Greenhithe Bridge Watermain Duplication and Causeway

Technical Report C - Groundwater

19 May 2015

Watercare
An Auckland Council Organisation

Revision	Status	Date	Description/Change to Report	Author(s)	Task Manager Check	Project Manager Approval
				Signatures		
1	Draft A	3/12/2014	Draft report for technical review	B. Savoldelli/G. Holmes - Jacobs		
2	Draft B	3/03/2015	Updated report following client review	G. Holmes - Jacobs		
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EXECUTIVE SUMMARY

Jacobs New Zealand Limited (Jacobs) has been commissioned by Watercare Services Limited (Watercare) to assess the potential hydrogeological effects related to the construction, operation and maintenance of Watercare' s proposed Greenhithe Bridge Watermain Duplication and Causeway Project. This report outlines a description of the environmental baseline for the groundwater potentially affected by the project as well as a description of the investigations undertaken to assess hydrogeology; a description of specific aspects of the project in relation to hydrogeology; a brief outline of the statutory framework relevant to hydrogeology; an assessment of the actual or potential effects on the environment including the identification of activities that could result in adverse effect; and any recommended mitigation and management measures proposed.

Regionally the geology of the project area is known to consist of fill materials overlying alluvial sediments, residual soils, and the weathered East Coast Bays Formation (ECBF), above the unweathered sandstone and siltstone units of the ECBF. The hydrogeology of the area has been significantly modified, predominately on the west end of the bridge, due to development (e.g. land reclamation, motorway expansion, bridge construction), with groundwater levels regionally flowing towards the harbour, and locally towards topographic low points. Recharge occurs via rainfall to the upper units, which are hydraulically connected to the lower ECBF.

A site investigation was completed by Opus to provide more details on the site specific geology and hydrogeology of the area, and consisted of completing auger holes and boreholes across the proposed works area. A total of 4 boreholes were drilled, with piezometers installed in three locations, BH201 and BH202 on the west end of the bridge and BH204 on the east end of the bridge. The piezometers were installed to analyse the groundwater levels and their response to rainfall events and tidal fluctuations, and to calculate the hydraulic conductivity of the aquifer.

Groundwater levels were recorded both manually and automatically using transducers in BH201, BH202 and BH204. Monitoring indicates that the long term groundwater levels in BH202 are relatively steady (maximum fluctuation of 0.06 m), which reflects a limited response to rainfall due to the reduced infiltration as a result of surrounding development. Groundwater levels at BH201 and BH204 show evidence of water level fluctuations of 0.45 m and 0.35 m, respectively.

Rising head tests completed by Jacobs on two of the piezometers indicate that hydraulic conductivity values in the project area are consistent with geology found at the site and are within the expected range, e.g. 3.15×10^{-5} m/s (for fill in BH201) and 2.24×10^{-5} m/s (for weathered soils in BH204). A bore search enquiry from Auckland Council's bore database was undertaken and identified four deep groundwater take bores and two site investigation bores within 1.5 km of the proposed works.

The proposed Greenhithe Bridge Watermain Duplication and Causeway Widening works assessed in this report are the construction, operation and maintenance of:

- Excavations occurring on the west end of the proposed works area, including a temporary jacking pit and receiving pit, with sheet piles proposed to be installed prior to the works; two valve chambers (pipe connections for NH1 and GBWD) located on either end of the connecting pipeline and a scour chamber located beside the GBWD valve chamber at the western end.

- Excavations for the causeway widening and the placement of both GBWD and NI pipes within the causeway; and

- Excavations occurring on the east end of the proposed works area, including an underground combined chamber (connection between NH1 and the new watermain).

The resultant assessment of effects is that the works associated with the Greenhithe Bridge Watermain Duplication and Causeway project will cause minimal disruption to the groundwater flow regime along the microtunnelled sections, during excavation and causeway widening as outlined below.

- At the western end of the bridge the temporary pipe jacking and receiving pits, GBWD valve chamber, and NH1-GBWD scour chamber will be constructed to a maximum depth of -0.6 mRL in an area where the water table has maximum recorded level of 1.85 mRL. Drawdown expected during construction is approximately 2.5 m in the immediate vicinity of the construction, with a zone of influence of 180 m. To mitigate the drawdown effects, sheet piles will be installed around the excavations. The overall effect on groundwater levels and flow in the area therefore will be minimal.

- The NH1-GBWD connecting pipeline will be microtunnelled under the motorway on the west end between the jacking and receiving pits. The invert level of the tunnel ranges from 0.5 to 1.0 m below the water table. Drawdown effects are expected to be minimal during tunnelling

- The causeway will be widened by approximately 15m from the edge of the cycleway for a length of approximately 860 m. In addition, a construction platform will be established approximately 600 m along the causeway from the western end. This platform will provide an additional area of approximately 150 m long by 53 m wide to enable the future construction of the harbour sections of the NI pipelines which will extend north under the harbour from this point. Groundwater ingress along this route during excavation will be removed via pumping. The pumping will have minimal impact as it will not interfere with the natural groundwater flow path. The trenching along the causeway will be filled with permanent rock which will also not affect the groundwater flow regime in the long term. In addition, the pipes to be constructed within the causeway for both GBWD and NI will be located above approximately 2 metres above the mean sea level, Based on groundwater levels recorded within BH204 (the closest groundwater bore to the causeway location), these pipes will be located above groundwater. As such, there will be no effect on groundwater flow as a result of the construction of these pipes.

Other than the installation of sheet piles for the pipe jacking and receiving pits, we do not consider any mitigation or monitoring is necessary to manage groundwater impacts from the proposed works because of the less than minor potentially adverse effects. It should be noted that some mitigation measures have been recommended from the settlement assessment that were based on these groundwater results.

1 INTRODUCTION

Jacobs New Zealand Limited (Jacobs) has been commissioned by Watercare Services Limited (Watercare) to assess the potential hydrogeological effects related to the construction, operation and maintenance of Watercare's Greenhithe Bridge Watermain Duplication and Causeway Project.

The project comprises:

- The construction of a new watermain on the northern side of the Greenhithe Bridge to supplicate the existing North Harbour 1 (NH1) Watermain already located on the southern side of the bridge, and

- Widening along the northern side of the existing State Highway 18 (SH18) motorway causeway to accommodate the new watermain, as well as wastewater pipelines and associated facilities which form part of Watercare's proposed Northern Interceptor project.

The proposed water and wastewater infrastructure is required in order to maintain water and wastewater service levels and to provide for future growth.

The Greenhithe Bridge Watermain Duplication and Causeway project requires various resource consents under the Resource Management Act 1991 ("RMA"). This technical report provides specialist input for the *Greenhithe Bridge Watermain Duplication– Assessment of Effects on the Environment* report ("the main AEE") report prepared by URS New Zealand and Jacobs New Zealand Limited which supports the resource consent application. The works described in the AEE have been considered in the technical assessment presented in this report.

This report provides the following:

- A brief overview of the proposed works (Section 2).
- A description of the environmental baseline for the particular receiving environment(s) potentially affected by the project as well as a description of the investigations undertaken to assess hydrogeology (Section 3);
- Description of specific aspects of the project in relation to the subject area being investigated (Section 4);
- A brief outline of the statutory framework relevant to hydrogeology (Section 5);
- An assessment of the actual or potential effects on the environment (construction, operation and maintenance), having reference to the statutory framework and any other environmental factors considered relevant. This includes the identification of activities that could result in adverse effects and, in turn, identifying design refinements or construction methodologies that could avoid, remedy or mitigate such effects (Section 6);
- Recommended mitigation and management measures (Section 7).

The new watermain will eventually form part of Watercare's future North Harbour 2 Watermain project. The proposed widening of the motorway causeway will also incorporate wastewater pipelines and associated facilities which form part of Watercare's proposed Northern Interceptor project. Separate technical reports have or will be prepared for the future North Harbour 2 Watermain project and for the balance of the Northern Interceptor project.

2 GREENHITHE BRIDGE WATERMAIN DUPLICATION AND CAUSEWAY PROPOSED WORKS

The Greenhithe Bridge Watermain Duplication and Causeway (GBWD) works assessed in this report are the construction, operation and maintenance of:

- The new watermain from Station Street in Hobsonville, under SH18 to the coastal edge – this could involve open trenching from Station Street to the motorway, and trenchless construction (pipe jacking) under the motorway;
- Causeway widening to accommodate the new watermain and wastewater pipelines. The existing SH18 causeway will be widened along the northern side by approximately 15 metres from the edge of the cycle way for a length of approximately 860 metres. In addition, a construction platform measuring approximately 150m x 53m will be established approximately 600m along the causeway from the western end;
- The new watermain attached to the underside of the Greenhithe Bridge; and
- A new watermain cross connection chamber close to the eastern abutment of the Greenhithe Bridge.

The proposed works are described in detail in the AEE. Key drawings showing the proposed works and construction methodology are provided in Volume 3 of the AEE - Drawings. The works described in the AEE and shown on the drawings are assessed in this report.

3 EXISTING ENVIRONMENTAL BASELINE

The existing environmental baseline relevant to hydrogeology is outlined below.

3.1 Geology

Regionally the area is known to consist of fill materials overlying alluvial sediments, residual soils, and the weathered East Coast Bays Formation (ECBF), above the unweathered sandstone and siltstone units of the ECBF (Edbrooke, 2001).

A site investigation, involving the completion of auger holes and boreholes by Opus, was undertaken across the proposed works area in order to provide site specific geology and hydrogeology information. Between 22 May and 3 July 2014, four boreholes (BH201, BH202, BH203, BH204) were drilled along the proposed pipeline route (borehole location and logs are located in **Appendix A** and **Appendix B**). Piezometers were installed in BH201 and BH202 on the west end of the bridge and BH204 on the east end of the bridge, with piezometer details found in **Table 1**. The purpose of these installations was to analyse the groundwater levels and their response to rainfall events and tidal fluctuations, and to calculate the hydraulic conductivity of the aquifer. These properties will inform the assessment of hydrogeological effects.

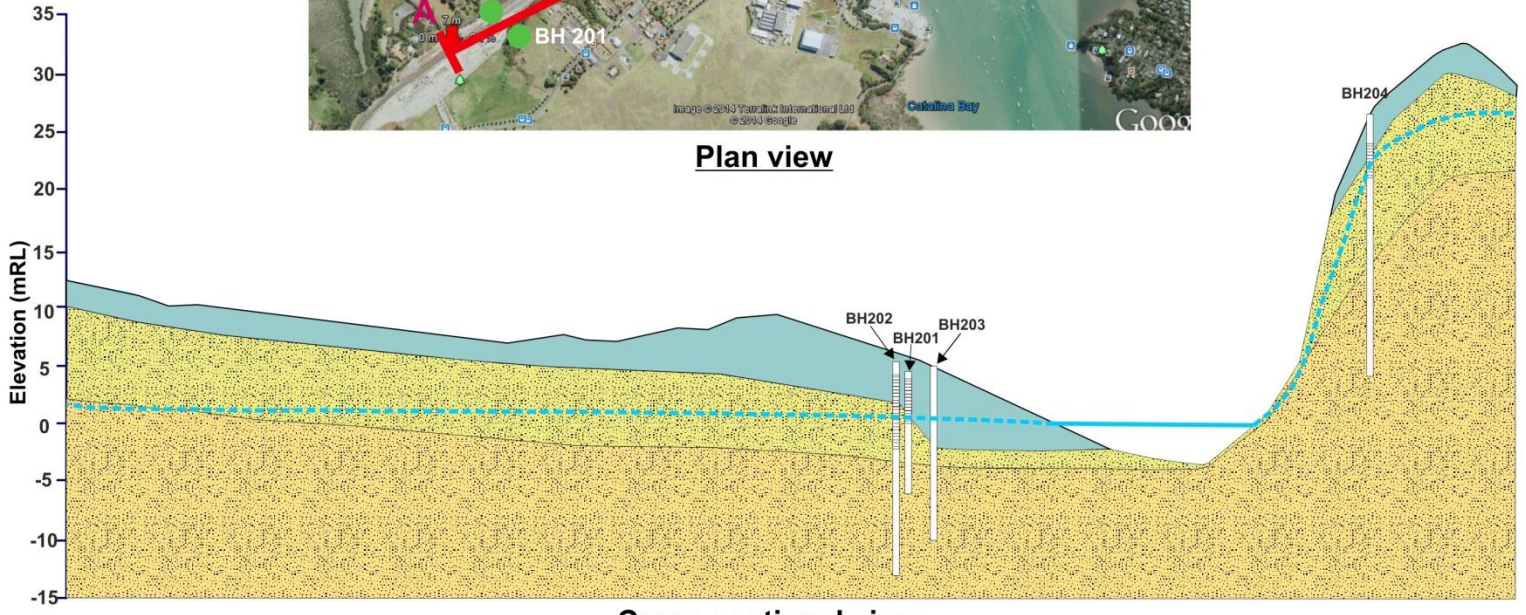
Table 1 Piezometer installation details

Borehole	Piezometer depths (mBGL)		Piezometer depths (mRL)	
	Top	Bottom	Top	Bottom
BH201	1.5	4.6	3.0	-0.1
BH202	1.0	7.0	4.3	-1.8
BH203	No piezometer installed			
BH204	2.5	7.5	20.1	15.1

Ground elevation on the west end of the bridge ranges from 12 mRL to sea level. Boreholes BH201 and BH202, drilled in the vicinity of the NH1 and GBWD valve chambers, indicate the geology underlying the proposed construction area consists primarily of (outlined in depth order) :

- Fill (approximately 3-5 m);
- Highly weathered to moderately weathered sand and silt units of the ECBF (5-10 m);
- Interlayered, highly fractured, ECBF sandstones and mudstones (**Figure 1**).

Plan view



Cross-sectional view

Legend:

- Fill
- Weathered ECBF
- Unweathered ECBF
- Groundwater level
- Borehole

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Filename	Name	Date
Proposed works.cdr	BAS	Dec-14

Data Notes:
Geology and water levels based on information gathered at BH201, BH202, BH203 and BH204 during the site investigation (Jul to Nov 2014).

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FIGURE 1. CROSS-SECTION OF PROPOSED WORKS AREA SHOWING GEOLOGY AND GROUNDWATER TABLE

Nearer the foreshore area, previous reclamation has led to a relatively thick layer of fill. The geologic profile at BH203 indicates 7 m of fill to an elevation of -2 mRL, and unweathered ECBF starting at -3 mRL.

