REPORT

Tonkin+Taylor

Tawariki Shafts Groundwater and Settlement Effects Assessment

Grey Lynn Tunnel - Tawariki Shafts

Prepared for
Watercare Services Limited

Prepared by
Tonkin & Taylor Ltd

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Exceptional thinking together

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1 Introduction

1.1 General

Watercare Services Limited (WSL) has engaged Tonkin and Taylor Limited (T+T) to undertake a groundwater dewatering and excavation induced settlement assessment to support a section 127 application to provide for the option of constructing the Tawariki Connector Sewer shaft concurrently with the main primary shaft as part of the Grey Lynn Tunnel project, and to relocate the secondary shaft approximately 20m to the west from 44 to 42 Tawariki Street. Results of this assessment are presented in this Groundwater and Settlement Effects Report (GWSER), which has been prepared in accordance with T+T's proposal dated 10 February 2022[1].

This assessment presents the results of undertaking the works concurrently in the one construction window, resulting in an upper bound effect. Should the works be undertaken in stages as currently provided for in the existing resource consents and designation, then the effects will be less and within the bounds of this assessment.

This report is based on the factual geotechnical information presented in the Geotechnical Factual Report[2] (GFR) and interpretive information presented in the Jacobs Geotechnical Interpretative Report[3] (GIR).

1.2 Overview

The Grey Lynn Tunnel is a wastewater interceptor pipeline that runs from the Central Interceptor (CI) at Western Springs to Tawariki Street, Grey Lynn. Resource consents were obtained from Auckland Council (AC) and the associated designation confirmed in 2019[4].

The Grey Lynn Tunnel terminates at 44 – 48 Tawariki Street (the 'Tawariki Street Shaft Site'). This site is designated[5] for the purpose of construction, operation, and maintenance of wastewater infrastructure and provides for two shafts, known as the primary and secondary shaft. The primary shaft is the termination site of the Grey Lynn Tunnel and will allow for the retrieval of the tunnel boring machine (TBM) and connections to the Tawariki Local Sewer and Orakei Main Sewer. The secondary shaft to be constructed at the Tawariki Street Shaft Site allows for the connection of future sewers from the Combined Sewer Overflow (CSO) network. This shaft was proposed to be constructed at least 2.5 years after the primary shaft site.

At the time of consenting and designating the sites, the groundwater and settlement assessments were undertaken on the basis that the two shafts would be constructed at least 2.5 years apart allowing for groundwater levels to recover reducing the effects of groundwater drawdown. Therefore, the assessment of the secondary shaft relied upon the envelope of effects anticipated for the primary shaft given its similar footprint, construction methodology and ground conditions.

Since the consenting and designating of the Grey Lynn Tunnel, Watercare has identified the potential to undertake the works for the two shaft sites within the one construction window. This will allow for efficiencies in construction and for future local connections to be made sooner.

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[1] Tonkin + Taylor Ltd, Planning and Geotechnical (Groundwater and Settlement), Central Interceptor (Grey Lynn Tunnel) – Tawariki Street Second Shaft, Job No. 30552.9090, dated 10 February 2022

[2] Beca Ltd, *Central Interceptor Variation SCN034 Tawariki Street,* Document Number: GAJV-RPT-00216, Revision: 1.0, November 2020

[3] Jacobs Ltd, Central Interceptor – Addendum No1 to Geotechnical Interpretative Report, Document Number: JNZ-RPT-00009, Revision: 4, May 2021

[4] Resource consent reference BUN60334952

[5] Designation 9468

Watercare has also purchased the property at 42 Tawariki Street and proposes to relocate the secondary shaft to this property.

Details of the works are summarised in Table 1.1 below.

Table 1.1: Summary of consented/designated works at the Tawariki Street Shaft site

Component	Description of Work
Main Shaft	• 25 m deep shaft with an internal diameter of approximately 10.8 m • Diversion of the Tawariki Local sewer to a chamber to the north of the shaft • Diversion of the Orakei Main sewer to a chamber to the south of the shaft • Construction of a stub pipe on the western edge of the shaft to allow for future connections • Construction of a grit trip at 48 Tawariki Street • Permanent retaining of the bank at the end of Tawariki Street • Construction of an above ground plant and ventilation building.
Tawariki Connector Sewer Shaft (Secondary shaft)	• 25 m deep drop shaft with an internal diameter of approximately 10.2 m • A sewer pipe constructed by pipe-jacking to connect the secondary shaft to the main shaft

1.3 Scope of works

Our scope of works for this project includes:

- Undertake a site walkover including to visually assess building type and condition of immediately surrounding buildings (as visible from the road).
- Develop a geotechnical/ hydrogeological conceptual model for the excavation area based on site information obtained from the GFR and excavation methodology information provided by WSL.
- Obtain and examine available underground utilities information and on surrounding groundwater bores information from Auckland Council's database.
- Identify buildings and utilities close to the excavations that are potentially sensitive to ground settlement.
- Excavation-induced mechanical settlement analysis.
- Groundwater numerical modelling to assess groundwater drawdown for the shaft excavations.
- Numerically assess the cumulative groundwater drawdown associated with the addition of the grit chamber excavation to that of the two shafts at the same time.
- Assess the zone of influence associated with mechanical ground settlement for the grit chamber (i.e. retaining wall deflection) utilising empirical methods.
- Use of the geotechnical/ hydrogeological conceptual model, in combination with the modelled drawdown values, to assess drawdown-induced ground settlement.
- Combine the developed settlements (drawdown and mechanical) to derive a total settlement contour plan, including:
  - Excavation-induced mechanical settlement.

  - Groundwater drawdown-induced settlement.
- Compare the derived total settlement values against the location of identified points of interest (buildings and utilities) close to the excavations that are potentially sensitive to ground settlement.
- Prepare this Assessment of Groundwater and Settlement Effects Report to support an Assessment of Effects on the Environment (AEE).

2 Planning considerations

At the time of consenting and designating the Grey Lynn Tunnel, the Groundwater and Settlement Assessment Reports assessed the effects of the works on the basis that the shafts would be constructed a minimum of 2.5 years apart and therefore groundwater would recover in the interim period.

Condition 1.1 of resource consent BUN60334952 (which includes groundwater permit WAT60334954) requires that the works be undertaken in accordance with the plans and reports submitted as part of the application. This condition reads as follows:

> ***Plans and Information***
>
> *1.1 Except as modified by the conditions below and subject to final design, the works shall be undertaken in accordance with the plans and information submitted with the application including:*
>
> *a) Assessment of Effects on the Environment, titled "Grey Lynn Tunnel – Notice of Requirement, Resource Consent Application and Assessment of Environmental Effects" prepared by Jacobs, dated February 2019.*
>
> *b) Drawings as detailed below:*
>
> *…*
>
> *c) Technical Reports as detailed below:*
>
> *…*
>
> - *Groundwater Assessment, prepared by Williamson Water & Land Advisory, dated 19 February 2019.*
> - *Settlement Assessment, prepared by McMillen Jacobs Associates, dated 31 January 2019.*
>
> *…*
>
> *d) Section 92 responses dated 18 April and 24 May 2019*

As a result of further design work and construction programme considerations as detailed above, Watercare is considering the option of constructing both shafts in the one construction period rather than separately. The secondary shaft will also be relocated approximately 20m to the east onto 42 Tawariki Street to provide for more space and greater construction efficiencies. Therefore, to provide for the relocated secondary shaft and the option of constructing the shafts in the one construction period, a section 127 application under the Resource Management Act 1991 (RMA) is required to change Condition 1.1 of BUN60334952.

The assessment to support this application is limited to the <u>*change in effects*</u> resulting from the change to conditions. In this case, to support this change to conditions an assessment of the groundwater and settlement effects of constructing the two shafts in the one construction period, and moving the secondary shaft from 44 to 42 Tawariki Street, is required as set out below.

3 Existing groundwater consent

Watercare currently holds a suite of resource consents for the construction of the Grey Lynn tunnel (inclusive of the shaft site at Tawariki Street). Specifically relevant to the proposed change to condition is groundwater permit WAT60334954.

The Settlement Assessment Report submitted as part of this resource consent application, and referenced in Condition 1.1 above, concluded that:

> *"The construction of the Tawariki Street shafts produces mechanical and groundwater settlement, that has been modelled and combined to produce a settlement contour plot. The maximum settlement from this is 14 mm occurring over the playing fields within St Paul's College to the east of the shafts. Settlements of this magnitude are insignificant in a greenfield environment and the potential settlement effects are considered to be less than minor.*
>
> *No buildings or utility services are predicted to be impacted by the construction of both the tunnel and shaft components of the Grey Lynn Tunnel."*

The Groundwater Assessment concluded that at the time of the secondary shaft being constructed (approximately 2.5 years after the primary shaft) groundwater drawdown from the primary shaft would have recovered. It was also considered that due to the slightly smaller size of the secondary shaft, the effects would be less than and within the envelope of effects considered through the assessment of the primary shaft. The assessment of the primary shaft therefore served as the assessment of the secondary shaft and a separate assessment was not required.

The Auckland Council decision report on the resource consent application (and Notice of Requirement) concluded that:

> *l. With regard to groundwater effects, dewatering/diversion and settlement effects that will arise from the proposal will not be felt or experienced by the public or wider environment given the depth of the works, remoteness from water-systems and construction methodology. While there will be adverse effects felt by [properties] surrounding the shaft site and potentially at points along the tunnel alignment that may result in settlement and damage to buildings, these can be mitigated by conditions that have been imposed, which ensure damage to buildings is remedied should this arise, and that a Monitoring and Contingency Plan is prepared to require on-going monitoring during the works.*

The groundwater permit includes a suite of conditions included in section 3: 'Specific conditions: G*roundwater permit conditions – WAT60334954'*. These conditions address monitoring, reporting and contingency measures, including relevant alert and alarm levels, pre- and post-construction condition survey requirements and repair measures (if required). It is not proposed to change any of these conditions as the proposed works will be able to meet these. This will be addressed through the Groundwater Monitoring and Contingency Plan (M&CP) required by Conditions 3.8 to 3.11.

4 Site setting

4.1 Site description

The site is located across 42 to 48 Tawariki Street in Ponsonby, Auckland.

Figure 4.1. Site location

As shown on Figure 4.1, the topography of the site is variable. The site is located within a regional gully feature with ground levels to the north and south rising from approximately 12 m RL to 45 m RL to the north, and 35 m RL to the south.

The site is bounded to the west and south by residential dwellings, by Marist Catholic School and Our Lady of Perpetual Help (a church) to the north, and St Paul's College field to the east.

4.2 Neighbouring bores

A review of the Auckland Council borehole database[6] shows that the closest recorded bore authorised for the take of groundwater to the proposed shaft locations is bore ID 31342, located approximately 1.8 km away. Further details of this bore are provided in Table 4.1.

Table 4.1: Auckland Council bore search results

Consent Reference	Consent Description	Easting NZTM	Northing NZTM	Activity Description	Distance to proposed excavation
31342	To authorise the taking of groundwater	1753464	5918870	Zoo animal watering	1.8 km

[6] Received via email from Auckland Council 11/11/2021

5 Proposed construction methodology

The underground structures at the Tawariki Street Shaft site that are part of this assessment include the following:

- Main shaft: 25 m deep with an internal diameter of 10.8 m.
- Secondary shaft: 25 m deep with an internal diameter of 10.2 m.
- A grit chamber approximately 13.5 m deep (varied due to topography change), 26 m long and 4.5 m wide.

For purposes of this assessment, the excavations required for the above structures are assumed to occur concurrently and therefore this assessment very much provides an upper bound effect. In practise, while there may be some cross-over in the construction of the three 'deeper' structures on site, they are likely to be constructed sequentially through the one construction window, or in separate construction windows as already provided for in the existing consents/designation.

The proposed concept construction methodology for the shafts and ancillary structures include the following temporary excavation supports:

- Secant piles within overburden soils (Tauranga Group Alluvium and ECBF soils). Lateral stiffening support may be provided by the use of ring beams.
- Rock bolts, shotcrete and/or rock mesh within weathered and/or fresh ECBF bedrock.
- The proposed concept construction methodology for the grit chamber may include sheet pile trench supports.

The temporary shaft excavation supports have been specified to impede groundwater flow into the shafts during construction, and therefore limit groundwater drawdown. Groundwater modelling undertaken to support the consent application incorporates a low permeability liner through the soils at the site.

It is expected that dewatering of the two shafts and grit chamber will occur over approximately 24 months and up to 36 months in total. This may be completed within the one construction window (as provided for in the s127 application) or across two construction periods as already provided for in the existing consents / designation.

Following construction, a permanent water-tight concrete lining will be installed around the shaft walls and base.

As part of preparing for the work, dwellings located at 42[7], 44, 46 and 48 Tawariki Street have been removed.

[7] Watercare now owns this property.

6 Ground model

6.1 Geological setting

6.1.1 Published geology

The 1:250,000 published geology for the Auckland Urban area[8] indicates that the area is generally underlain by East Coast Bays Formation (ECBF). Materials of ECBF are described as interbedded greenish grey siltstone and sandstone with occasional inclusions of volcanic grit.

The ECBF deposits are indicated in orange on Figure 6.1 and were deposit in large submarine fan environments during the Miocene period. Cycles of erosion, along with sea level rise and fall have varied the material type from siltstone to sandstone. Intermittent volcanism within the area deposited volcanic grit within sediments.

The subsurface materials encountered during borehole investigation were generally consistent with the published geological map. The ground model is further discussed in subsequent sections.

Figure 6.1: Geological map of the area. Image retrieved from T+T Mapviewer derived from Edbrooke, 2001, on 13 April 2022.

[8] Edbrooke, S.W. 2001. Geology of the Auckland area: Scale 1:250,000. Institute of Geological & Nuclear Sciences Limited.

6.1.2 Site investigations

Beca Ltd, on behalf of Jacobs Ltd, carried out a geotechnical ground investigation of the Tawariki Street site on two occasions between 2018 and 2020. This information is provided in their Geotechnical Factual Report[9] and in Jacobs Geotechnical Interpretative Report[10]. This report considers information supplied by these reports with considerable focus on boreholes BH03, BH04 and BH05 which are attached in Appendix A.

6.1.3 Geological interpretation

T+T's assessment of the subsurface geological conditions outlines how the factual data from the site investigations has been interpreted to develop a simplified geological model that we consider suitable for the purpose of this assessment. The model is based on the geomorphology, published geology and previously collected site specific investigations.

The subsurface at the Tawariki Street site is interpreted to comprise the following geological units:

1 Fill; overlying
2 Tauranga Group sediments; overlying
3 Weathered ECBF, overlying
4 ECBF rock.

Material descriptions can be generalised as:

- **Fill (made ground)** deposits comprise a mixture of high plasticity, very soft clay and loose silty sand and sand. Soils are expected to have derived from the Tauranga Group sediments in the area and placed from cut slopes. The fill material contains occasional organics and manmade objects such as metal.
- **Tauranga Group** sediments has been broken down into two units by Jacobs[10] as cohesive and granular soils. However, only cohesive materials are identified in site specific investigations of BH03-05. These cohesive materials are described as high plasticity, very soft silty clay and clay.
- It should be noted that a thickening of the Tauranga Group sediments to the west of the shaft locations (down slope) is expected. This prediction is based on geomorphology of the valley and the stream (Cox's Creek) which flows in the western direction. It is also expected that fill deposits will thicken in the western direction due to the presence of reclaimed land in this area.
- **Weathered ECBF** materials are identified as extremely weak, residually to moderately weathered rock. Rock is interbedded siltstone and sandstone.
- **ECBF rock** deposits are identified as extremely to very weak, moderately to slightly weathered rock. Rock is interbedded siltstone and sandstone with occasional shallow to steep angled discontinuity.

The ground model presented in Table 6.1 has been used for geotechnical assessment and geological cross sections are provided in Appendix B.

The ground model adopted by the hydrogeological and mechanical settlement assessments is consistent with this model.

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[9] Beca Ltd, *Central Interceptor Variation SCN034 Tawariki Street,* Document Number: GAJV-RPT-00216, Revision: 1.0, November 2020

[10] Jacobs Ltd, *Central Interceptor – Addendum No1 to Geotechnical Interpretative Report,* Document Number: JNZ-RPT-00009, Revision: 4, May 2021

Table 6.1: Tawariki Street shafts ground model summary.

Unit		Depth to top of unit (m)	Unit thickness (m)	Peak shear vane reading range [average] (kPa)	SPT n values (average)
1	Fill	0	0.5 – 2.2	Not recorded	1 – 4 (2)
2	Tauranga Group	0.5 – 2.2	2.3 – 3.0		1 – 20 (12)
3	Weathered ECBF	3.5 – 4.5	1.0 – 8.0		20 – 50+ (35)
4	ECBF rock	5.3 – 11.5	>20	N/a	50+ (50)

6.2 Geotechnical parameters

Geotechnical parameters have been collated from the Jacobs' Geotechnical Interpretative Report[10] and reviewed against the interpretation of geology described above. The values used for the Tawariki Street ground settlement assessment are given in the table below.

Table 6.2: Geotechnical analysis parameters for ground settlement.

Geological Unit	Fill	Tauranga Group	Weathered ECBF	ECBF rock
Unit weight, kN/m^3	15	16	19	20
Secant stiffness at 50% of ultimate deviatoric stress at reference pressure, ε_{50} (MPa)	15	20	30	540
Unloading-reloading stiffness, ε_{ur} (MPa)	45	60	90	1090
Normally consolidation coefficient, K_{nc} Note(1)	0.47	0.67	0.67	0.46
Elastic modulus exponent, m	0.5	0.5	0.5	0
Poisson's ratio, v	0.3	0.4	0.4	0.2
Reference pressure, p_{ref} (kPa)	100	100	100	100
Friction angle, Φ	32	28	32	33
Cohesion, c (kPa)	1	7	6	75
K0	0.5	0.5	0.5	1.2

Note (1): Calculated based on the larger of 1-sin(Φ) and v/(1-v).

6.3 Hydrogeological setting

6.3.1 Method

The hydrogeological setting was characterised by combination of:

- Identification of hydrostratigraphic units, based on T+T's geological interpretation presented in section 6.1.3.
- Review of previous documents provided to T+T. The focus of the review was to establish the following key groundwater assessment components adopted previously:

- Aquifer properties for each identified hydrostratigraphic unit.
- Pre-construction groundwater levels and flow direction in the immediate vicinity (i.e. 200 m radius) of the site.

6.3.2 Previous reporting

As described in section 1 and section 2, the previous groundwater assessment[11] was based on construction of one shaft only (i.e. assumed that groundwater would recover prior to construction of the secondary shaft).

Following the applicant's resource consent submission, Auckland Council engaged ENGEO Ltd and WGANZ Pty Ltd (ENGEO/WGA) to undertake a regulatory review of the dewatering and groundwater diversion application (WAT60334954) lodged by Watercare Services Ltd (WSL). The regulatory review[12] focused on the construction of two shafts proposed at 44-48 Tawariki Street, the magnitudes of mechanical settlement (settlement caused by ground relaxation due to excavations) and consolidation settlement (ground settlement due to lowering of groundwater levels) due to the construction, and the effect of these settlements on adjacent buildings and structures.

