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Stevenson Aggregates Ltd

Clevedon Quarry Proposed Expansion

GROUNDWATER ASSESSMENT

WGA251647

WGA251647-RP-HG-0005_C

23 October 2026



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Revision History

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Executive Summary

Stevenson Aggregates Ltd (SAL) engaged Wallbridge Gilbert Aztec (WGA) to undertake a hydrogeological assessment to support the substantive resource consent application for the proposed expansion of the Clevedon Quarry. The proposed design extends the Quarry footprint eastwards and southwards beyond the currently consented 2018 pit design, across a staged extraction sequence. This report documents the development, calibration, and application of a numerical groundwater model to assess the potential groundwater and surface water effects of the expanded Quarry, assessed at the Stage 1 and Stage 5 pit designs.

Modelling indicates that the proposed pit designs would alter groundwater flow patterns and reduce baseflow contributions to nearby streams, with effects increasing as extraction progresses from Stage 1 to Stage 5. The predicted stream effects presented in this assessment relate to changes in the groundwater contribution to streamflow/baseflow only from the greywacke groundwater system and do not include direct rainfall runoff, stormflow, or other surface-water runoff components. Predicted effects include:

- **Stream 1:** Baseflow reduction of approximately 1.23 L/s (19%) under the Stage 1 design, increasing to approximately 3.10 L/s (48%) under the Stage 5 design.
- **Stream 2:** Baseflow reduction of approximately 0.37 L/s (25%) under Stage 1. From Stage 2 onwards, Stream 2 will be progressively reclaimed with surface water and groundwater being redirected into the pit.
- **Stream 2A**: Effects are negligible under Stage 1 (less than 0.0001 L/s) and remain minor under Stage 5 (approximately 0.04 L/s, or 18%).
- **Stream 3:** Effects are negligible under the Stage 1 design (approximately 0.01 L/s, or 0.1%), but the Stage 5 expansion increases depletion to approximately 1.50 L/s (20%) due to the expanded drawdown influence and reduced groundwater contribution.
- **Pit Dewatering Requirements:** Groundwater inflow to the pit is predicted to be approximately 162 m^3/day (1.88 L/s) at Stage 1 and 544 m^3/day (6.30 L/s) at Stage 5, reflecting the larger excavation footprint and increased interception of groundwater flow. The Stage 5 groundwater inflow equates to approximately 199,000 m^3/year.

No material drawdown interference effects were predicted at the identified off-site bore locations for the proposed pit designs. The modelled steady-state 0.25 m drawdown contour does not extend beyond the Wairoa River, and the nearest production bore (approximately 1.4 km north-west and separated by the river) and Cosseys Reservoir (approximately 2 km south-east) are both outside the zone of influence.

Groundwater inflow to the proposed pit at Stage 5 (approximately 6.3 L/s) exceeds the combined predicted baseflow reductions in Streams 1 and 3 (approximately 4.6 L/s) and provides a potential reliable source for streamflow mitigation. As such, there is potential for stream augmentation with suitable water pre-treatment, as a practical mitigation measure for offsetting predicted baseflow reductions in Streams 1 and 3 and maintaining environmental flow conditions downstream.

The proposed quarry expansion will intercept groundwater from the Hunua Wairoa Greywacke aquifer. The site is not located within a High Use Aquifer Management Area or a Water Supply Management Area, and the intercepted groundwater does not represent an abstraction from a highly allocated groundwater resource. Accordingly, the predicted groundwater inflows are not expected to materially affect groundwater availability for other users.

CONTENTS

1 INTRODUCTION 1
1.1 Background 1
1.2 Project Description 1
1.3 Purpose of this Document 1
1.4 Objectives 1
2 EXISTING ENVIRONMENT 3
2.1 Topographic Setting 3
2.2 Geological Setting 3
2.2.1 Tauranga Group 3
2.2.2 Weathered Greywacke 3
2.2.3 Basement 3
2.2.4 Local Faulting 5
2.3 Hydrogeological Setting 5
2.3.1 Groundwater Conceptual Model 5
2.3.2 Groundwater Levels 6
2.3.3 Hydraulic Characteristics of Greywacke 9
2.3.4 Local Hydraulic Testing 9
2.3.5 Quarry Production Bore 31427 10
2.4 Surface Water Flow 11
2.4.1 Site Setting 11
2.4.2 Rainfall 11
2.4.3 Prior Surface Water Flow Gauging Assessments 11
2.4.4 Current Stream Gauging and Characterisation 13
2.4.5 Streamflow Synthesis and Baseflow Analysis 15
2.4.6 Groundwater Recharge 16
2.5 Water Quality 16
2.5.1 Production Bore Water Quality 17
2.5.2 Surface Water 17
2.5.3 Summary 17
2.6 Groundwater Allocation Zone 17
2.7 Water Supply Management Areas 17
2.8 Water Supply Bores 18
3 MODELLING METHODOLOGY 19
3.1 Modelling Overview 19
3.2 Pit Designs 19
4 GROUNDWATER EFFECTS ASSESSMENT 22
4.1 Introduction 22
4.2 Projected Drawdown Effects 22
4.2.1 Drawdown on Nearby Bores 22
4.2.2 Other Drawdown Effects 25

4.3 Effects on Surface Water Bodies 25
4.3.1 Stream 1 25
4.3.2 Stream 2 25
4.3.3 Stream 2A 25
4.3.4 Stream 3 25
4.3.5 Stream Segmentation 25
4.3.6 Wairoa River 26
4.3.7 Other Western Streams 26
4.3.8 Eastern Streams 26
4.3.9 Pit Inflow 26
4.4 Stream Augmentation Potential 28
4.5 Sensitivity and Uncertainty Analysis 29
5 GROUNDWATER AND SURFACE WATER MONITORING 30
5.1 Groundwater Level Trigger Framework 32
6 SUMMARY 33
7 REFERENCES 34
8 LIMITATIONS 36

Figures

Figure 1: Site Map and Watercourses 2
Figure 2: Geological Map and Water Bores 4
Figure 3: Site Monitoring and Production Bore Locations 8
Figure 4: Watercourse Gauging Locations 12
Figure 5: Stage 1 Proposed Pit Design 20
Figure 6: Stage 5 Proposed Pit Design 21
Figure 7: Proposed Stage 1 Drawdown 23
Figure 8: Proposed Stage 5 Drawdown 24
Figure 9: Stream Segments 27

Tables

Table 1: Site Bore Water Levels 7
Table 2: Hydraulic Conductivity of Greywacke Material from Nearby Sites 9
Table 3: Hydraulic Testing at Clevedon Quarry 9
Table 4: Quarry Production Bore Details 10
Table 5: Monthly Abstraction of Production Bore 31427 10
Table 6: Recorded Streamflow during January and February 2017 (PDP 2017) 13
Table 7: MALF Results in Stream 1 and Index Site 13
Table 8: Clevedon Quarry Stream Gauging Locations 14
Table 9: Gauge Discharge Summary 14
Table 10: Estimated Baseflow (MALF-equivalent) at Each Stream Site 16

Table 11: Water Bores within a 3 km Radius of the Clevedon Quarry 18
Table 12: Segment Stage 5 Depletion Rates 26
Table 13: Modelled Groundwater Inflow to the Pit 28
Table 14: Proposed Monitoring Plan 31
Table 15: Simulated Drawdown at Monitoring Wells 32

Appendices

APPENDIX A GROUNDWATER MODEL SETUP AND CALIBRATION
APPENDIX B PREDICTIVE MODEL RESULTS
APPENDIX C STREAMFLOW ANALYSIS
APPENDIX D WATER QUALITY
APPENDIX E STREAM GAUGING REPORT
APPENDIX F HYDRAULIC TESTING ANALYSIS SHEETS
APPENDIX G BORE LOGS
APPENDIX H COMPLIANCE GROUNDWATER LEVEL RECORD
APPENDIX I ANALYTICAL PIT MODEL

1 INTRODUCTION

1.1 Background

Stevenson Aggregates Limited (SAL) is seeking resource consents authorising the expansion of the existing Clevedon Quarry (the Quarry). The draft pit expansion plan indicates an expansion eastwards and southwards of the existing quarry area is sought, together with a change in the quarry geometry and floor elevation.

SAL has an existing resource consent to expand quarrying operations across six discrete stages of rock extraction and overburden disposal. SAL is seeking to expand the existing quarry over a greater footprint relative to the consented design. SAL has retained Wallbridge Gilbert Aztec (WGA NZ Pty Ltd; WGA) to undertake an assessment of the effects this planned expansion may have on the groundwater system and nearby surface water features. This report documents WGA's assessment of the potential hydrogeological effects of the expansion.

1.2 Project Description

Currently, SAL extracts approximately 200,000 to 300,000 tonnes of aggregate annually from Clevedon Quarry. SAL holds an existing consent (granted in 2018) allowing expansion of the current pit to enable the extraction of approximately 60 million tonnes (MT) of aggregate and overburden over 35 years, across six stages, at an annual extraction rate of approximately 3 MT per year.

To continue to provide a reliable local supply of aggregate, SAL proposes to progressively expand the existing Quarry, located at 546 McNicol Road, south-eastward within the SAL landholdings.

1.3 Purpose of this Document

This groundwater assessment has been prepared to support the substantive application for the proposed quarry expansion under a fast-track consenting process. It provides an evaluation of potential groundwater and surface water effects associated with the proposed development, based on currently available information and a calibrated numerical groundwater model.

This assessment quantifies the modelled long-term magnitude and extent of groundwater drawdown, potential changes to stream baseflow, and anticipated dewatering requirements arising from the proposed expansion. To address uncertainty in key hydrogeological parameters, sensitivity and uncertainty analyses have been undertaken using alternative recharge and hydraulic conductivity scenarios, providing a bounded assessment of potential effects. Predicted dewatering inflows have been independently checked using an analytical pit inflow method.

This document presents an assessment of groundwater effects suitable to support the fast-track substantive application.

1.4 Objectives

The primary objective of this assessment is to simulate the groundwater system surrounding Clevedon Quarry under baseline conditions and to model the potential environmental effects arising from groundwater drawdown related to the proposed quarry expansion. Specifically, the model has been developed to help quantify the following potential effects from the quarry expansion:

- The potential magnitude and extent of groundwater drawdown
- Reductions in surface water baseflows
- Groundwater flows to the quarry pit





LEGEND

- Watercourses
- Proposed Stage 5 Extent
- Proposed Stage 1 Extent

N

0 50 100 150 200 m

Scale 1:10,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **1**
Site Map and Watercourses

Clevedon Quarry

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Any relevance placed on such information shall be at the risk of the user.

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2 EXISTING ENVIRONMENT

2.1 Topographic Setting

The site is situated within the Clevedon Valley, approximately 5.45 km south-east of the Clevedon township, occupying land between Orum Road and the Wairoa River. It lies within the sub-catchments of two east-west trending streams, which drain the surrounding hill country before discharging into the Wairoa River.

The Quarry catchment is characterised by steep hills and valleys, incised by small streams. On the western margin of the quarried area, the Wairoa River meanders northward, at an elevation of approximately 13 mRL (metres relative level, or metres above mean sea level) adjacent to the quarry entrance on McNicol Road. The topographic elevation rises toward the east, reaching a crest of approximately 335 mRL along the ridges to the east of the Quarry.