On the east end of the bridge the land rises sharply to approximately 30 mRL approximately 80 m from the coast. The geological profile at BH204 indicates approximately 2 m of fill overlying 10 m of weathered ECBF before the unweathered and fractured ECBF is encountered at 14 mRL.

3.2 Regional hydrogeology

Regionally, groundwater flows from all directions towards the harbour where it discharges, and locally towards topographic low points. The hydrogeology of the area has been modified (i.e. some localised groundwater diversion), predominantly in the vicinity of the west end of the bridge, due to development (e.g. land reclamation, motorway expansion, bridge construction).

Recharge occurs via rainfall to the upper units (e.g. fill, weathered soils), which are hydraulically connected to the lower ECBF. In general, hydraulic conductivity (permeability) varies dependent on the specific geological units, as outlined below:

- fractured sandstone units have a hydraulic conductivity in the order of 10^{-6} to 10^{-7} m/s depending on the extent of fracturing (Domenico, 1990),
- weathered soils have a hydraulic conductivity ranging from 10^{-4} to 10^{-7} m/s (Heath, 1983), depending on the silt/clay content, and
- fill can range from 10^{-2} to 10^{-7} m/s depending on the nature of the fill material.

3.3 Site specific groundwater levels

Groundwater levels were recorded both manually using a dipper, and automatically with Solinst levelogger transducers in piezometers BH201, BH202 and BH204. Note, the water level readings between July and September 2014 were recorded by Opus as part of the geotechnical investigation, and water level readings in November 2014 were recorded by Jacobs as part of the hydrogeological investigation.

The transducers were installed in BH201, BH202, and BH204 on 12 November 2014 and removed on 25 November 2014. The water level readings (**Figure 2** to **Figure 4**) indicate maximum water levels of 1.85 mRL (2.6 to 3.4 mBGL) on the west end of the bridge where the NH1-GWBD connecting pipe is to be tunnelled under SH18 and 22.80 mRL (3.8 mBGL) on the east end of the bridge near the value chamber at the new watermain and NH1 pipe connection.

Monitoring also indicates groundwater levels at BH202 are relatively steady (maximum fluctuation of 0.06 m) whereas water levels at BH201 and BH204 show evidence of water level fluctuation of 0.45 m and 0.35 m, respectively. This was investigated further by assessing the transducer data collected in the piezometers.

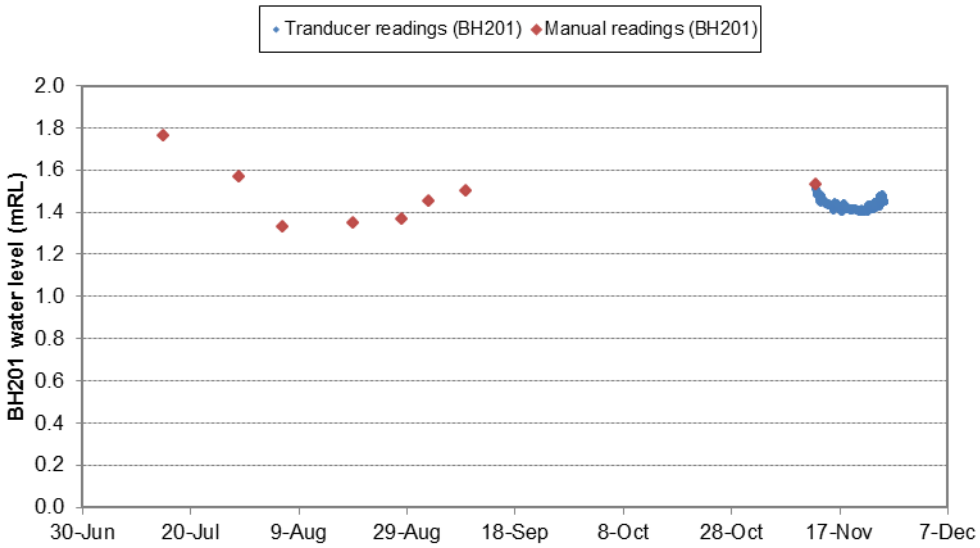


Figure 2 Recorded groundwater levels (mRL) at BH201

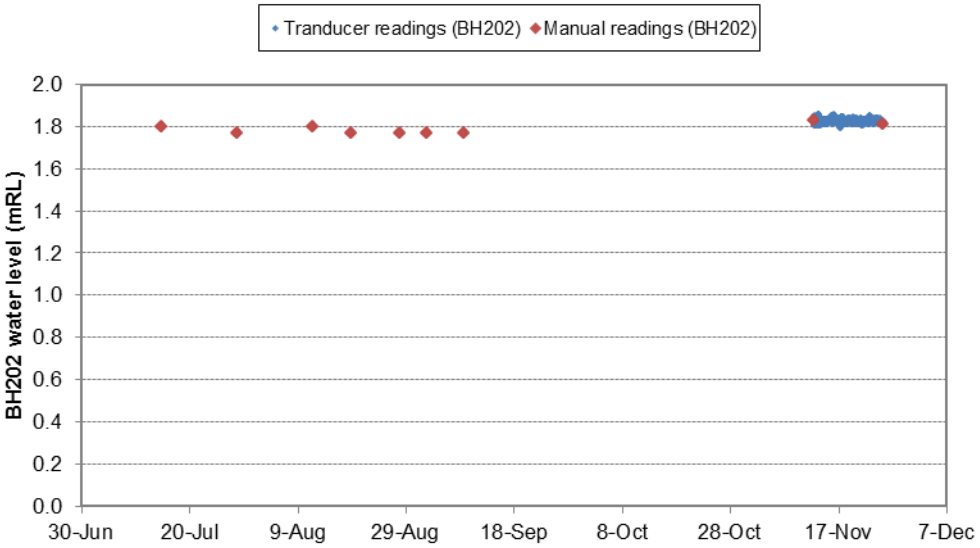


Figure 3 Recorded groundwater levels (mRL) at BH202

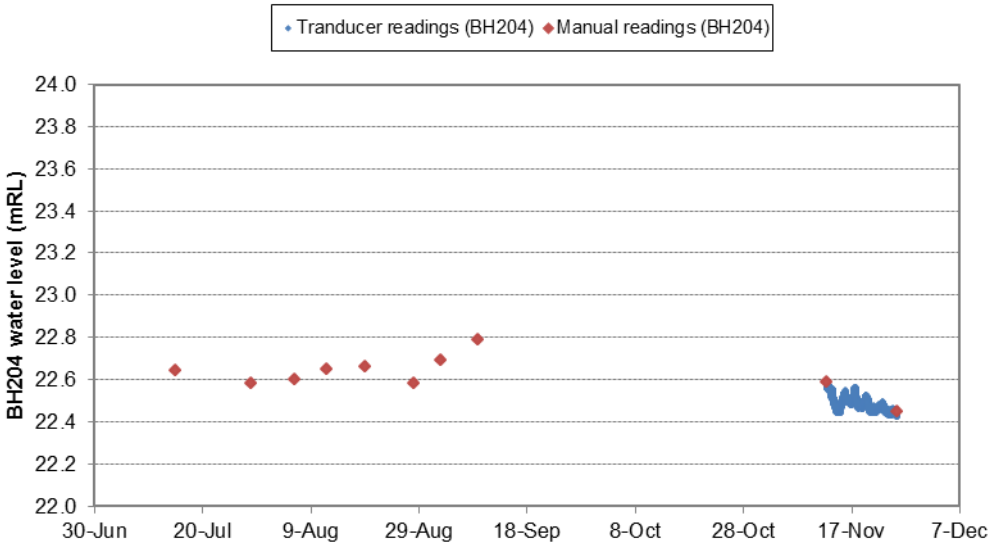


Figure 4 Recorded groundwater levels (mRL) at BH204

Figure 5 to **Figure 7** compare the water level monitoring data with the local rainfall recorded at North Shore Albany Ews (Cliflo, 2014), located approximately 6 km north-west of the Greenhithe Bridge. BH201 water level fluctuations show some evidence of sensitivity to rainfall (17 November); however, the data is dominated by sharp intermittent increases in the later part of the record that may indicate anthropogenic influence as it cannot be directly related to rainfall. Water levels in BH202 and BH204 show evidence of tidal influence and rainfall; however, the response to rainfall in BH202 is limited due to the high level of development in the surrounding area (e.g. reduced infiltration).

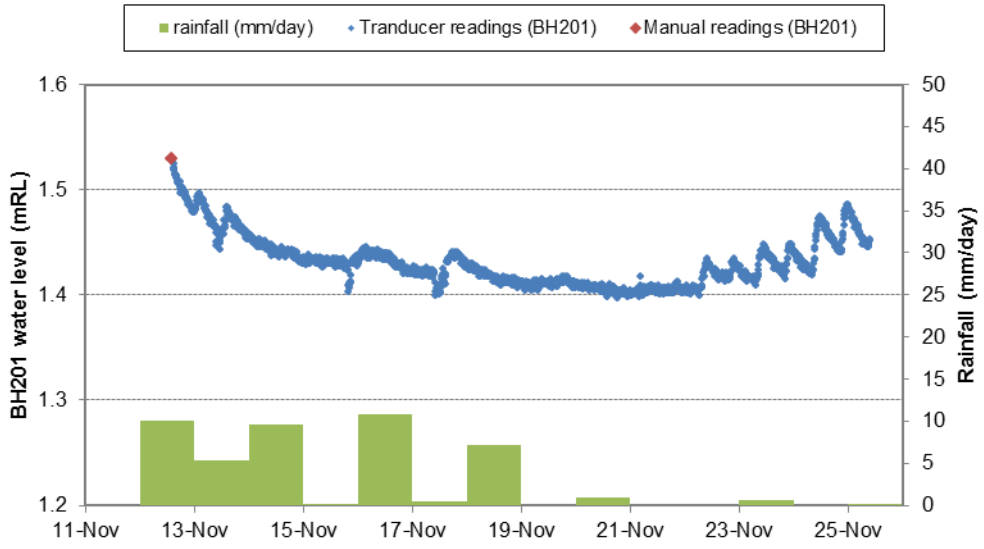


Figure 5 Continuous water level readings at BH201 between 12 and 25 November 2014

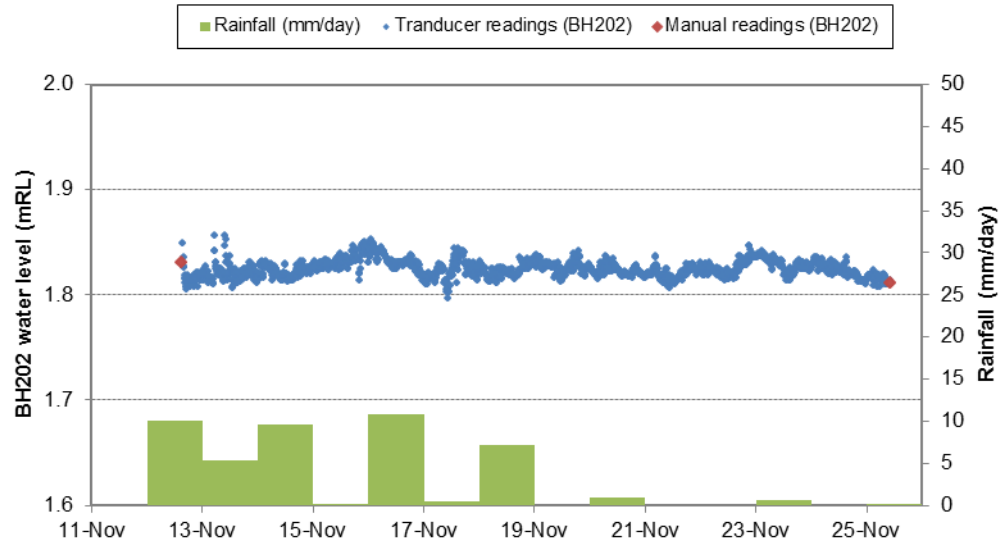


Figure 6 Continuous water level readings at BH202 between 12 and 25 November 2014

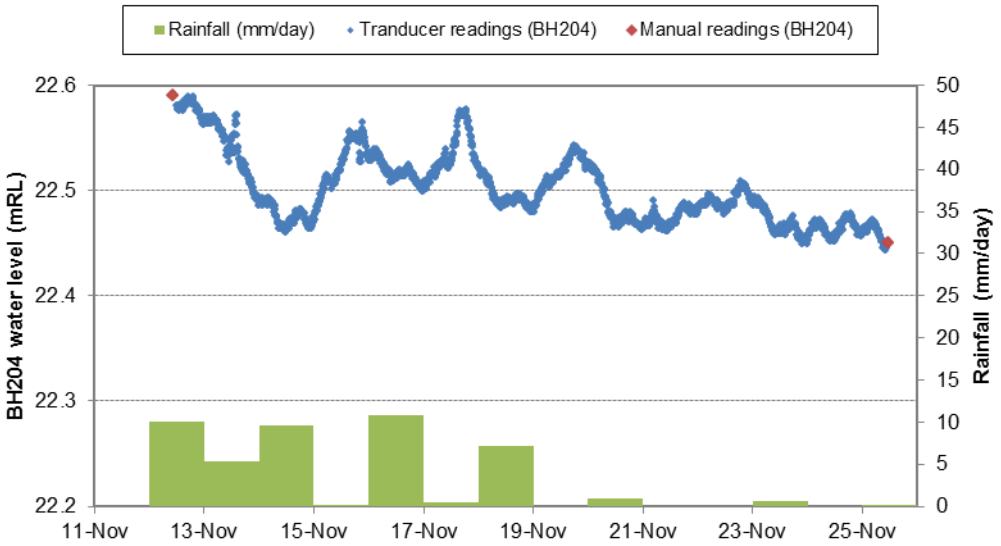


Figure 7 Continuous water level readings at BH204 between 12 and 25 November 2014

3.4 Site specific hydraulic conductivity

Rising head tests were conducted by Jacobs to estimate the hydraulic conductivity on either end of the bridge: BH201 represents the properties on the west end and BH204 the east end (**Appendix C**).