During the Section 92 review process, further information was provided by WSL, listed below as follows:

- Report titled *"Grey Lynn Interceptor Resource Consent Application: RMA Section 92 Responses Pertaining to Groundwater Assessments",* prepared by Williamson Water & Land Advisory Ltd, Ref. WWA0047, dated 17 April 2019.
- Report titled *"Grey Lynn Interceptor Resource Consent Application: RMA Section 92 Responses Pertaining to Groundwater Assessments",* prepared by Williamson Water & Land Advisory Ltd, Ref. WWA0047, dated 21 May 2019.
- Memorandum titled *"Grey Lynn Tunnel Resource Consent Application: RMA Section 92 Review Reponses"*, prepared by Jacobs/AECOM/McMillen Jacobs Associates, dated 27 May 2019. The list of Section 92 queries raised by ENGEO/WGA and responses from WSL are outlined in the following document:
  - Report titled *"44-48 Tawariki Street, Grey Lynn (Grey Lynn Tunnel and Tawariki Street Shafts) – S92 Review"*, prepared by ENGEO/WGA, Rev. 4, dated 8 August 2019.

6.3.3 Results

The hydrostratigraphic units identified include:

- Fill; overlying
- Tauranga Group sediments (TGA); overlying
- Weathered ECBF, overlying
- ECBF rock.

The previous assessment[11] reported:

- *The shaft will be situated primarily within the ECBF formation with thin Weathered ECBF or TGA deposits overlaying at the land surface. These deposits are considered to have negligible*

[11] Grey Lynn Tunnel - Groundwater Effects Assessment, prepared by Williamson Water & Land Advisory Ltd, dated Feb 2019.
[12] "Auckland Council Technical Memo - Specialist Unit", prepared by Jeffrey Peng. Geotechnical Engineer, ENGEO Ltd and Brett Sinclair. Principal Hydrogeologist, WGANZ Pty Ltd, dated 2 October 2019.

influence on groundwater impacts from shaft construction because they are hydraulically similar to the ECBF (i.e. both of low permeability) and only occur near the land surface. Therefore, only the ECBF was considered for groundwater dewatering modelling purposes.

The regulatory review[12] completed in 2019 summarised the following key groundwater components presented in the previous groundwater assessment, and included:

- Aquifer properties:
  - *Slug tests performed in piezometers installed into the ECBF at the site indicated horizontal hydraulic conductivity for the unweathered to slightly weathered ECBF of between 1 x 10^{-6} m/s and 1 x 10^{-7} m/s.*
  - *Packer tests performed on the highly weathered to slightly weathered ECBF during drilling investigations returned horizontal hydraulic conductivity results of between 2.8 x 10^{-8} m/s and 2.6 x 10^{-7} m/s, although these results are of lower reliability than the slug test results. The vertical hydraulic conductivity of ECBF rocks is commonly accepted as being approximately one order of magnitude less than the horizontal hydraulic conductivity.*
- Hydrostratigraphic units:
  - *The TGA and the highly weathered ECBF are considered to form a hydraulic confining layer above the slightly to unweathered ECBF. Furthermore, the highly weathered ECBF forms an aquitard between the unweathered rock mass and the TGA.*
- Groundwater levels:
  - *Groundwater measurements in three piezometers installed on site indicated the groundwater pressure in the ECBF ranges from 10.91 m RL to 15.04 m RL. These pressures equate to a range from 1.04 m below ground level to 2.77 m above ground level (artesian pressure).*

The previous assessment documents the groundwater model developed to investigate the effects of the proposed shaft dewatering. The model was developed using the MODFLOW finite difference modelling code within the GMS10.2 modelling platform. Nine layers were defined in the model, with hydraulic parameters applied to the simulated layers within the model. The calibrated hydraulic parameters presented in the previous assessment are shown on Table 6.3.

Table 6.3: Calibrated hydraulic parameters presented in the previous assessment

Material	Hydraulic Conductivity (m/s)	Vertical Anisotropy	Storage (Layers 2-9)	Specific Yield (Layer 1)
ECBF	3 x 10^{-7}	30	0.0005	0.25

The hydraulic head distribution representative of the calibrated hydraulic parameters and initial (pre-construction dewatering) conditions are presented in the previous groundwater assessment undertaken, an extract is shown on Figure 6.2. These initial heads represent results obtained from the steady-state model simulation from Layer 1 (the unconfined groundwater system).

T+T completed a visual review of the hydraulic head contours which indicates the direction of groundwater flow in the immediate vicinity of the site (i.e. 200 m radius) is relatively uniform and is generally from east to west. The hydraulic gradient is also relatively uniform. The change in head between 200 m upgradient of the site and 200 m downgradient of the site is approximately 10 m, resulting in a hydraulic gradient of approximately 0.025 (or 2.5%).

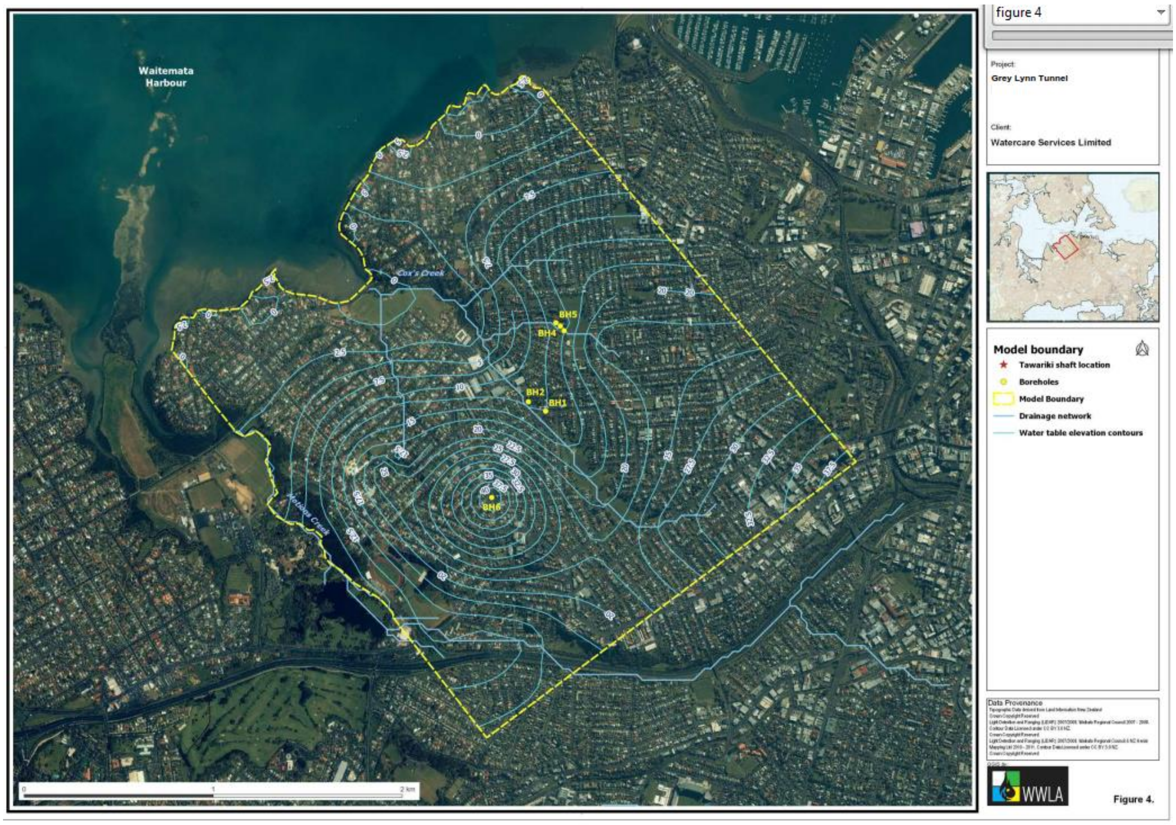


Figure 6.2: An extract of the hydraulic head distribution representative of initial (pre-construction dewatering) conditions from the previous groundwater assessment undertaken[11]

7 Hydrogeological assessment

7.1 Method

Analytical Element Method (AEM) groundwater flow modelling software Analytical Aquifer Simulator (AnAqSim[13]) was used to estimate time dependent (transient) groundwater drawdown during the construction period. AnAqSim is capable of modelling groundwater flow in three dimensions.

The following method was used to assess the potential impact of dewatering at the site:

- A steady-state model was developed to represent initial groundwater conditions prior to construction of the two shafts and grit chamber.
- The hydraulic heads produced by the steady-state model were used as initial conditions for subsequent transient simulations. The transient model represents the aquifer under conditions resulting from dewatering pumping and includes the proposed retention around the perimeter of the shafts and the grit chamber. The retention acts to impede groundwater flow.
- Drawdown-induced settlement was calculated using an incremental layer summation method using python programming (refer Appendix C). This approach calculated the decrease in pore water pressure and corresponding increase in effective stress at the centre of each incremental layer caused by the groundwater drawdown in the unconfined units. This method assumed that the competent ECBF unit was incompressible.
- A sensitivity analysis was undertaken to assess how sensitive the drawdown and settlement model outputs were to changes in input values selected for the retention system conductance (leakiness).

The adopted modelling approach made the following assumptions:

- Infiltration recharge does not occur (resulting in a more conservative drawdown assessment).
- The initial groundwater level at the site centre was approximately 15 m RL.
- The initial groundwater surface was applied was planar enforcing a uniform hydraulic gradient of 2.5% and uniform flow direction of east to west.
- Groundwater drawdown associated with the construction of the tunnel connecting the shafts is considered to have a negligible contribution based on its size and depth. While a detailed assessment has not been undertaken, the contribution of the connecting tunnel upon groundwater drawdown is assessed to be within the bounds of the assessment below.

7.2 Steady state model

The outer boundary conditions used in the steady-state model comprised ‘head specified external line boundaries’ extending 1 km radius from the site centre. The groundwater flow direction was set to flow from east to west, and a uniform gradient of 0.025 was applied.

The input parameters used to setup the steady-state model are shown on Table 7.1.

The resulting groundwater levels from the steady-state simulation (m RL) are shown with respect to ground level (m RL) and shaft location on Figure 7.1.

[13] www.fittsgeosolutions.com

Table 7.1. Steady-state model setup

Model layer	Top elevation (m RL)	Bottom elevation (m RL)	Hydraulic head at site centre	Kh (m/s)	Kv (m/s)	Aquifer type
1	50[1]	5	15 m RL	1 x 10^{-6}	1 x 10^{-7}	Confined[2]
2	5	-25	15 m RL	1 x 10^{-6}	1 x 10^{-7}	Confined

1-Arbitrary, not used for any calculation when subsequent transient model is set to unconfined (calculation based on saturated conditions only).

2-Set to confined for the steady-state model only, to enforce a uniform hydraulic gradient.

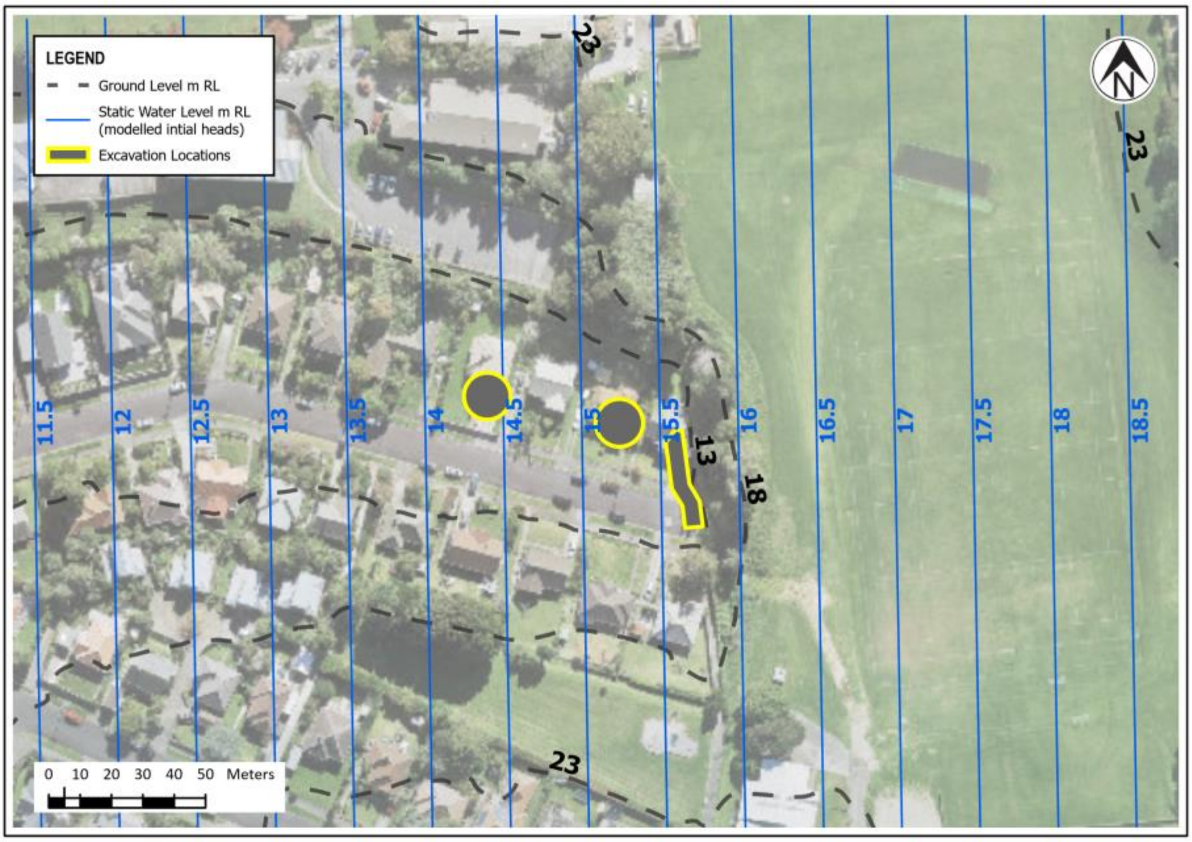


Figure 7.1. Static water level (m RL) and initial (steady-state) heads adopted for modelling purposes. Planar surface / uniform gradient and flow direction applied. Relative to ground level contours (m RL, coarse 5 m resolution).

7.3 Transient model

The hydraulic heads produced by the steady-state model (described above) were used as initial conditions for subsequent transient simulations.

The setup of the transient model was the same model as the steady-state model, with the following updates:

- Excavation retention added to the numerical model, along the perimeter of the proposed shafts and grit chamber footprint to a level of 5 m RL (approx. 7 m bgl). This was achieved using a leaky barrier boundary condition (refer Table 7.3).
- Groundwater levels within the shaft(s) footprint lowered from the initial head to the base of the shaft at -13 m RL (approx. 25 m bgl) refer Table 7.4.
- Groundwater levels within the grit chamber footprint lowered from the initial head to the base of the excavation at 0 m RL (approx. 13.5 m bgl) refer Table 7.4.
- Layer 1 set to unconfined with a specific yield value of 0.25 (refer Table 7.2)
- Layer 1 set to confined with a storativity value of 1×10^{-4}.

Table 7.2. Transient model setup

Model layer	Top elevation (m RL)	Bottom elevation (m RL)	Kh (m/s)	Kv (m/s)	Sy	S	Aquifer type setting
1	50[1]	5	1×10^{-6}	1×10^{-7}	0.25	-	Unconfined
2	5	-25	1×10^{-6}	1×10^{-7}	-	1×10^{-4}	Confined

1-Arbitrary, not used for any calculation when transient model is set to unconfined (calculation based on saturated conditions only).

Performance of the retention system is uncertain due to various contributing factors such as the type and the sequence of activities undertaken by the construction contractor. To assess the impact of this uncertainty, a parameter sensitivity analysis on the retention conductance (leakiness) was completed (refer Table 7.3).

Table 7.3. Leaky barrier boundary condition and retention conductance applied

Run ID	Retention conductance / leaky barrier boundary condition (day^{-1})	Retention conductance interpretation
Run0	1×10^{-2} Applied to model layer 1	**<u>Potential short-term scenario:</u>** • Allows for temporary hydraulic defects in the retention system and associated leakage during the construction/ dewatering period. • In this event, we expect that the contractor would use practical measures to control these (e.g. by grouting or plugging gaps) to reduce groundwater leakage into the shaft. • Adopted conservative value for the purpose of assessing potential effects.
Run1	1×10^{-3} Applied to model layer 1	**<u>Expected long-term / average scenario:</u>** • Retention system performs as designed / intended. • Largely impermeable medium, but accounts for some groundwater leakage through the retention system.

Notes: Conductance C = K*/b*, where K* = hydraulic conductivity of the retention, and b* = thickness of the retention system (b* = 0.5 m for the secant piles at the shaft locations, and 13 mm for the sheet pile at the grit chamber location).

Table 7.4. Internal boundary conditions applied

Type	Setting	Value (m RL)
Head specified line boundaries (HSLB)	NA	-13 m RL for shafts 0 m RL for grit chamber
Spatially variable area sinks (SVAS)	Head dependent flux	-13 m RL for shafts 0 m RL for grit chamber

7.3.1 Output format

The transient model outputs are provided at a single 365 day timestep, selected to represent pseudo steady-state (long-term) conditions.

The model outputs are presented at drawdown observation points along four lines of section (north: N, south: S, east: E, west: W) as shown on Figure 7.2.

The drawdown and settlement results are also presented as contour plots in Figure 7.5. The method applied includes:

- Drawdown contours were generated directly from AnAqSim software.
- Drawdown-induced settlement contours were generated using Surfer software applying the Kriging interpolation method to the observation points shown on Figure 7.2.

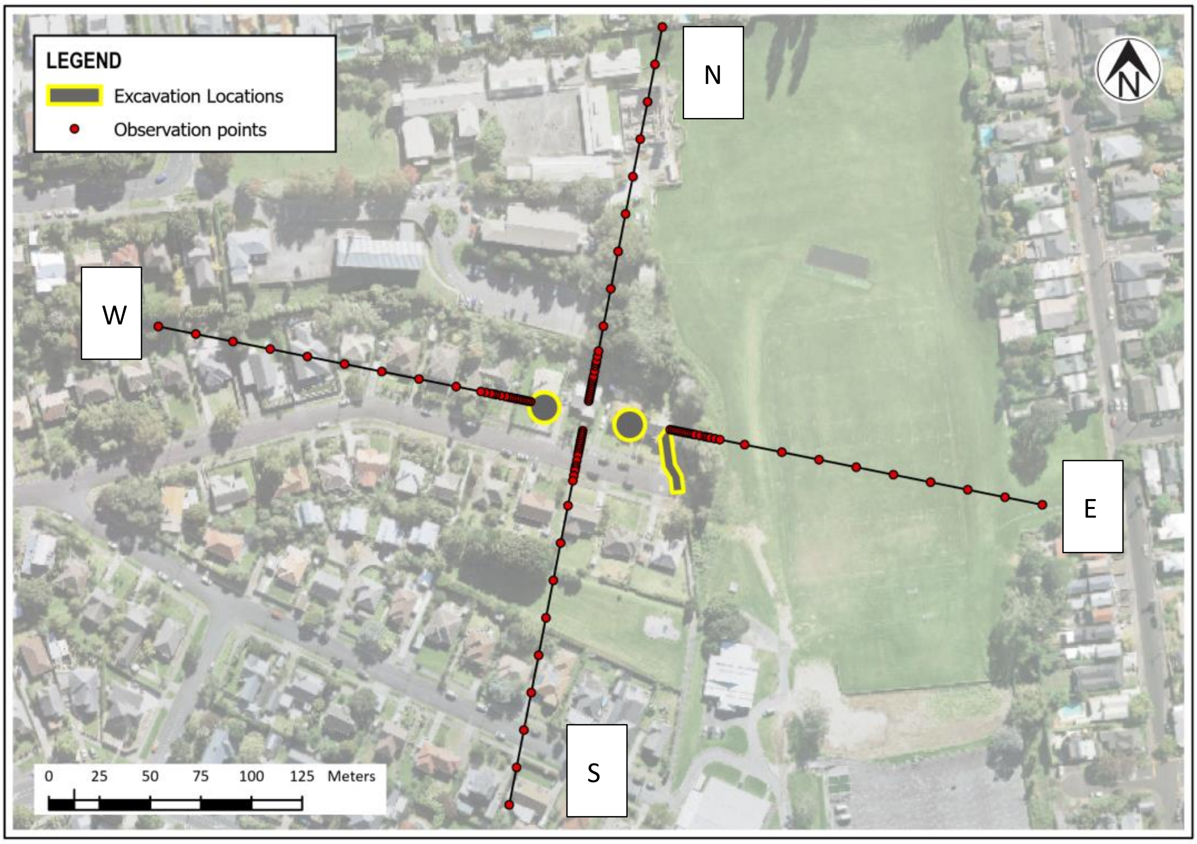
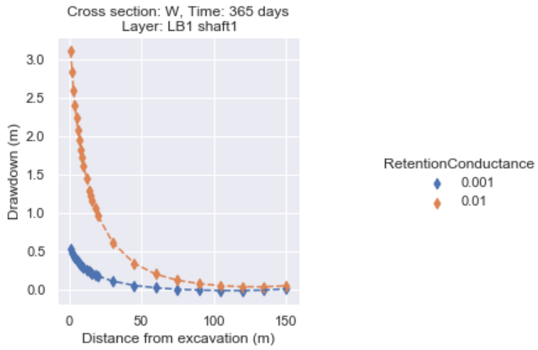


Figure 7.2. Modelled shaft locations, and position of drawdown and settlement observation points along lines of section (north: N, south: S, east: E, west: W).