2.2 Geological Setting

2.2.1 Tauranga Group

At the lower end of the Quarry access road, surficial deposits of the Tauranga Group (Middle to Late Pleistocene age) are present. These sediments represent river and hillslope deposits that have accumulated within low-lying areas of the landscape.

The deposits are composed of unconsolidated sand, silt, clay, and localised peat layers, reflecting a variable depositional environment influenced by fluvial, colluvial, and swamp environments. The Tauranga Group materials typically display high heterogeneity, with interbedded fine to coarse grained horizons, and may contain organic-rich horizons associated with former wetland conditions.

2.2.2 Weathered Greywacke

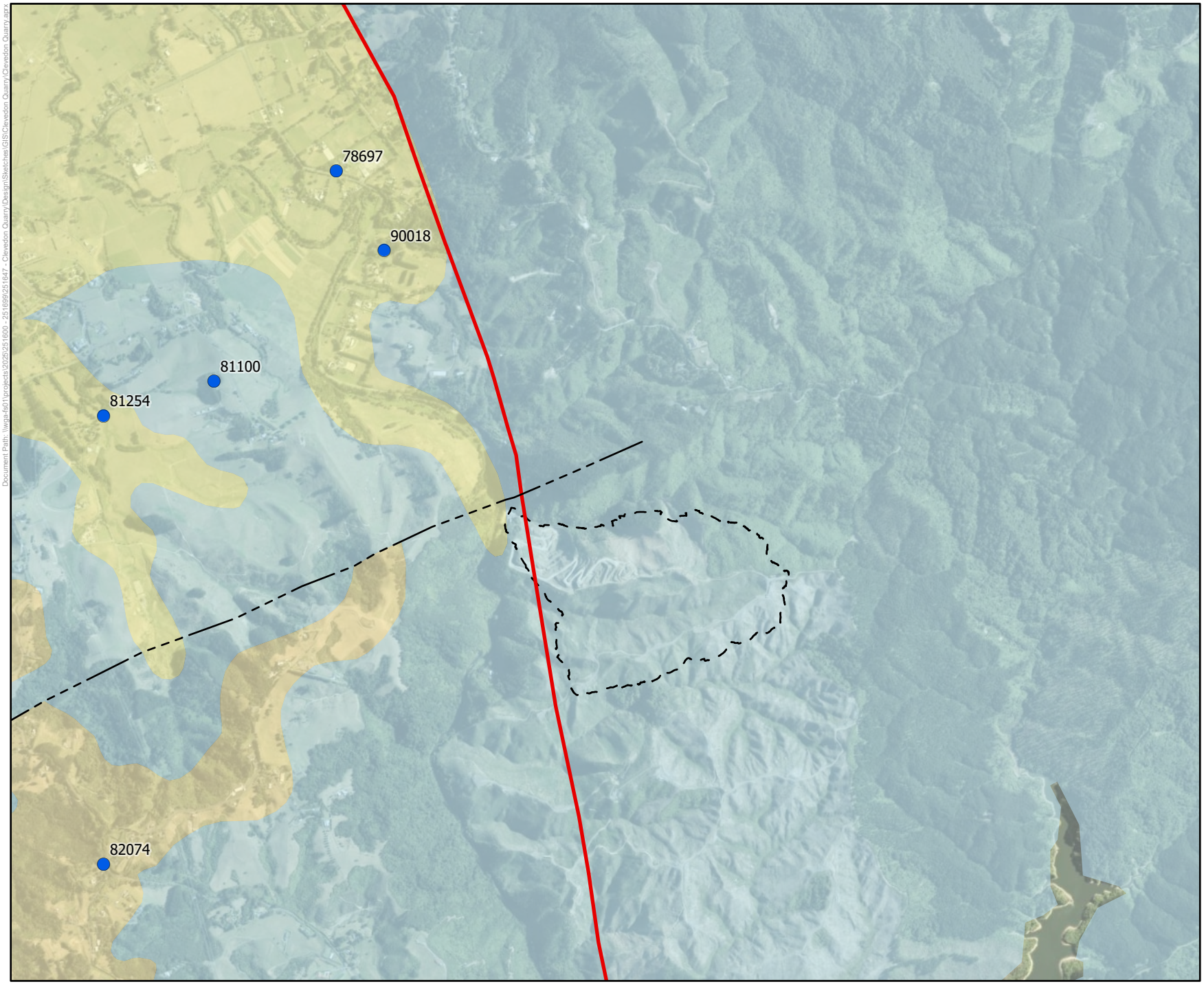
A residual weathered greywacke zone, typically 5 to 30 m thick, underlies the topsoil across the proposed extraction area. This layer predominantly comprises clays and is described as highly to completely weathered and weak to very weak. It is variably sandy and includes fine gravels of extremely weak siltstone. This weathered profile forms the upper, more permeable part of the greywacke groundwater system (PDP, 2017).

2.2.3 Basement

The Quarry is underlain by greywacke of the Waipapa Group, which represents the basement rock within the Clevedon Valley and is widely exposed in the surrounding hill country. The Waipapa Group consists primarily of indurated and fractured sandstones, argillite, and chert, deposited as part of a Mesozoic accretionary complex (Adams et al., 2009; Edbrooke, 2005).

Regional tectonic processes have subjected these rocks to significant deformation, resulting in strongly faulted and fractured strata. These structural features are commonly infilled by mineralised veins containing quartz, calcite, prehnite, chlorite, and zeolites. The combination of lithological variability and structural complexity gives the Waipapa Group rocks a heterogeneous character, with localised zones of enhanced permeability along fractures contrasting with generally low matrix porosity.

The basement rocks are considered to have low matrix porosity and permeability, such that intergranular fluid storage is generally very limited. Locally increased secondary permeability may result from tectonic jointing and shearing (Marshall and Petch, 1985).





LEGEND

- Water Supply Bores
- Proposed Stage 5 Extent

NZL GNS 250K Faults

- Wairoa North Fault
- Inactive Fault

NZL GNS 250K Geological Units

- OIS1 River Deposits
- Waipapa Greywacke
- Waitemata Group

N

0 100 200 300 400 m

Scale 1:24,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **2**
Geological Map
and Water Bores

Clevedon Quarry

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2.2.4 Local Faulting

The regional geological setting for the Quarry is influenced by the presence of the Wairoa North Fault, a northwest-southeast trending fault associated with deformation of the Waipapa Group greywacke bedrock (Figure 2). Published geological mapping indicates that the Wairoa North Fault extends through the wider Clevedon area and is inferred to be downthrown to the southwest. An unnamed subsidiary fault is also mapped to the west of the Wairoa North Fault.

Site-specific geological observations (Baseline Geotechnical, 2026) indicate that the principal geomorphic expression of the Wairoa North Fault is associated with the Wairoa River corridor rather than the quarry footprint itself. Although published geological maps show the fault traversing the Quarry area (Figure 2), no comparable regional-scale structure was identified from existing Quarry exposures. Instead, the available geological evidence indicates that the Wairoa River valley is controlled by the northwest-southeast strike of the major fault zone.

While local faulting and structurally controlled features were observed within the Quarry, these are interpreted to represent subordinate structures rather than the primary Wairoa North Fault itself. The absence of a major fault zone within Quarry exposures supports the interpretation that the main displacement associated with the Wairoa North Fault is concentrated within the Wairoa River corridor, outside the principal area of Quarry excavation.

2.3 Hydrogeological Setting

2.3.1 Groundwater Conceptual Model

The hydrogeological conceptual model of the site under current conditions has been developed from an assessment of piezometric data from the paired piezometer installations at FH1, FH2, FH3 and MW01 and the single-completion bores GW1 and GW2N, the geological logs and falling-head test results from these bores (Appendix F and Appendix G), stream flow gauging, site observations of seepage and fracturing, and a review of relevant local literature.

Groundwater within the greywacke is treated as one continuous flow system that extends from the water table to depth. Hydraulic properties vary with depth. They change from the clay-rich weathered profile, typically 5 to 30 m thick, to fresh fractured greywacke below. No confining layer has been identified between the two. The downward hydraulic gradients recorded between paired installations are consistent with recharge beneath elevated topography within a vertically anisotropic system, rather than with hydraulic separation. Localised perched groundwater may occur within clay-rich horizons of the weathered profile (e.g., MW01-Shallow).

Groundwater generally moves from elevated ridge areas towards the Wairoa River and incised streams. Groundwater flow pathways are considered to be governed predominantly by secondary permeability features, such as fault and fracture zones, rather than by the primary porosity within the rock matrix, with the main groundwater movement occurring in the upper section of the greywacke where fractures are frequent.

The combination of the Wairoa River and the associated Wairoa North Fault corridor is considered to represent a hydrogeological model boundary. This conceptualisation is considered appropriate because the fault zone is interpreted as likely to limit seepage flows across it while the river would act as a groundwater discharge zone. The use of the Wairoa River fault corridor as a model boundary is also consistent with the conceptual geological model, which recognises that major regional faulting has influenced the present-day geology and topography of the area.

Flowing artesian groundwater pressures are present within the deep fractured greywacke at the western end of the Quarry, as demonstrated by data from the Quarry Production Bore (Bore 31427). Drilling records indicate that flowing artesian pressures generated a discharge to surface of approximately 0.1 L/s when the hole had reached a depth around 108 m from a collar elevation of 26 mRL (-82 mRL). Further drilling resulted in a discharge to surface of approximately 0.3 L/s, once the hole had reached a depth of 139.5 m (-113.5 mRL). By extrapolation, we estimate that flowing artesian pressure is unlikely to be represented above an elevation of approximately -65 mRL.

Taking into account that the proposed pit floor only extends down to 22.5 mRL, and the flow rates of the flowing artesian pressures into the Production Bore were very low, the conceptual model does not take into account a need to simulate pressure gradients at depth beneath the quarry floor.

2.3.2 Groundwater Levels

Groundwater level information available for the site comprises data collected during investigations undertaken by Pattle Delamore Partners (PDP, 2017), supplemented by field measurements collected by WGA on 11 May 2026 and ongoing groundwater monitoring undertaken by SAL as part of the site compliance programme. The 2018 Quarry expansion consent included a groundwater and surface water monitoring programme to manage and assess the effects of Quarry dewatering. The consent required monthly groundwater-level monitoring of FH1-Shallow, FH1-Deep, FH2-Shallow, FH2-Deep and GW2N (Figure 3). A record has been provided by SAL that extends from 2017 to 2026 and includes gaps where access was unavailable or equipment issues were noted. The recorded water level from this period is provided in Appendix H.

These datasets provide groundwater level information from a range of hydrogeological settings across the site, including river alluvium, weathered greywacke, and fresh fractured greywacke. Bore construction records and geological logs (Appendix G) were reviewed alongside the groundwater level data to assess the hydrogeological significance and reliability of each monitoring location. The monitoring network includes bores completed within alluvium, weathered greywacke and fresh greywacke. The bores are described in Table 1 and locations provided in Figure 3.

Monitoring bore GW2N is screened between approximately 24 and 30 m bgl within fresh greywacke. The bore partially collapsed and required redrilling. As such, monitoring data is not continuous across this record.