The results of the analysis (**Table 2**) indicate hydraulic conductivity values that are consistent with the geology found at the site: fill material dominates BH201 down to a depth of 4 m (0.5 mRL) and BH204 consists of weathered silty sand and medium sandy silt the full length of the piezometer. General hydraulic conductivity values for fill material and weathered soils range from 10^{-2} to 10^{-7} m/s and 10^{-4} to 10^{-7} m/s, respectively (**Section 3.1**). Consequently, the rising head test results indicate the

hydraulic conductivity in the area surrounding the bridge is within the expected range. Note, due to the shallow nature of the GBWD works, no hydraulic testing of the lower ECBF was undertaken.

Table 2 Hydraulic conductivity results from rising head tests

Borehole	Piezometer depths (mBGL)	Hydraulic conductivity	Geology
BH201	1.5 to 4.6	3.15×10^{-5} m/s	Fill: Silty CLAY with gravel; fine sand SILT
BH204	2.5 to 7.5	2.24×10^{-5} m/s	Weathered silty fine SAND; medium sandy SILT

3.5 Groundwater use

The new watermain will be constructed in the Kumeu Waitemata Aquifer zone. A bore search enquiry from Auckland Council's bore database was undertaken to identify any boreholes located within the vicinity of the proposed works. This search identified four deep groundwater take bores and two site investigation bores within 1.5 km of the GBWD (**Table 3** and **Figure 8**).

Table 3 Groundwater takes within 2 km radius of proposed works

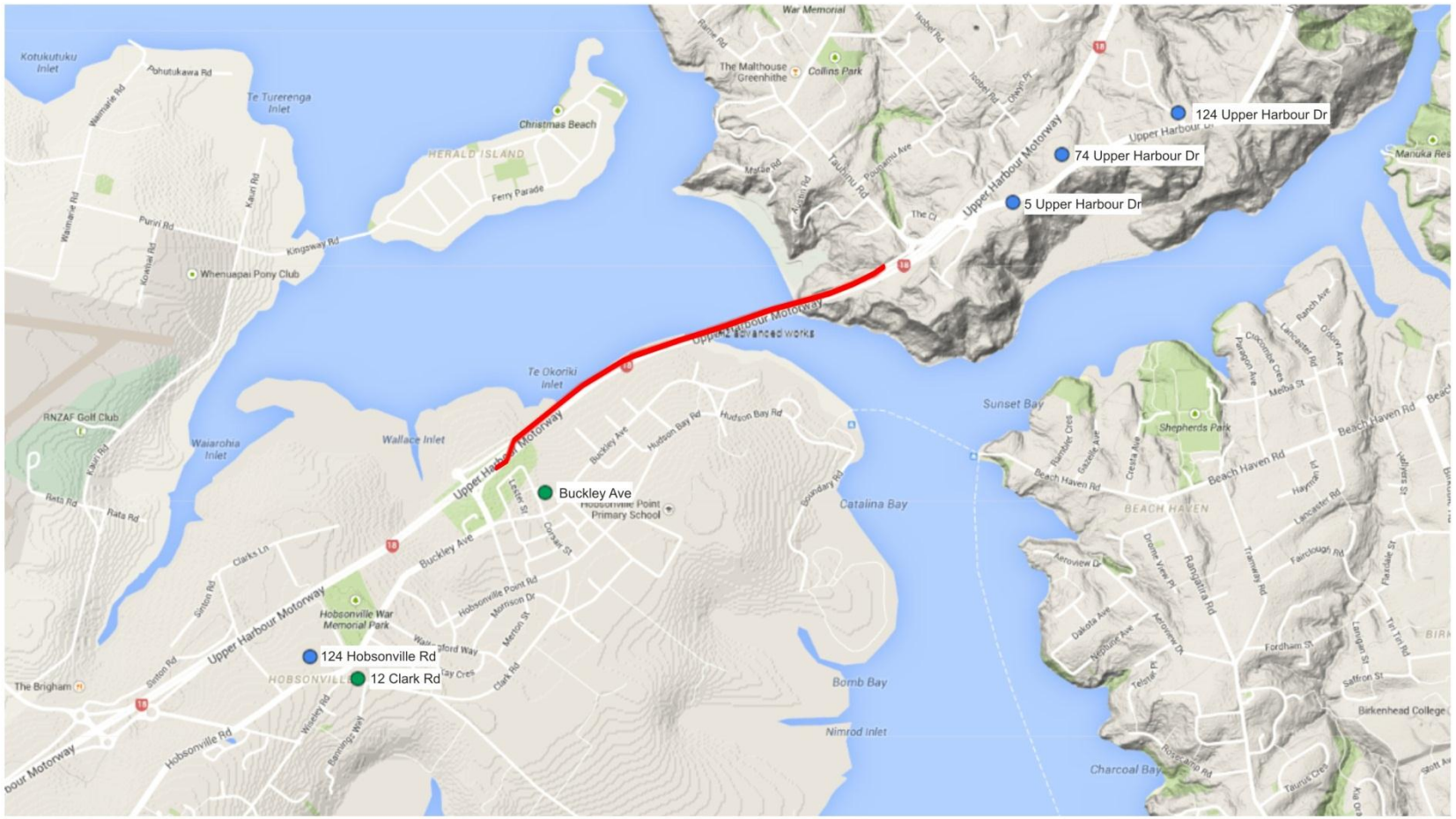
Consent no.	Depth (m)	Casing depth (m)	Purpose	Address	Distance from proposed works (km)
-	-	-	Groundwater and contaminated site investigation	12 Clark Road (BP Oil NZ Limited)	1.2
28653	5	2.6	Monitoring (3 bores)	0 Buckley Avenue	0.5
13844	200	65	Stock and domestic supply	124 Hobsonville Road	1.3
23230	200	65	Stock and domestic supply	5 Upper Harbour Drive	0.9
21320	200	65	Domestic supply	74 Upper Harbour Drive	1.0
27736	200	70	Domestic supply	124 Upper Harbour Drive	1.5

3.6 Surface water connections

The works for the GBWD are located at the coast which acts as the groundwater discharge point. In addition, there is a small ravine, with stagnant water, adjacent to BH201. This ravine potentially acts as a discharge point for the culvert located to the south. Water level records for BH201 (**Figure 5**) indicate a possible connection between water being discharged to the ravine and groundwater levels.

3.7 Groundwater quality

Groundwater quality is not considered in this report. For further details on groundwater quality see the Technical Report – Soil, Sediment and Groundwater Contamination (Jacobs, 2015).



Legend:

- Site investigation/ monitoring bores
- Groundwater supply
- GBWD proposed works

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Filename	Name	Date
Proposed works.cdr	BAS	Dec-14

Data Notes:

Bore locations and purpose are based on bores search completed by Auckland Council (AC, 2014).

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FIGURE 8. BOREHOLE LOCATION IN VICINITY OF PROPOSED WORKS

4 DESCRIPTION OF PROJECT ASPECTS APPLICABLE TO HYDROGEOLOGY

4.1 Location

The new watermain route is shown on drawing 2010674.001 and Figures 1 to 5 of the NH2 Advanced Works Geotechnical Factual Report (Opus, 2014), copies of which are located in **Appendix A** of this report.

4.2 Excavation dimensions

The proposed works excavation dimensions are shown on drawings 2010674.002 to 2010674.006 (URS, 2015), and outlined in the AEE in Section 2. Specific details of the excavations are outlined below and have been divided into three sections:

- New Watermain to NH1 pipe connection – west;
- Causeway widening and extension; and
- New Watermain to NH1 pipe connection – east.

4.2.1 New Watermain to NH1 pipe connection - west

The proposed pipeline has a diameter of 1,200 mm from its start to the bridge crossing where it reduces in size to a nominal 800 mm diameter pipeline. The invert depth for the first approximately 900 m, along the proposed causeway embankment extension (before the bridge crossing), varies from 2 to 3.5 mBGL with the invert level ranging from approximately 6.6 mRL at the start of the proposed pipeline route to -0.2 mRL.

The pipeline connecting the existing NH1 pipeline to the GBWD pipeline has a diameter of 800 mm. Invert depth along the connecting pipeline route ranges between 2.5 to 11.5 mBGL with invert levels ranging from approximately 8.4 mRL to 0.89 mRL (drawing 2010674.005). Further details of the pipeline are as follows:

- the first 60 m has a shallow gradient (-1%), invert depth between 2.5 and 4 mBGL, and invert levels starting at 8.4 mRL and finishing at 7.8 mRL;
- between 60 m and 67.5 m the pipeline descends sharply (-83% gradient) to an elevation of 1.3 mRL with maximum invert depth of 11.0 mBGL;
- the connecting 800 mm diameter pipeline from 67.5 m to 192.2 m is microtunnelled under the bridge and is surrounded by a 1,200 mm diameter sleeve pipe, which has a shallow descending gradient (-0.35%) and invert levels ranging from 1.3 mRL to 0.9 mRL.

In preparation for microtunnelling the pipe under SH18 there will be a temporary jacking pit (on the north side, GBWD) and receiving pit (south side, NH1). The jacking pit is proposed to be approximately 4 m long by 3 m wide by 6 m depth with a maximum invert level of approximately -0.6 mRL. The receiving pit will be approximately 6 m long by 4 m wide by 13m depth, from the existing

ground level, with a maximum invert level of -0.20 mRL. Around the jacking pit and receiving pit areas, 12 m long sheet pile walls will be installed prior to works.

Valve chambers will be constructed within the jacking and receiving pits to house the connections to NH1 and the new watermain. The GBWD chamber will measure approximately 4 m long x by 5 m wide by 3 m deep (2.2 mRL). To the south of SH18 (around NH1) the chamber will measure approximately measure 4 m long by 3 m wide by 3.3 m deep (8.8 mRL). The NH1/new watermain scour chamber will be installed alongside the valve chamber to the north of SH18.

4.2.2 Causeway widening and extension

The proposed plan is to widen the existing causeway by 15 m along the northern side for a length of approximately 860 m. In addition, a construction platform will be established approximately 600 m along the causeway from the western end. This platform will provide an additional area of approximately 150 m long by 53 m wide to enable the future construction of the harbour sections of the NI pipelines which will extend north under the harbour from this point. Specific details of proposed construction of the causeway are outlined in Section 2.3.4 of the AEE. However, in general the causeway will be constructed in cells, which create areas that are separated from coastal waters. In each of the cells, an amphibious excavator will excavate a trench along the toe of the future batter during low tide, before it is filled with rock fill to the existing ground levels.

4.2.3 New Watermain to NH1 pipe connection - east

On the east end of the works, the new watermain will be constructed adjacent to the NH1 pipeline and the connections between the pipes will be made within a valve chamber. The only excavation on this side of the bridge is the combined chamber which measures 6 m long by 4 m wide by 3.5 m deep (approximately 26 mRL).

5 STATUTORY FRAMEWORK

The statutory framework relevant to hydrogeology is the Objectives, Policies and Rules outlined in both the Auckland Regional Plan: Air, Land and Water (ALW Plan) and the Proposed Auckland Unitary Plan (PAUP).

5.1 Auckland Air, Land and Water Plan

Specific rules related to groundwater in the ALW Plan are as follows.

Permitted Activities - Rule 6.5.76

The diversion of groundwater in an unconfined aquifer caused by changing the permeability of the aquifer at the location of the works by trenching, digging or tunnelling is a Permitted Activity, subject to the following conditions:

(a) The diversion shall not change the water level regime or direction of flow of the aquifer after completion of the works; and

(b) Any resulting settlement shall not cause adverse effects on buildings, structures and services.

The permeability of the aquifer will not be changed by the proposed trenching or tunnelling, and as such this activity would be classified as a permitted activity.

5.2 Proposed Auckland Unitary Plan

Specific rules related to groundwater in the PAUP cover both groundwater take and use during dewatering and groundwater diversion. These rules are as follows.

Permitted (3.1.3)

4. Dewatering or groundwater level control associated with a groundwater diversion permitted under clause 3.1.4 below:

a. the water take must not be geothermal water

b. the water take must not be for a period of more than 30 days

c. the water take must only occur during construction of the excavation, trench, tunnel or thrust bore.

The proposed dewatering of the receiving/jacking pits is expected to take approximately four months, and as such does not comply with 4b above. As such, consent is required as a restricted discretionary activity.

Permitted (3.1.4)

The diversion of groundwater caused by any excavation, trench, tunnel up to 1m diameter, or thrust bore is permitted if it meets the following controls:

1. The diversion must not be for the purpose of taking groundwater.
2. Any excavation that extends below natural groundwater level, including any staging of the same proposal, must not exceed:
   a. 1ha in total area for development, operation, maintenance or upgrading of a network utility.
   b. 0.5ha in total area and 4m depth below the natural ground level.
3. The natural groundwater level must not be reduced by more than 2m.
4. Any structure that physically impedes the flow of groundwater must not:
   a. exceed 20m in length, including any staging of the same proposal; or
   b. extend more than 2m below the natural groundwater level.
5. The distance to any existing building or structure from the edge of any:

a. trench or open excavation that extends below natural groundwater level must be 4m or greater
b. tunnel with a diameter of 0.2-1.0m that that extends below natural groundwater level must be 2m or greater

Note: A tunnel with a diameter of up to 0.2m that that extends below natural groundwater level has no building separation requirement

6. The distance from the edge of any excavation, including any staging of the same proposal, must not be less than 50m from any:
   a. Wetland Management Area
   b. scheduled historic heritage place or scheduled sites and places of significance to Mana Whenua
   c. surface water body
   d. lawful groundwater take.
7. For activities other than the development, operation, maintenance or upgrading of a network utility, the length of any excavation, trench, tunnel, or thrust bore, including any staging of the same proposal, must be no greater than 50m.
8. For the development, operation, maintenance or upgrading of a network utility, including any staging of the same proposal, any backfilled trench must be designed and constructed with impenetrable seepage collars / barriers installed at intervals of no greater than 50m along the alignment.

The proposed new watermain will result in minimal groundwater flow diversion; however it will impede the flow and will exceed 20 m in length. Hence, consent is required as a restricted discretionary activity.

6 ASSESSMENT OF POTENTIAL OR ACTUAL EFFECTS

6.1 Potential groundwater drawdown

6.1.1 West end

Construction of the GBWD pipeline will predominantly be above the current groundwater levels. The only locations of potential groundwater drawdown are the temporary jacking and receiving pits, the GBWD valve chamber and scour chamber, and the tunnelling of the pipeline connecting the existing NH1 pipeline to the GBWD pipeline (**Figure 9** and **Figure 10**)

The receiving pit (south side of motorway) will be 6 m long, 4 m wide, and approximately 13 m deep with a maximum invert level of -0.2 mRL. The jacking pit (north side of motorway) is expected to be 6 m long, 4 m wide, and approximately 6 m deep with a maximum invert level of -0.6 mRL.

