT321	411741.49	795016.87	11.21	19.98	High pore water pressure
CPT322	412399.13	794695.43	6.40	17.33	High total load
CPT323	412459.03	794671.52	6.77	24.39	High total load
CPT324	412528.19	794645.41	7.74	16.66	High total load
CPT325	412545.69	794612.34	8.65	19.01	High total load
CPT327	412273.70	794838.46	9.10	21.39	High total load
CPT328	411893.102	794990.00	11.84	22.89	Danger of buckling rods
CPT329	412307.406	794654.07	8.48	25.25	Danger of buckling rods

2.5.2 Pore pressure dissipation testing

A total of 9 pore pressure dissipation tests were completed in CPTs to assess in situ permeability behaviour. Pore pressure dissipation tests in EB3C were generally scheduled within units that may pose a settlement risk or to fill gaps in permeability/conductivity information. Dissipation tests, excluding CPT301 and CPT323 which had space and time constraints respectively, were undertaken in a second adjacent CPT at a depth selected from inspection of the initial output of the first CPT; these CPTs are identified with a D suffix on the location plans. Generally, the dissipation tests were carried out for a maximum of two hours, this duration was intended to be sufficient to exceed T50 (time to 50% dissipation) and in some cases to achieve T90. In a few cases, tests were extended in an attempt to reach T50 up to a maximum of 4.75 hours. Pore pressure dissipation test data is summarised in Table 5 and the full data is presented in Appendix 6.

Table 5 Pore Pressure Dissipation Test Summary

CPT ID	Depth (m BGL)	U_0[A] (kPa)	U_{max}[B] (kPa)	U_{fin}[C] (kPa)	T_{fin}[D] (s)
CPT301	4.59	231	231	46	9442
CPT301	13.29	478	706	158	10645
CPT322	5.51	340	463	67	9631
CPT323	5.14	359	366	84	10171
CPT328	8.50	586	596	102	14790
CPT329	3.50	6	8	8	811
CPT329	5.33	-10	33	29	17798
CPT329	7.4	7	83	35	15391
CPT329	11.33	223	429	142.5	20654

[A] Pore pressure at the start of the test

[B] Peak pore pressure during the test

[C] Pore pressure at the end of the test

[D] Test duration

2.5.3 Seismic CPTs

A total of 7 seismic cone penetration tests (sCPT) were undertaken by Ground Investigation Limited. These tests were used to obtain shear wave data and material properties. sCPT testing was undertaken in accordance with (ASTM D7400-08, 2008). sCPTs are summarised in Table 6 and reports are presented in Appendix 5.

Table 6 sCPT summary

ID	Easting (m NZGD2000)	Northing (m NZGD2000)	Surface Elevation (m RL, Auckland 2016)	Total Depth (m BGL)	Refusal Comment
sCPT303	411332.509	794920.631	6.53	12.61	High friction resistance
sCPT305	411477.65	795014.006	8.85	14.43	High pore water pressure
sCPT307	411495.955	795053.234	8.88	17.71	High pore water pressure
sCPT308	411512.138	795064.651	8.81	16.10	Inclination high or rapid increase
sCPT309	411583.235	795079.22	7.84	12.88	High pore water pressure
sCPT314	411925.211	794997.724	11.92	22.03	Danger of buckling rods
sCPT324	412528.19	794645.41	7.74	16.66	High total load

2.5.4 Permeability testing

Falling and rising head permeability testing (slug testing) was conducted in all piezometers post development, as listed in Table 3, and where there was enough groundwater present for testing. Prior to testing, the LevelSCOUT monitoring transducers were generally set with a recording interval of five seconds. Due to fast response times, testing at DH319_P, DH322_P and DH328A_P were repeated with a recording interval of 1 second. Manual dipping also took place during slug testing. To start a falling head test the slug was first dropped in, then, after the displaced groundwater had dissipated, it was pulled out to start the follow-on rising head test. Following completion of the slug testing, the transducers were redeployed for long term monitoring and the recording interval was reset to fifteen minutes.

Test records are presented in Appendix 8 and transducer data is appended digitally.

3. Laboratory Testing

A combination of thin-walled push tubes, disturbed bag samples and core samples were collected from machine drillholes and hand augerholes.

Geotechnical laboratory testing was carried out by Geotechnics Ltd and Hill Laboratories Ltd in general accordance with International Accreditation New Zealand (IANZ) laboratory guidelines and the associated New Zealand Standards.