Monitoring bore FH1 comprises a paired piezometer installation located near the McNicol Road entrance to the Quarry. FH1-Shallow is screened within river alluvium, whereas FH1-Deep is screened within fresh greywacke beneath the alluvial deposits. Groundwater levels recorded in both installations during the monitoring period are broadly similar. This correspondence suggests hydraulic connectivity between the alluvial groundwater system and the underlying bedrock aquifer at this location, supporting the assumption that the Wairoa River represents a western hydraulic boundary of the Quarry. The bore logs indicate that the alluvial sediments are relatively thin, allowing close hydraulic interaction with the underlying greywacke. FH1-Shallow and FH1-Deep collapsed and have been relocated to Bore ID FH1-Shallow New and FH1-Deep New. The construction details of FH1-Shallow New are to be confirmed. FH1-Deep New is the monitoring ID name applied to existing Production Bore (31427).

Monitoring site FH2 comprises a paired piezometer installation near the ridge crest. FH2-Shallow is screened between approximately 29 and 35 m bgl within weathered greywacke, while FH2-Deep is screened between approximately 220 and 234 m bgl within fresh greywacke. FH2-Shallow groundwater elevations derived from compliance monitoring indicate levels at around 208 to 211 mRL, with low variability through time.

FH2-Shallow groundwater levels are relatively stable and are consistent with expected higher groundwater levels. In contrast, FH2-Deep records show a much deeper groundwater level, which is consistent with a strongly downward hydraulic gradient and recharge occurring in higher topographic areas.

Monitoring bores FH3-Shallow and FH3-Deep have comparatively narrow historical groundwater-level ranges. There is approximately 10 m difference in the reported head between the two bores, indicating a downward hydraulic gradient at the location. As at FH2, this is consistent with recharge beneath higher topographic areas. It is noted that the FH3-Deep reportedly collapsed and yielded anomalous water level data that was reported by PDP (2017).

Monitoring bore GW1 and the MW01 installations are represented by single measurements and should be treated as point-in-time observations rather than monitored ranges. MW01-Shallow is interpreted as perched groundwater within weathered greywacke due to its screened location within a very thick layer of mottled brown stiff, silty clay of low plasticity. MW01-Deep records groundwater within unweathered greywacke.

Table 1: Site Bore Water Levels

BORE	GEOLOGY	MONITORING TYPE	SCREEN OR OPEN HOLE INTERVAL (m RL) [1]	DEPTH TO GROUNDWATER (m BGL)	GROUNDWATER LEVEL (m RL)
GW2N [1]	Fresh greywacke	Pressure Transducer, Baro and Manual	-3.5 – 2.5	0.6 [2] – 3.8	23.6 – 26.8 [2]
FH1 – Shallow [3]	River alluvium	Manual	9.4	2.1 – 5.6	15.4 – 18.9
FH1 – Deep [3]	Fresh greywacke	Manual	-15 – -9	3.7 – 6.7	14.3 – 17.3
FH2 – Shallow	Weathered greywacke	Manual	198 – 204	17.9 – 38.7	194.3 – 215.1
FH2 – Deep	Fresh greywacke	Manual	-1 – 13	52.0 – 192.5	40.6 – 181.0
FH3 – Shallow	Fresh greywacke	N/A	134.5 – 140.5	27.7 – 28.9	175.6 – 176.8
FH3 – Deep	Fresh greywacke	N/A	>134.5 (collapsed)	29.7 – 41.7	4.9 – 174.8 [4]
GW1	Fresh greywacke	Not monitored	-17 – 13	1.3	26.5
MW01 Shallow	Weathered greywacke	Not monitored	251.5 – 254.5	13.5	251
MW01 Deep	Fresh greywacke	Pressure Transducer	164.6 – 173.6	42.8	222.6

Note:

[1] Partial collapse of GW2N occurred and required re-drilling. Compliance water level data from part of 2021 and 2022 is unavailable as a result.

[2] A negative groundwater level has been reported from GW2N (PDP 2017). However, on-going compliance monitoring in this bore indicates the negative value is a documentation error and has been assumed positive.

[3] FH1-Shallow and FH1-Deep have collapsed and been replaced with FH1-Shallow New and FH1-Deep New. The details of these new bores are TBC.

[4] PDP (2017) reported FH3-Deep collapsed, yielding anomalous data inconsistent with the stable values recorded prior.





LEGEND

- Bore Locations

N

0 50 100 150 200 m

Scale 1:6,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **3**
Site Bore Locations

Clevedon Quarry

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2.3.3 Hydraulic Characteristics of Greywacke

Hydraulic conductivity values for greywacke materials have been compiled in Table 2, based on results from hydraulic testing and groundwater modelling undertaken across the Waikato and Auckland regions. These values provide an indication of the expected range of aquifer properties within the site. The moderately low hydraulic conductivity values presented in Table 2 reflect the generally low primary porosity of greywacke and the dominance of secondary permeability features such as fractures and fault zones.

Table 2: Hydraulic Conductivity of Greywacke Material from Nearby Sites

LOCATION	HYDRAULIC CONDUCTIVITY (m/day)	HYDRAULIC CONDUCTIVITY (m/s)	REFERENCE
Whitford Quarry	0.026	3.0×10^{-7}	PDP (2002)
Beachlands Quarry	0.013	1.5×10^{-7}	PDP (2006)
Hunua Quarry	0.75	8.7×10^{-6}	PDP (2011)
Brookby Quarry	0.015	1.7×10^{-7}	PDP (2023)
Beachlands South	0.28	3.2×10^{-6}	WGA (2023a)
Waingaro Quarry	0.001 – 0.005	1.2×10^{-8} - 5.8×10^{-8}	WGA (2025)

2.3.4 Local Hydraulic Testing

Falling head tests undertaken by PDP (2017) in seven piezometers at the site have been collated in Table 3, with copies of the test sheets provided in Appendix F. The locations of the piezometers are shown in Figure 3. The derived hydraulic conductivity values show a high degree of variability, which is consistent with the heterogeneous nature of fractured greywacke aquifers. The hydraulic conductivity geometric mean from the greywacke values presented in Table 3 of 0.01 m/day aligns with the range of values reported for greywacke materials in other regional studies (Table 2). This alignment suggests that while individual test results may vary due to localised fracture conditions, the overall hydraulic behaviour of the formation is comparable to that documented elsewhere.

Table 3: Hydraulic Testing at Clevedon Quarry

PIEZOMETER ID	HYDRAULIC CONDUCTIVITY (m/day)	HYDRAULIC CONDUCTIVITY (m/s)
GW2N	0.001	1.2×10^{-8}
FH1 – Shallow	4.93	5.7×10^{-5}
FH1 – Deep	0.04	4.3×10^{-7}
FH2 – Shallow	0.1	1.3×10^{-6}
FH2 – Deep	<0.0009	$<1 \times 10^{-8}$
FH3 – Shallow	0.03	3.8×10^{-7}
FH3 – Deep	0.01	1.2×10^{-7}

During the WGA site visit in winter 2025, no signs of seepage or baseflow into the Quarry drains were observed. The greywacke appeared to have relatively low level of fracturing in the exposed pit faces. SAL noted the general lack of any observed seepage in the existing Quarry. On this basis, the local hydraulic conductivity in the immediate area of the existing Quarry is expected to be relatively low.

2.3.5 Quarry Production Bore 31427

Bore ID 31427 was constructed for Stevenson Aggregates Limited under Permit PLUC70022050 to serve as a dedicated water supply under water permit WAT60302444. Drilling was completed May 2023 by Drill Force New Zealand Ltd utilising a rotary mud method. Details of the bore are provided in Table 4.

Table 4: Quarry Production Bore Details

PARAMETERS	PRODUCTION BORE
Bore Number	31427
Drilling Date	16 May 2023
Easting NZTM(1)	1784706
Northing NZTM(1)	5900038
Total Depth (m)(1)	156.5
Casing Depth (m)(1)	96.3
Bore Elevation (m RL)(1)	26
Static Water Level (m)	Flowing artesian
Diameter of Casing (mm)(1)	100

Notes:

(1) Data provided from Bore Construction Details (Drill Force New Zealand Limited).

The flow rate (L/s) and cumulative volume (L) were recorded for Bore 31427 at 15-minute intervals. The pumped volumes have been summarised on a monthly basis in Table 5 for the period 1 August 2024 to 31 July 2025. During this period, flow measurements were captured by a Krohne Optiflux 2000 50 mm pulse flow meter.

Table 5: Monthly Abstraction of Production Bore 31427

MONTH	VOLUME (m^3)
August 2024	3,322
September 2024	3,057
October 2024	2,553
November 2024	3,088
December 2024	1,915
January 2025	2,849
February 2025	2,569
March 2025	2,382
April 2025	2,060
May 2025	2,146
June 2025	1,741
July 2025	357
Total	**28,038**

2.4 Surface Water Flow

2.4.1 Site Setting

The Clevedon Quarry is surrounded by a series of small streams that discharge to the Wairoa River, which forms the principal receiving watercourse for the site. Four streams were monitored in and around the Quarry premises to characterise surface water flows in the context of the proposed pit expansion.

The streams are small, steep, forested headwater catchments that drain westward and ultimately discharge to the Wairoa River. The stream catchment areas are:

- Stream 1 - approximately 1.088 km^2
- Stream 2 - approximately 0.358 km^2
- Stream 2A - approximately 0.073 km^2
- Stream 3 - approximately 1.161 km^2

A topographic ridgeline defines the eastern boundary of the stream catchments. On the eastern side of the crest, surface water drains away from the site into an unnamed stream that discharges to Cosseys Reservoir, rather than to the Wairoa River. The ridge crest therefore forms the surface water divide for the monitored catchments.

The Wairoa River is the regional receiving environment. At the Wairoa River monitoring station at Tourist Road (Site 8516 – see Figure 4), the river drains a catchment of approximately 156 km^2.

2.4.2 Rainfall

Rainfall has been monitored at the site as part of the consent compliance programme. The record supplied by SAL extends from November 2023 to August 2026 during which a total of approximately 3,648 mm was recorded, equivalent to a mean annual rainfall of approximately 1,289 mm/year (Appendix H). Within this record, the July 2025 to June 2026 monitoring year totalled approximately 1,450 mm, and the preceding July 2024 to June 2025 year totalled approximately 1,259 mm.

The average annual rainfall at Ardmore Climate Station C74091, located approximately 9.5 km west of the site, is 1,241 mm/year. The rainfall recorded at the site during the monitoring period was therefore approximately 48 mm higher than the nearby long-term average. It should also be noted that the Ardmore Climate Station is located within an area of flat topography, rather than the western side of a hill range where the Quarry is located.

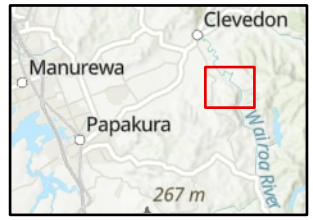
2.4.3 Prior Surface Water Flow Gauging Assessments

Pattle Delamore Partners (PDP) has undertaken surface water monitoring and low-flow assessments for the Clevedon Quarry streams over an extended period, in support of the site's historic surface water take consent. Their work provides the historical baseline against which the current gauging programme is compared. In PDP's (2017) report, Stream 1 is referred to as the Northern Stream and Stream 2 as the Southern Stream.