BH201 and BH202, located near the receiving pit and jacking pit respectively, both indicate maximum groundwater levels of 1.9 mRL. Drawdown levels in the immediate vicinity of the pits would be expected to be approximately 2.5 m. Flow rates associated with such a drawdown, excavation dimensions, and hydraulic conductivity of $3x10^{-5}$ m/s are expected to be minimal with a limited zone of influence, i.e. a radius of influence of 180 m, as shown on **Figure 11**. Construction plans include the installation of sheet pile walls (12 m in length) that will reduce the calculated drawdown effects caused by the excavation.

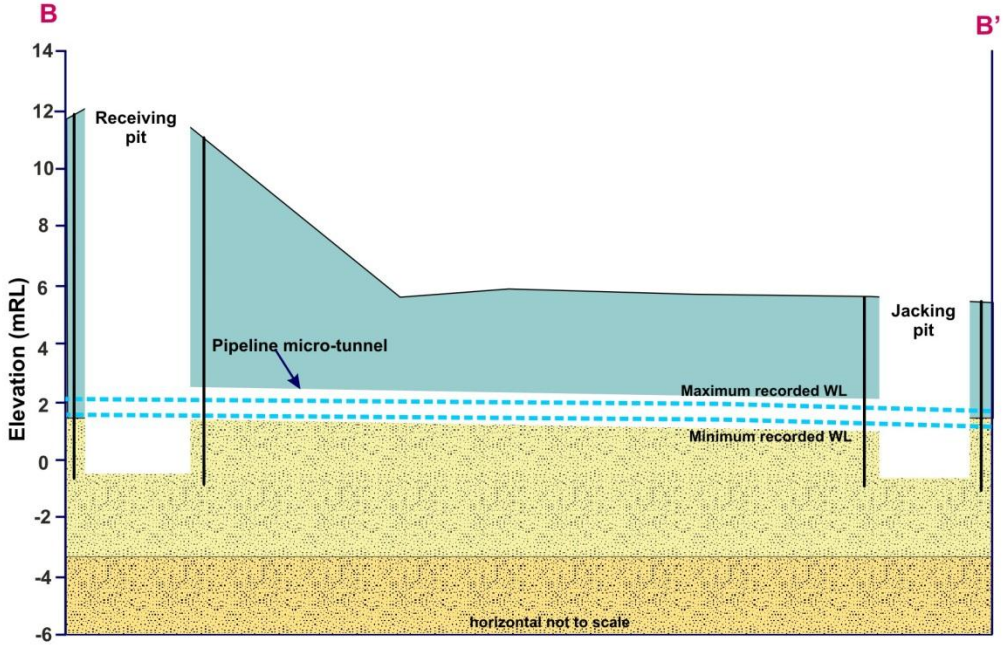
The GBWD valve and scour chambers will be constructed within the sheet piles for the jacking pit, and will have maximum depth to -0.20 mRL and a combined footprint of 38 m^2. Maximum drawdown in the immediate vicinity of the pit, therefore, is expected to be approximately 2 m. As with the construction of the jacking pit, drawdown is expected to be confined to the immediate area of construction (e.g. in the order of 180 m) and the installation of the sheet piles will further reduce any potential drawdown.

The NH1-GBWD connecting pipeline will be tunnelled under the motorway via pipe jacking. The invert level of the pipeline ranges between 0.5 to 1.0 m below the water table (**Figure 9**). Any potential drawdown due to the tunnelling will be minimal and confined to the immediate vicinity of the works. Consequently, the tunnelling is not expected to have an adverse effect on the surrounding groundwater levels.

6.1.2 The causeway

During construction of the causeway, groundwater ingress along the coastal excavation path is expected. It is proposed that the groundwater ingress will be pumped and dealt with on site as part of the Erosion and Sediment Control Plan. Pumping to remove the water is not expected to have any adverse effects as groundwater flow directions will remain unchanged and the ingress per metre length is expected to be less than minor, e.g. less than 3 L/s/m of excavation although dependent on depth and width of excavation.

Plan view



Cross-sectional view

Legend:

- Jacking and receiving pits
- Borehole
- Fill
- Groundwater level
- Weathered ECBF
- Sheet piles
- Unweathered ECBF

Document Status:

I:\AENVA\Projects\AE04521\

Filename	Name	Date
Proposed works.cdr	BAS	Dec-14

Data Notes:

Geology and water levels based on information gathered at BH201 and BH202 during the site investigation (Jul to Nov 2014).

Assumed position of the jacking and receiving pits are based on AEE.

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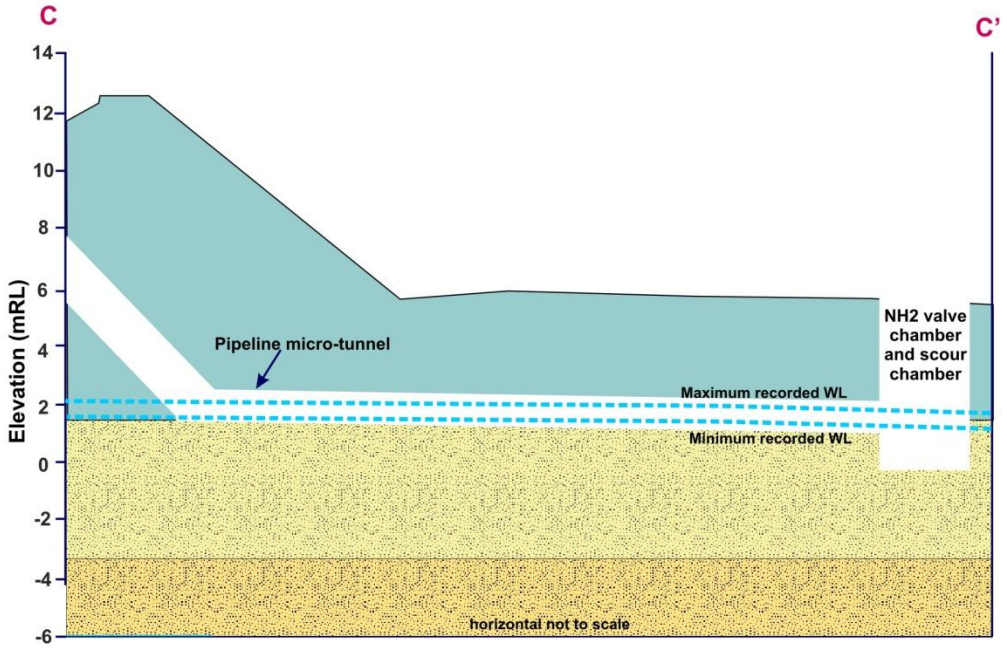
Fax + 64 9 9138901

Title:

FIGURE 9. SCHEMATIC DIAGRAM SHOWING TEMPORARY WORKS AT MICRO-TUNNEL SECTION RELATIVE TO WATER

Plan view



Cross-sectional view

Legend:

- NH2 valve chamber and scour chamber
- Fill
- Weathered ECBF
- Unweathered ECBF
- Borehole
- Groundwater level
- Sheet piles

Document Status:

I:\AENVA\Projects\AE04521\

Filename	Name	Date
Proposed works.cdr	BAS	Dec-14

Data Notes:

Geology and water levels based on information gathered at BH201 and BH202 during the site investigation (Jul to Nov 2014).

Exact positions of the NH2 valve chamber and scour chamber have been estimated based on location shown in drawing no. 2010674.005 (URS, 2014)

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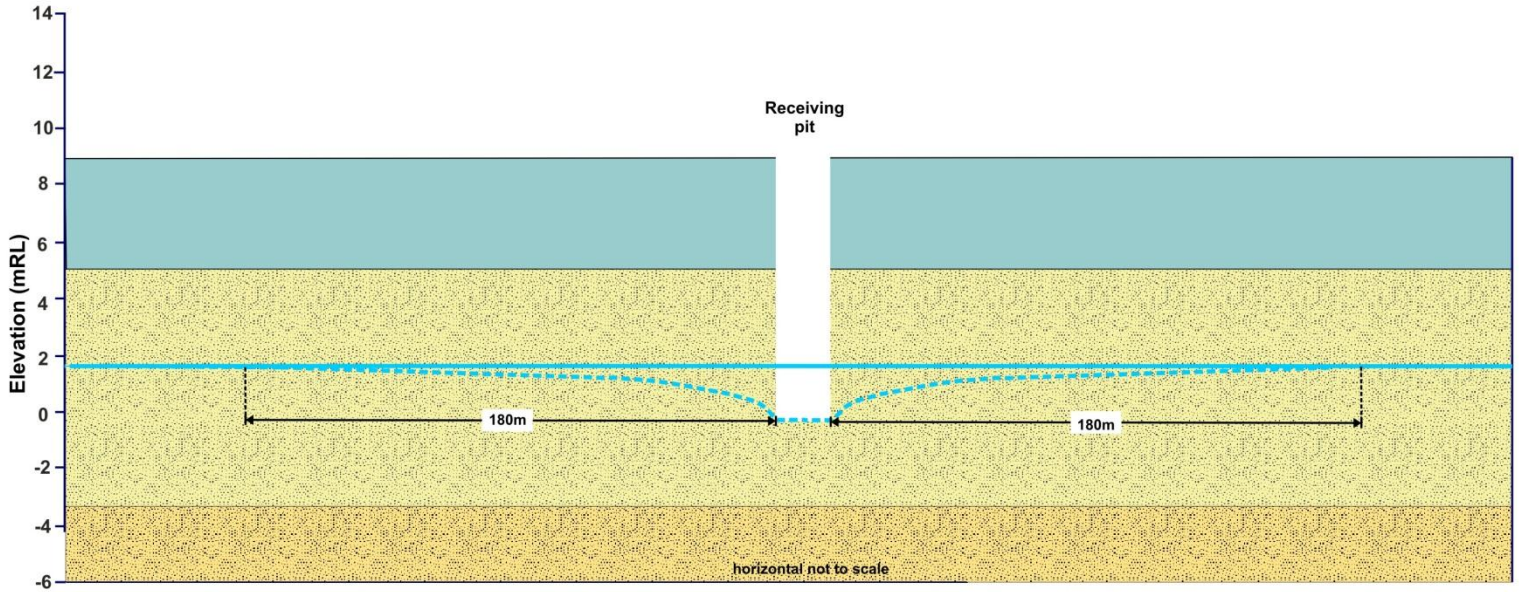
Title:

FIGURE 10. SCHEMATIC DIAGRAM SHOWING PERMANENT PIPELINE STRUCTURES RELATIVE TO WATER TABLE AT MICRO-TUNNEL SECTION



Legend:

- Fill
- Weathered ECBF
- Unweathered ECBF
- Static groundwater level
- Groundwater drawdown level

Document Status:

I:\AENVA\Projects\AE04521\

Filename	Name	Date
Proposed works.cdr	BAS	Dec-14

Data Notes:

Geology and water levels based on information gathered at BH201 and BH202 during the site investigation (Jul to Nov 2014).

Static water level is assumed to be 1.85 mRL (maximum water level recorded in BH201 and BH202).

Drawdown estimate assumes no sheet pile are installed.

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FIGURE 11. SCHEMATIC DIAGRAM SHOWING DRAWDOWN AT RECEIVING PIT

6.1.3 East end

The combined chamber is expected to measure 6 m long, 4 m wide, and 3.5 m deep (approximately 26 mRL). Water levels recorded at BH204, located in the vicinity of the proposed chamber, shows water levels range from 3.8 to 4.1 mBGL (22.8 to 22.5 mRL) as shown in **Figure 12**. Consequently, there is unlikely to be any groundwater drawdown due to the construction works on the east end of the bridge and no mitigation measures are required.

6.2 Groundwater diversion

6.2.1 West end

The jacking and receiving pits are temporary, and consequently, will not affect groundwater flow paths long term.

The valve and scour chambers will be permanent and will cause some groundwater diversion around the structures; however, the diversion will be in the direction of the natural flow paths and will not change the overall flow regime (groundwater will continue to discharge to the harbour). In addition, the diversion will not result in increased surface flooding.

The NH1-GBWD connecting pipeline tunnelled under the motorway will intersect the water table but will cause minimal groundwater diversion, as once again the diversion will be in the direction of natural flow paths. An assessment of potential settlement as a result of the minimal groundwater diversion is outlined in Section 6.4.6 of the AEE.

6.2.2 The causeway

The causeway trenching along the toe of the proposed causeway widening will be filled with permanent rock fill, which will not impede or alter groundwater flow to the harbour, hence no groundwater diversion will occur as a result of the causeway widening. In addition, the pipes to be constructed within the causeway for both GBWD and NI will be located above approximately 2 metres above the mean sea level, Based on groundwater levels recorded within BH204 (the closest groundwater bore to the causeway location), these pipes will be located above groundwater. As such, there will be no effect on groundwater flow as a result of the construction of these pipes.

6.2.3 East end

The base of the connection chamber is expected to be above the water table, and therefore, will not result in any change to the groundwater flow regime.

6.3 Potential impact on neighbouring groundwater users

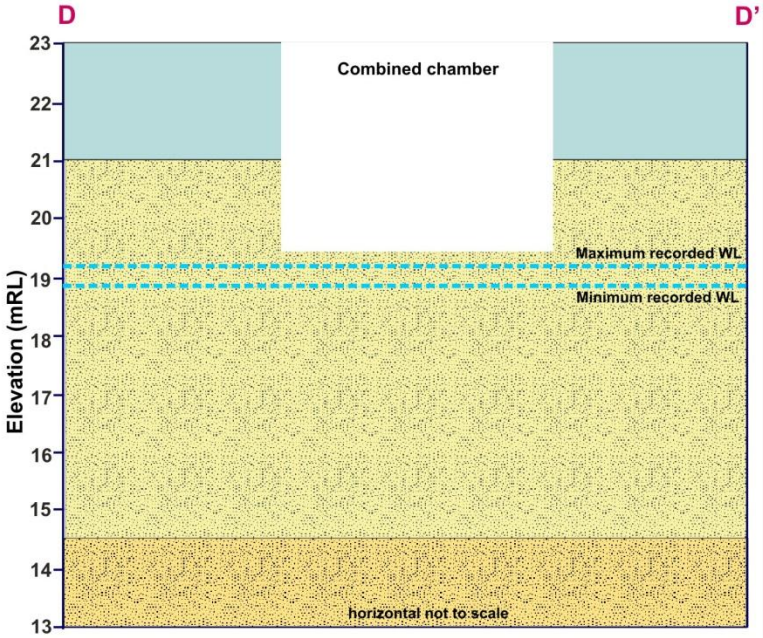
Section 3.5 outlined the groundwater users that were identified from the Auckland Council bore database as being located within 1.5 km of the proposed works. In total, four groundwater bores were identified that abstracted groundwater for domestic and stock purposes.