7.3.2 Results

The groundwater model drawdown and drawdown induced settlement results along the four lines of



section are presented on

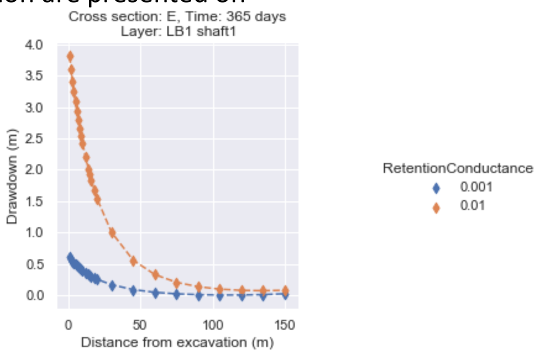


Figure 7.3 and Figure 7.4 respectively. Adopting a conservatively leaky retention condition (Run0), these results show that the modelled drawdown is generally even in all directions around the proposed excavations with a slight ellipsoidal shape immediately around the excavations, becoming radial with distance away. Maximum groundwater drawdown levels up to **4.0 m** are predicted next to the excavations, reducing to less than **0.5 m at approximately 50 m distance**, and **near zero to within generally 100 m** distance.

Modelled groundwater induced ground settlement immediately outside the excavation ranges from approximately **14 mm** to **25 mm**, with the larger settlements observed on the western side due to the greater thickness of compressible soils. Surface ground settlement reduces with increasing distance from the excavation, decreasing to less than 12 mm at adjacent dwellings.

Figure 7.5 shows the Run0 drawdown results exported from AnAqSim software. This is the upper bound (worst) case from an effects perspective. An interpolated settlement contour plot is presented on Figure 7.5 which was derived using our settlement analysis results along the lines of section specified and engineering judgement. For illustrative purposes, contours extending from the shaft edge to the 14 mm settlement contour line have been excluded. For assets where settlements are larger than 14 mm our analysis relies on the interpretation of results from Figure 7.4.

A summary of the drawdown-induced settlements at assessed structures is presented in Section 10.

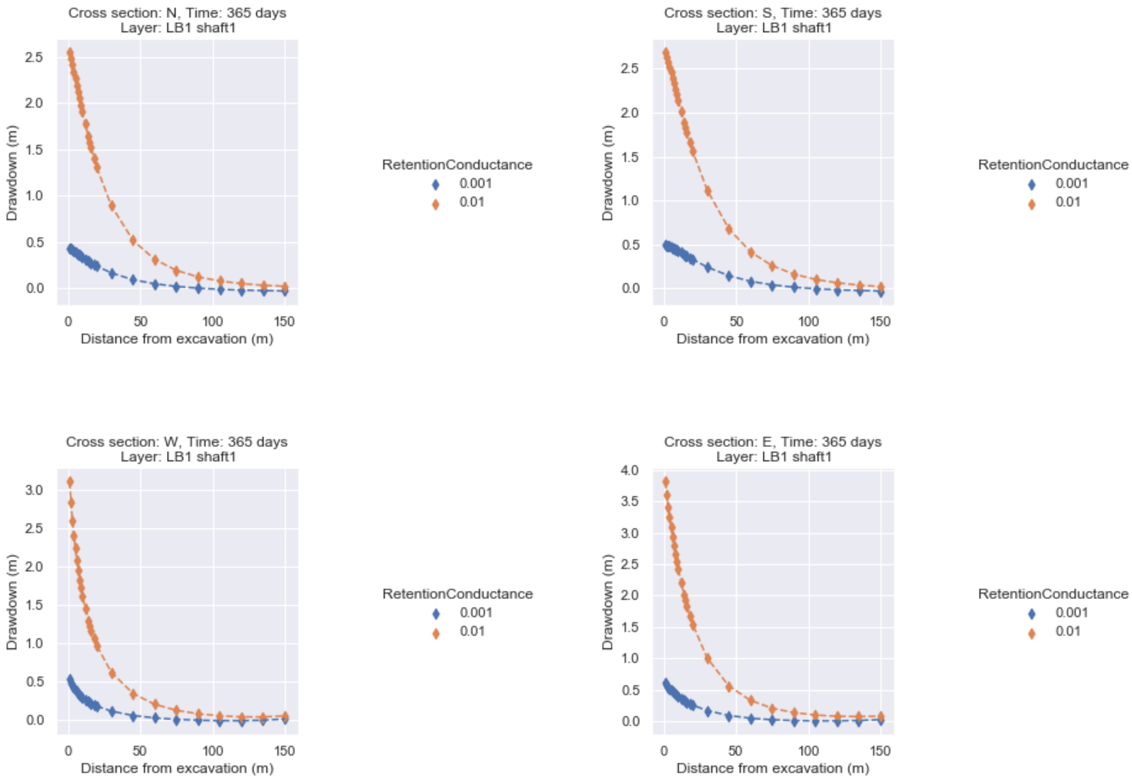


Figure 7.3. Drawdown results along lines of section (north: N, south: S, east: E, west: W)

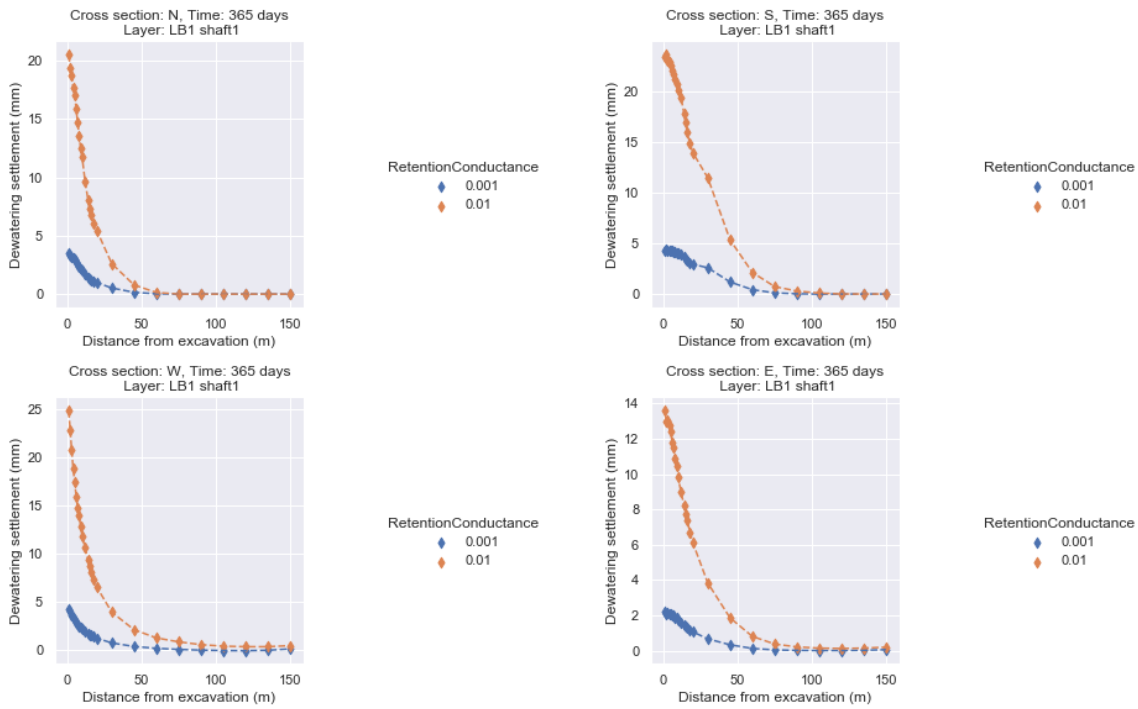


Figure 7.4. Drawdown-induced settlement results along lines of section (north: N, south: S, east: E, west: W)

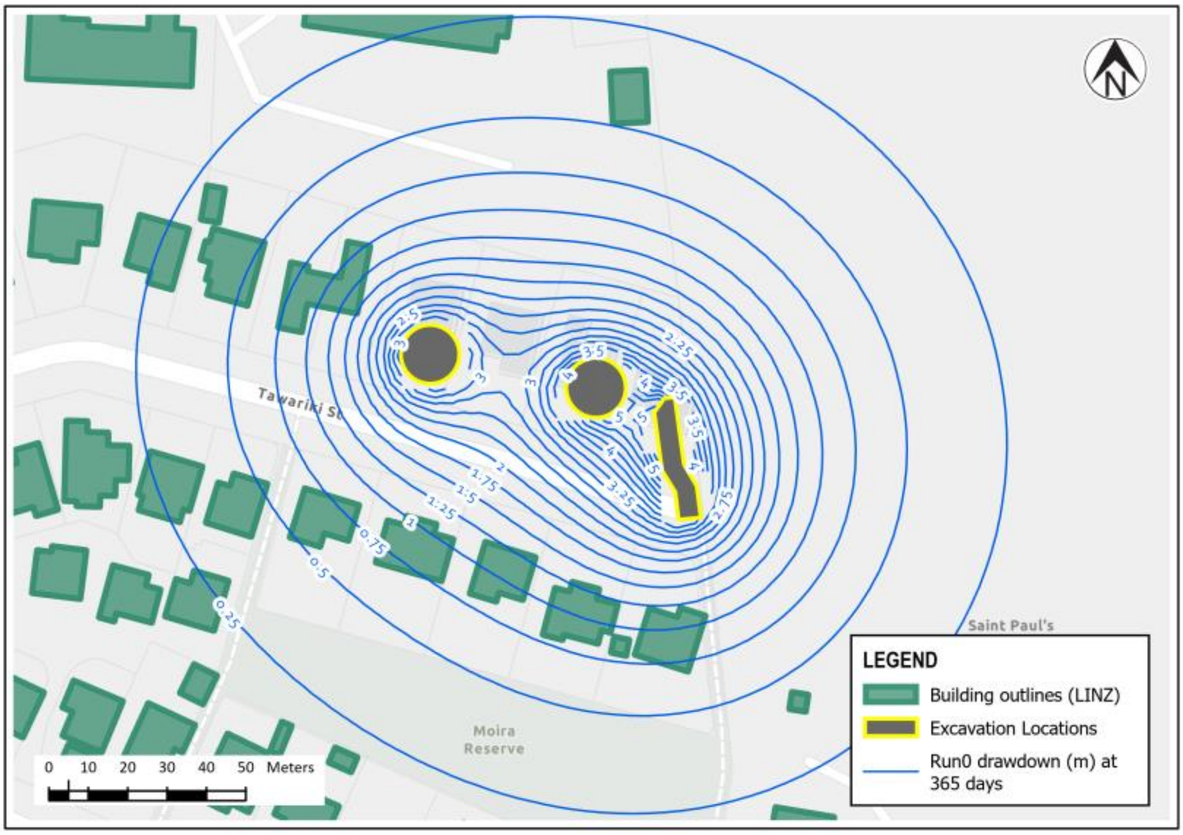


Figure 7.5. Drawdown (m) contours relative to adjacent buildings. Results from model Run0 (retention conductance set to 0.01 day^{-1}) at 365 days.

Figure 7.6. Drawdown-induced settlement (mm) contours relative to adjacent buildings. Results from model Run0 (retention conductance set to 0.01 day^{-1}) at 365 days.

8 Mechanical settlement assessment

8.1 Grit chamber

8.1.1 Method

Empirical methods from CIRIA C760 have been adopted to assess the zone of influence behind the grit chamber excavation subject to mechanical settlement.

To compute the zone of influence (ZOI) corresponding to the associated ground movements behind the wall, it has been assumed that:

- ground movement will only occur within the soil material and not within the ECBF rock.
- soils conservatively extend up to 11.5 m depth.
- The excavation retention will be laterally restrained.
- Corner and edge effects are conservatively ignored.

8.1.2 Results

Adopting the method outlined in Figure 6.17 of CIRIA C760, the ZOI subject to ground deformation behind the grit chamber excavations is assessed to be 11.5 m (this is equivalent to a 45 degrees line back from the top of the ECBF rock).

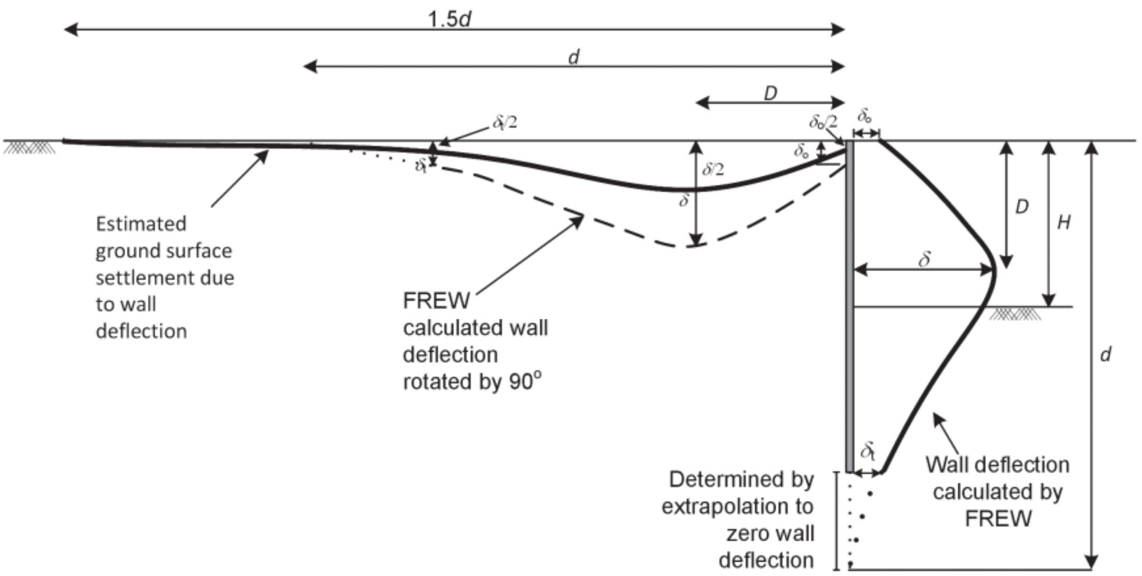


Figure 7: Relationship between assessed wall deflections and predicted ground surface settlements utilising CIRIA C760 Figure 6.17

Within the ZOI, there are no existing structures which may be impacted by ground deformation which already do not need to be relocated as a result of the proposed excavations. The only structures within the ZOI are a series of public underground services which are expected to be relocated as they currently reside within the proposed excavation footprint, and the road pavement which will need to be reinstated post excavation and construction works.

On this basis, a detailed assessment to estimate ground settlement magnitudes within the ZOI has not been undertaken. We also note that other than a potential change to the construction sequence, there is no change to the grit chamber from that originally considered and addressed in the resource consents and designation.

8.2 Drop shaft

8.2.1 Method

Two dimensional Fast Lagrangian Analysis of Continua (FLAC Version 7.0, Itasca Consulting Group) was used to model soil-structure interaction and estimate a settlement profile for both Tawariki Street shafts. Figure 8.8 shows the model generated in FLAC.

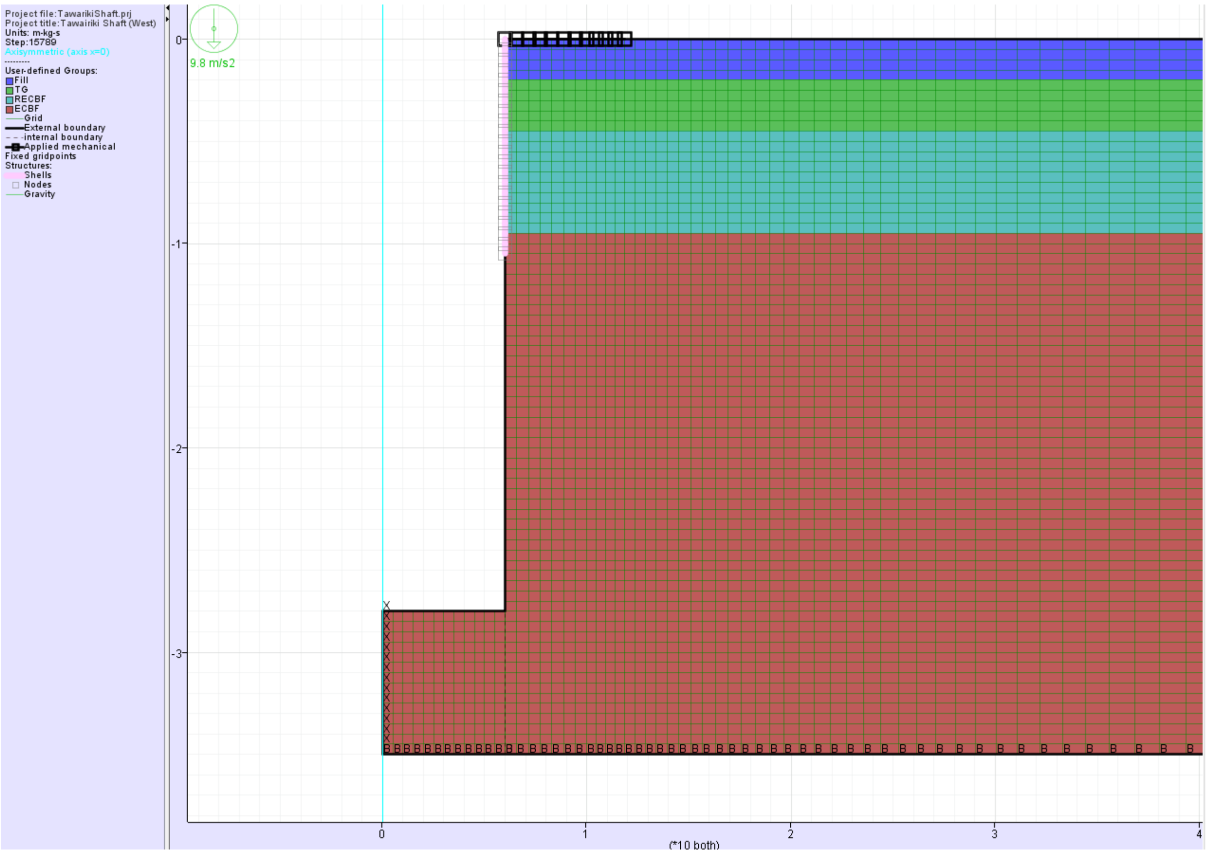


Figure 8.8: Cross section of FLAC model.