Initial baseline gauging (PDP 2017)

PDP established the initial surface water baseline through two rounds of spot gauging in January and February 2017. Gauging was completed at four locations along the Northern Stream (Sites N1 to N4) and three along the Southern Stream (Sites S1 to S3), with Sites N4 and S3 representing the monitoring points closest to the Wairoa River. Recorded discharges ranged from approximately 8 to 10 L/s along the Northern Stream and 0.3 to 1.2 L/s along the Southern Stream. Given the limited dataset, PDP concluded the gaugings were unlikely to fully represent baseflow conditions and have been summarised in Table 6 as indicative flow only.





LEGEND

- Watercourse Gauging Locations

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **4**
Watercourse Gauging Locations

Clevedon Quarry

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Any relevance placed on such information shall be at the risk of the user.

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Table 6: Recorded Streamflow during January and February 2017 (PDP 2017)

SITE	CATCHMENT AREA (km^2)	ELEVATION (m RL)	AVERAGE DISCHARGE (L/s)	DISCHARGE ($L/s/km^2$)
N1	0.77	115	10.1	13.1
N2	0.93	60	7.9	8.5
N3	1.03	27	8.7	8.4
N4	1.07	20	8.7	8.1
S1	0.093	188	0.33	3.5
S2	0.179	93	0.7	3.9
S3	0.335	21	1.2	3.6

Continued Monitoring and MALF Derivation

Routine streamflow monitoring has been undertaken along Stream 1 from 2017 onward, with gauging undertaken on a twice-yearly basis at the consent-relevant sites (N3 and N4).

To derive a seven-day Mean Annual Low Flow (7-day MALF) from these periodic manual gaugings, PDP adopted an index-site correlation approach. Concurrent stream and Wairoa River flows (Wairoa River station at Tourist Road) were used to develop a linear regression relationship, which was then applied to the long-term Wairoa low-flow record to produce a synthetic MALF for each gauging station. PDP 2024 reported the results summarised below.

Table 7: MALF Results in Stream 1 and Index Site

GAUGING STATION	CATCHMENT AREA (km^2)	R^2	MALF ($L/s/km^2$)	MALF (L/s)
Wairoa River (@ Clevedon Quarry)(1)	151	0.90	1.87	282
Wairoa River (@ Tourist Rd)	156	—	2.95	460
N3 (Stream 1)	1.02	0.92	7.37	7.52
N4 (Stream 1)	1.06	0.87	7.63	8.08

Note:

(1) Derived from PDP (2026).

2.4.4 Current Stream Gauging and Characterisation

Overview and Monitoring Purpose

A permanent monitoring network was established in 2026 to characterise streamflow conditions in four streams located near the Quarry, in the context of a proposed Quarry pit expansion. Flow and stage data were collected by Hydro Logic NZ Ltd (Hydro Logic) on behalf of SAL as part of groundwater modelling development associated with the Clevedon Quarry. The Hydro Logic (2026) report detailing this work and rating curve development is provided in Appendix E and the locations are summarised below in Table 8.

Table 8: Clevedon Quarry Stream Gauging Locations

SITE ID	NZTM EASTING	NZTM NORTHING
Trib 1 US	1784978	5899964
Trib 1 DS	1784725	5900023
Trib 2 US	1784883	5899556
Trib 2 DS	1784702	5899630
Trib 2A US	1784862	5899318
Trib 2A DS	1784673	5899448
Trib 3 DS	1784447	5898967

The monitoring network provides coverage of the principal western-draining catchments surrounding the quarry and forms the basis for the streamflow characterisation, baseflow assessment and groundwater model calibration described later in this report.

Gauging Programme and Flow Measurement

Records from flow monitoring undertaken for the current investigation span approximately mid-February to late April 2026, a total period of approximately 11 weeks. Stream 1 gauging commenced on 11 February 2026, while the remaining gauges began between 16 and 17 February 2026. All records share a common end date of 29 April 2026, corresponding with a Hydro Logic site visit. Gauging station flow values have been summarised in Table 9.

Discharge at each monitoring point was measured using a calibrated OTT current meter at sites of sufficient cross-sectional area, and by volumetric container at the very low-flow locations (Stream 2 downstream, and the upstream section at Stream 2A). Water levels have been recorded at a uniform 15-minute interval, yielding approximately 6,900 to 7,400 observations per monitoring station.

Table 9: Gauge Discharge Summary

STREAM	REACH	GAUGED DISCHARGE RANGE (L/s)	NUMBER OF GAUGINGS
1	Upstream	10.6 – 13.9	3
1	Downstream	18.2 – 22.2	3
2	Upstream	3.8 – 4.4	3
2	Downstream	2.3 – 4.5	3
2A	Upstream	0.039 – 0.045	2 (29 April not gauged due to access limits)
2A	Downstream	0.22 – 0.50	3
3	Downstream	13.7 – 24.4	3

Rating Curve Development and Quality

Rating curves were derived for each gauged reach from the three-visit gauging dataset. A common constraint across the network is that two of the three gaugings at most sites were obtained at a similar water level, producing a narrow range of stages. Rating quality varies between streams as a function of flow magnitude, channel control, and the sensor-to-gauging offset, as summarised below:

- **Stream 1**: Both the upstream and downstream reaches have comparatively high flows (approximated at 10 to 23 L/s), and the available flow magnitude and channel conditions are more suitable for rating-curve development. The present three gaugings are insufficient to achieve a high degree of confidence.
- **Stream 2:** Flows are generally low (approximately 2 to 5 L/s). The very small differences in flow and water level measured between visits, combined with an unsteady channel control, indicate a generally less reliable flow dataset. The ratings from Stream 2 should be treated as estimates only.
- **Stream 2A:** Flows are extremely low (approximately 0 to 0.5 L/s), and an accurate rating is not considered achievable by Hydro Logic. As with Stream 2, the very small stage/flow variation and an unsteady control preclude a defensible relationship, and the upstream reach has only two gaugings owing to a lack of site access on 29 April 2026. These ratings should be treated as estimates only.
- **Stream 3:** Carrying comparatively high flows (approximately 13 to 25 L/s), this site is identified as the most suitable location in the network for constructing an accurate rating. The single station returned a well-distributed set of gaugings.

Overall Confidence and Limitations

The reliability of the derived ratings is governed principally by flow magnitude, where the higher-flow streams (1 and 3) support more reliable ratings, whereas the low to extremely low-flow streams (2 and 2A) yield indicative estimates only. Across all sites, the limited number of gaugings, the narrow range of measured stages, and the physical separation of the water level sensors from the gauging cross-sections constrain confidence. Additional gaugings, captured across a wider range of flow conditions, would materially improve the accuracy of the ratings and are recommended for on-going monitoring through the Quarry development stages.

2.4.5 Streamflow Synthesis and Baseflow Analysis

The rating curves developed for the four streams by Hydro Logic 2026 contain limitations to derive low-flow statistics directly, as described above. As such, the manual gaugings at each site were instead indexed directly against the long-term Wairoa River record (Site 8516) to derive a first-order estimate of baseflow (MALF-equivalent flow) at each stream site.

The approach to deriving baseflow approximations first established a long-term MALF for the Wairoa River, then used the flow relationship between each stream and the Wairoa at the time of gauging to scale the stream gaugings to an equivalent low-flow condition.

The Wairoa MALF was derived by reducing the 5-minute, 10-year record (August 2016 to August 2026) to daily mean flow, computing a trailing 7-day mean, and extracting the annual minimum 7-day mean for each hydrological year (1 July to 30 June). Averaging the annual minimums over the nine complete hydrological years (2017/18 to 2025/26) gave a Wairoa MALF of 517 L/s (Appendix C).

For each manual gauging, the concurrent Wairoa flow and daily mean flow were then retrieved, and each stream gauging was scaled by the ratio of the Wairoa MALF to the Wairoa daily mean flow at that time. The mean of the scaled gaugings provides the estimated MALF-equivalent baseflow at each site, on the assumption that the streams and the Wairoa recede in proportion under regional baseflow control.

All twenty usable gaugings from the site streams were taken when the Wairoa River was flowing at approximately 2.3 to 3.1 times its MALF. The timing and Wairoa River hydrograph indicate that the gaugings were undertaken during moderate, generally receding flows. Adopting the raw gauged flows would therefore overstate true baseflow. As such, the scaled MALF-equivalent values are considered more appropriate figures for a low-flow assessment.

Results

The estimated MALF-equivalent baseflow at each stream site is presented in Table 10. Values are grouped by stream, with separate estimates for the upstream and downstream gauging points.

Table 10: Estimated Baseflow (MALF-equivalent) at Each Stream Site

SITE	LOCATION	NO. GAUGINGS	MEAN GAUGED FLOW (L/s)	ESTIMATED MALF-EQUIV. BASEFLOW (L/s)	RANGE (L/s)	DISCHARGE (L/s/km^2)
Trib 1 US	Stream 1	3	12.01	4.5	4.3 – 4.7	4.92
Trib 1 DS	Stream 1	3	19.92	7.5	6.8 – 8.5	7.34
Trib 2 US	Stream 2	3	4.10	1.6	1.4 – 1.8	6.41
Trib 2 DS	Stream 2	3	3.68	1.5	1.0 – 1.9	4.53
Trib 2A US	Stream 2A	2	0.04	0.02	0.02 – 0.02	0.56
Trib 2A DS	Stream 2A	3	0.36	0.1	0.10 – 0.16	2.28
Trib 3	Stream 3	3	19.39	7.2	6.1 – 8.0	6.20

Independent Verification

The adopted values were checked against the PDP (2024) MALF values provided in Table 7. PDP derived a MALF for Stream 1 of 8.08 L/s at Site N4, using an index-site regression against the same Wairoa River gauge. The closest comparable gauging site measured by Hydro Logic (2026) is Stream 1 DS, located approximately 20 m from N4. The downstream MALF-equivalent baseflow derived in this assessment for Stream 1 is 7.5 L/s, which indicates a reasonable match.

2.4.6 Groundwater Recharge

Groundwater recharge is derived from direct infiltration of rainfall across the greywacke terrain underlying the site. Recharge rates are estimated to range from approximately 65 mm/year to 180 mm/year (PDP, 2017). These values correspond to about 5% and 15% of the total annual rainfall of 1,241 mm/year, as measured at the Ardmore Climate Station (C74091).

The MALF-equivalent baseflows for Streams 1, 2, and 3 (Table 10) correspond to groundwater recharge estimates ranging from 143 to 231 mm/year, with a mean of 185 mm/year. These recharge rates were considered the most reliable range to adopt for the purpose of numerical modelling, excluding the very low flows derived from Stream 2A.

2.5 Water Quality

Samples for water quality analysis have been collected from three separate locations:

- Stream 1, at gauging location referred to as Trib 1 US
- Stream 3 at the gauging location
- The deep Production Bore 31427

The water quality analysis results are provided in Appendix D and summarised below.