There will be no effect on these abstractions as a result of the proposed works given the minimal drawdown anticipated during the construction work, as well as the fact that all of the bores abstract water from the deep aquifer.

6.4 Effects on groundwater quality

This report evaluates the construction and operations effects on groundwater drawdown and diversion only. For a full discussion regarding the effects on groundwater quality please refer to the Technical Report – Soil, Sediment and Groundwater Contamination (Jacobs, 2015).

Plan view



Cross-sectional view

Legend:

- Combined chamber
- Borehole
- Fill
- Groundwater level
- Weathered ECBF
- Unweathered ECBF

Document Status:

I:\AENVA\Projects\AE04521\

Filename	Name	Date
Proposed works.cdr	BAS	Dec-14

Data Notes:

Geology and water levels based on information gathered at BH204 during the site investigation (Jul to Nov 2014).

Assumed position of the combined chamber is based on AEE.

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Title:

FIGURE 12. SCHEMATIC DIAGRAM SHOWING EAST END COMBINED CHAMBER RELATIVE TO WATER TABLE

7. MITIGATION AND MANAGEMENT MEASURES

Other than the proposed sheet piles for the pipe jacking and receiving pits, we do not consider any mitigation or monitoring is necessary for groundwater impacts from the proposed works because of the less than minor potential adverse effects.

Section 6.4.6 of the AEE (Settlement Assessment) outlines some mitigation measures for potential settlement issues.

8. CONCLUSION

Construction of the GBWD works will cause minimal disruption to the groundwater flow regime as outlined below:

- On the west end of the bridge the temporary jacking and receiving pits, GBWD valve chamber, and NH1-GBWD scour chamber will be constructed to a maximum depth of -0.6 mRL in an area where the water table has maximum recorded level of 1.85 mRL. Drawdown expected during construction is approximately 2.5 m in the immediate vicinity of the construction. To mitigate the drawdown effects, sheet piles will be installed around the excavations. The overall effect on groundwater levels and flow in the area will be minimal.

- The tunnel under SH18 on the west end will be constructed between the jacking and receiving pits. The invert level of the tunnel ranges from 0.5 to 1.0 m below the water table. Drawdown effects are expected to be minimal during tunnelling.

- The causeway will be widened by 15 m for a distance of 860 m. Groundwater ingress along this route during excavation will be removed via pumping and will be dealt with on site as part of the Erosion and Sediment Control plan. The pumping will have minimal impact as it will not interfere with the natural groundwater flow path. The trenching will be filled with permanent rock which will also not affect the groundwater flow regime in the long term.

- In addition, the pipes to be constructed within the causeway for both GBWD and NI will be located above approximately 2 metres above the mean sea level, Based on groundwater levels recorded within BH204 (the closest groundwater bore to the causeway location), these pipes will be located above groundwater. As such, there will be no effect on groundwater flow as a result of the construction of these pipes.

- Overall groundwater effects are considered to be less than minor.

7 REFERENCES

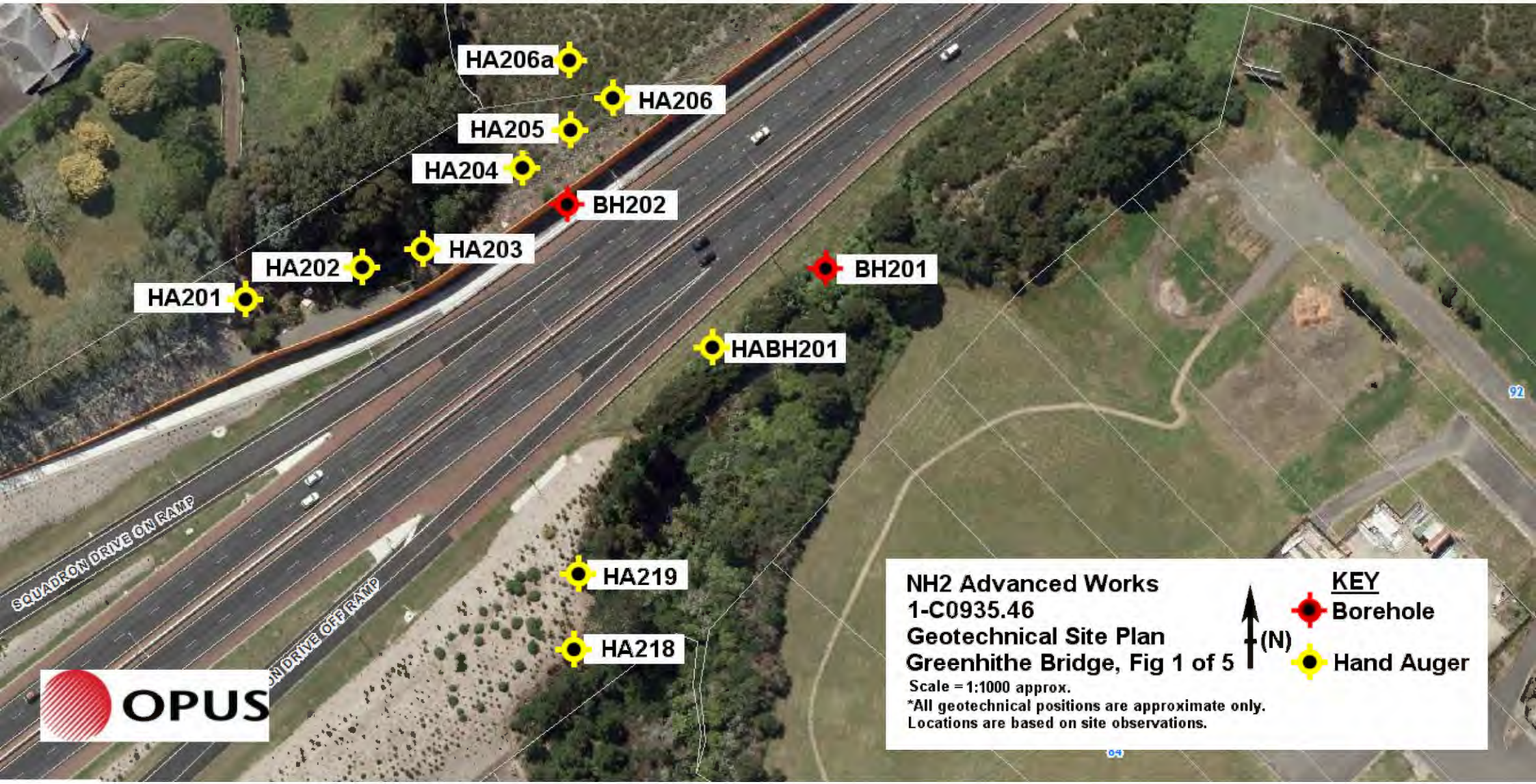
Domenico, P.A. and F.W. Schwartz, 1990. Physical and Chemical Hydrogeology, John Wiley & Sons, New York, pg. 824.

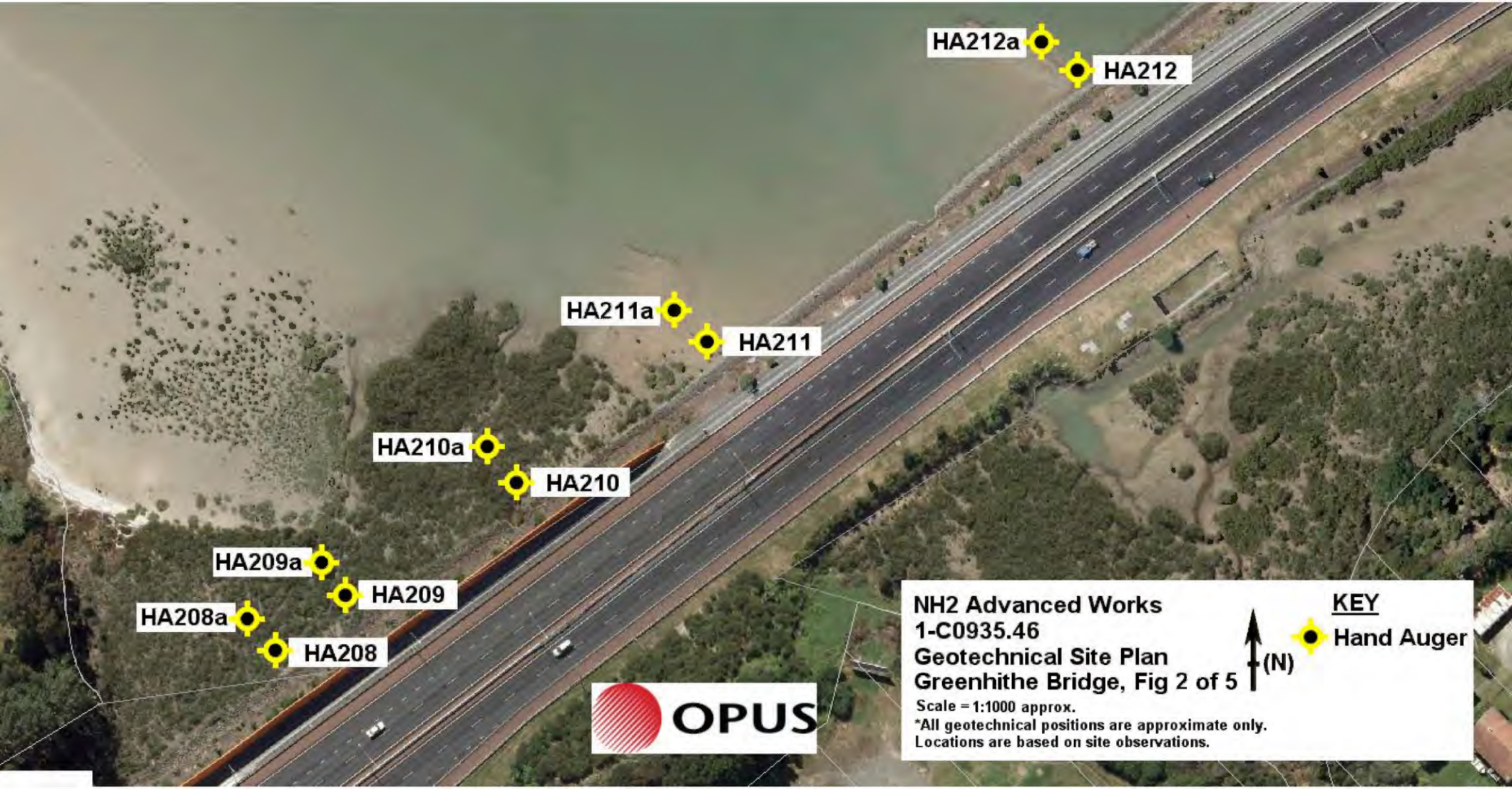
Edbrooke, S.W. 2001 Geology of the Auckland Area, Institute of Geological and Nuclear Sciences Limited.

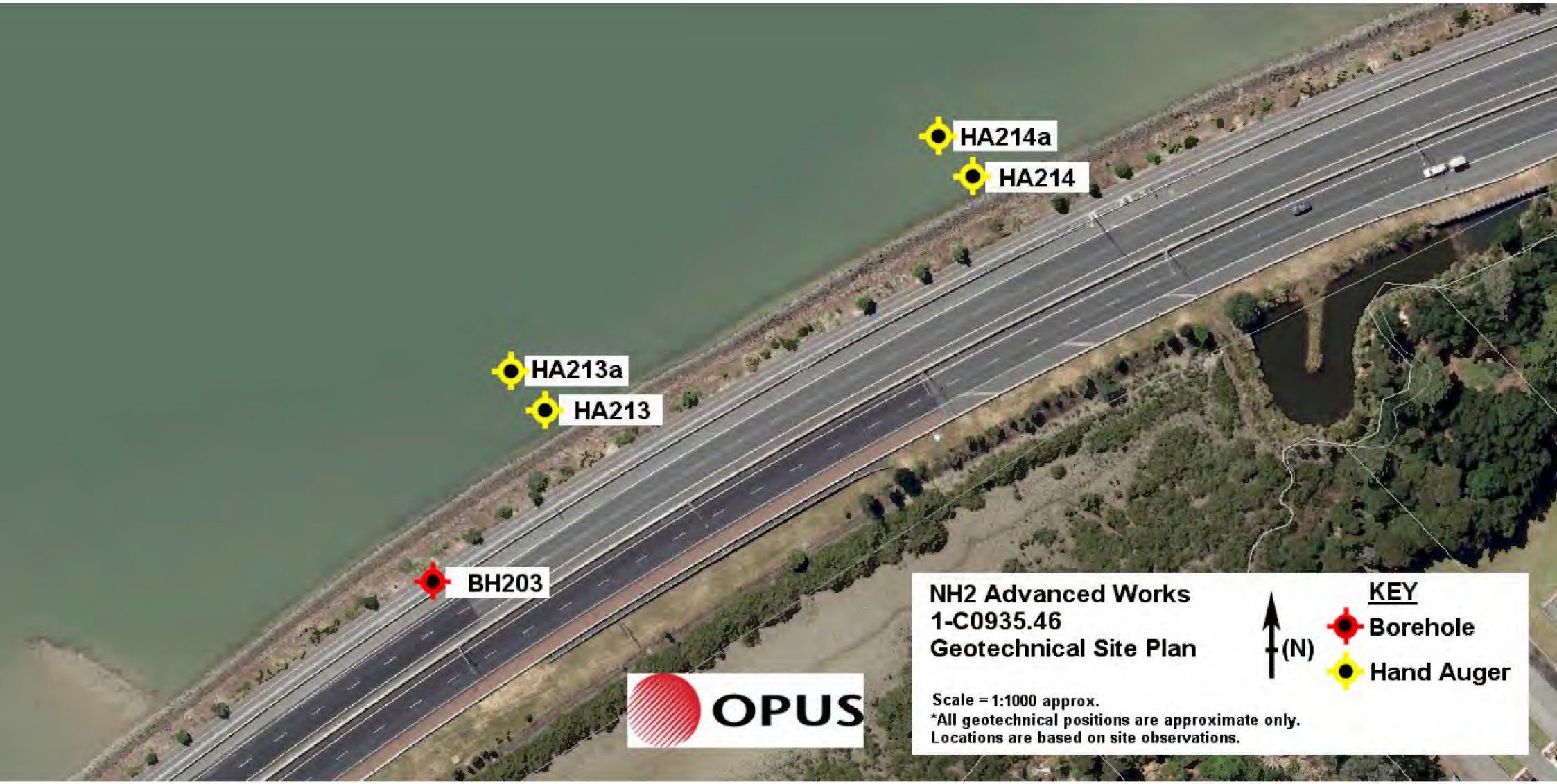
Jacobs, 2015. Greenhithe Bridge Watermain Duplication and Causeway - Technical Report – Soil, Sediment and Groundwater Contamination. Report prepared for Watercare Services Limited

Heath, R.C., 1983. Basic groundwater hydrology, US Geological Survey Water Supply Paper 2220, pg. 86.