The ground conditions are conservatively based on the western section of the west Tawariki secondary shaft, where the alluvium soil is the thickest. The ground model has been simplified by using horizontal layers as summarised in Table 8.1 below.

Table 8.1 Geological model used for modelling

Depth (m)	Geological model
0 to 2.0	Fill
2.0 to 4.5	Tauranga Group
4.5 to 9.5	Residual ECBF
9.5 to 35	ECBF rock

The secant piles are assumed to be constructed with 1.0 m of minimum embedment into ECBF rock. The top of ECBF rock is likely to vary across the circumference of the shaft, and therefore the depth of piles could vary with ECBF rock level.

Table 8.2 Dimensions of shaft

Shaft depth (m)	Diameter (m)	Support
0 to 10.5	12.0m	Secant pile (extends 1.0m into ECBF rock)
10.5 to 28		Unlined (not supported)

Note: Shotcrete has not been modelled as the ECBF rock mass is self-supporting. However, the designer or contractor would likely need to shotcrete to prevent localised failure of the ECBF rock face. Any reduction in settlement estimates due to a shotcrete layer are expected to be negligible.

The modelled groundwater level has been conservatively assumed to be at the ground surface outside of the shaft throughout the construction. The shaft will be excavated "dry", and therefore the groundwater level inside the shaft is assumed to be at the base of the excavation. This is considered appropriately conservative for the assessment of mechanical settlement as the secant piles will be subject to higher retention pressures compared to if groundwater drawdown was modelled.

A 35kPa surcharge has been modelled over a 7m wide area directly behind the shaft opening to account for construction machinery. This is based on a 120tonne crane on a 7m x 5m wide pad.

8.2.2 Structural properties of ring beam installation

The properties in Table 8.3 have been adopted in our model.

Table 8.3 Structural properties used for modelling

Structural member	Modelled structure element	Average Young's Modulus, E (GPa)	Poisson's ratio	Thickness (m)
Secant pile	Axisymetric shell element	13*	0.2	0.55**

*Average of pile young's modulus based on contribution from hard piles only (30MPa compressive strength concrete). The contribution of soft piles are conservatively ignored.

**Based on the overlap thickness of a 750mm diameter piles at 500mm centre-to-centre spacing.

8.2.3 Construction sequence

The following sequence has been assumed for the construction of the Tawariki Shafts:

1 Construct secant pile in a hard and soft sequence with min 1.0m embedment into ECBF rock.

2 Excavate down to final depth (28m below ground surface modelled)

8.2.4 Assumptions and analysis limitations

The modelling results are based on the following assumptions:

1 An axisymmetric model has been used, which does not allow for the explicit modelling of unbalanced loading (variation in ground conditions, groundwater conditions or ground surcharges). However, we expect the effect on settlement is negligible.
2 The secant piles are interconnected and behave as a compression ring. Any adverse effect from loss of contact between secant piles has not been analysed.
3 Mechanical settlement associated with the construction of the tunnel connecting the shafts is considered to have a negligible contribution based on its size and depth. A detailed assessment has not been undertaken. The contribution of the connecting tunnel upon surface ground settlement is assessed to be within the bounds of the assessment below.

8.2.5 Results

8.2.5.1 Settlement profile

Figure 8.9 below presents the settlement predicted on the ground surface due to the shaft excavation.

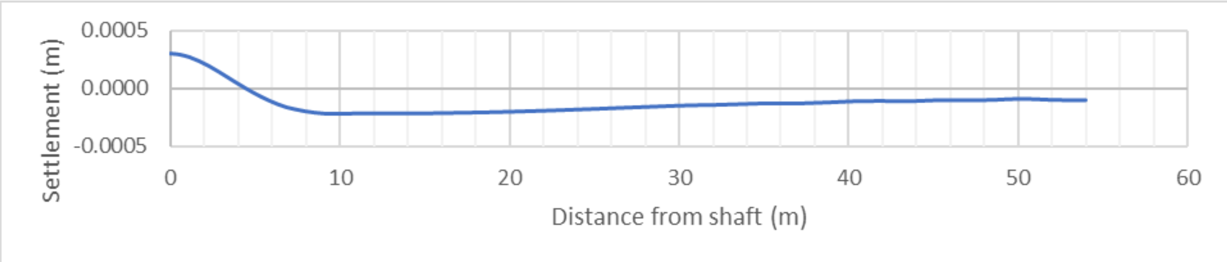


Figure 8.9 Ground surface settlement prediction

The results indicate that mechanical induced settlement from the construction of Tawairiki Shaft is less than 1 mm (that the scale for the y-axis only covers 1 mm).

8.2.5.2 Retaining wall deflection

Figure 8.10 below presents the deflection predicted for the secant pile wall after the completion of shaft excavation.

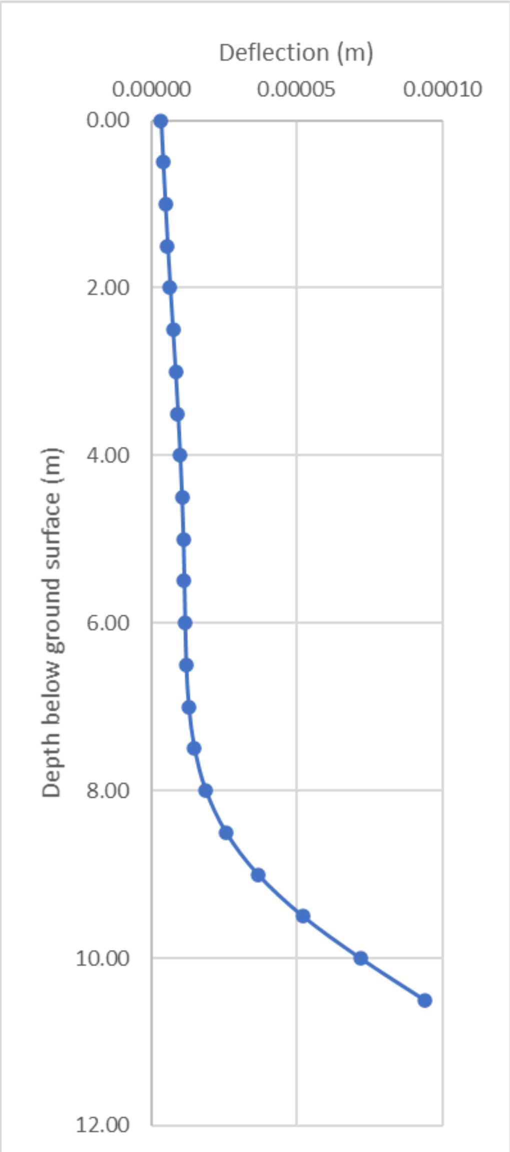


Figure 8.10 Retaining wall deflection prediction (positive deflection values indicate movement into the excavation)

The modelling results indicate that the deflection of the secant pile wall is minimal (less than 1 mm).

9 Effects assessment methodology

9.1 Geotechnical effects

9.1.1 Overview and objective

Ground settlement associated with the project construction methodologies are expected to be derived from two sources, these being:

- Mechanical settlement – settlement due to the physical movement of the ground, as a result of lateral movement at the boundary of trenches and/or excavations. This type of settlement typically occurs within a short period of time and can be controlled by good construction practices and engineering solutions.
- Consolidation settlement – settlement due to an increase in effective stress associated with the lowering of groundwater levels. This settlement is dependent on the rate and extent of groundwater level lowering and the susceptibility of the soils to consolidation. This type of settlement typically occurs more slowly than mechanical settlement and can be controlled by specific pipeline and structure design, and by good construction methodologies, practices, and reduced programme durations.

The construction of the project has the potential to induce vertical and lateral ground movements that can affect the condition of structures within the zone of influence. For purpose of this assessment, we have considered the zone of influence as the area where total ground settlements associated with the projects may be equal to or greater than 5 mm. Settlement guidelines are presented below for the potentially affected structures.

9.1.2 Settlement tolerance

9.1.2.1 Buildings

The proposed works are expected to be constructed near existing structures, principally private dwellings. In general, a building structure's tolerance to total and differential settlement depends upon the materials used in construction as well as type of foundation system adopted (shallow versus piled), the quality of the structure, and the existing condition of the structure.

The limiting values of total settlement and angular distortion along with damage classification as presented in CIRIA PR30 1996 have been used as guidance for assessment of potential effects on buildings. In addition, the New Zealand Building Code states that designers should limit the probable maximum differential settlement of a building to 1V:240H (25 mm over a 6 m horizontal distance) under serviceability limit state loading, or total settlement to 50 mm unless the structure is specifically designed to resist damage under a greater settlement. While the NZ Building Code applies to these structures, the residential house dwellings are likely to have been designed using acceptable solutions outlined in NZS 3604 which is appropriate for ground with movements less than 25mm. The ground deformation limits outlined in NZS 3604 are approximately equivalent to Risk Category 2 in CIRIA PR30.

A review of aerial photographs and Google Street View identifies buildings to the west and south of the proposed works to comprise single level residential dwelling that are expected to be supported on shallow foundations. Cladding was observed to comprise timber weather board, brick and plaster render. These structures are summarised in Table 9.1 below. We assess these buildings as having some tolerance to ground settlement.

Table 9.1: Summary of buildings within the 5mm contour line

Property Address	Property Type	Dwelling Levels	Cladding Type	Foundation Type
29 Tawariki Street	Single Family Residential	1 level	Timber clad, crawl space is concrete or concrete block with plaster render	Shallow - suspended floor foundation with concrete perimeter foundation
33 Tawariki Street	Single Family Residential	1 level	Timber clad, crawl space is concrete or concrete block with plaster render	Shallow - suspended floor foundation with concrete perimeter foundation
35 Tawariki Street	Single Family Residential	1 level	Brick clad, crawl space is concrete or concrete block with plaster render	Shallow - suspended floor foundation with concrete perimeter foundation
37 Tawariki Street	Single Family Residential	1 level	Brick clad, crawl space is concrete or concrete block with plaster render	Shallow - suspended floor foundation with concrete perimeter foundation
38 and 40 Tawariki Street	Single Family Residential (two dwellings)	1 level	Brick clad, crawl space is concrete or concrete block with plaster render	Shallow - suspended floor foundation with concrete perimeter foundation
39 Tawariki Street	Single Family Residential	1 level	Timber and plaster render, crawl space is concrete or concrete block with plaster render	Shallow - suspended floor foundation with concrete perimeter foundation
41 Tawariki Street	Single Family Residential	1 level	Brick clad, crawl space is concrete or concrete block with plaster render	Shallow - suspended floor foundation with concrete perimeter foundation

It is important to note that the values presented in in the New Zealand Building Code are total amounts of movement over the life of a building. The buildings in the vicinity of the project are existing, with unknown histories; and therefore, may have already been subjected to some movement. To account for historical movement, buildings that are subjected to less than 5 mm vertical settlement and differential settlement slopes no greater than 1:1000, have been assessed to have a negligible risk to damage and would not need to be further assessed.

For the purposes of this assessment, the settlement criteria in Table 9.2 (which is generally based on the Burland (1995), and Mair et al (1996) classification) has been adopted for our assessment:

Table 9.2: Settlement criteria for properties and buildings along the proposed project alignment

Risk Category	Maximum settlement of building (mm)	Maximum differential settlement	Description of risk	General Category
0	-	-	Negligible: superficial damage unlikely	Aesthetic Damage
1	<10	< 1 in 500	Very Slight: Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building. Cracks in exterior visible upon close inspection. Typical crack widths up to 1mm.	
2	10 to 50	1 in 500 to 1 in 200	Slight: Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible, some repainting may be required for weather-tightness. Doors and windows may stick slightly. Typical crack widths up to 5 mm.	
3	50-75	1 in 200 to 1 in 50	Moderate: Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Brick pointing and possible replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather tightness often impaired. Typical crack widths are 5 to 15 mm or several greater than 3 mm	Serviceability Damage
4	> 75	1 in 200 to 1 in 50	Severe: Extensive repair involving removal and replacement of walls especially over door and windows required. Window and door frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably. Some loss of bearing in beams. Utility services disrupted. Typical crack widths are 15 to 25 mm but also depend on the number of cracks.	
5	> 75	> 1 in 50	Major repair required involving partial or complete reconstruction. Beams lose bearing walls lean badly and required shoring. Windows broken by distortion. Danger of instability. Typical crack widths are greater than 25 mm but depend on the number of cracks	Structural Damage

9.1.2.2 Underground services

Published literature[14] indicates that the maximum differential settlement for cast iron pipes and brittle services with a diameter of 200 mm or greater is in the order of 1:250. Most of the major services near the proposed works appear to be more flexible materials such as concrete pipe, polyethylene pipes, electrical cables etc. Services running perpendicular to the excavation works are considered to be at the highest risk of damage. In general, where a service is parallel to the excavation works, it may experience horizontal displacement associated with ground loss at the excavation face, as well as similar total settlement but with a gentler settlement slope, i.e., differential settlement.

Settlement tolerance of a service will be dependent on the condition of the current asset and its tolerance to deformation. An allowable differential ground settlement of 1:500 has been conservatively adopted for the services along the proposed excavation works to assess the potential for adverse effects. For any services passing within a zone of potential settlement, the service will need to be checked during detailed design for its tolerance to the predicted settlement magnitude and shape, with specific mitigation measures developed in the instance where tolerances may be approached or exceeded. Each service may differ in its acceptable movement tolerance (to be defined by the respective asset owner), so each shall be assessed individually during the detailed design stage.

A review of publicly available information retrieved from BeforeUdig and Auckland Council Geomaps indicates a series of public services within the zone of influence. These are shown on Figure 1 in Appendix D.

9.1.3 Combination of mechanical and consolidation settlement effects

The total settlement that occurs at the ground surface is a combination of consolidation settlement induced by groundwater drawdown and mechanically induced settlement. The mechanically induced settlement is expected to occur relatively quickly, compared to the consolidation settlement resulting from groundwater drawdown.

We have adopted a method to combine the calculated settlements and report the total estimated settlement a set horizontal distances from the excavations.

9.2 Groundwater effects

9.2.1 Overview

These potential groundwater effects have been assessed:

- Effect of diversion – groundwater flow is diverted into and/or around structures which are installed in the ground such as temporary sheet piling and final permanent works
- Effect on neighbouring bores – upstream groundwater levels may be increased by the damming effect of installed structures and reduced by the dewatering required to keep the excavation dry, which affects the ability of bores to provide a water supply.

[14] O'Rourke, T D, and C H Trautmann. 1982. Buried pipeline response to tunnel ground movements. In Europipe 82 Conf., Basel, Switzerland, paper 1.

9.2.2 Groundwater diversion

The effect of diversion is to alter the path of existing groundwater flow. This assessment method considers whether the groundwater flow is permanently diverted by the installed structures and causes increases or decreases in groundwater levels such that these affect lawful groundwater users.

9.2.3 Neighbouring bores

Neighbouring bores may be affected by groundwater level changes, occurring during dewatering activities. These effects are significant if the groundwater supply can no longer be obtained from these neighbouring bores.

10 Effects assessment

This section presents the general range of effects that might arise from the project's construction activities, provides guidance on acceptable settlement amounts, and summarises the specific effects that are estimated for the areas considered to be of particular interest or critical to the project.

10.1 Geotechnical settlement effects

This section presents the general range of geotechnical effects that we have estimated that could occur from the project's construction activities and summarises the specific effects that are estimated for the areas considered to be of particular interest or critical to the project.

The estimated total ground settlements are summarised in the following sections and presented as a contour plan in Appendix D.

10.1.1 Assessment of effects on buildings

Total and differential settlement have been estimated for existing buildings near the proposed excavation works. Table 9.1 presents buildings that have been assessed for potential damage induced by ground settlement associated with the proposed excavation works.

Properties at 35, 37, 38 and 40 Tawariki Street are closest to the proposed excavations works. Subsequently, they are assessed to experience the greatest total and differential surface ground settlements. However, even at these properties, differential settlements are not expected to be steeper than 1V:1500H. Strictly applying the damage categories presented in Table 9.2, dwellings at 35 and 37 Tawariki Street would classify as damage category 2 based on total settlement, but as damage categories 0-1 based on differential settlement. Based on the building type and condition visually observed from the road, we assess that these buildings are more sensitive to differential settle rather than total settlement, and as such, have assessed a damage category of 1. The dwellings at 38 and 40 Tawariki Street are structurally connected and are likely to have a greater vulnerability, particularly in the area where they are connected and hence they have been assessed as a damage category 2. The type of damage that could occur is surficial cosmetic (non-structural) cracking at the location where the buildings are joined (both internal and external) and is readily repairable. We expect that the risk of damage can be managed through a baseline survey, visual monitoring of the property during construction, and as part of the consent conditions.

Properties 29, 33, 39 and 41 Tawariki Street are further away from the proposed works and are assessed to experience comparatively lower levels of differential settlement. Adopting the damage categories presented in Table 9.2, we assess these properties to be within the 0 to 1 damage categories.

Relevant settlement contours for the assessed buildings are presented in Appendix D.

Table 10.1: Summary of total settlements from excavation works at assessed structures

Location	Approximate Horizontal distance from edge of nearest excavation to dwelling[1]: (m)	Estimated Horizontal distance from edge of excavation to 5 mm or less settlement contour (m)	Estimated total maximum surface ground settlement (mm)	Estimated approximate maximum differential surface ground settlement across building	Damage category and description to existing structures[2]
29 Tawariki Street	44	60	6	<1V:4000H	0-1
33 Tawariki Street	34	60	10	1V:3000H	0-1
35 Tawariki Street	34	60	12	1V:2500H	1[3]
37 Tawariki Street	37	60	12	1V:2500H	1[3]
39 Tawariki Street	27	35	9	1V:2500H	1
38 Tawariki Street	23	35	7	1V:3000H	2
40 Tawariki Street	14	30	12	1V:1500H	2
41 Tawariki Street	22	24	6	1V:3000H	0-1

1. Horizontal distances are approximate and calculated using aerial imagery. Horizontal distances should be confirmed during detailed design.
2. Damage category and description as described in Table 9.2.
3. Damage category assessed using engineering judgement and descriptions in Table 9.2 taking into account the very low differential settlement predictions.

Given the analysis undertaken, we assess that the ground settlement effects on buildings to be generally negligible to very slight risk of damage. Damage that may occur is assessed to likely be aesthetic related and readily repaired.

We recommend that building condition surveys are undertaken for 35, 37, 38, 39 and 40 Tawariki Street. We understand that the building conditions surveys for 38 and 40 Tawariki Street will be in addition to the conditions of the Resource Consent. The other properties are already addressed through the existing consent conditions.

10.1.2 Assessment of effects on underground services

Maximum total and differential settlements are assessed to be 25 mm and 1V:1000H respectively. At this level of total and differential settlement, we assess that the risk of damage to underground services is negligible to very slight.