2.5.1 Production Bore Water Quality

The groundwater sample collected from the Clevedon Quarry Production Bore appears typical of water that has spent a long time moving through fractured greywacke rock. The water is slightly alkaline (pH 9.1 - 9.4), indicating a naturally high pH environment. Electrical conductivity and dissolved salts are relatively low, indicating that the groundwater is not highly mineralised. Nitrate concentrations were below laboratory detection limits, providing little evidence of contamination from agricultural or other surface-derived nutrient sources. Dissolved metals, including iron, manganese, copper and zinc, were either not detected or present at very low concentrations. The groundwater is dominated by sodium and bicarbonate ions, which is consistent with water that has undergone prolonged interaction with rock minerals at depth.

2.5.2 Surface Water

The surface water samples from Stream 1 Upstream and Stream 3 were collected 14 January 2026 at 16:10 and 14:55, respectively. The results show similar water quality characteristics and are indicative of relatively unimpacted streams. Both sites had near-neutral pH values (7.39 - 7.44). Electrical conductivity was between 177 and 193 µS/cm. Total dissolved solids were between 115 and 136 mg/L.

Nutrient concentrations were low. Nitrate-nitrogen concentrations ranged from 0.33 to 0.41 mg/L, while ammoniacal nitrogen was below detection limits at both sites. Dissolved reactive phosphorus concentrations were very low (0.03 - 0.04 mg/L).

Metal concentrations were generally very low, with arsenic, cadmium, lead and zinc below detection limits. Small amounts of naturally occurring iron, manganese, aluminium and calcium were detected.

Suspended sediment concentrations were also low, particularly at Stream 1 Upstream (5 mg/L), indicating relatively clear water at the time of sampling. Stream 3 recorded slightly higher suspended sediment (16 mg/L).

2.5.3 Summary

The available water quality data indicate that groundwater from the Production Bore has a distinctly different chemical composition to surface water samples collected from Stream 1 and Stream 3. The groundwater is characterised by elevated pH, higher sodium concentrations, higher alkalinity, and lower nutrient concentrations relative to the streams. These differences indicate that the Production Bore draws groundwater from longer, deeper flow paths within the greywacke. Groundwater discharging to the streams is likely to come from shorter flow paths and more recent recharge.

2.6 Groundwater Allocation Zone

The Clevedon Quarry is designated within the Hunua Wairoa Greywacke aquifer, based on historical overlays from the Auckland Council Data Portal.

While the Clevedon Quarry is not situated within a designated High Use Aquifer Management Area, the site sits adjacent to a High Use Aquifer Management Area, the ‘Clevedon East Waitemata Aquifer’.

Section D1 Table D1.3.1 of the Auckland Unitary Plan defines the Clevedon East Waitemata Aquifer as “Includes all rocks of the Waitematā Group, but not the underlying greywacke (Waipapa Group) or the overlying Tauranga Group or Kaawa Formation.” As such this High Use Aquifer Management Area is not considered relevant to groundwater abstraction at the site.

2.7 Water Supply Management Areas

The Clevedon Quarry is not situated within a Water Supply Management Area as designated by Auckland Council (2025). The closest designation is the Hunua area, located approximately 650 m east of the current pit extent (i.e., eastward of Orum Road).

2.8 Water Supply Bores

There are no production bores located within a 3 km radius of the proposed Quarry footprint as listed within the Wells NZ database (2026), with the exception of the Clevedon Quarry Production Bore (31427). The closest production bore identified in the New Zealand Geotechnical Database (NZGD ID 90018) is located approximately 1.4 km north-west of the entrance of Clevedon Quarry (Figure 2). A list of water bores within 3 km of the Clevedon Quarry is provided in Table 11.

Table 11: Water Bores within a 3 km Radius of the Clevedon Quarry

BORE ID	NORTHING	EASTING	BORE DEPTH (m)	SOURCE	DRILL DATE
78697	5901600	1783875	110.1	Historic Waterbore Information (NZGD)	11/27/1983
81100	5900630	1783310	116.9	Historic Waterbore Information (NZGD)	7/05/1999
81254	5900470	1782800	81	Historic Waterbore Information (NZGD)	04/13/1998
82074	5898400	1782800	176	Historic Waterbore Information (NZGD)	02/19/1991
90018	5901234	1784096	94	Not Recorded (NZGD)	12/10/2015

3 MODELLING METHODOLOGY

3.1 Modelling Overview

The development and use of the groundwater models documented in this report followed a stepwise approach. The general steps were as follows:

1. Develop a conceptual groundwater model that outlines the potential area influenced by the expanded Quarry and potential hydrogeological boundary conditions that may be used to define the limits of a numerical model. The spatial extent of the numerical groundwater model has principally been based on preliminary drawdown projections.
2. Set up the groundwater modelling package Groundwater Vistas (GV) and determine a suitable spatial discretisation to ensure key areas are appropriately simulated.
3. Define hydraulic boundary conditions, initial bulk rock mass characteristics, observed groundwater levels and observed base flow rates for streams simulated in the model.
4. Adjust the rock mass characteristics manually to gain an understanding of how the model functions hydraulically.
5. Use the PEST (Parameter Estimation) package available in GV to run a calibration process to generate a 'best fit' model outcome to match observed groundwater levels and stream base flows.
6. Incorporate the final rock mass characteristics and boundary conditions from the calibrated model into the model simulating the Proposed Stage 1 and Stage 5 pit designs.
7. Evaluate model sensitivity and predictive uncertainty using alternative recharge and hydraulic conductivity scenarios and independently verify predicted pit inflows using the analytical method of Marinelli and Niccoli (2000).

The modelling process involved the construction of three separate models:

1. **Baseline Model** – Represents the current Quarry layout, groundwater conditions, and flow to streams. Parameters in this model have been modified to reflect observations (i.e., flow in the streams and groundwater levels).
2. **Stage 1 Pit Design** – The Quarry design for Stage 1 is simulated using the same parameters from the calibrated baseline model. Dewatering of the pit occurs as it intersects the groundwater table.
3. **Stage 5 Pit Design** – The Quarry design for Stage 5 is simulated using the same parameters from the calibrated baseline model. Dewatering of the pit occurs as it intersects the groundwater table.

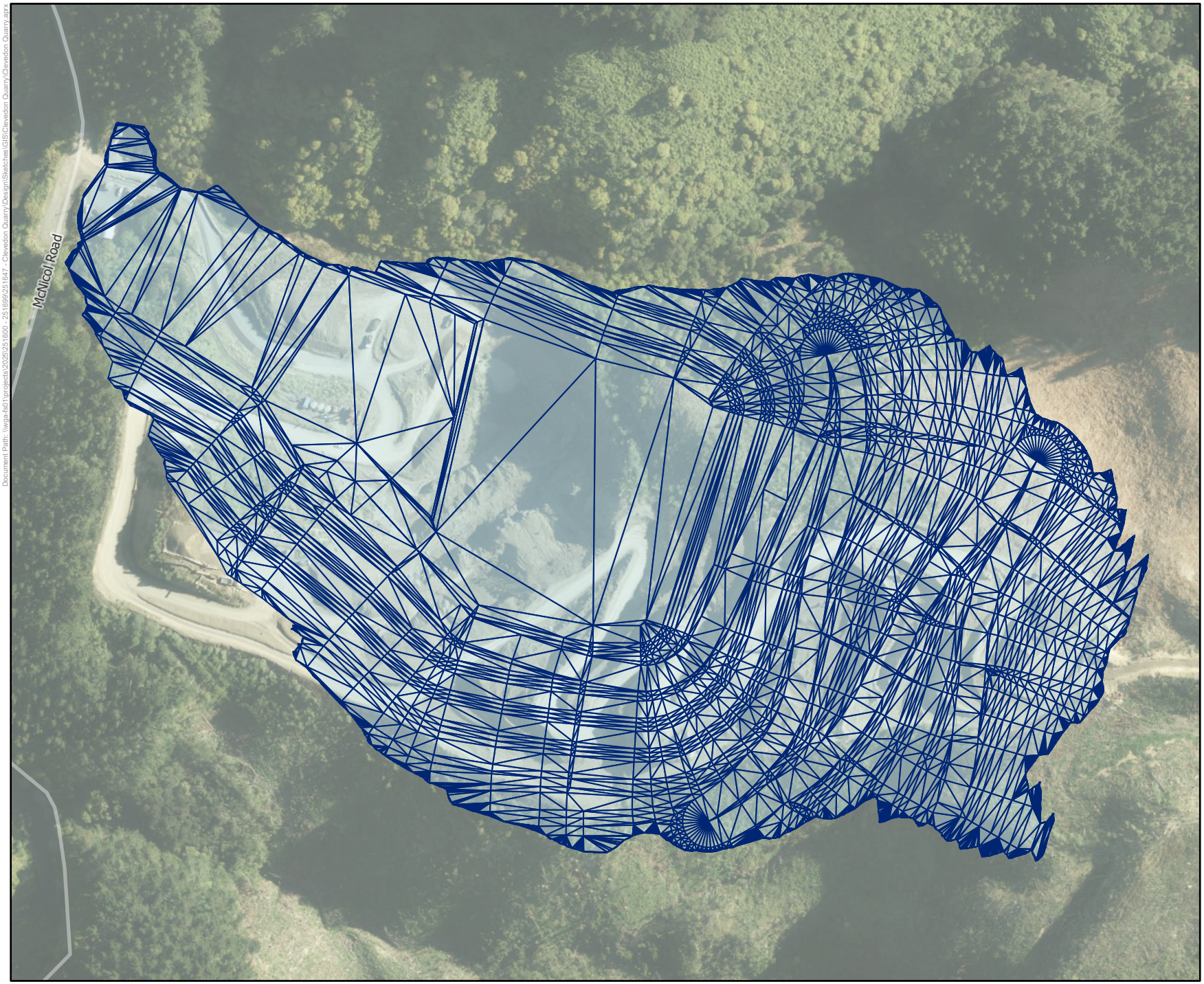
3.2 Pit Designs

The calibrated Baseline model have been compared against two simulated pit designs:

1. **Stage 1:** The Quarry floor has a footprint of approximately 4.6 ha. The lower terrace (i.e., towards the Quarry entrance) has an elevation of 22.5 mRL, and the upper terrace has an elevation of 31 mRL. The total area of the pit spans 16.3 ha.
2. **Stage 5:** The Quarry floor has a footprint of approximately 23.6 ha. The lower terrace has an elevation of 22.5 mRL, and the upper terrace has an elevation of 31 mRL. The total area of the pit spans 74.3 ha. Stage 5 represents the full-life-of-quarry development and provides an assessment of the maximum potential groundwater and surface water effects associated with the ultimate pit envelope.

The extent and geometry of each pit is illustrated in Figure 5 and Figure 6. These pit geometries formed the basis for evaluating potential groundwater and surface water interactions under both the Stage 1 and Stage 5 designs.