Laboratory testing is summarised in Table 7. A master list of tests scheduled and test reports received to date are presented in Appendix 9.

Table 7 Geotechnical Laboratory Testing Summary

Test	Standard(s)	Number of Tests
Organic matter content	NZS 4402: 1986: Test 3.1.2	13
Determination of water content	NZS 4402:1986: Test 2.1	17
Corrosivity suite[A]	DIN4030 Part 2 Section 5.3.5 BS1377: Part 3: 1990 Section 9.5 BS1377: Part 3: 1990 Section 5.3.3, 5.5	14
Atterberg limits	NZS4402: 1986: Test 2.2, 2.3, 2.4	17
Particle size distribution (wet sieve/hydrometer)	NZS4402: 1986: Test 2.8.1, 2.8.4	19
Solid density of soil particles	NZS4402: 1986: Test 2.7.2	1
Uniaxial compressive strength (UCS)[B]	NZS 4402:1986: Test 6.3.1 ASTM D7012-14e1 - Method C	16
Uniaxial compressive strength (UCS) with strain measurement	ASTM D7012-14e1 - Method D	1
Point load test (axial)	ASTM D5731-16	30
One dimensional consolidation	NZS4402: 1986: Test 7.1	19
Unconsolidated undrained (UU) triaxial – 3 stage	BS1377: Part 7: 1990: Test 9	20
Consolidated undrained (CU) triaxial – 3 stage	ISO 17892-9:2018 Part 9	8

[A] Corrosivity suite includes pH, chloride, water soluble sulphate, water soluble sulphate as SO_4 and water soluble sulphate as SO_3 (g/100g dry wt and g/L in extract)

[B] UCS testing was carried out without strain measurement using a concrete machine. The test results are not IANZ accredited.

4. Geophysics

Geophysical investigations were commissioned by the Alliance and completed between February 2023 and April 2023. The primary purpose of the geophysical investigations was to determine major soil and rock boundaries, basalt extent, and shear wave velocities within the estuarine inlet of Pakuranga Creek, near to the proposed bridge crossing by Chinatown. Testing was also done within Riverhills Park and beneath Ti Rakau Bridge to correlate geophysical results with existing drillhole and CPT data.

Scantec Ltd were engaged to complete Horizontal to Vertical Spectral Ratio (HVSR) analysis, magnetic survey, and sub-bottom profiling in a combination of overwater and on-land locations. RDCL completed the only downhole testing, which was a downhole seismic survey within DH332, located on the peninsula across the estuary, northwest of Chinatown. Geophysical test locations are presented on the plans in Appendix 1.

The geophysical test scope comprised:

- 16 HVSR microseismic measurements
- Marine and on-land geomagnetic survey
- Marine sub-bottom profiling
- Downhole seismic testing in DH332

Testing methodology and results are in the Scantec and RDCL geophysical reports, which are included in Appendix 10.

5. References

ASTM D5778-20. (2020). *Standard Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils.* ASTM International.

ASTM D7400-08. (2008). *Standard Test Methods for Downhole Seismic Testing.* ASTM international.

NZGS. (2001). *Guideline for hand held shear vane test.* New Zealand Geotechnical Society Inc. (NZGS).

NZGS. (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. (NZGS).

NZGS. (2017). *New Zealand Ground Investigation Specification, Volume 1: Master Specification.* New Zealand Geotechnical Society Inc. (NZGS).

NZS4402 Test 6.5.1. (1988). *Methods of Testing Soils for Civil Engineering Purposes, Determination of the penetration resistance of a soil - Test 6.5.1 Standard Penetration Test.* NZ Standard.

NZS4402 Test 6.5.2. (1988). *Methods of Testing Soils for Civil Engineering Purposes, Determination of the penetration resistance of a soil - Test 6.5.2 Hand method using a dynamic cone penetrometer.* NZ Standard.

6. Limitations

The information contained in this document was produced by the Alliance for the sole use of Auckland Transport (the Client).

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Appendix 1. Geotechnical Investigation locations

Appendix 2. Drillhole Logs & Photographs

Appendix 3. Hand Augerhole Logs & Photographs

Appendix 4. Calibration Certificates

Appendix 5. CPT, sCPT Reports

Appendix 6. Pore Pressure Dissipation Test Records

Appendix 7. Groundwater Monitoring Records

Appendix 8. Permeability Test Records

Appendix 9. Geotechnical Laboratory Test Records

Appendix 10. Geophysical Investigations