10.2 Groundwater effects

10.2.1 Groundwater diversion

The proposed shafts will be constructed within the groundwater table. The groundwater flow direction of the shallow aquifer is expected to be a muted reflection of the site topography, i.e., flowing from higher to lower ground in a generally westward direction. Groundwater at depth is assumed to flow towards the north west and discharging into Cox's creek.

Groundwater that is not intercepted by the dewatering associated with shaft construction take will be diverted around the proposed secant piled structures. However, the diverted groundwater is still expected to continue to discharge to Cox's Creek. Given the relatively sealed construction method proposed, and fixed dewatering period, the effect of dewatering on the regional groundwater levels is expected to be inconsequential.

10.2.2 Neighbouring bores

The nearest groundwater take bore is approximately 1.8 km away from the proposed shaft excavation works which is outside the zone of expected groundwater drawdown influence. We therefore assess that there are no groundwater take bores in the area impacted by the proposed shaft construction.

10.3 Long-term effects

Ongoing long-term groundwater drawdown is considered to be unlikely as the completed infrastructure should be a closed or watertight system. Groundwater levels are expected to return back to similar levels as prior to construction. Settlements associated with construction are likely to occur in a relatively short period of time and stop once the excavations are complete and backfilled. Nevertheless, settlements that occur during construction are considered to generally not fully recover and are therefore permanent, even when groundwater levels recover.

10.4 Monitoring programme

A groundwater and settlement monitoring programme during construction is required by existing consent conditions. The requirements of the monitoring programme, including Alert and Alarm levels, will be set out in the Groundwater and Surface Monitoring Contingency Plan (GSMCP). The plan includes groundwater drawdown, surface settlement, building settlement monitoring and visual observation monitoring.

Given the low levels of expected ground deformation associated with the proposed works, baseline monitoring of ground surface settlement and building settlement points is recommended to be undertaken prior to commencement of construction to establish seasonal variability. While we would recommend this is undertaken for at least 12 months prior to commencement of construction, we understand this is not practical given a construction start date of March 2023. As such, monitoring should commence as soon as practically possible.

In addition, groundwater monitoring bores located within the boreholes BH03, BH04 and BH05 (referenced in this assessment) should be monitoring for a minimum period of 6 months prior to commencement of construction to establish baseline levels.

We understand that our baseline monitoring recommendations are already a condition of the Resource Consent.

11 Conclusion

This technical Assessment of Groundwater and Settlement Effects Report has been prepared by T+T to support an Assessment of Effects on the Environment (AEE) and S127 to the existing resource consent.

Our assessment presents the results of undertaking the works concurrently in one construction window, resulting in an upper bound effect. Should the works be undertaken in stages (i.e. in separate construction seasons), then the effects will be less and within the bounds of this assessment.

Structures closest to the excavation and immediately to the west are expected to experience the greatest levels of ground settlement due to their distance from the excavation and thickness of compressible material. With distance from the excavation, settlement values diminish. Total surface ground settlements at adjacent dwellings is assessed to be 12 mm or less with differential settlements no steeper than 1V:1500H. At adjacent services, settlements are limited to less than 25 mm with differential settlements no steeper than 1V:1000H.

Based on our technical assessment, we assess:

- Ground settlement effects arising from construction and operating the Tawariki Shafts on surrounding structures is assessed to generally be negligible (0) to very slight risk (1) of damage.
- Ground settlement effects at 38 and 40 Tawariki Street are assessed to be at the lower bound of Slight (2) particularly where they are connected due to the form of the building. The type of damage that could occur is surficial cosmetic (non-structural) cracking at the location where the buildings are joined (both internal and external) and is readily repairable.
- This can be managed by a baseline survey and as part of consent conditions any damage caused will need to be repaired. As it is limited to cosmetic damage, it will be relatively easy to repair (internal decorating) and external whether tightness
- Effects upon groundwater levels are expected to localised to within generally 100 m distance of the proposed excavation and temporary in nature. Upon completion and sealing of the shafts, groundwater levels are expected to return to levels prior to construction.
- Based on the assessment of groundwater and settlement effects set out above, the effects of constructing the two shafts and associated grit chamber within the one construction period, and relocating the secondary shaft from 44 to 42 Tawariki Street, are within the consented envelope of effects.

12 Applicability

This report has been prepared for the exclusive use of our client Watercare Services Limited, 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.

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

Tonkin & Taylor Ltd

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Appendix A: Ground Investigation Data

- **Figure 1 – Site Plan**
- **Borehole Logs (BH03, BH04 and BH05)**

C:\Troy\GIS\CI Shafts\Tawariki Shafts\Tawariki Shafts.aprx Layout: T+T A3 Landscape Map Template 2022-Apr-29 10:03 AM Drawn by TRMC

Tonkin+Taylor

Exceptional thinking together www.tonkintaylor.co.nz

NOTES:
Basemap NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.. Google Satellite: © OpenStreetMap (and) contributors, CC-BY-SA

REV	DESCRIPTION	GIS	CHK	DATE
0	First version	TRMC	EDMA	29/4/22

LOCATION PLAN

PROJECT No.	30552.9090	
DESIGNED	TRMC	MAY.22
DRAWN	TRMC	MAY.22
CHECKED		
APPROVED		DATE

CLIENT WATERCARE SERVICES LTD

PROJECT CENTRAL INTERCEPTOR - TAWARIKI STREET SHAFTS

TITLE GEOLOGICAL CROSS SECTION LOCATIONS

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

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Central Interceptor CIGI5**	**Borehole**
Location: **41 Tawariki Street, Grey Lynn** Project No: **AE04725**	Hole ID: **CIE-BH03**
Client: **Watercare**	Date: **23/03/2018**

Started:	23/03/2018	Remarks Packer Test at 20.00-24.50 m Artesian piezometer, low pressure gauge installed.. Pressure reading on 25/05/2018 was 21 kPa. Hole location determined by Survey.	Co-ordinates: 5920068.77mN 1754833.35mE
Finished:	27/03/2018		Elevation: 13.34mRL
Driller:	McMillan		Inclination: -90°
Plant:	Rig N101 (McMillan)		
Logged:	A. Coutts		
Checked:	CS		Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Central Interceptor CIGI5**

Borehole

Location: **41 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH03**

Client: **Watercare**

Date: **23/03/2018**

Columns: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) (25 50 75) | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) (500 100 50 10) | Relative Strength (EW VW W MS S VS) | Weathering Grade (UW SW MW HW CW RW) | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description key:

TYPE		SURFACE		APERTURE	
CS	Clay seam	C	Clean	T	0mm
C	Clevage	Mc	Mineral coat	Vn	0-2mm
CR	Crushed zone	Si	Soil infill	N	2-6mm
DZ	Decomposed zone	Sn	Surface stain	Mn	6-20mm
DB	Drilling induced fracture	V	Veneer	Mw	20-60mm
FL	Foliation			W	60-200mm
FZ	Fracture zone	*PLANARITY*		Vw	>200mm
IF	Incipient fracture	P	Planar		
JT	Joint	St	Stepped		
SC	Schistosity	U	Undulating		
SH	Shear				
SZ	Shear Zone	*ROUGHNESS*			
SL	Sill	R	Rough		
VN	Vein	Ss	Slickensided		
VD	Void	Sm	Smooth		

R.L. (m) scale: 13, 12, 11, 10, 9, 8, 7, 6, 5, 4. Depth (m) scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

Drilling method / core recovery:

Drilling Method	TCR (SCR) [RQD] %
VAC EX	0
HQ3 (23/03/2018 8:00:00 AM)	100
TBX	70
HQ3	100
SPT	100
TBX	100
HQ3	100
SPT	78
HQ3	81 (74) [74]
SPT	100
HQ3	92 (92) [92]
SPT	0
HQ3	75 (75) [75]
SPT (23/03/2018 3:00:00 PM; 26/03/2018 9:00:00 AM Water depth 1.8m)	0
HQ3	100 (100)

Flush Type: **Water**; Flush Colour: **Grey**

Sampling: TW, TW, TW

In-Situ Testing:
- SPT$_s$ 3,7,13 N=20
- SPT$_s$ 13,14,33 N=47
- SPT$_s$ 19,40 N>50 40/150 bouncing
- SPT$_c$ 34,33 N>50 33/75 bouncing
- SPT$_c$ 44 N>50 44/150 bouncing

Description of Strata:

Vacuum Excavation.

Silty CLAY with minor rootlets; light grey mottled orange and dark brown. Very soft, saturated, high plasticity.
1.70m: Becomes minor sand. Sand is fine.
1.90m: Becomes dark grey.

PUSH TUBE: Material at top and bottom comprises: CLAY with minor silt and trace fine sand; dark grey mottled light brownish grey. Soft, saturated, low plasticity.

CORE LOSS.

CLAY with some silt; dark grey mottled light brownish grey. Soft, wet, high plasticity.

SILT with minor clay and trace sand and rootlets; dark grey mottled orange. Very stiff, moist, low plasticity. Sand is fine.

PUSH TUBE: Material at top is too deep in tube to obtain sample. Material at base is: Sandy SILT; dark grey. Hard, moist. Sand is fine.

Highly weathered, dark grey, massive, fine grained SANDSTONE. Extremely weak. Recovered as fine SAND with some silt; Dense, moist.
4.48m to 4.50m: Becomes silty CLAY. Hard, moist, low plasticity.
4.70m to 4.77m: Becomes SILT. Hard, moist, low plasticity.

CORE LOSS.

Highly weathered, dark grey, massive, fine grained SANDSTONE. Extremely weak. Recovered as fine SAND with some silt; Dense, wet.

Moderately weathered, interbedded, grey MUDSTONE and grey speckled white, green with trace red flecks SANDSTONE. Very weak. Mudstone beds are laminated to thin, sandstone beds are thin to moderately thin, sub-horizontal. With minor laminated to thin carbonaceous beds.
5.15m to 5.00m: Thin, sub-horizontal, grey speckled black, discontinuous carbonaceous bed.

Moderately weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With trace coarse sand and fine gravel, subrounded, mudstone.

CORE LOSS.

Moderately weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With trace coarse sand and fine gravel, subrounded, mudstone.
6.30m: Becomes slightly weathered.
6.40m to 6.50m: Very thin, moderately inclined carbonaceous bed.

Slightly weathered, grey, massive, fine grained SANDSTONE. Very weak.

Slightly weathered, grey, medium grained SANDSTONE. Extremely weak. Recovered as fine to medium SAND with some silt; Very dense.

CORE LOSS.

Slightly weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With minor coarse sand grains and trace fine gravel, subrounded, mudstone.

CORE LOSS.

Slightly weathered, grey speckled white, green with trace red flecks, medium grained SANDSTONE. Very weak. With minor coarse sand grains and trace fine gravel, subrounded, mudstone.

Slightly weathered, grey speckled white and green with red flecks, massive, fine to coarse volcaniclastic SANDSTONE, very weak. With trace fine gravel sized, subrounded to subangular mudstone and

Comments:
- 2.7m: Rods sinking under own weight.
- 3.45m: Push tube could only be pushed 250mm, too hard.
- 6.3m: Core biscuiting with drilling.

Geological Unit: MG, Tp, Wwc, Wwnc, Wuw, Wpvc, Wuw, Wpvc, Wuw, Wpvc

Started:	23/03/2018
Finished:	27/03/2018
Driller:	McMillan
Plant:	Rig N101 (McMillan)
Logged:	A. Coutts
Checked:	CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
Packer Test at 20.00-24.50 m
Artesian piezometer, low pressure gauge installed..
Pressure reading on 25/05/2018 was 21 kPa.
Hole location determined by Survey.

Co-ordinates:
5920068.77mN
1754833.35mE
Elevation: 13.34mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Borehole

Project: **Central Interceptor CIGI5**

Location: **41 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH03**

Client: **Watercare**

Date: **23/03/2018**

R.L. (m)	Depth (m)	Shift Details & Standing Water Level / Drilling Method	Drilling Flush Return (%)	TCR (SCR) [RQD] %	Spacing of Natural Defects (mm)	Relative Strength	Weathering Grade	Sampling	In-Situ Testing	Geology Legend	GroundWater
3, 2, 1, 0, -1, -2, -3, -4, -5, -6	11, 12, 13, 14, 15, 16, 17, 18, 19, 20	SPT, HQ3, SPT, HQ3, HQ3, HQ3, HQ3, HQ3, HQ3, HQ3	25 50 75; Flush Type: **Water**; Flush Colour: **Grey**	[100]; 0; 100 (100) [100]; 0; 96 (96) [96]; 93 (87) [87]; 93 (93) [93]; 93 (93) [93]; 100 (100) [100]; 100	500 100 50 10	EW VW W MS S VS	UW SW MW HW CW RW		SPT$_c$ 51 N>50 51/125 bouncing; SPT$_c$ 55 N>50 55/125 bouncing		

Description of Strata

BOUNDARY: Well defined; Gradational; Poorly defined

sandstone clasts.

Moderately weathered, grey, interbedded, fine grained SANDSTONE and MUDSTONE . Very weak. Sandstone beds are thin to moderately thin, gently inclined. Mudstone beds are laminated to thin, gently inclined.

10.05m to 10.15m: Moderately thin, sub-horizontal, grey speckled black, discontinuous carbonaceous bed.

CORE LOSS.

Slighlty weathered, grey, bedded, medium grained SANDSTONE. Very weak. Beds are thin to moderately thin, gently inclined. With trace laminated, gently inclined, black carbonaceous beds.

CORE LOSS.

Slightly weathered, grey, interbedded, medium grained SANDSTONE and MUDSTONE. Very weak. Sandstone beds are thin to moderately thin, gently inclined. Mudstone beds are laminated to thin, gently inclined.

13.92m: Very thin, gently inclined, black carbonaceous bed.

14.67m: Laminated, sub-horizontal, grey speckled black, discontinuous carbonaceous bed.

CORE LOSS.

Slightly weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With minor coarse sand grains and trace fine gravel, subrounded, mudstone.

Moderately weathered, grey speckled white and green with red flecks, massive, fine to coarse volcaniclastic SANDSTONE, very weak. With trace fine gravel sized, subrounded to subangular mudstone and sandstone clasts.

15.32m to 15.52m: Coarse gravel sized, subrounded mudstone clasts.

Moderately weathered, grey speckled white, green with trace red flecks, massive, medium grained SANDSTONE. Very weak. With minor coarse sand grains and trace fine gravel, subrounded, mudstone.

15.49m: Very thin, gently inclined, black carbonaceous bed.

15.95m to 16.15m: Becomes extremely weak. Recovered as fine to medium sand; Very dense.

16.20m: Very thin, moderately inclined carbonaceous bed.

CORE LOSS.

Highly weathered, grey speckled white and green with red flecks, massive, medium grained SANDSTONE, very weak. With trace fine gravel sized, subrounded to subangular mudstone and sandstone clasts and trace fine to medium gavel sized carbonaceous clasts.

CORE LOSS.

Slightly weathered, grey speckled white and green with red flecks, massive, fine to medium grained SANDSTONE, very weak. With trace fine to medium gravel sized, subrounded to subangular mudstone and sandstone clasts.

18.47m to 18.54m: Moderately thin, sub-horizontal, grey banded and speckled black, discontinuous carbonaceous bed.

18.90m to 19.00m: Becomes fine grained with carbonaceous clasts.

19.56m: Very thin, gently inclined, black carbonaceous bed.

Defect Description

TYPE		SURFACE		APERTURE	
CS	Clay seam	C	Clean	T	0mm
C	Clevage	Mc	Mineral coat	Vn	0-2mm
CR	Crushed zone	Si	Soil infill	N	2-6mm
DZ	Decomposed zone	Sn	Surface stain	Mn	6-20mm
DB	Drilling induced fracture	V	Veneer	Mw	20-60mm
FL	Foliation			W	60-200mm
FZ	Fracture zone	**PLANARITY**		Vw	>200mm
IF	Incipient fracture	P	Planar		
JT	Joint	St	Stepped		
SC	Schistosity	U	Undulating		
SH	Shear				
SZ	Shear Zone	**ROUGHNESS**			
SL	Sill	R	Rough		
VN	Vein	Ss	Slickensided		
VD	Void	Sm	Smooth		

10.05: Jt 15° R, P, Vn, C.

10.97: Jt 5° Sm, P, T-Vn, C.

13.09: Jt 10° R, U, Vn, C.

13.20: Jt 5° Sm, P, T-Vn, C.

13.61: Jt 0° Sm, P, N, Si of clay.

14.35-14.45: Jt 75° Sm, U, Vn, C.

14.47-14.51: Jt 75° Sm, St, Vn, C.

16.61: Jt 5° Sm, U, Vn, C.

16.99-17.03: Jt 85° Sm, P, T-Vn, C.

18.38: Jt 0° Sm, P, N, Si of clay.

Comments

10.63m: Very closely spaced to closely spaced driling induced fractures.

Geological Unit

Wuw

Wpvc

Backfill / Installation

Started: 23/03/2018

Finished: 27/03/2018

Driller: McMillan

Plant: Rig N101 (McMillan)

Logged: A. Coutts

Checked: CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks

Packer Test at 20.00-24.50 m
Artesian piezometer, low pressure gauge installed..
Pressure reading on 25/05/2018 was 21 kPa.
Hole location determined by Survey.

Co-ordinates:
5920068.77mN
1754833.35mE

Elevation: 13.34mRL

Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Central Interceptor CIGI5**

Borehole

Location: **41 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH03**

Client: **Watercare**

Date: **23/03/2018**

Depth (m)	Drilling Method	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Comments	Geological Unit
20.00–20.43	HQ3	(100) [100]		20.08: Jt 0° R, P, Vn, C.		Wpvc(Contd.)
20.43–21.44	HQ3	90 (70) [70]		20.43-20.53: Jt 85° R, P, Vn, C. 20.55-20.61: Jt 85° R, P, Vn, C. 21.14-21.19: Jt 0° R, P, Mw, Si of rock fragments. 21.22: Jt 0° R, P, Mn, Si of clay.		
21.44–22.54	HQ3	94 (94) [94]	CORE LOSS. Slightly weathered, grey speckled white and green with red flecks, massive, fine to medium grained SANDSTONE, very weak. With trace fine to medium gravel sized, subrounded to subangular mudstone and sandstone clasts.			
22.54–24.04	HQ3	100 (53) [53]	CORE LOSS. Slightly weathered, grey speckled white and green with red flecks, massive, medium grained SANDSTONE, very weak. With trace fine to medium gravel sized, subrounded to subangular mudstone and sandstone clasts. *23.30m to 24.00m: Becomes extremely weak. Recovered as fine to medium SAND with minor silt; Very dense.*			
24.04–24.54	HQ3	42 (26) [26]	CORE LOSS. Infer sandstone broke and washed away while trying to recover run. Slightly weathered, grey speckled white and green with red flecks, massive, fine to coarse grained SANDSTONE, very weak. With trace fine gravel sized, subrounded mudstone and sandstone clasts.		24m: Difficulty recovering run. Third attempted recovered with fingered catcher. 24.47m: Dipped hole for packer test. Replaced mud pit with fresh water.	
24.54–26.04	HQ3	92 (92) [92]	Slightly weathered, interbedded, medium grey speckled white, green and flecks of red, medium grained SANDSTONE and dark grey MUDSTONE . Very weak. Sandstone beds are thin to moderately thin, mudstone beds are laminated to thin, gently inclined. *25.30m: Very thin, sub-horizontal, black carbonaceous bed.* *25.63m to 25.88m: Beds become steeply inclined.* CORE LOSS. Slightly weathered, grey, massive, medium grained SANDSTONE. Very weak.			Wuw
26.04–27.50	HQ3	100 (100) [100]	Slightly weathered, grey speckled white, green and flecks of red, massive, medium grained SANDSTONE. Very weak.			Wpvc

CIE-BH03 terminated at 27.50m. Target Depth

Shift details & standing water level: 26/03/2018 4:00:00 PM(Water depth 0.9m); 27/03/2018 8:00:00 AM(Water depth 0.9m); 27/03/2018 2:00:00 PM(Water depth 0.9m); 28/03/2018 9:15:00 AM(Water depth 0.7m)

Flush Type: Water, Flush Colour: Clear, slightly cloudy; Flush Type: Water, Flush Colour: Grey

Started: 23/03/2018
Finished: 27/03/2018
Driller: McMillan
Plant: Rig N101 (McMillan)
Logged: A. Coutts
Checked: CS

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations

Remarks
Packer Test at 20.00-24.50 m
Artesian piezometer, low pressure gauge installed..
Pressure reading on 25/05/2018 was 21 kPa.
Hole location determined by Survey.