APPENDIX A – PLAN VIEW OF BOREHOLE LOCATIONS


HA206a
HA206
HA205
HA204
BH202
HA203
HA202
HA201
BH201
HABH201
HA219
HA218
SQUADRON DRIVE ON RAMP
OPUS
NH2 Advanced Works
1-C0935.46
Geotechnical Site Plan
Greenhithe Bridge, Fig 1 of 5
Scale = 1:1000 approx.
*All geotechnical positions are approximate only.
Locations are based on site observations.
(N)
KEY
Borehole
Hand Auger


HA212a
HA212
HA211a
HA211
HA210a
HA210
HA209a
HA209
HA208a
HA208
OPUS
NH2 Advanced Works
1-C0935.46
Geotechnical Site Plan
Greenhithe Bridge, Fig 2 of 5
(N)
KEY
Hand Auger
Scale = 1:1000 approx.
*All geotechnical positions are approximate only.
Locations are based on site observations.


HA214a
HA214
HA213a
HA213
BH203
OPUS
NH2 Advanced Works
1-C0935.46
Geotechnical Site Plan
(N)
KEY
Borehole
Hand Auger
Scale = 1:1000 approx.
*All geotechnical positions are approximate only.
Locations are based on site observations.


HA215a
HA215
HA216a
HA216
HA217a
HA217
HA207a
HA207
UPPER HARBOUR MOTORWAY
OPUS
NH2 Advanced Works
1-C0935.46
Geotechnical Site Plan
Greenhithe Bridge, Fig 4 of 5
Scale = 1:1000 approx.
*All geotechnical positions are approximate only.
Locations are based on site observations.
(N)
KEY
Hand Auger

OPUS

NH2 Advanced Works
1-C0935.46
Geotechnical Site Plan
Greenhithe Bridge, Fig 5 of 5

(N)

KEY
Borehole

Scale = 1:1000 approx.
*All geotechnical positions are approximate only.
Locations are based on site observations.

APPENDIX B – BOREHOLE LOGS

BOREHOLE LOG

OPUS GEOTECHNICAL

HOLE NO. **BH201**			
PROJECT: **NH2**	CO-ORD.: **1747971 E 5927253 N**	R.L.: **4.47 m**	SHEET: **1 of 2**
LOCATION: **See site plan, SH16, Hobsonville**	REF. GRID:	DATUM: **MSL**	HOLE LENGTH: **10.61 m**

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m) / DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK STRENGTH	ROCK WEATHERING	DEFECT SPACING	DIP (degrees 0–90)	DETAILED DESCRIPTION	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
Fill	Clayey SILT; with trace fine sand and traces of fine angular gravel and rootlets, brown, stiff, moist, slightly plastic, trace rootlets.	4										100	HA	HA				P1	
	Silty CLAY; with trace fine sand and trace fine to 2cmØ gravels, greyish brown mottled orange, stiff, moist, plastic.																		
	Fine to 5cmØ GRAVELS; with trace silt, medium dense, moist, brittle.	1										18	HQ						
	Poor recovery from 0.95m to 1.4m. Inferred 'silty clay'. Material washed away during drilling due to gravel interference.																		
	Silty CLAY; with trace fine to 1cmØ angular gravels, orange mottled brownish orange, hard, plastic. Trace organics, trace pockets of brown silty clay.			10	2//2/3/3/2							82	SPT						
		2																	
	Inclusions of larger 3 to 6cmØ angular gravels at 2.8m. No recovery from 3.0m to 3.45m. Inferred 'clay'. Material not obtained in SPT due to gravel interference.											52	HQ						
		3		1	4//0/0/0/1							0	SPT						
	Push tube attempted at 3.5m. No recovery and material becomes too hard to penetrate at 3.7m.																		
	Poor recovery from 3.7m to 4.4m. Clayey SILT; with some fine sand, grey, stiff, plastic.	4				CW						17	HQ						
	Fine sandy SILT; with minor clay, grey, hard, brittle but slightly plastic once reworked.	0		60+	13//14/16/22/8 for 25mm	CW						100	SPT						
	Muddy fine grained SANDSTONE; grey, extremely weak, moderately weathered.	5				EW	MW												
	Alternating sequence of moderately thick to thick bedded muddy fine grained SANDSTONE (50%); grey, extremely weak, slightly weathered with MUDSTONE (50%); grey, very weak, slightly weathered. Moderately inclined bedding planes, planar to undulating.				UCS: 1600 kPa	EW	SW			Fracture, 11° dip; undulating, rough, no coating at 5.1m. Shattered segment of core from 5.2m to 5.25m. Two fractures, 44° and 48° dips; undulating, rough, no coating at 5.5m and 5.55m. Fracture, 16° dip; planar, smooth, trace clay coating at 5.6m. Fracture, 58° dip; undulating, smooth, no coating at 5.8m. Shattered segment of core from 5.85m and 6.0m.	63	100	HQ							
		6		60+	25//29/29/2 for 5mm								SC	SPT						
		-2								Two fractures, 10° and 16° dips; undulating, smooth, no coating at 6.4m and 6.55m.	78	100	HQ						
	MUDSTONE; grey, very weak, unweathered to slightly weathered. 1cm thick bed of 'soft' MUDSTONE; extremely weak, highly weathered.	7		60+	60 for 140mm	VW	SW			Shattered core. 51° dip fracture; planar, smooth, no coating cross cut by a 73° dip fracture; undulating, smooth, no coating from 6.9m to 7.1m.			SC	SPT						
	Fine grained SANDSTONE; grey, extremely weak, moderately weathered.	8				EW	MW			Fracture, 38° dip; planar, smooth, trace clay coating. Shattered segment of core from 7.95m to 8.15m. Fracture, 70° dip; undulating, smooth, no coating at 8.3m.	74	100	HQ							
		-4			UCS: 3200 kPa								SC	SPT						
	MUDSTONE; grey, very weak, slightly weathered.					VW	SW												
	Muddy fine grained SANDSTONE; grey, extremely weak, slightly weathered.	9		60+	60 for 100mm	VW	SW			Fracture, 68° dip; undulating/ stepped, smooth, no coating at 9.5m. Fracture, 26° dip; undulating, smooth, no coating at 9.6m.	71	100	HQ							
Waitemata Group						VW	SW												

HQTT

NOTES

SWL 9-6-2014 = 1.9m (5pm)
SWL 10-6-2014 = 2.2m (8am)
Single piezometer installed upon completion.
Contamination samples taken at 0.1m, 1.0m and 2.0m.

STARTED: 6-06-2014	FINISHED: 10-06-2014
DRILLER: Billy	DRILLING CO.: DF
INCLINATION/ AZIMUTH: -90°	DRILLING RIG: CAT
LOGGED: T Van Deelen	CHECKED: G Knocker
CLIENT: Watercare Services Limited	JOB NO.: 1-C0935.46

BH201

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

BOREHOLE_LOG_A3 (&PHOTO PAGE) 1-C0935.46 NH2.GPJ OPUS CHCH DEC12.GDT 1-8-14

Scale 1:33.33

BOREHOLE LOG

OPUS GEOTECHNICAL

HOLE NO. **BH201**			
PROJECT **NH2**	CO-ORD. **1747971 E 5927253 N**	R.L. **4.47 m**	SHEET **2 of 2**
LOCATION **See site plan, SH16, Hobsonville**	REF. GRID	DATUM **MSL**	HOLE LENGTH **10.61 m**

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m) / DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK STRENGTH	ROCK WEATHERING	DEFECT SPACING	DIP (degrees 0–90)	DETAILED DESCRIPTION	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
	Fine grain sandy MUDSTONE; very weak, slightly weathered.	-6		60+	60 for 110mm	VW	SW			Two cross-cut fractures, 26° and 41° dips; undulating, smooth, no coating at 9.95m. Shattered segment of core from 9.9m to 10.0m.	71	100	HQ	HQTT				P1	
												SC	SPT						
	End of Borehole at 10.61m.	11 / -8 / 12 / 13 / -10 / 14 / 15 / -12 / 16 / 17 / -14 / 18 / 19																	

NOTES

SWL 9-6-2014 = 1.9m (5pm)
SWL 10-6-2014 = 2.2m (8am)
Single piezometer installed upon completion.
Contamination samples taken at 0.1m, 1.0m and 2.0m.

STARTED 6-06-2014	FINISHED 10-06-2014
DRILLER Billy	DRILLING CO. DF
INCLINATION/ AZIMUTH -90°	DRILLING RIG CAT
LOGGED T Van Deelen	CHECKED G Knocker
CLIENT Watercare Services Limited	JOB NO. 1-C0935.46

BH201

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

BOREHOLE_LOG_A3 (&PHOTO PAGE) 1-C0935.46 NH2.GPJ OPUS CHCH DEC12.GDT 1-8-14

Scale 1:33.33

BOREHOLE LOG

OPUS GEOTECHNICAL

HOLE NO. **BH202**			
PROJECT: **NH2**	CO-ORD.: **1747902 E 5927258 N**	R.L.: **5.25 m**	SHEET: **1 of 2**
LOCATION: **See site plan, SH16, Hobsonville**	REF. GRID:	DATUM: **MSL**	HOLE LENGTH: **18.1 m**

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m)	DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK STRENGTH	ROCK WEATHERING	DEFECT SPACING	DIP (degrees 0–90)	DETAILED DESCRIPTION	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
Fill	Fine to 10cmØ angular GRAVELS in a SILT matrix; with trace clay, brown, dense, brittle, moist.																		P1	
	SILT: with some clay and some hard 2cmØ angular silt fragments, grey mottled bluish grey very stiff, slightly plastic, moist.		1										100	HA	HA					
	CLAY; with some silt, greyish brown, very stiff, plastic, moist.	4																		
	Fine to 3cmØ angular BASALT fragments in a CLAY matrix; some silt, greyish brown, very stiff, plastic, moist.		2		34	12//11/7/7/9							24	SPT		40%				
	Large angular BASALT BOULDERS; dark grey, 'strong', slightly weathered.												100	HQ		100%				
Alluvium	Fine sandy CLAY; with some silt, light greyish brown, firm to stiff, plastic, trace rootlets.	2	3										80	HQ					15-7-2014	
Waitemata Gorup	Silty CLAY; dark grey, stiff, plastic.		4										100	PT						
	SILT; with some clay, grey, stiff, slightly plastic.	0			4	0//1/1/1/1							78	SPT						
	Fine sandy SILT; grey, stiff, brittle.		5										100	HQ	HQTT					
			6										100	PT						
	Silty fine SAND; grey, loose, brittle.				10	2//2/2/3/3							100	SPT						
	Fine SAND; with some silt, grey, loose, brittle.	-2	7		9	2//2/2/3/2							100	HQ						
	SILT; with some clay and trace fine sand, grey, stiff, slightly plastic. Gently inclined bedding plane at 7.9m.		8					CW					100	SPT						
	SILT; with some fine sand and trace clay, grey, very stiff, brittle but slightly plastic once reworked.	-4	9		16	4//3/4/3/6		HW			Moderately inclined, laminae, carbonaceous organic streaks at 9.2m.		68	HQ						
													67	SPT						
								EW	HW			4	57	HQ						

NOTES

SWL 28-5-2014 = 3.5m (5pm)
SWL 29-5-2014 = 3.5m (8.30am)
Single piezometer installed upon completion.
Contamination samples taken at 0.1m, 1.0m and 2.1m.