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LEGEND

Stage 1 Proposed Pit Geometry

N

0 25 50 75 100 m

Scale 1:3,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

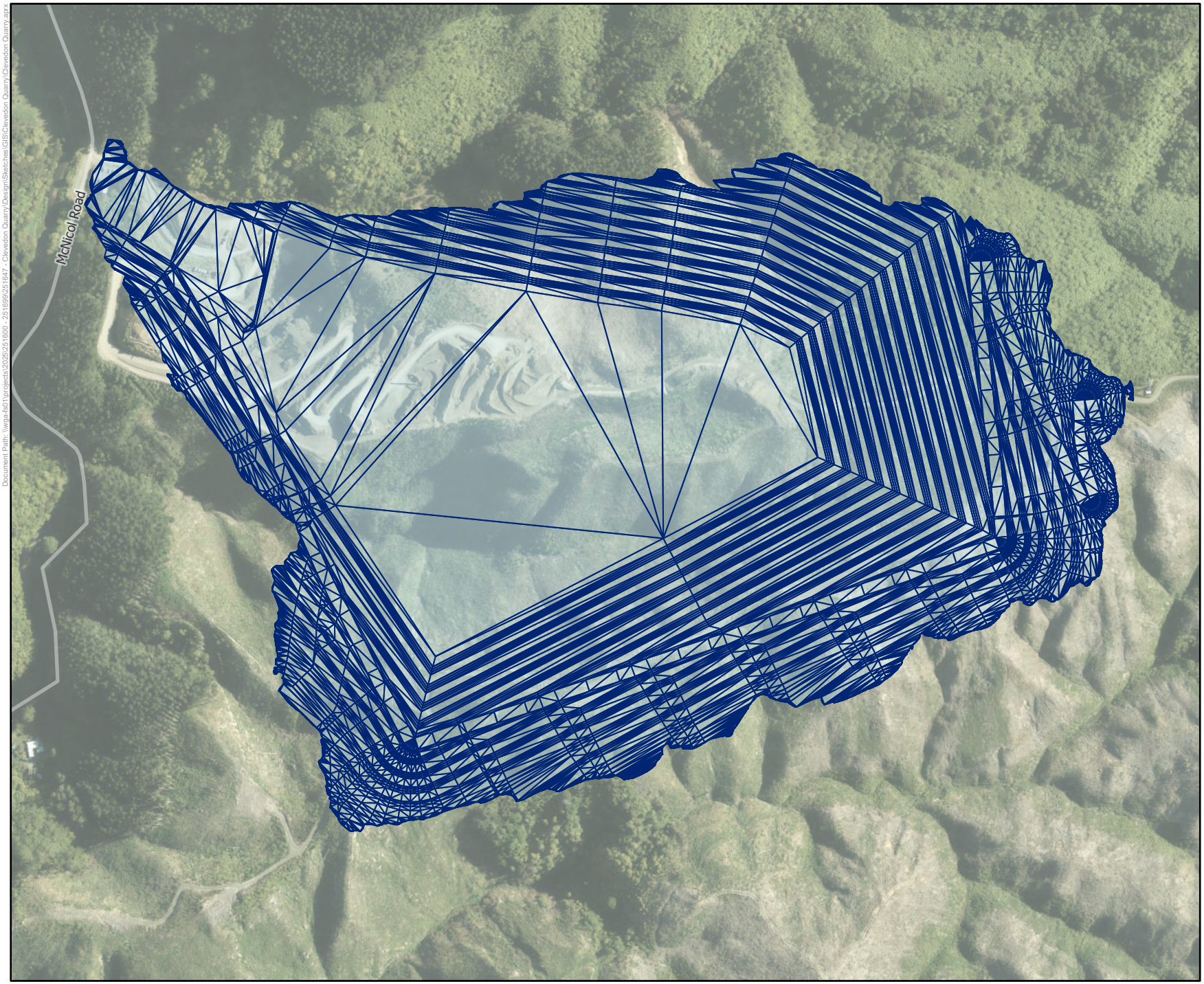
Figure **5**
Stage 1 Proposed Pit Design

Clevedon Quarry

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LEGEND

Stage 5 Proposed Pit Geometry

N

0 50 100 150 200 m

Scale 1:6,500 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **6**
Stage 5 Proposed Pit Design

Clevedon Quarry

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4 GROUNDWATER EFFECTS ASSESSMENT

4.1 Introduction

The potential effects of the proposed Quarry expansion have been assessed using the groundwater model as detailed in Section 3. The groundwater model setup and calibration of the Baseline Model is detailed in Appendix A. The simulated effects from Stage 1 and Stage 5, based on the numerical modelling, are documented in Appendix B. In addition, predictive uncertainty was assessed using alternative parameter sets and groundwater inflow to the proposed pit was independently checked using an analytical solution of Marinelli and Niccoli (2000) (Appendix I). The results are summarised below.

4.2 Projected Drawdown Effects

The groundwater model represents the weathered and fractured greywacke as a single flow system. The predicted drawdown described below therefore represents the bulk response of the greywacke groundwater system.

Localised perched groundwater retained within low-permeability clay-rich horizons, such as that interpreted at MW01-Shallow, is by definition hydraulically isolated from the water table and is not expected to be materially affected beyond the immediate quarry footprint.

The drawdown contours simulated after the long-term construction of Stage 1 and Stage 5 are provided in Figure 7 and Figure 8, respectively.

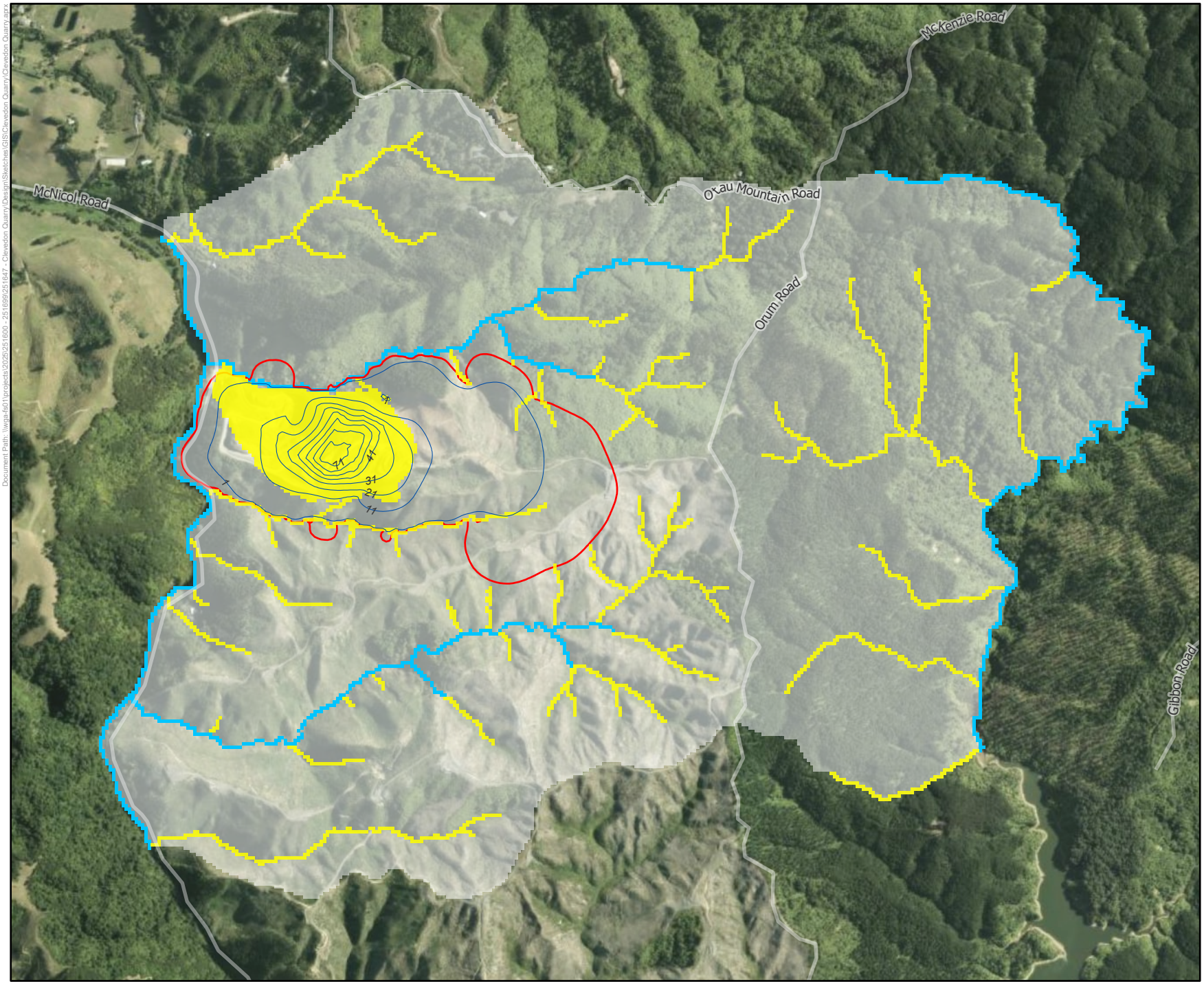
Drawdown from the Stage 1 simulation is generally confined to the area between the Wairoa River, Streams 1, and 2. The zone of influence, defined as the 0.25 m drawdown contour, extends eastward where there is no boundary condition to a maximum distance of approximately 630 m, measured from the eastern pit boundary. A drawdown of less than 0.25 m is unlikely to be discernible from natural variability in the groundwater records from monitoring wells, especially if the change occurs slowly over a period of years.

Drawdown from the Stage 5 simulation is generally confined to the area within the Wairoa River, Stream 1 and Stream 3, as the Stream 2 catchment has largely been removed through expansion of the Quarry. As with the drawdown shape of Stage 1, the Stage 5 zone of influence extends predominantly eastward where no nearby head-dependent surface-water boundary limits drawdown propagation. This zone of influence extends to a maximum distance of approximately 650 m from the eastern pit wall and is confined to the eastern side of the Wairoa River.

The model domain was sufficiently large that drawdown calculated at the edges of the model was negligible. This outcome indicates groundwater drawdown within the model was appropriately captured and the selected model-domain extent did not materially constrain the simulated drawdown extent.

4.2.1 Drawdown on Nearby Bores

The modelled steady state zone of influence (i.e., area where drawdown exceeds 0.25 m) does not extend to the west past the Wairoa River under either Stage 1 or Stage 5 conditions (Figure 7 and Figure 8). As such, the closest off-site production bore, located approximately 1.4 km north-west of the Quarry, and separated from the Quarry by the Wairoa River, is simulated to have negligible drawdown interference effects.