Co-ordinates:
5920068.77mN
1754833.35mE
Elevation: 13.34mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

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AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project:	**Central Interceptor CIGI5**		**Borehole**
Location:	**46 Tawariki Street, Grey Lynn**	Project No: **AE04725**	Hole ID: **CIE-BH04**
Client:	**Watercare**		Date: **5/07/2018**

Started:	5/07/2018	**Remarks**	Co-ordinates:
Finished:	10/07/2018	Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL. Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0. Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.	5920092.60mN
Driller:	McMillan		1754813.92mE
Plant:	Rig N111 (McMillan)		Elevation: 12.29mRL
Logged:	S. Burgess		Inclination: -90°
Checked:	LD		Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

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AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Borehole

Project: **Central Interceptor CIGI5**

Location: **46 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH04**

Client: **Watercare**

Date: **5/07/2018**

Column headings: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) 255075 | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) 500 100 50 10 | Relative Strength EW VW W MS S VS | Weathering Grade UW SW MW HW CW RW | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description key:
TYPE: CS Clay seam; C Cleavage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VO Void
SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer
PLANARITY: P Planar; St Stepped; U Undulating
ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth
APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm

R.L. scale: 12, 11, 10, 9, 8, 7, 6, 5, 4, 3. Depth scale: 1 to 10 m.

Drilling Method	TCR (SCR) [RQD] %
VAC EX	0
SPT	33
HQ3	81
SPT	100
HQ3	59
SPT	100
HQ3	95 (35) [35]
SPT	0
HQ3	98 (71) [95]
SPT	0
HQ3	100 (100) [100]
SPT	0
HQ3	96 (96)

Shift details: 5/07/2018 4:00:00 PM(Water depth 0m); 6/07/2018 7:30:00 AM(Water depth 1.33m)

Flush Type: Water
Flush Colour: Grey

In-Situ Testing:
- SPT_s 0,0,0 N<1
- SPT_s 2,6,10 N=16
- SPT_s 8,17,20 N=37
- SPT_c 50 N>50 50/140
- SPT_c 26,35,15 N>50 50/220
- SPT_c 50 N>50 50/110

Description of Strata:

Vacuum Excavation.

Silty SAND, trace rootlets, gravel; brown, homogeneous. Very soft, moist, insensitive; one angular gravel clast (50 mm).

Silty SAND to CLAY with some organics, trace gravel; brown and grey, mixed. Very soft, moist, low plasticity, debris found throughout including sharp metal fragments and gravel. Soil is uncontrolled fill and randomly changes from silty sand to clay throughout this depth.

2.60m: Metal Fragment.

CORE LOSS.
3.45m: Vitrified clay cobble (60mm).
3.55m: 3 basalt/brick gravel sized fragments (50mm).

Silty SAND to CLAY with some organics, trace gravel; brown and grey mixed. Very soft, moist, low plasticity, debris found throughout including sharp metal fragments and gravel. Soil is uncontrolled fill and randomly changes from silty sand to clay throughout this depth.

Residually weathered, SANDSTONE. Silty fine SAND, with some clay; dark grey, homogeneous. Soft, moist, low plasticity, moderately sensitive.
4.59m to 4.65m: Residual Mudstone bed. Dark grey CLAY

5.20m to 5.30m: Residual Mudstone bed. Dark grey CLAY

Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak. Bedding is gently inclined, sandstone beds are moderately thin, mudstone beds are thin. Sandstone has occasional red flecks. Black carbonaceous beds approx 5mm thick present throughout deposit at very widely spaced intervals.

6.58m: Becomes moderately weathered and weak.

7.45m to 7.50m: Fracture zone.

9.50m: Becomes very weak

Defect Description:
- 6.85: Jt 90° R, P, Vn, C.
- 7.03: Jt 45° R, St, Vn, C.
- 7.05: Jt 70° R, P, Vn, C.
- 7.21: Jt 70° R, St, Vn, C.
- 7.33: Jt 45° R, St, Vn, C.
- 7.40: Jt 70° R, P, Vn, Si of clay.
- 7.45-7.50: Sz.
- 9.30: Jt 90° R, P, Vn, C.

Comments: 3m: Cased to 3.0 m.

Geological Unit: MG; Wwc; Wwnc

Started: 5/07/2018
Finished: 10/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-3.78	14/09/2018		Midday WL

Remarks
Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5920092.60mN
1754813.92mE
Elevation: 12.29mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Central Interceptor CIGI5

Borehole

Location: 46 Tawariki Street, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH04

Client: Watercare

Date: 5/07/2018

Columns: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) (25 50 75) | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) (500, 100, 50, 10) | Relative Strength (EW, VW, W, MS, S, VS) | Weathering Grade (UW, SW, MW, HW, CW, RW) | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description

TYPE: CS Clay seam; C Clevage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VD Void

SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer

PLANARITY: P Planar; St Stepped; U Undulating

ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth

APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm

R.L. (m): 2, 1, 0, -1, -2, -3, -4, -5, -6, -7

Depth (m): 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

Drilling Method: HQ3

Shift details: 6/07/2018 4:00:00 PM HQ3 9/07/2018 7:30:00 AM(Water depth 2m)

Flush Type: Water; Flush Colour: Grey

TCR (SCR) [RQD] %: [96]; 100 (94) [94]; 47 (23) [23]; 90 (87) [87]; 97 (97) [97]; 83 (83) [83]; 100 (100) [100]

Description of Strata

CORE LOSS.

Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Extremely weak. Bedding is sub-horizontal, sandstone beds are moderately thin, mudstone beds are thin. Sandstone has occasional red flecks. Black carbonaceous beds approx 5mm thick present throughout deposit at very widely spaced intervals.

Highly weathered, dark grey, homogeneous, fine grained SANDSTONE. Extremely weak.

Highly weathered, dark grey, homogeneous, medium grained SANDSTONE. Extremely weak.
11.83m to 11.85m: Very thin, sub-horizontal, black carbonaceous bed.

CORE LOSS.

Completely weathered, dark grey, homogeneous, fine grained SANDSTONE. Recovered as fine silty SAND, trace clay.Tightly packed, moist.

CORE LOSS.

Completely weathered, dark grey, homogeneous, fine grained SANDSTONE. Recovered as fine silty SAND, trace clay.Tightly packed, moist.

Highly weathered, dark grey, homogeneous, fine grained SANDSTONE. Extremely weak. Minor white clasts present throughout matrix (1mm). Silty SAND. Loosely packed, moist.

15.05m to 15.55m: Trace green clasts (1-3 mm)
15.10m: Becomes moderately weathered

15.45m to 15.50m: Thin, sub-horizontal, black carbonaceous bed.

Highly weathered, dark grey, homogeneous, fine to medium grained SANDSTONE. Extremely weak. Minor white clasts present throughout matrix (1mm). Silty SAND. Loosely packed, moist.

CORE LOSS.

Moderately weathered, dark grey, interbedded, fine to coarse grained SANDSTONE and MUDSTONE. Very weak. Bedding is sub-horizontal, sandstone beds are moderately thin, mudstone beds are thin. Black carbonaceous beds, laminated to thin, present throughout deposit at widely spaced intervals.

18.13m to 18.15m: Thin, sub-horizontal, black carbonaceous bed.

18.70m to 19.30m: Laminated to thin, sub-horizontal, black carbonaceous beds.

Defects

10.17: Jt 70° R, P, Vn, C.
10.68: Jt 85° R, U, Vn, C.
10.75: Jt 85° R, U, Vn, C.
10.77: Jt 85° R, U, Vn, C.
17.45: Jt 85° R, P, Vn, C.
18.00: Jt 85° R, St, Vn, C.
18.72: Jt 85° R, P, Vn, C.
18.94: Jt 85° R, P, Vn, C.
19.30: Jt 85° R, St, Vn, C.
19.43: Jt 85° R, St, Vn, C.

Geological Unit: Wwnc(Contd.); Wpvc; Wwnc; Wpvc; Wwnc; Wuw

Started:	5/07/2018
Finished:	10/07/2018
Driller:	McMillan
Plant:	Rig N111 (McMillan)
Logged:	S. Burgess
Checked:	LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-3.78	14/09/2018		Midday WL

Remarks

Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5920092.60mN
1754813.92mE
Elevation: 12.29mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Central Interceptor CIGI5

Borehole

Location: 46 Tawariki Street, Grey Lynn   **Project No:** AE04725

Hole ID: CIE-BH04

Client: Watercare

Date: 5/07/2018

R.L. (m)	Depth (m)	*Shift Details & Standing Water Level* Drilling Method	Drilling Flush Return (%) 25 50 75	TCR (SCR) [RQD] %	Spacing of Natural Defects (mm) 500 100 50 10	Relative Strength EW VW W MS S VS	Weathering Grade UW SW MW HW CW RW	Sampling	In-Situ Testing	Geology Legend	GroundWater	Description of Strata	Defect Description	Comments	Geological Unit	Backfill / Installation
-8		HQ3		93 (93) [93]									20.30: Jt 75° R, P, Vn, C.		Wuw(Contd.)	
	21											CORE LOSS.				
-9		HQ3		100 (96) [96]								Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak. Bedding is gently inclined, sandstone beds are moderately thin, mudstone beds are thin. Black carbonaceous beds, laminated to thin, present throughout deposit at widely spaced intervals. *21.45m to 21.48m: Fracture zone. Coal.*	21.20: Jt 75° R, P, Vn, C. 21.39: Jt 75° R, P, Vn, C. 21.45-21.48: Sz Vn, C, Highly fractured coal. 21.58: Jt 50° R, U, Vn, C. 21.97: Jt 75° R, P, T, C. 22.14: Jt 75° R, U, Vn, C.			
-10	22											Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm). Local, very thin mudstone beds are present.			Wpvc	
-11	23	*9/07/2018 1:45:00 PM(Water depth 0.97m)* HQ3		100 (100) [100]												
-12	24											Moderately weathered, dark grey, homogeneous, fine grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm). Local, very thin mudstone beds are present. *24.30m: Becomes medium grained.* *24.68m: Becomes fine grained.* *24.82m: Thin, gently inclined, grey speckled black, discontinuous carbonaceous bed.* *24.92m: Becomes medium grained.* *25.11m to 25.22m: Mudstone bed.* *25.68m to 25.71m: Mudstone bed.*	24.82: Jt 75° R, P, Vn, C.		Wuw	
-13	25	HQ3	*Flush Type: Water* *Flush Colour: Grey*	100 (100) [100]												
-14	26	HQ3		93 (93) [93]												
	27											CORE LOSS.				
-15												Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm). *27.16m to 27.18m: Mudstone bed.*				
-16	28	*9/07/2018 4:00:00 PM* HQ3 *10/07/2018 7:30:00 AM(Water depth 0.6m)*		96 (96) [96]								Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm). *28.05m to 28.25m: Becomes coarse grained.*			Wpvc	
	29											CORE LOSS.				
-17		HQ3		95 (95) [95]								Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm). *28.90m: Becomes extremely weak.* *29.27m: Becomes slightly weathered and strong.* *29.47m: Becomes moderately weathered and very weak.*	29.37: Jt 30° R, P, T, C.			
	30															

BOUNDARY
Well defined
Gradational
Poorly defined

TYPE
CS Clay seam
C Clevage
CR Crushed zone
DZ Decomposed zone
DB Drilling induced fracture
FL Foliation
FZ Fracture zone
IF Incipient fracture
JT Joint
SC Schistosity
SH Shear
SZ Shear Zone
SL Sill
VN Vein
VD Void

SURFACE
C Clean
Mc Mineral coat
Si Soil infill
Sn Surface stain
V Veneer

PLANARITY
P Planar
St Stepped
U Undulating

ROUGHNESS
R Rough
Ss Slickensided
Sm Smooth

APERTURE
T 0mm
Vn 0-2mm
N 2-6mm
Mn 6-20mm
Mw 20-60mm
W 60-200mm
Vw >200mm

Started: 5/07/2018
Finished: 10/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-3.78	14/09/2018		Midday WL

Remarks
Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5920092.60mN
1754813.92mE
Elevation: 12.29mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Central Interceptor CIGI5**

Borehole

Location: **46 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH04**

Client: **Watercare**

Date: **5/07/2018**

R.L. (m)	Depth (m)	Drilling Method	Drilling Flush Return (%)	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Geological Unit
-18					CORE LOSS.		
		HQ3	Flush Type: Water; Flush Colour: Grey	94 (94) [94]	Moderately weathered, dark grey, homogeneous, medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm), trace dark brownish green mudstone clasts (2-6 mm).	30.47: Jt 30° P, T, C. 30.54: Jt 30° P, T, C. 30.61: Jt 30° P, T, C. 30.68: Jt 30° P, T, C. 30.75: Jt 30° P, T, C.	Ww
	31				*31.06m to 31.11m: Mudstone bed.*		
-19							

CIE-BH04 terminated at 31.50m. Target Depth

10/07/2018 4:00:00 PM

17/07/2018 7:30:00 AM(Water depth 0.8m)

Started: 5/07/2018
Finished: 10/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-3.78	14/09/2018		Midday WL

Remarks
Packer Test 1 at 9.75-12.00 m, Packer Test 2 at 19.25-22.50 m, Packer Test 3 at 28.50-31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.1 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946
Hole location determined by Survey.

Co-ordinates:
5920092.60mN
1754813.92mE
Elevation: 12.29mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates	**Preliminary Log of Investigation**
Project: **Central Interceptor CIGI5**	**Borehole**
Location: **44 Tawariki Street, Grey Lynn** Project No: **AE04725**	Hole ID: **CIE-BH05**
Client: **Watercare**	Date: **11/07/2018**

Started: 11/07/2018 Finished: 13/07/2018 Driller: McMillan Plant: Rig N111 (McMillan) Logged: S. Burgess Checked: LD	Remarks Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m. Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m. Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0. Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.	Co-ordinates: 5920115.28mN 1754793.05mE Elevation: 11.59mRL Inclination: -90° Log cover page

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Central Interceptor CIGI5

Borehole

Location: 44 Tawariki Street, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH05

Client: Watercare

Date: 11/07/2018

Depth (m)	Drilling Method	TCR (SCR) [RQD] %	In-Situ Testing	Description of Strata	Comments	Geological Unit
0.00	VAC EX	0		Vacuum Excavation		MG
1.50	SPT	100	SPT 1,2,2 N=4	Silty CLAY; light grey mottled orange. Very soft, moist, high plasticity, not dilatant.		T
	HQ3	100		*2.25m: Becomes brown grey with some wood fragments. Soft.*		
				2.70m: Becomes firm.		
3.00	TBX	100		Push Tube. Material change at 3.1m from silty CLAY to silty clayey SAND.	3m: Cased to 3.0 m.	
3.50	SPT	100	SPT 0,0,1 N=1	Residually weathered, SANDSTONE. Clayey silty fine SAND; dark grey, homogeneous. Soft, moist, low plasticity, low dilatancy.		Wwc
	HQ3	100				
4.50	TBX	100		Push Tube. *4.50m: Becomes firm.*		
5.00	SPT	100	SPT 6,11,12 N=23	Residually weathered, SANDSTONE. Clayey silty fine SAND; dark grey, homogeneous. Firm, moist, low plasticity, Insensitive		
				CORE LOSS.		
	HQ3	77 (77) [77]		Highly weathered, fine grained SANDSTONE. Extremely weak. Clayey silty fine SAND; dark grey, homogeneous. Dense, moist.		
	SPT	100	SPT 5,9,11 N=20	*6.45m to 6.80m: Recovered as Silty fine SAND*		
	HQ3	67 (33) [33]		CORE LOSS.		
	SPT	100	SPT 8,12,19 N=31	Highly weathered, fine grained SANDSTONE. Extremely weak. Silty fine SAND, some clay; dark grey, homogeneous. Dense, moist.		
	HQ3	71 (65) [65]		Highly weathered, dark grey, BRECCIA with fine to medium gravel sized, angular to sub-rounded mudstone clasts in a well cemented fine sandstone matrix. Extremely weak.		Wwnc
				Core loss. Infer BRECCIA and a mudstone clast blocked catcher.		
				Highly weathered, dark grey, BRECCIA with fine to medium gravel sized, angular to sub-rounded mudstone clasts in a well cemented fine sandstone matrix. Extremely weak.		
	SPT	100	SPT 12,20,30 N>50 50/290	Highly weathered, fine grained SANDSTONE. Extremely weak. Silty fine SAND, some clay; dark grey, homogeneous. Very dense, moist.		
				Highly weathered, dark grey, BRECCIA, fine to medium gravel sized, sub- rounded mudstone and fine grained sandstone clasts in a fine		Wwc

Shift details & Standing Water Level: 11/07/2018 7:30:00 AM (Water depth 0.3m); 11/07/2018 4:00:00 PM; 12/07/2018 7:30:00 AM (Water depth 0.2m)

Flush Type: **Water** Flush Colour: **Grey**

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description — TYPE: CS Clay seam, C Cleavage, CR Crushed zone, DZ Decomposed zone, DB Drilling induced fracture, FL Foliation, FZ Fracture zone, IF Incipient fracture, JT Joint, SC Schistosity, SH Shear, SZ Shear Zone, SL Sill, VN Vein, VO Void. SURFACE: C Clean, Mc Mineral coat, Si Soil infill, Sn Surface stain, V Veneer. PLANARITY: P Planar, St Stepped, U Undulating. ROUGHNESS: R Rough, Ss Slickensided, Sm Smooth. APERTURE: T 0mm, Vn 0-2mm, N 2-6mm, Mn 6-20mm, Mw 20-60mm, W 60-200mm, Vw >200mm

Started: 11/07/2018
Finished: 13/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-4.39	13/09/2018		End of Day WL

Remarks
Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m.
Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.