STARTED: 27-05-2014		FINISHED: 29-05-2014	
DRILLER: Billy		DRILLING CO.: DF	
INCLINATION/ AZIMUTH: -90°		DRILLING RIG: CAT	
LOGGED: T Van Deelen		CHECKED: G Knocker	**BH202**
CLIENT: Watercare Services Limited		JOB NO.: 1-C0935.46	

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

BOREHOLE_LOG_A3 (&PHOTO PAGE) 1-C0935.46 NH2.GPJ OPUS CHCH DEC12.GDT 1-8-14

Scale 1:33.33

BOREHOLE LOG

OPUS GEOTECHNICAL

HOLE NO. **BH202**			
PROJECT: **NH2**	CO-ORD.: **1747902 E 5927258 N**	R.L.: **5.25 m**	SHEET: **2 of 2**
LOCATION: **See site plan, SH16, Hobsonville**	REF. GRID:	DATUM: **MSL**	HOLE LENGTH: **18.1 m**

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m) / DEPTH (m)	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK STRENGTH	ROCK WEATHERING	DEFECT SPACING	DIP (degrees 0–90)	DETAILED DESCRIPTION	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
Waitemata Gorup	MUDSTONE; grey, extremely weak, highly weathered.				EW	HW			Two fractures, 12° and 14° dips; undulating, smooth, trace sand coating at 10.05m and 10.10m.	4	57	HQ					P1	
	CLAY; with some silt, grey, 'very soft', plastic.					CW												
	MUDSTONE; grey, extremely weak, highly weathered.		27	5//6/8/8/5							100	SPT						
		11 / -6		UCS: 810 kPa	EW	HW			Two fractures, 57° and 21° dips; planar, smooth, trace clay coating at 11.10m and 11.15m.	90	100	HQ						
									Two fractures, 31° and 24° dips; planar, smooth, trace clay coating at 11.50m and 11.55m.									
	Alternating sequence of moderately thick bedded MUDSTONE (65%); grey, extremely weak, moderately weathered with fine to medium SAND (35%); with some silt, dense, brittle, weakly cemented. Moderately inclined bedding planes, planar to undulating.	12	60+	38//31/29 for 75mm					Shattered segment of core from 11.8m to 11.9m. Moderately inclined, very thin, carbonaceous organic streak at 11.95m.		SC	SPT						
					EW	HW												
		13							Shattered segment of core from 12.8m to 12.95m.	71	100	HQ						
	MUDSTONE; grey, extremely weak to very weak, slightly weathered.	-8	60+	60 for 120mm UCS: 1500 kPa	VW	SW			Shattered segment of core from 13.3m to 13.4m. Fracture, 35° dip; planar, smooth, no coating at 13.4m.		SC	SPT						
		14								71	100	HQ						
	Fine grained SANDSTONE; very weak, moderately weathered.				VW	MW												
	MUDSTONE; grey, extremely weak to very weak, highly weathered.								Shattered core from 14.4 to 15.0m.									
		15 / -10	60+	35//41/19 for 25mm	EW	HW					SC	SPT						
	MUDSTONE; grey, extremely weak, highly weathered.								Shattered core from 15.3 to 15.6m.	68	100	HQ						
	Fine sandy MUDSTONE; grey, weak concretion, slightly weathered.				W	SW												
	Muddy fine grained SANDSTONE; very weak, slightly weathered. Becomes very weak from 16.2m.	16							Shattered segment of core from 16.05m to 16.15m. Fracture, 42° dip; planar, smooth, trace clay coating at 16.15m.									
	MUDSTONE; grey, very weak, slightly weathered.		60+	60 for 140mm					Shattered core from 16.45m to 17.0m.		SC	SPT						
		17 / -12			VW	SW												
	Muddy fine grained SANDSTONE; very weak, slightly weathered.								Shattered segment of core from 17.3m to 17.4m.	30	100	HQ						
		18	60+	60 for 100mm					Shattered segment of core from 17.9m to 17.95m.		SC	SPT						
	End of Borehole at 18.1m.	19 / -14																

HQTT

NOTES

SWL 28-5-2014 = 3.5m (5pm)
SWL 29-5-2014 = 3.5m (8.30am)
Single piezometer installed upon completion.
Contamination samples taken at 0.1m, 1.0m and 2.1m.

STARTED: 27-05-2014	FINISHED: 29-05-2014		
DRILLER: Billy	DRILLING CO.: DF		
INCLINATION/ AZIMUTH: -90°	DRILLING RIG: CAT		
LOGGED: T Van Deelen	CHECKED: G Knocker	**BH202**	
CLIENT: Watercare Services Limited	JOB NO.: 1-C0935.46		

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

BOREHOLE_LOG_A3 (&PHOTO PAGE) 1-C0935.46 NH2.GPJ OPUS CHCH DEC12.GDT 1-8-14

Scale 1:33.33

BOREHOLE LOG

OPUS GEOTECHNICAL

HOLE NO. **BH203**			
PROJECT: **NH2**	CO-ORD.: **1748181 E 5927462 N**	R.L.: **4.90 m**	SHEET: **1 of 2**
LOCATION: **See site plan, SH16, Hobsonville**	REF. GRID:	DATUM: **MSL**	HOLE LENGTH: **15.12 m**

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m)	DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK STRENGTH	ROCK WEATHERING	DEFECT SPACING	DIP (degrees 0–90)	DETAILED DESCRIPTION	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
Fill	Fine to 10cmØ angular GRAVELS in a SILT matrix; brown, dense, brittle, moist, trace rootlets.	4	1										100	HA	HA					
	CLAY; with trace silt and trace 1cmØ to 3cmØ angular gravels, orangish brown, stiff, plastic, moist. No more gravel from 0.6m.																			
	Becomes brownish grey streaked orange from 1.0m.												100	SPT						
	CLAY; with some silt and trace fine sand, light grey mottled orangish brown, very stiff, plastic.		2		9	2//1/2/3/3							100	HQ						
	Silty fine SAND; dark brownish grey, medium dense, brittle.	2	3		34	11//10/6/9/9							60	SPT						
	Poor recovery from 3.45m to 4.0m due to gravel interference with the core barrel. Inferred 'large gravels in a sand matrix'.												5	HQ						
	No recovery from 4.0m to 4.5m. Inferred 'fine sand', very loose.		4													100%				
	1cm to 3cmØ angular GRAVELS in a SILT matrix; brown, dense, brittle, moist, trace rootlets.	0			14	9//4/3/3/4							53	SPT						
	Poor recovery from 4.95m to 6.4m due to gravel interference with the core barrel. Large angular gravels in an inferred 'sand matrix'.		5										22	HQ	HQTT					
			6										100	Push Tube						
	Silty fine SAND; with trace clay, light grey, loose, brittle but slightly plastic once reworked.	-2											100	HQ						
Waitemata Group	Silty CLAY; grey mottled orange, very stiff, plastic.		7		14	3//2/3/4/5		RS					100	Push Tube						
	Silty fine SAND; grey mottled orange, medium dense, brittle.												100	SPT						
	Silty fine SAND; grey, dense, brittle, weakly cemented.							CW												
	Alternating sequence of moderately thin to moderately thick bedded fine to medium grained SANDSTONE (80%); grey, very weak, slightly weathered with MUDSTONE (20%); grey, very weak, slightly weathered. Gently inclined bedding planes, planar.	-4	8								Relict fracture, 24° dip; planar, rough, no coating at 7.8m.	90	100	HQ						
			9		60+	60 for 130mm		VW			Shattered core from 8.7m to 8.8m.		100	SPT						
								SW			Fracture, 29° dip; stepped, smooth, no coating at 9.2m.	100	100	HQ						

NOTES

SWL 30-5-2014 = 6.8m (3.30pm)
SWL 3-6-2014 = 5.3m (8am)
Borehole backfilled.

STARTED: 29-05-2014	FINISHED: 3-06-2014
DRILLER: Billy	DRILLING CO.: DF
INCLINATION/AZIMUTH: -90°	DRILLING RIG: CAT
LOGGED: T Van Deelen	CHECKED: G Knocker
CLIENT: Watercare Services Limited	JOB NO.: 1-C0935.46

BH203

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

BOREHOLE_LOG_A3 (&PHOTO PAGE) 1-C0935.46 NH2.GPJ OPUS CHCH DEC12.GDT 1-8-14

Scale 1:33.33

BOREHOLE LOG

OPUS GEOTECHNICAL

HOLE NO. **BH203**			
PROJECT: **NH2**	CO-ORD.: **1748181 E 5927462 N**	R.L.: **4.90 m**	SHEET: **2 of 2**
LOCATION: **See site plan, SH16, Hobsonville**	REF. GRID:	DATUM: **MSL**	HOLE LENGTH: **15.12 m**

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m) / DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK STRENGTH	ROCK WEATHERING	DEFECT SPACING	DIP (degrees 0–90)	DETAILED DESCRIPTION	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
Waitemata Group	Alternating sequence of moderately thin to moderately thick bedded fine to medium grained SANDSTONE (80%); grey, very weak, slightly weathered with MUDSTONE (20%); grey, very weak, slightly weathered. Gently inclined bedding planes, planar.	11		60+	60 for 120mm	VW	SW			Gently inclined, very thin, carbonaceous organic streaks at 9.9m.	100	100	HQ	HQTT					
												SN	SPT						
		-6			UCS: 3600 kPa					Fracture, 22° dip; stepped, smooth, no coating at 10.8m.									
	Fine to medium grained SANDSTONE; grey, very weak, unweathered.					VW	UW				100	100	HQ						
	MUDSTONE; grey, very weak, slightly weathered.	12				VW	SW			Two fractures, 55° and 61° dips; undulating, rough, no coating at 11.7m and 11.9m.									
	Fine to medium grained SANDSTONE; grey, very weak, unweathered.			60+	60 for 100mm	VW	UW					SN	SPT						
	Alternating sequence of thin to moderately thick bedded fine to medium grained SANDSTONE (75%); grey, very weak, slightly weathered with MUDSTONE (25%); grey, very weak, slightly weathered. Gently inclined bedding planes, planar.									Fracture, 6° dip; planar, smooth, fine sand filling at 12.2m.									
		-8								Fracture, 46° dip; undulating, rough, no coating at 12.7m.	75	100	HQ						
		13		60+	29//27/27/6 for 10mm					Shattered core from 13.25m to 13.5m.									
						VW	SW					SN	SPT						
		14								Fracture, 15° dip; undulating, smooth, no coating at 14.1m.									
										Shattered core from 14.4m to 14.5m.	89	100	HQ						
		-10			UCS: 3600 kPa					Gently inclined, closely spaced, laminae, carbonaceous organic streaks from 14.65m to 15.0m.									
		15		60+	60 for 120mm							SN	SPT						
	End of Borehole at 15.12m.	16																	
		-12																	
		17																	
		18																	
		-14																	
		19																	

NOTES

SWL 30-5-2014 = 6.8m (3.30pm)
SWL 3-6-2014 = 5.3m (8am)
Borehole backfilled.

STARTED: 29-05-2014	FINISHED: 3-06-2014
DRILLER: Billy	DRILLING CO.: DF
INCLINATION/ AZIMUTH: -90°	DRILLING RIG: CAT
LOGGED: T Van Deelen	CHECKED: G Knocker
CLIENT: Watercare Services Limited	JOB NO.: 1-C0935.46

BH203

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

BOREHOLE_LOG_A3 (&PHOTO PAGE) 1-C0935.46 NH2.GPJ OPUS CHCH DEC12.GDT 1-8-14

Scale 1:33.33

BOREHOLE LOG

OPUS GEOTECHNICAL

HOLE NO. **BH204**			
PROJECT **NH2**	CO-ORD. **1749087 E 5927788 N**	R.L. **26.58 m**	SHEET **1 of 3**
LOCATION **See site plan, SH16, Greenhithe**	REF. GRID	DATUM **MSL**	HOLE LENGTH **22.57 m**

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m) / DEPTH (m)	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK WEATHERING	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
Fill	Clayey SILT; brown, stiff, plastic, dry, trace rootlets.						100	HA	HA				P1	
	Silty CLAY; with trace fine to 4cmØ angular gravels and trace fine pockets of fine sandy silt, greyish brown, stiff, plastic, moist.	26												
	SILT; with some clay and trace fine to 2cmØ angular gravels, dark greyish brown, stiff, plastic, trace fibrous wood.	1	6	1//2/1/1/2			47	SPT						
Waitemata Group	Silty fine SAND; light grey mottled orange, loose, brittle.	2			RS		100	HQ						
	SILT; with some clay, grey mottled orange, hard, plastic.	24												
	Silty fine SAND; grey streaked orange, medium dense, brittle.	3	20	4//4/5/5/6			100	SPT						
	Silty fine SAND; light greyish brown mottled orange, medium dense, brittle.	4					49	HQ					15-7-2014	
		22	21	5//3/5/6/7			100	SPT						
		5					59	HQ	HQTT					
	Trace clay and slightly plastic once reworked from 5.8m.													
	Silty fine SAND; orange brown mottled light greyish brown, medium dense, brittle.	6	24	6//4/6/6/8	CW		100	SPT						
		20												
	Trace carbonaceous organics from 7.0m.	7					100	HQ						
	Fine sandy SILT; grey, hard, slightly plastic.		31	6//6/6/9/10			100	SPT						
	Silty fine SAND; grey, medium dense, brittle.	8												
	Fine sandy SILT; grey, very stiff, brittle. Gently inclined bedding plane, planar.	18					23	HQ						
		9	27	6//5/6/7/9			100	SPT						
	Silty fine SAND; medium dense, brittle.													
	Becomes weakly cemented from 9.8m.						48	HQ						

NOTES

SWL 4-6-2014 = 3.9m (4.30pm)
SWL 5-6-2014 = 5.75m (7.30am), 3.5m (4.30pm)
SWL 6-6-2014 = 4.9m (8am)
Single piezometer installed upon completion.
Contamination samples taken at 0.1m, 1.0m and 2.0m.

STARTED 3-06-2014	FINISHED 5-06-2014
DRILLER Billy	DRILLING CO. DF
INCLINATION/ AZIMUTH -90°	DRILLING RIG CAT
LOGGED T Van Deelen	CHECKED G Knocker
CLIENT Watercare Services Limited	JOB NO. 1-C0935.46

BH204

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

Scale 1:33.33

BOREHOLE LOG

OPUS GEOTECHNICAL

PROJECT: NH2	CO-ORD.: 1749087 E 5927788 N	R.L.: 26.58 m	HOLE NO.: BH204
LOCATION: See site plan, SH16, Greenhithe	REF. GRID:	DATUM: MSL	SHEET: 2 of 3
			HOLE LENGTH: 22.57 m

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m) / DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK STRENGTH	ROCK WEATHERING	DEFECT SPACING	DIP (degrees 0–90)	DETAILED DESCRIPTION	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
Waitemata Group	Silty fine SAND; medium dense, brittle.	16		27	5//4/7/7/9		CW			Relict fracture, 61° dip; planar, rough, no coating at 9.9m.		48	HQ					P1	
	Occasional very thin layers of SILT; with some clay, hard, slightly plastic from 10.5m.											SC	SPT						
	Becomes dense from 11.5m.	11										100	HQ						
		12		60+	33//60 for 70mm							SC	SPT						
	Fine grained SANDSTONE; grey, very weak, slightly weathered.					VW	SW												
	MUDSTONE; grey, very weak, unweathered.	14								Gently inclined, lamanae, carbonaceous organic streaks at 12.4m.									
	Muddy fine grained SANDSTONE; grey, very weak, unweathered.	13								Fracture, 19° dip; planar, smooth, no coating at 12.75m.	100	100	HQ						
				60+	60 for 90mm UCS: 3900 kPa	VW	UW			Fracture, 8° dip; undulating, rough, no coating at 13.2m. Gently inclined, lamanae, carbonaceous organic streaks at 13.3m.		SC	SPT						
		14									100	100	HQ						
	Fine grained SANDSTONE; grey, very weak, unweathered.	12								Gently inclined, lamanae, carbonaceous organic streaks from 14.5m to 14.6m.									
		15		60+	60 for 80mm UCS: 490 kPa							SC	SPT						
	Silty fine SAND; very dense, brittle, weakly cemented.						HW				8	100	HQ						
		16										SC	SPT						
	Alternating sequence of moderately thick bedded fine grained SANDSTONE (80%); grey, very weak, unweathered with thin bedded MUDSTONE (20%); grey, very weak, unweathered. Gently inclined bedding planes, planar to undulating.	10		60+	49//60 for 30mm					Gently inclined, lamanae, carbonaceous organic streaks from 16.8m to 16.85m. Fracture, 9° dip; undulating, rough, 1cm thick clay gouge at 16.95m. Gently inclined, closely spaced, very thin, carbonaceous organic streaks from 17.2m to 17.5m. Moderately inclined, closely spaced, very thin, carbonaceous organic streaks from 17.6m to 17.7m.	100	100	HQ						
		17										SC	SPT						
				60+	60 for 110mm	VW	UW				100	100	HQ						
	MUDSTONE; grey, very weak, unweathered.	18										SC	SPT						
	Fine grained SANDSTONE; very weak, unweathered, massive.	8									100	100	HQ						
		19		60+	60 for 70mm							SC	SPT						
											100	100	HQ						

HQTT

NOTES

SWL 4-6-2014 = 3.9m (4.30pm)
SWL 5-6-2014 = 5.75m (7.30am), 3.5m (4.30pm)
SWL 6-6-2014 = 4.9m (8am)
Single piezometer installed upon completion.
Contamination samples taken at 0.1m, 1.0m and 2.0m.