LEGEND

- River Cells
- Drain Cells
- Drawdown (m)
- Zone of Influence (0.25 m drawdown)
- Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

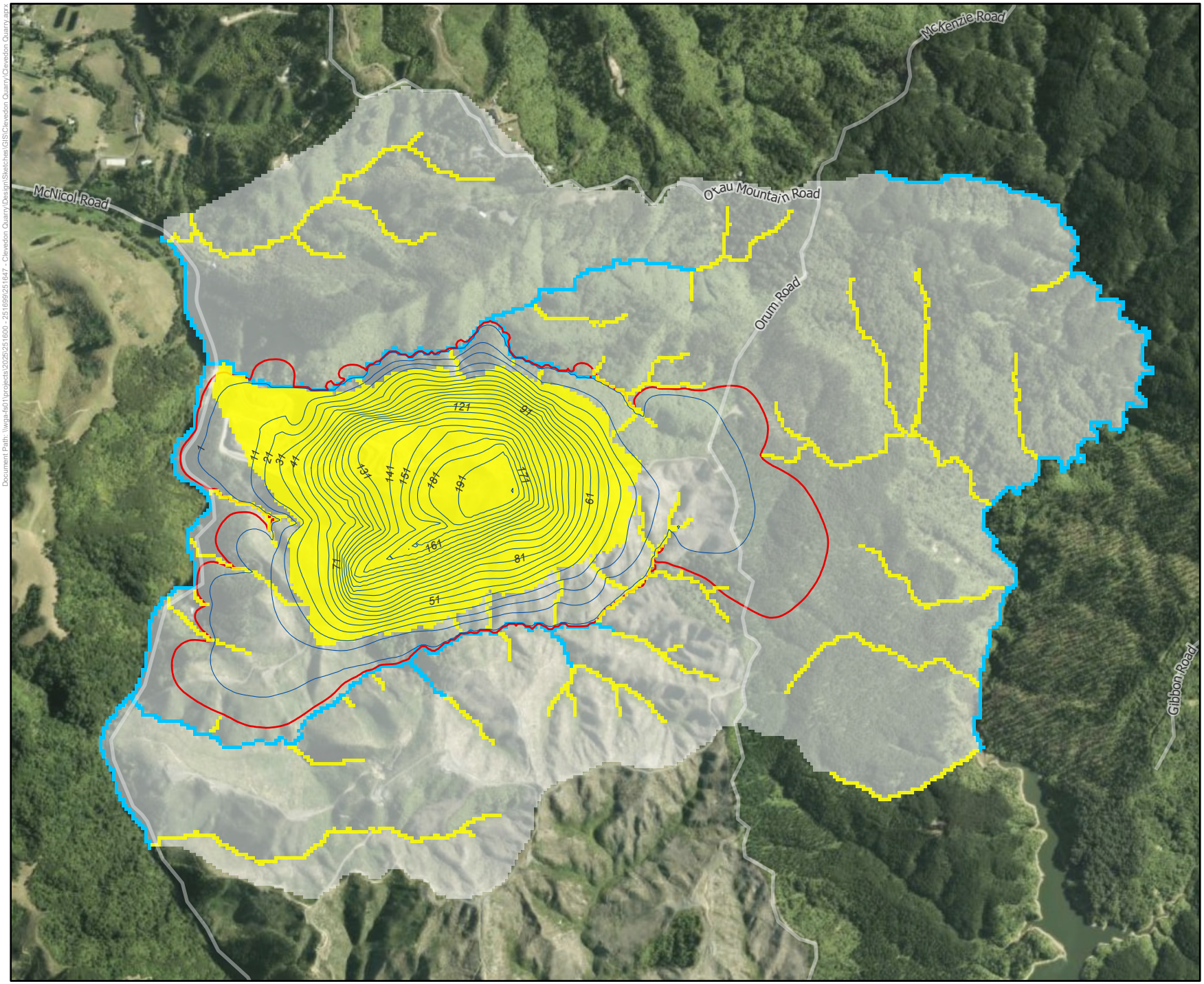
Figure **7**
Proposed Stage 1 Drawdown

Clevedon Quarry

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LEGEND

- Drawdown (m)
- Zone of Influence (0.25 m drawdown)
- Drain Cells
- River Cells
- Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **8**
Proposed Stage 5 Drawdown

Clevedon Quarry

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4.2.2 Other Drawdown Effects

Cosseys Reservoir, located approximately 2 km southeast of the site, is outside the drawdown zone of influence (Appendix B2 and B4). Further, the simulated depletion effects on streams draining towards Cosseys Reservoir are considered negligible, as described in Section 4.3.8.

4.3 Effects on Surface Water Bodies

The stream depletion assessment uses the groundwater model to estimate changes in groundwater discharge, or baseflow, to streams. The modelling was undertaken under steady-state conditions and therefore represents long-term average groundwater responses after the system has equilibrated. The reported effects relate only to the reduction in the groundwater contribution to stream baseflow and do not include direct runoff or stormflow components. Seasonal variability, droughts, storm events, and year-to-year climate variability are not represented.

Stream depletion effects and pit inflow have been calculated based on the Stage 1 and Stage 5 pit designs. These effects are described below, and the numerical changes are provided in Appendix B.

4.3.1 Stream 1

Stream 1 has a simulated baseline groundwater contribution of approximately 6.45 L/s. Under the Stage 1 scenario, groundwater discharges reduce to approximately 5.22 L/s, representing a depletion of 1.23 L/s (19%). Under the Stage 5 scenario, groundwater discharges reduce further to approximately 3.36 L/s, representing a depletion of 3.10 L/s (48%). Stream 1 therefore experiences the largest absolute reduction in groundwater contribution of the four streams assessed.

4.3.2 Stream 2

Stream 2 has a simulated baseline groundwater contribution of approximately 1.47 L/s. Under Stage 1, groundwater discharge decreases to approximately 1.10 L/s, corresponding to a depletion of 0.37 L/s (25%). From Stage 2 onwards, the Stream 2 channel and the contributing catchment are progressively removed or reclaimed by the expanded pit area.

4.3.3 Stream 2A

Stream 2A has a substantially smaller groundwater contribution than the other streams, with a simulated baseline contribution of approximately 0.24 L/s. Stage 1 depletion is negligible, amounting to less than 0.0001 L/s. Under Stage 5, there is a small catchment loss related to the expanded pit footprint. As such, groundwater contribution decreases by approximately 0.04 L/s (18%), reducing net gain to approximately 0.19 L/s.

4.3.4 Stream 3

Stream 3 has a simulated baseline groundwater contribution of approximately 7.62 L/s, representing the largest baseline groundwater discharge within the modelled stream network. Stage 1 effects are negligible, with predicted depletion of only 0.009 L/s (0.1%). Under Stage 5, groundwater contribution decreases to approximately 6.12 L/s, representing a depletion of 1.50 L/s (20%).

4.3.5 Stream Segmentation

Additional stream segmentation (i.e., stream depletion assessment at a greater resolution) was undertaken to provide support to the ecological assessment and identify potential target locations for stream augmentation. That is, depletion effects on individual reaches of Stream 1 and Stream 3 were assessed. These individual stream segments are illustrated in Figure 9, and individual segment depletion rates are described in Table 12. Additional details are provided in Appendix B.

The depletion results are model-based subdivisions of the streams and were not independently calibrated. Confidence is therefore generally greater at the whole-of-stream scale than at individual segment scales.

Table 12: Segment Stage 5 Depletion Rates

STREAM/REACH	STAGE 5 DEPLETION (L/s)	STAGE 5 DEPLETION (%)
Stream 1 - Segment 1	2.31	89.6%
Stream 1 - Segment 2	0.01	0.2%
Stream 1 - Segment 3	0.79	52.7%
Stream 3 - Segment 1	0.14	3.3%
Stream 3 - Segment 2	1.35	40.2%

These depletion rates are not cumulative within the catchments. That is, the depletion rate across a given segment represents the modelled change in groundwater discharge within that individual stream reach only and does not include the flow that is entering from upstream reaches.

These results indicate that depletion effects are concentrated within particular reaches rather than being distributed evenly throughout the stream network. Stream 1 Segment 1 experiences the largest proportional reductions, while Stream 1 Segment 2 was simulated with negligible depletion. The upper section of Stream 3 (Segment 2) is simulated with greater depletion than the lower section (Segment 1).

These results provide insight into where stream augmentation might be most suitable.

4.3.6 Wairoa River

Groundwater discharge directly to the Wairoa River (i.e., excluding all simulated streams) decreases from approximately 173 m^3/day (2.0 L/s) under baseline conditions to approximately 166 m^3/day (1.9 L/s) under Stage 1 and 164 m^3/day (1.9 L/s) under Stage 5. This equates to a reduction of approximately 9 m^3/day, or around 0.1 L/s, under Stage 5.

For context, the Wairoa River MALF, located directly outside Clevedon Quarry, is estimated at approximately 24,364 m^3/day (282 L/s) (Table 7). The modelled change to the MALF outside the quarry represents a 0.037% reduction. As such, this reduction is considered negligible to the flow regime of the Wairoa River.

4.3.7 Other Western Streams

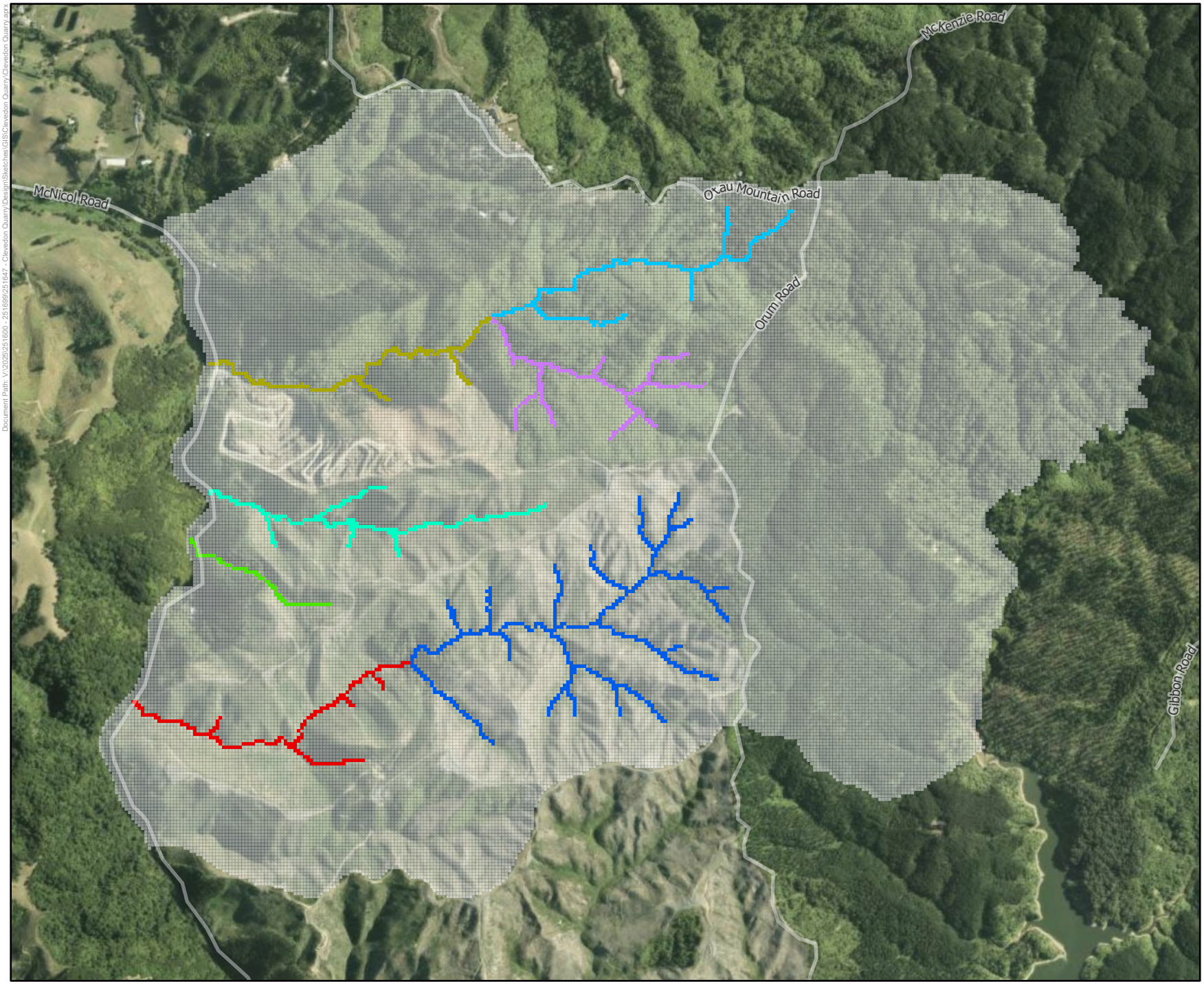
The aggregate western stream drain network simulated within the model domain decreases at a negligible level under Stage 1. Under Stage 5, this equates to a reduction of approximately 1 m^3/day, indicating minimal change outside the explicitly assessed streams.