Co-ordinates: 5920115.28mN 1754793.05mE
Elevation: 11.59mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Borehole

Project: **Central Interceptor CIGI5**

Location: **44 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH05**

Client: **Watercare**

Date: **11/07/2018**

R.L. (m)	Depth (m)	Shift Details & Standing Water Level / Drilling Method	Drilling Flush Return (%)	TCR (SCR) [RQD] %	In-Situ Testing	Description of Strata	Defect Description	Geological Unit
		HQ3		58 (25) [25]		grained sandstone matrix. Recovered as clasts with silty fine SAND; dense.		Wwc(Contd.)
1		SPT		100	SPT$_s$ 10,16,25 N=41	Highly weathered, dark grey, interbedded, moderately thinly bedded fine grained SANDSTONE and thinly bedded MUDSTONE. Sub-horizontal bedding. Extremely weak. Mudstone has trace black carbonaceous material.		
	11					CORE LOSS. Infer residual BRECCIA from 10.2m. Clast blocked catcher.		Wwnc
0		HQ3		76 (48) [48]		Completely weathered, dark grey, BRECCIA recovered as a silty CLAY with subangular mudstone clasts (5-10mm). Soft, moist, low plasticity.		
						Highly weathered, dark grey, BRECCIA with fine to coarse gravel sized, sub-angular to sub-rounded mudstone clasts and some wood fragments in a fine grained sandstone matrix. Very weak. *11.57m: Recovered as clasts only; infer matrix washed out.*		
	12	SPT		100	SPT$_s$ 13,24,26 N>50 50/280	CORE LOSS.		Wwc
-1						Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Sandstone beds are moderately thin, sub-horizontal. Mudstone beds are thin to moderately thin, sub-horizontal. Very weak.	12.43: Jt 90° Sm, P, Vn, C. 12.45: Jt 90° Sm, P, Vn, C. 12.67: Jt 90° R, St, Vn, C.	
	13	HQ3		89 (89) [87]				
-2		SPT		0	SPT$_c$ 50 N>50 50/120	CORE LOSS.	13.37: Jt 70° R, P, Vn, C.	
	14	HQ3		91 (91) [91]		Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Sandstone beds are moderately thin, moderately inclined. Mudstone beds are thin to moderately thin, moderately inclined. Very weak.	13.65: Jt 70° Sm, U, Vn, Si of sandy clay. 13.95: Jt 70° R, P, Vn, C.	
-3						CORE LOSS.		
	15	SPT		0	SPT$_c$ 50 N>50 50/82	Highly weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Sandstone beds are moderately thin, moderately inclined. Mudstone beds are thin to moderately thin, moderately inclined. Very weak. *14.70m to 15.00m: Becomes interbedded with laminated carbonaceous beds (black).* *14.77m: Becomes weak.* *15.12m to 15.33m: Moderately weathered, moderately thick SANDSTONE bed. Moderately strong.*	14.90: Jt 70° R, St, Vn, C. 15.34: Jt 70° R, P, Vn, C.	
-4	16	HQ3		92 (92) [92]		Moderately weathered, dark grey, homogeneous fine grained SANDSTONE.Weak, moderately inclined. *15.83m: Becomes medium grained with white and cream fine gravel sized clasts and black speckles inferred as trace carbonaceous material.*	16.15: Jt 70° R, P, Vn, C.	Wuw
-5						CORE LOSS.		
						Moderately weathered, dark grey, homogeneous, fine grained SANDSTONE. Weak, moderately inclined. Minor white clasts present throughout matrix (1mm).		
	17	HQ3		83 (83) [83]		Moderately weathered, dark grey, homogeneous, fine to medium grained SANDSTONE. Weak. Minor white clasts present throughout matrix (1mm). *17.10m to 17.45m: Extremely weak.*		Wpvc
-6						CORE LOSS.		
	18					Slightly weathered, dark grey, fine to medium grained SANDSTONE. Strong. Matrix has some sand to fine gravel sized white and cream clasts and discontinuous black carbonaceous beds.		
-7		HQ3		97 (97) [97]		Moderately weathered, dark grey, fine to medium grained SANDSTONE. Very weak. Minor white clasts present throughout matrix (1mm). *18.26m: Becomes extremely weak* *18.50m: Becomes very weak.*	18.55: Jt 10° Sm, P, T, C, joint is displaced by 10mm.	
	19	12/07/2018 4:00:00 PM; 13/07/2018 7:30:00 AM(Water depth 0m)						
-8	20					Moderately weathered, dark grey, medium to coarse grained SANDSTONE. Extremly weak. Minor white clasts present throughout matrix (1mm).		

Flush Type: Water
Flush Colour: Grey

Key — BOUNDARY: Well defined; Gradational; Poorly defined.
TYPE: CS Clay seam; C Cleavage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VD Void.
SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer.
PLANARITY: P Planar; St Stepped; U Undulating.
ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth.
APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm.

Started: 11/07/2018
Finished: 13/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-4.39	13/09/2018		End of Day WL

Remarks
Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m.
Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.

Co-ordinates:
5920115.28mN
1754793.05mE
Elevation: 11.59mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: Central Interceptor CIGI5

Borehole

Location: 44 Tawariki Street, Grey Lynn **Project No:** AE04725

Hole ID: CIE-BH05

Client: Watercare

Date: 11/07/2018

BOUNDARY: Well defined; Gradational; Poorly defined

Defect Description key:

TYPE: CS Clay seam; C Clevage; CR Crushed zone; DZ Decomposed zone; DB Drilling induced fracture; FL Foliation; FZ Fracture zone; IF Incipient fracture; JT Joint; SC Schistosity; SH Shear; SZ Shear Zone; SL Sill; VN Vein; VD Void

SURFACE: C Clean; Mc Mineral coat; Si Soil infill; Sn Surface stain; V Veneer

PLANARITY: P Planar; St Stepped; U Undulating

ROUGHNESS: R Rough; Ss Slickensided; Sm Smooth

APERTURE: T 0mm; Vn 0-2mm; N 2-6mm; Mn 6-20mm; Mw 20-60mm; W 60-200mm; Vw >200mm

Columns: R.L. (m) | Depth (m) | Shift Details & Standing Water Level / Drilling Method | Drilling Flush Return (%) 25 50 75 | TCR (SCR) [RQD] % | Spacing of Natural Defects (mm) 500 100 50 10 | Relative Strength EW VW W MS S VS | Weathering Grade UW SW MW HW CW RW | Sampling | In-Situ Testing | Geology Legend | GroundWater | Description of Strata | Defect Description | Comments | Geological Unit | Backfill / Installation

Drilling method: HQ3 throughout. Flush Type: Water; Flush Colour: Clear.

Depth (m)	TCR (SCR) [RQD] %	Description of Strata	Defect Description	Comments	Geological Unit
20.0 – 20.9	93 (93) [93]	Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak, moderately inclined. Sandstone beds are moderately thick, mudstone beds are thin. With trace laminated to thin carbonaceous beds.	20.75: Jt 70° R, P, Vn, C.	20m: Borehole becomes artesian.	Wuw(Contd.)
20.9 – 21.1		CORE LOSS.			
21.1 – 22.4	87 (87) [87]	Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak, moderately inclined. Sandstone beds are moderately thick, mudstone beds are thin. With trace laminated to thin carbonaceous beds. *21.23m to 21.53m: Moderately thick sandstone bed.* *22.01m to 22.65m: Thick sandstone bed.*	21.08: Jt 70° R, P, Vn, C. 21.30: Jt 70° R, P, Vn, C. 21.45: Jt 70° R, P, Vn, C. 21.69: Jt 70° R, P, Vn, C.		
22.4 – 22.6		CORE LOSS.			
22.6 – 24.5	96 (96) [96]	Moderately weathered, dark grey, interbedded, fine grained SANDSTONE and MUDSTONE. Very weak, moderately inclined. Sandstone beds are moderately thick, mudstone beds are thin. With trace laminated to thin carbonaceous beds. *23.24m to 23.41m: Slightly weathered, moderately thick, fine grained sandstone bed. Strong.* *23.41m to 24.20m: Moderately thick medium grained sandstone bed.*	22.79: Jt 70° R, U, Vn, C. 23.15: Jt 70° R, P, Vn, C. 23.48: Jt 70° R, P, Vn, C. 24.00: Jt 70° R, P, Vn, C. 24.25-24.30: Fz R, St, Mw, Si of rock fragments and sandy clay. 24.27: Jt 70° R, P, Vn, C.		
24.5 – 25.0	87 (76) [76]	Moderately weathered, grey with trace white speckles, fine grained to coarse SANDSTONE. Very weak. With trace fine gravel sized mudstone clasts.			
25.0 – 25.4		Moderately weathered, dark grey, BRECCIA with fine to medium gravel sized, angular to sub-rounded mudstone clasts in a fine sandstone matrix. Extremely weak.	25.13: Jt 70° R, U, Vn, C.		
25.4 – 25.6		CORE LOSS.			
25.6 – 27.0	93 (93) [93]	Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts. *25.82m: Becomes weak.* *26.20m to 26.35m: Moderately thick medium grained sandstone bed.*	26.39: Jt 70° R, U, Vn, C.		Wpvc
27.0 – 27.1		CORE LOSS.			
27.1 – 28.3	83 (83) [83]	Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts.	27.20: Jt 50° R, P, Vn, C. 27.34: Jt 70° R, P, Vn, C. 27.86: Jt 70° R, P, Vn, C.		
28.3 – 28.6		CORE LOSS.			
28.6 – 30.0	100 (100) [100]	Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts. *29.48m to 29.54m: Moderately thin bed of discontinuous carbonaceous material.*	29.42: Jt 70° R, P, Vn, C.		

R.L. (m): -9 (20.6), -10 (21.6), -11 (22.6), -12 (23.6), -13 (24.6), -14 (25.6), -15 (26.6), -16 (27.6), -17 (28.6), -18 (29.6)

Started:	11/07/2018
Finished:	13/07/2018
Driller:	McMillan
Plant:	Rig N111 (McMillan)
Logged:	S. Burgess
Checked:	LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-4.39	13/09/2018		End of Day WL

Remarks

Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m.
Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.

Co-ordinates: 5920115.28mN 1754793.05mE
Elevation: 11.59mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Jacobs in association with
AECOM and McMillen Jacobs Associates

Preliminary Log of Investigation

Project: **Central Interceptor CIGI5**

Borehole

Location: **44 Tawariki Street, Grey Lynn** Project No: **AE04725**

Hole ID: **CIE-BH05**

Client: **Watercare**

Date: **11/07/2018**

R.L. (m)	Depth (m)	Shift Details & Standing Water Level / Drilling Method	Drilling Flush Return (%)	TCR (SCR) [RQD] %	Spacing of Natural Defects (mm)	Relative Strength	Weathering Grade	Sampling	In-Situ Testing	Geology Legend	GroundWater	Description of Strata	Defect Description	Comments	Geological Unit	Backfill / Installation
-19	31	HQ3	Flush Type: Water; Flush Colour: Clear	93 (93) [93]								Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts. *30.78m to 30.96m: Strong bed.*			Wpw (Contd.)	
												CORE LOSS.				
												Moderately weathered, dark grey speckled white, coarse grained SANDSTONE. Very weak. With trace fine to medium gravel sized, sub-angular mudstone clasts.				
		13/07/2018 4:00:00 PM; 18/07/2018 7:30:00 AM(Water depth -2.9m)										CIE-BH05 terminated at 31.50m. Target Depth				

Started: 11/07/2018
Finished: 13/07/2018
Driller: McMillan
Plant: Rig N111 (McMillan)
Logged: S. Burgess
Checked: LD

Groundwater Observations

No.	Struck (m)	Date	Standing (m)	Observations
1	-4.39	13/09/2018		End of Day WL

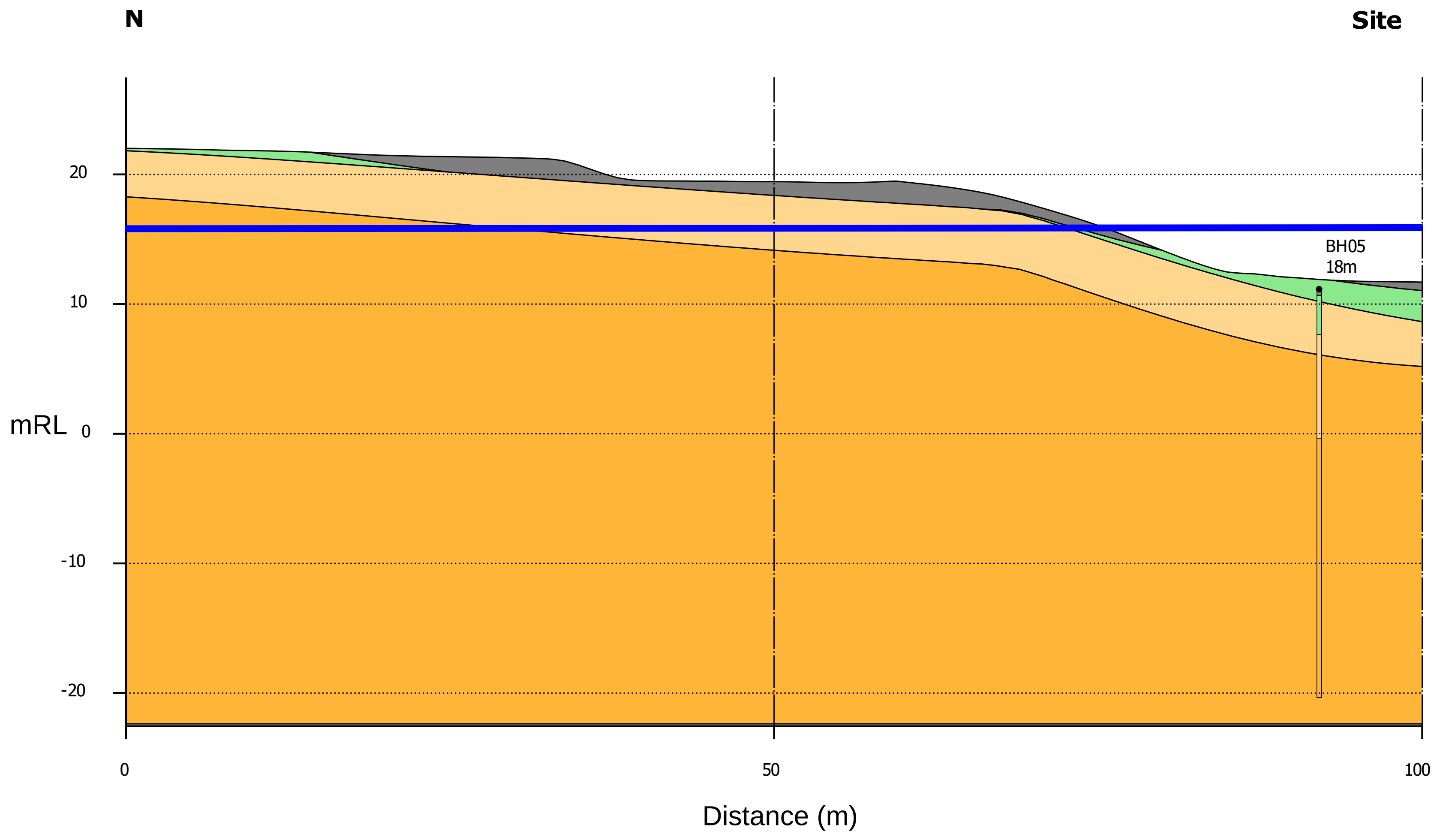
Remarks
Packer Test 1: 11.00 - 13.50 m, Packer Test 2: 19.00 - 21.00 m, Packer Test 3: 28.50 - 31.50 m.
Vibrating wire piezometer installed with sensor at 26.0m. Water level = 16.0 m RL.
Joint angles are relative to the core axis. If a borehole is true vertical; horizontal=90, vertical=0.
Hole location is in NZTM projection. Elevation is relative to Auckland Vertical Datum 1946 Hole location determined by Survey.

Co-ordinates:
5920115.28mN
1754793.05mE
Elevation: 11.59mRL
Inclination: -90°

See key sheet for an explanation of symbols and abbreviations. Material descriptions as per NZGS Guidelines - December 2005.

Appendix B: Geological Cross Section and Site Plan

Central Interceptor Tawariki Shafts - Cross Section North



Responsible dept.	Technical reference	Creator	Approved by
Geotechnical	Section North	TRMC	

Legal owner

Document type: Cross Section	Document status: Draft
Title: Central Interceptor Tawariki Shafts	Identification number: 30552.9090

Rev.	Date of issue	Sheet
1		1

Legend

Ground Model

- Fill
- Tauranga Group
- Rock ECBF
- Weathered ECBF

Location

N: 1754830, 5920202

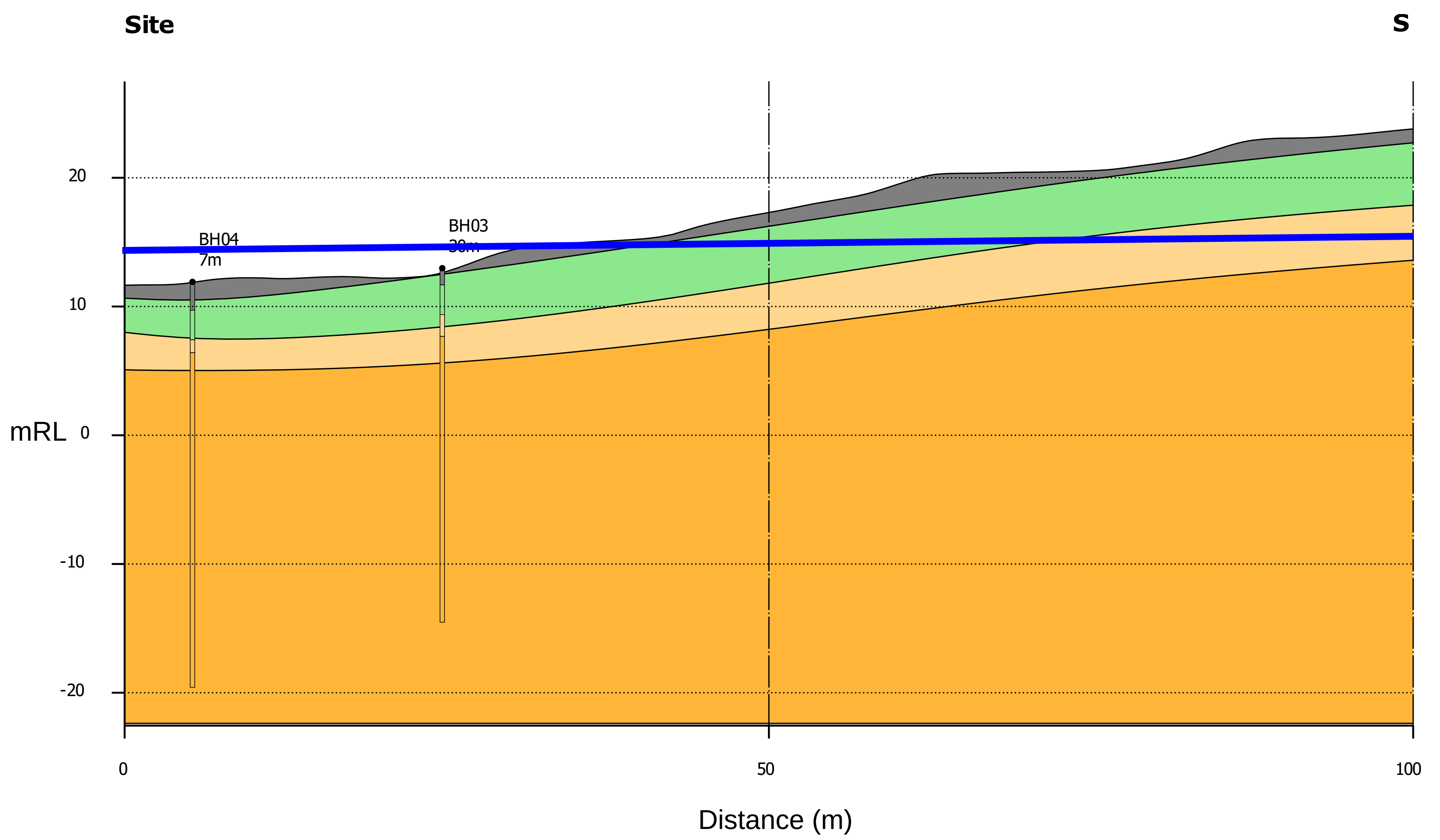
Site: 1754809, 5920104

Scale: 1:500

Vertical exaggeration: 1x

0m 50m

Central Interceptor Tawariki Shafts - Cross Section South



Responsible dept.	Technical reference	Creator	Approved by	
Geotechnical	Section South	TRMC		