STARTED: 3-06-2014		FINISHED: 5-06-2014	
DRILLER: Billy		DRILLING CO.: DF	
INCLINATION/ AZIMUTH: -90°		DRILLING RIG: CAT	
LOGGED: T Van Deelen		CHECKED: G Knocker	BH204
CLIENT: Watercare Services Limited		JOB NO.: 1-C0935.46	

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

BOREHOLE_LOG_A3 (&PHOTO PAGE) 1-C0935.46 NH2.GPJ OPUS CHCH DEC12.GDT 1-8-14

Scale 1:33.33

BOREHOLE LOG

OPUS GEOTECHNICAL

HOLE NO. **BH204**			
PROJECT: **NH2**	CO-ORD.: **1749087 E 5927788 N**	R.L.: **26.58 m**	SHEET: **3 of 3**
LOCATION: **See site plan, SH16, Greenhithe**	REF. GRID:	DATUM: **MSL**	HOLE LENGTH: **22.57 m**

GEOLOGY/UNIT	MAIN DESCRIPTION	R.L. (m) / DEPTH (m)	GRAPHIC LOG	TESTS: SPT 'N' VALUE	TESTS: SPT BLOW COUNTS OR SHEAR VALUE	ROCK STRENGTH	ROCK WEATHERING	DEFECT SPACING	DIP (degrees 0–90)	DETAILED DESCRIPTION	CORE: RQD (%)	CORE: TOTAL CORE RECOVERY (%)	CORE: SAMPLE TYPE	DRILLING: METHOD	DRILLING: FLUID LOSS	DRILLING: CASING	BASE OF HOLE & WATER LEVEL	PIEZOMETER DETAILS	OTHER INSTRUMENTATION
Waitemata Group	Fine grained SANDSTONE; very weak, unweathered, massive.	6 / 21		60+	60 for 90mm	VW	UW			Gently inclined, moderately thick, carbonaceous organic streaks at 20.7m.	100	100	HQ	HQTT				P1	
												SC	SPT						
	Fine to coarse grained SANDSTONE; very weak, unweathered, massive.	22									100	100	HQ						
		4		60+	60 for 70mm							SC	SPT						
	End of Borehole at 22.57m.	23 / 24 / 2 / 25 / 26 / 0 / 27 / 28 / -2 / 29																	

NOTES

SWL 4-6-2014 = 3.9m (4.30pm)
SWL 5-6-2014 = 5.75m (7.30am), 3.5m (4.30pm)
SWL 6-6-2014 = 4.9m (8am)
Single piezometer installed upon completion.
Contamination samples taken at 0.1m, 1.0m and 2.0m.

STARTED: 3-06-2014	FINISHED: 5-06-2014
DRILLER: Billy	DRILLING CO.: DF
INCLINATION/ AZIMUTH: -90°	DRILLING RIG: CAT
LOGGED: T Van Deelen	CHECKED: G Knocker
CLIENT: Watercare Services Limited	JOB NO.: 1-C0935.46

BH204

LOGGED IN ACCORDANCE WITH NZ GEOTECHNICAL SOCIETY (2005) GUIDELINES

SEE ATTACHED KEY SHEET FOR EXPLANATION OF SYMBOLS

BOREHOLE_LOG_A3 (&PHOTO PAGE) 1-C0935.46 NH2.GPJ OPUS CHCH DEC12.GDT 1-8-14

Scale 1:33.33

APPENDIX C - RISING HEAD TEST ANALYSIS

Borehole Variable Head Permeability Test

Borehole ID

NHWM BH201

Project Details

Project Name	NHWM
Project Number	AE04521
Test Date	12/11/2014
Tested	JB
Analysed	BS

Test Parameters

Top of screen	1.500 m
Bottom of Screen, *a*	4.600 m
Screen Length, *L*	3.100 m
Static Water Level, *H*	7.160 m
Initial Water Level, H_0	7.110 m
Hole Radius, *R*	0.130 m
Casing Radius, *r*	0.040 m
Well Penetration	Partial
Water Table Height, *D*	20.000 m

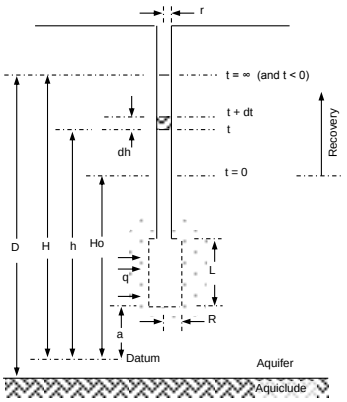
Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all positive, the answer will be correct.

Result

Hydraulic Conductivity

***K* = 3.15E-05 m/s**

Test Schematic



Bouwer-Rice (1976) Method:

$$K = \frac{r^2 \ln(R_e / R)}{2d} \frac{1}{t} \ln\left(\frac{H - H_0}{H - h}\right)$$

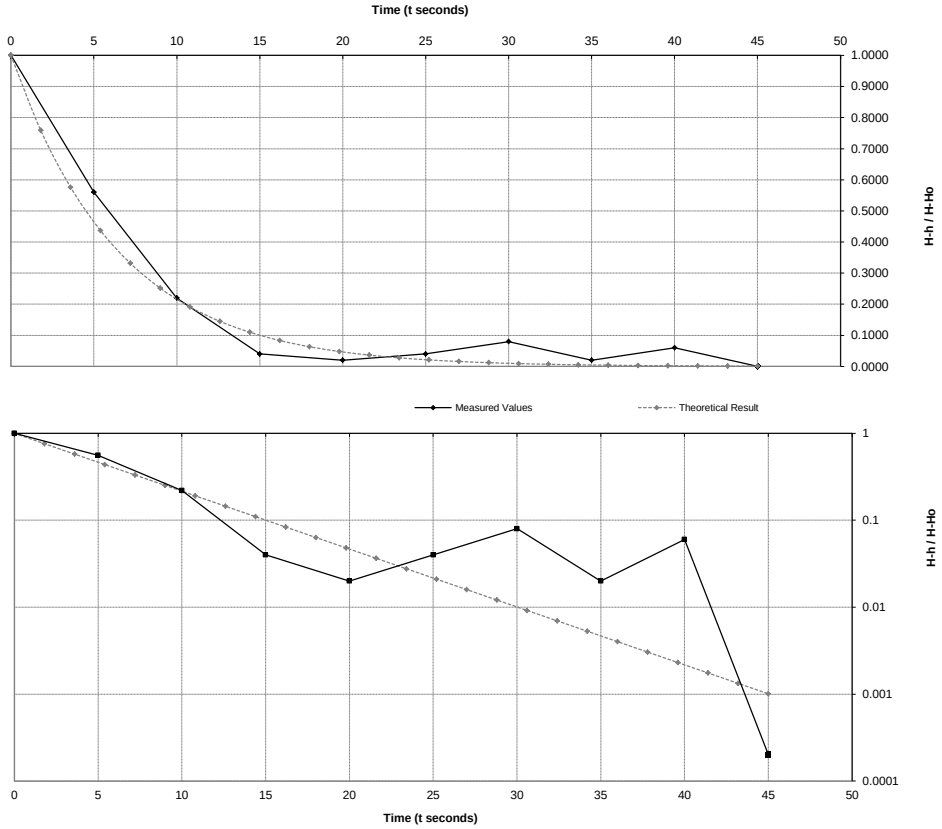
Calibrated Parameters

$\ln(R_e/R)$	2.242
$1/t * \ln(h_y/h_i)$	0.067

Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
0	7.110	0.05	1.00
5	7.132	0.03	0.56
10	7.149	0.01	0.22
15	7.158	0.00	0.04
20	7.159	0.00	0.02
25	7.158	0.00	0.04
30	7.156	0.00	0.08
35	7.159	0.00	0.02
40	7.157	0.00	0.06
45	7.160	0.00	0.00

Graphs of Bouwer-Rice (1976) Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)



Borehole Variable Head Permeability Test

Borehole ID

NHWM BH204

Project Details

Project Name	NHWM
Project Number	AE04521
Test Date	12/11/2014
Tested	JB
Analysed	BS

Test Parameters

Top of screen	2.500 m
Bottom of Screen, *a*	7.500 m
Screen Length, *L*	5.000 m
Static Water Level, *H*	6.135 m
Initial Water Level, H_0	6.080 m
Hole Radius, *R*	0.130 m
Casing Radius, *r*	0.040 m
Well Penetration	Partial
Water Table Height, *D*	20.000 m

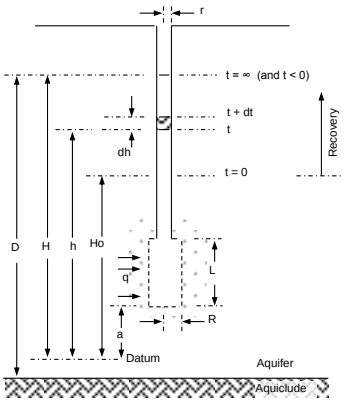
Note: If the datum is above the hole, the height/depth readings do not have to be negative numbers - as long as they are either all negative or all positive, the answer will be correct.

Result

Hydraulic Conductivity

***K* = 8.41E-06 m/s**

Test Schematic



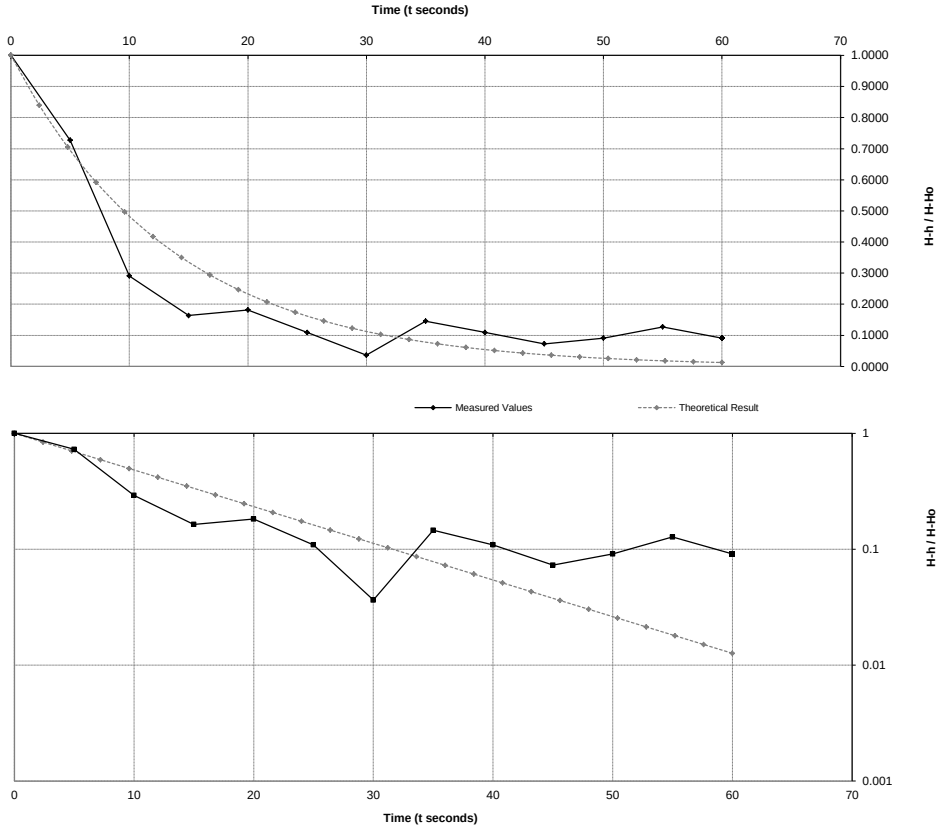
Bouwer-Rice (1976) Method:

$$K = \frac{r^2 \ln(R_e / R)}{2d} \frac{1}{t} \ln\left(\frac{H - H_0}{H - h}\right)$$

Calibrated Parameters

$\ln(R_e/R)$	1.892
$1/t * \ln(h_y/h_i)$	0.032

Graphs of Bouwer-Rice (1976) Piezometer Test (top graph has normal axes and bottom graph has a log H-h/H-Ho axis)



Measured Data

Time (Secs)	Depth (h) (m)	H - h (m)	H-h / H-H0
0	6.080	0.05	1.00
5	6.095	0.04	0.73
10	6.119	0.02	0.29
15	6.126	0.01	0.16
20	6.125	0.01	0.18
25	6.129	0.01	0.11
30	6.133	0.00	0.04
35	6.127	0.01	0.15
40	6.129	0.01	0.11
45	6.131	0.00	0.07
50	6.130	0.00	0.09
55	6.128	0.01	0.13
60	6.130	0.00	0.09