Legal owner

Document type: Cross Section	Document status: Draft
Title: Central Interceptor Tawariki Shafts	Identification number: 30552.9090

Rev.	Date of issue	Sheet
1		1

Legend

Ground Model

- Fill
- Tauranga Group
- Rock ECBF
- Weathered ECBF

Location

Site: 1754809, 5920099

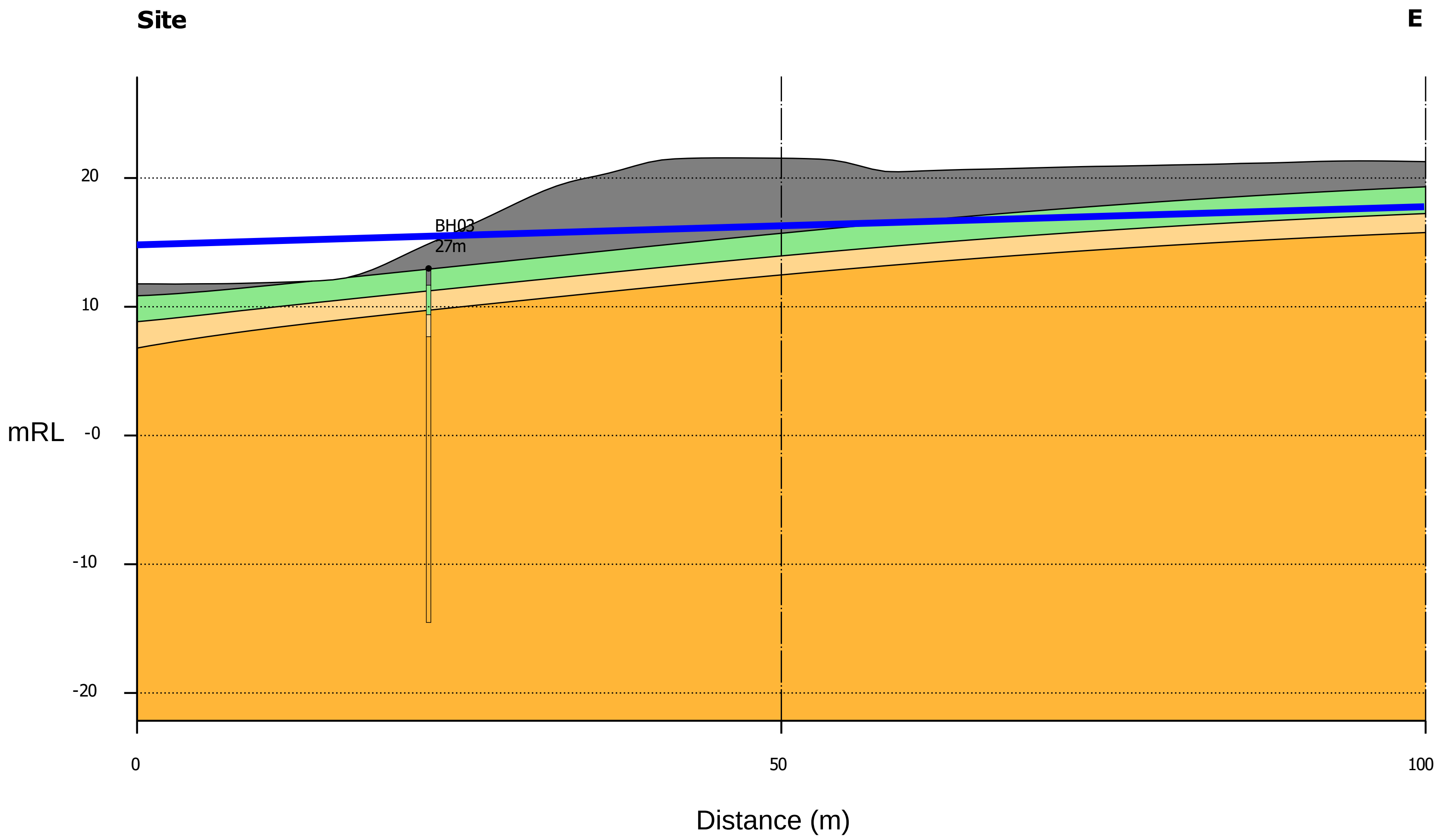
S: 1754788, 5920001

Scale: 1:500

Vertical exaggeration: 1x

0m 50m

Central Interceptor Tawariki Shafts - Cross Section East



Responsible dept.	Technical reference	Creator	Approved by	
Geotechnical	Section East	TRMC		
Legal owner		Document type: Cross Section	Document status: Draft	
		Title: Central Interceptor Tawariki Shafts	Identification number: 30552.9090	
			Rev.: 1	Date of issue:	Sheet: 1

Legend

Ground Model

- Fill
- Tauranga Group
- Rock ECBF
- Weathered ECBF

Location

Site: 1754817, 5920100

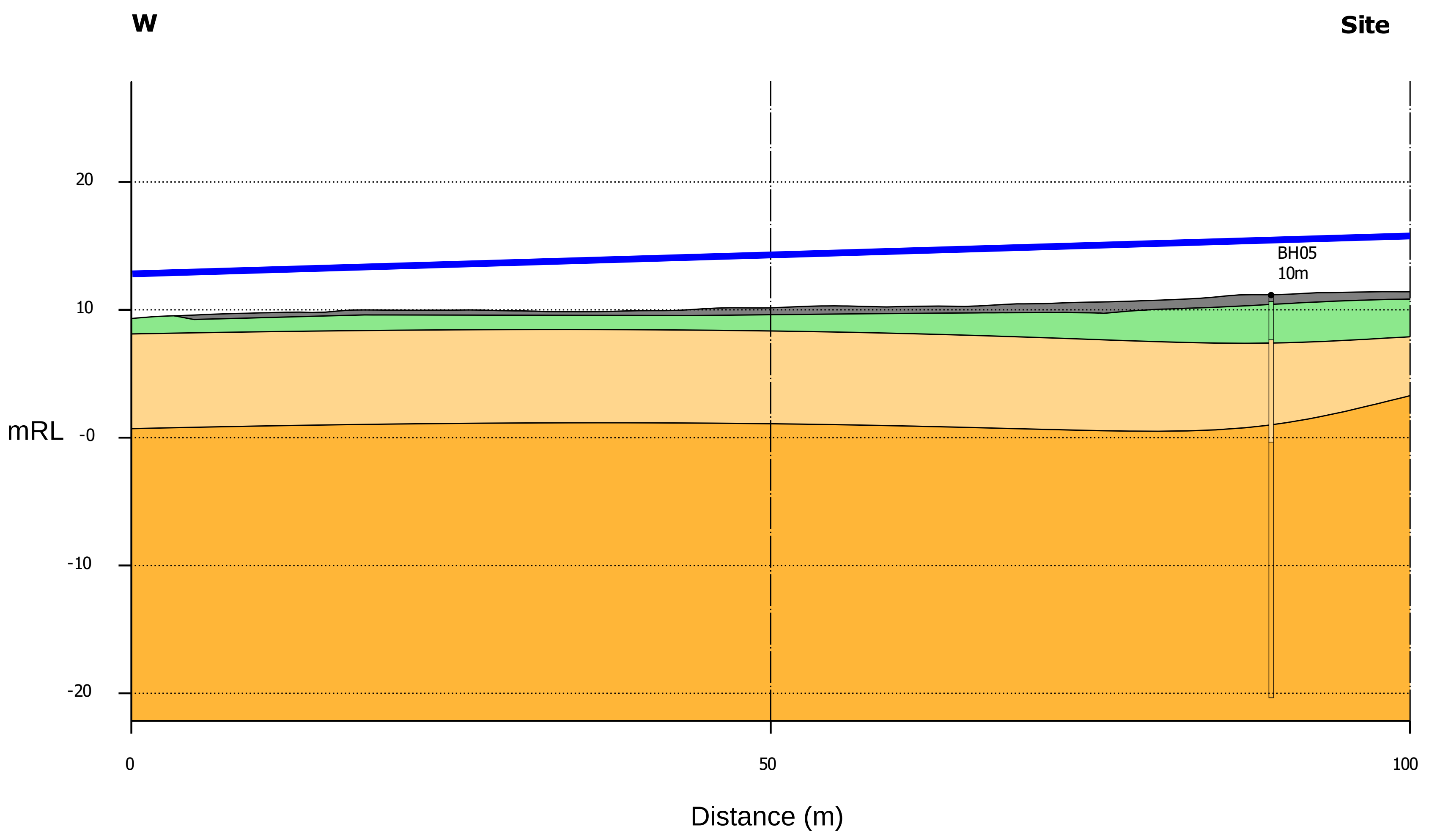
E: 1754915, 5920080

Scale: 1:500

Vertical exaggeration: 1x

0m 50m

Central Interceptor Tawariki Shafts - Cross Section West



Responsible dept. Geotechnical	Technical reference Section West	Creator TRMC	Approved by	
Legal owner	Document type: Cross Section		Document status Draft	
	Title: Central Interceptor Tawariki Shafts		Identification number 30552.9090	
		Rev. 1	Date of issue	Sheet 1

Legend

Ground Model

- Fill
- Tauranga Group
- Rock ECBF
- Weathered ECBF

Location

W: 1754704, 5920123

Site: 1754802, 5920103

Scale: 1:500

Vertical exaggeration: 1x

0m 50m

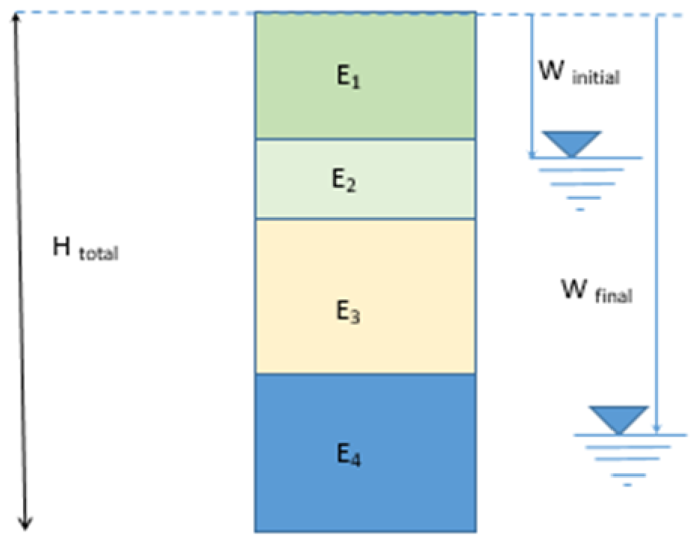
Appendix C: Drawdown induced settlement method

Drawdown-induced settlement method

Observation points were used for assessing groundwater drawdown due to dewatering. These observation points were positioned along four (4) lines of section labelled north: N, south: S, east: E, west: W as shown below.

Drawdown-induced settlement was estimated for each observation point using the following approach:

- Observation points (X,Y) obtained from lines of section N, S, E, W.
- Geological contact elevation (Z) values (m RL) obtained from LeapFrog model.
- Static water level ($W_{initial}$) adopted from the initial heads from the dewatering assessment.
- Final groundwater level (W_{final}) obtained from the AnAqSim model results.
- 1D settlement assessment using an incremental layer-wise summation method calculated in a Python[1] script.
  - Divided the geological profile (H_{total}) into incremental units for calculation, in this case 0.1 m thick.
  - Assigned assumed constrained modulus to each unit.
  - Calculated the change in pore water pressure at the centre of each incremental layer caused by the groundwater drawdown (refer Equation 1).
  - Estimated the settlement of each incremental unit layer and sum the incremental settlement (refer Equation 2).
- The following assumptions were made for the settlement assessment:
  - Initial static water levels were considered hydrostatic.
  - ECBF unit was considered incompressible.



Example soil column and initial/final water level for calculating settlement using layer-wise summation method.

[1] www.python.org

Equation 2: Change in pore water pressure:

$$\Delta P = \gamma_w (Water_{initial} - Water_{final})$$

$$\Delta P = change\ in\ pore\ water\ pressure\ (kPa)$$

$$\gamma_w = unit\ weight\ of\ water\ (kPa)$$

$$Water_{initial} = Piezomteric\ head\ before\ dewatering\ (m)$$

$$Water_{final} = Piezomteric\ head\ after\ dewatering\ (m)$$

Equation 1: Layer wise summation method:

$$S = \sum_{i=1}^{n} \left(\varphi \frac{\Delta P_i}{E_i} H_i \right)$$

$$S = total\ settlement\ caused\ by\ dewatering\ (m)$$

$\Delta P = change\ in\ pore\ water\ pressure$ *(Equation 2)*

$$\Delta P_i = additional\ load\ of\ the\ calculated\ soil\ layer\ caused\ by\ dewatering\ (kPa)$$

$$\varphi = \text{empirical coefficient, defined as 1 in this calculation}$$

$$E_i = compression\ modulus\ of\ the\ calculated\ soil\ layer\ (kPa)$$

$$H_i = thickness\ of\ the\ calculated\ soil\ layer\ (m)$$

Appendix D: Ground Settlement Contour Plan

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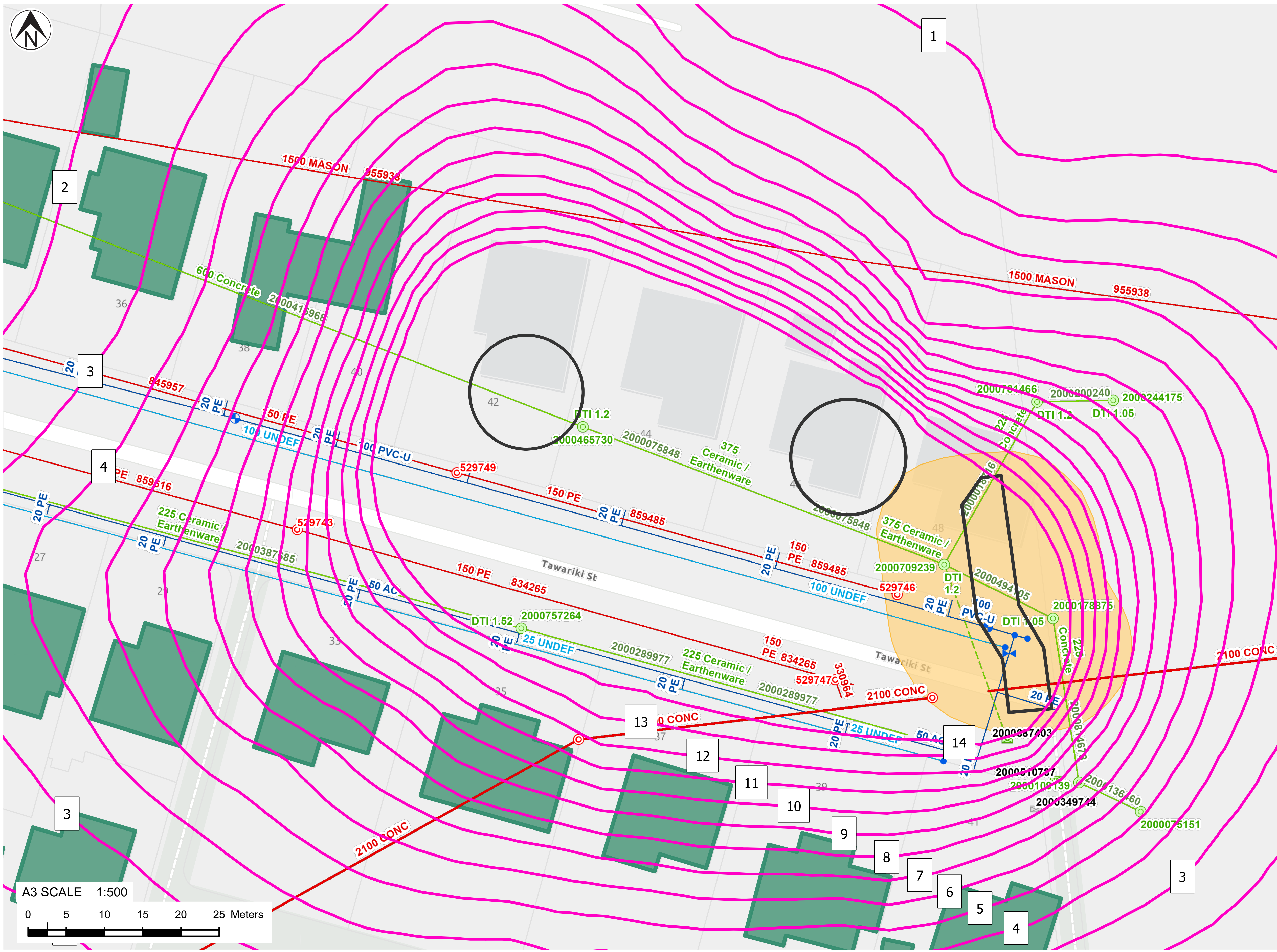
C:\Users\trmc\Desktop\Tawariki GIS\gis_Aug22.aprx Layout: Map1 2022-Sep-12 9:44 am Drawn by TRMC



LEGEND

- Run0_Drawdown-induced settlement (mm)
- Excavation Locations
- Building outlines (LINZ)
- Mechanical Settlement Zone of Influence

Wastewater Pipe (Local)
- Operational
- Wastewater Manhole (Local)

Wastewater Pipe (Transmission)
- Operational
- Wastewater Manhole (Transmission)

Stormwater Manhole And Chamber
- Public - Standard/ Custom

Stormwater Catchpit
- Public
- Private

Stormwater Pipe
- Public - Gravity Mains

Stormwater Connection
- Public

Water Pipe (Local)
- Operational (Potable)
- Abandoned / Not Operational
- Water Valve (Local)
- Water Hydrant (Local)
- Water Other Fitting (Local)

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NOTES:
Basemap UndergroundServices: public. NZ Light Grey Canvas (Vector): Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.. NZ Navigation Map: Eagle Technology, LINZ, StatsNZ, NIWA, Natural Earth, © OpenStreetMap contributors.
Underground services (AC database), Building outlines (LINZ)

REV	DESCRIPTION	GIS	CHK	DATE
0	First version			

LOCATION PLAN: Auckla

PROJECT No.	30552.9090	
DESIGNED	TRMC	SEP.22
DRAWN	TRMC	SEP.22
CHECKED	SVB	SEP.22
APPROVED		DATE

CLIENT WATERCARE SERVICES LTD

PROJECT CENTRAL INTERCEPTOR TAWARIKI ST. SHAFTS

TITLE DRAWDOWN-INDUCED SETTLEMENT RESULTS RELATIVE TO UNDERGROUND SERVICES AND RESIDENTIAL DWELLINGS NEARBY

SCALE (A3) 1:500 FIG No. FIGURE 1. REV 0