4.3.8 Eastern Streams

Eastern-draining streams remain essentially unchanged, decreasing from approximately 471 m^3/day under baseline conditions to approximately 469 m^3/day under Stage 5. Eastern boundary river fluxes remain effectively unchanged throughout all simulations.

4.3.9 Pit Inflow

The simulated groundwater inflow to the Quarry pit increases progressively as Quarry development advances. This increase reflects groundwater that would otherwise discharge to nearby streams and drains being intercepted by the excavation. The projected rates are presented in Table 13.





LEGEND

Stream Segments

- Trib 1.1
- Trib 1.2
- Trib 1.3
- Trib 2
- Trib 2A
- Trib 3.1
- Trib 3.2

Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **9**
Stream Segments

Clevedon Quarry

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Any relevance placed on such information shall be at the risk of the user.

Note: The information shown on this map is a copyright of WGA 2026

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Table 13: Modelled Groundwater Inflow to the Pit

PARAMETER	FLOW		
Simulation	Existing Quarry	Stage 1	Stage 5
Pit Inflow (m^3/day)	25.0	162.1	544.4
Pit Inflow (L/s)	0.29	1.88	6.30

An independent check on the outcomes of the numerical model has been undertaken. Groundwater inflow to the Stage 5 excavation was assessed using the analytical method of Marinelli and Niccoli (2000) and calculation sheets shown in Appendix I. The analytical calculation indicated an inflow to the Stage 5 Quarry of approximately 540 m^3/day, which compares well with the numerical model prediction of approximately 544 m^3/day (approximately 199,000 m^3/year), providing confidence that the predicted pit inflow is of the correct order of magnitude.

4.4 Stream Augmentation Potential

The modelling indicates that groundwater intercepted by the Quarry would otherwise contribute primarily to Streams 1 and 3. By Stage 5, the combined reduction in groundwater discharge to these streams is approximately 4.6 L/s, comprising approximately 3.1 L/s from Stream 1 and 1.5 L/s from Stream 3.

Based on the initial model results, the indicative maximum augmentation requirement for Streams 1 and 3 is approximately 1.24 L/s, or 107 m^3/day, under Stage 1, increasing to approximately 4.6 L/s, or 397 m^3/day, under Stage 5. These values represent the modelled reduction in groundwater contribution to stream baseflow and provide an initial basis for considering potential augmentation flows.

The predicted pit inflow is greater than the estimated augmentation requirement. Simulated groundwater inflow to the Quarry was 544 m^3/day (6.3 L/s) under Stage 5 conditions. This indicates that intercepted groundwater could provide a potential source of augmentation water, either from a future quarry sump following suitable treatment, or from an onsite bore.

The available pit inflows indicate that sufficient water would be available in principle to offset the predicted reductions in groundwater contributions to Streams 1 and 3 during low-flow conditions.

The final augmentation regime should be informed by monitoring and adaptive management. Ongoing streamflow and groundwater monitoring would be used to confirm the timing, magnitude and location of any baseflow depletion effects during quarry development. The augmentation regime could then be refined, if required, to target the affected stream reaches and provide appropriate mitigation during low-flow conditions. This monitoring and adaptive management approach is addressed through the updated Groundwater and Surface Water Monitoring and Contingency Plan recommendations (see Section 5).

4.5 Sensitivity and Uncertainty Analysis

The numerical groundwater model is based on available hydrogeological information and, as with all groundwater models, contains inherent uncertainty associated with the conceptualisation of the groundwater system, hydraulic parameter values, recharge estimates, and representation of stream-aquifer interactions. To assess the potential influence of these uncertainties on model predictions, sensitivity and predictive uncertainty analyses were undertaken as part of the modelling process. The methodology and results are presented in detail within Appendix A (Sensitivity Analysis) and Appendix B (Uncertainty Analysis).

The sensitivity analysis tested the response of the calibrated model to variations in key model parameters, including hydraulic conductivity, recharge, and surface-water boundary conditions. The results indicate that the model predictions are most responsive to parameters that control groundwater gradients and groundwater discharge elevations, while uncertainty associated with conductance values has comparatively little influence on model outcomes.

Predictive uncertainty was evaluated by re-running the model using alternative recharge and hydraulic conductivity parameter sets around the calibrated model. Across all scenarios assessed, the overall pattern of stream depletion and pit inflow remained consistent with the calibrated model predictions. While the magnitude of predicted effects varied between simulations, the uncertainty analysis indicates that Streams 1 and 3 remain the principal receptors affected by quarry dewatering.

An additional separate check of the predicted pit inflow was undertaken using the analytical method of Marinelli and Niccoli (2000). The analytical estimate produced a Stage 5 pit inflow prediction that closely matched the numerical model result, providing further confidence that the simulated inflows are of an appropriate order of magnitude.

Overall, the sensitivity and uncertainty analyses indicate that the model conclusions are reasonable and that the key findings of this assessment are not materially altered by the range of hydrogeological parameters tested.

5 GROUNDWATER AND SURFACE WATER MONITORING

It is recommended that the existing Groundwater and Surface Water Monitoring and Contingency Plan (GSWMCP) framework established under the 2018 consent be updated for the expanded operation, incorporating the new groundwater monitoring sites and surface water gauging sites. The existing framework provides an integrated monitoring, trigger and contingency structure covering pit groundwater inflow, quarry pit sump water levels, monitoring bore water levels and surface water flows.

The objectives of the updated programme are to verify the groundwater and surface water effects predicted by this assessment, provide early detection of any responses that exceed the predicted magnitudes, and provide the data required to refine the numerical model as the Quarry develops.

Consistent with the findings of this assessment, the programme places particular emphasis on Streams 1 and 3, which are identified as the principal receptors of predicted baseflow depletion, and on the groundwater monitoring locations closest to the expanding pit (notably GW2N and MW01-Deep). Continued monitoring of the compliance bores retained from the 2018 consent maintains continuity with the historical record and supports the separation of Quarry-induced change from natural climatic variability.

Trigger levels should be derived for the key groundwater and surface water sites from the established baseline ranges and the effects predicted in this assessment and incorporated into the updated GSWMCP. Simulated drawdowns used to inform future trigger levels are presented in Table 15. Exceedance of a trigger would initiate defined investigation and, where warranted, contingency actions. Given the volume of groundwater intercepted by the pit relative to the predicted baseflow reductions in Streams 1 and 3 (Section 4.4), managed stream augmentation using appropriately treated pit water, or an onsite bore if required, represents a practicable contingency measure.

The following recommendations are based on extending the existing monitoring plan to reflect the revised pit geometry and effects identified in this assessment. Monitoring data should be reviewed annually against the model predictions, with the numerical model updated as the monitoring record lengthens and as each extraction stage is completed.

Table 14: Proposed Monitoring Plan

MONITORING COMPONENT	MONITORING SITE	MONITORING FREQUENCY/REQUIREMENT
Piezometers (1)	GW2N; FH1 – Shallow New; FH2 – Shallow; FH2 – Deep; MW01-Deep	At least quarterly groundwater levels.
Piezometers (1)	GW2N (transducer and barometer) and MW01-Deep (transducer);	Automated groundwater-level and barometric-pressure monitoring at 15-minute intervals, with data downloaded and reviewed quarterly.
Manual groundwater checks	All accessible piezometers in the groundwater monitoring network	Manual water-level dips during quarterly downloads, where practicable, to confirm logger performance and datum consistency.
Surface water sites (2)	Trib 1 US; Trib 1 DS; Trib 2 US; Trib 2 DS; Trib 2A US; Trib 2A DS; Trib 3 DS	Continuous water-level monitoring at 15-minute intervals where permanent gauge installations are maintained, with data downloaded and reviewed quarterly.
Surface water flow gauging (2)	Stream 1, Stream 2, Stream 2A and Stream 3 monitoring sites	At least twice yearly during low-flow conditions until a site-specific MALF is established.
Rainfall	On-site rainfall gauge	Continuous rainfall monitoring, reported as daily rainfall totals and reviewed alongside groundwater levels, stream levels and flow-gauging data.
Pit inflow	Quarry pit dewatering discharge/pit inflow measurement location	Annual measurement of pit groundwater inflow, with additional checks following material Quarry-stage changes or where monitoring indicates a change in groundwater response.
Water quality	Dewatering sump discharge; selected stream monitoring sites, including Stream 1 and Stream 3; production bore or representative groundwater source where relevant to augmentation assessment	Annual sampling, and prior to any stream augmentation discharge, for field parameters and laboratory analytes relevant to receiving-water compatibility, including pH, electrical conductivity, suspended solids/turbidity, nutrients, major ions and dissolved metals.
Review and reporting	Groundwater, surface water, rainfall, pit inflow and water-quality dataset	Annual reporting to Council, including review of monitoring trends, rating-curve confidence, and whether groundwater model refinement or updated effects assessment is required.

Note:
(1) Piezometer locations identified in Figure 3.
(2) Surface water sites are located in Figure 4 and coordinates in Table 8.

5.1 Groundwater Level Trigger Framework

Groundwater-level monitoring is recommended to provide an early indication of groundwater responses that may differ from those predicted by the numerical model. The model represents the greywacke as a single groundwater system. Trigger levels are therefore based on the bulk groundwater response at each monitoring location.

The existing monitoring network provides representative coverage of the principal compliance boundaries surrounding the quarry. FH1-Shallow New, located adjacent to the Wairoa River, is proposed as the western compliance monitoring bore. GW2N is proposed as the northern compliance monitoring bore, FH2 as the eastern compliance monitoring bore, and MW01 as the southern compliance monitoring bore. Together, these locations provide coverage of the principal areas where off-site groundwater effects could occur.

Modelled drawdown at these locations provides a rational basis for developing groundwater-level triggers. The predicted maximum drawdowns at the compliance monitoring locations are summarised in Table 15.

Table 15: Simulated Drawdown at Monitoring Wells

MONITORING BORE	COMPLIANCE BOUNDARY	STAGE 1 DRAWDOWN (m)	STAGE 5 DRAWDOWN (m)
FH1-Shallow New	West (Wairoa River)	0.1	0.1
GW2N	North	3.21	3.21
FH2 (1)	East	0.00	0.01
MW01-Deep (2)	South	0.12	100.14 (3)

Note:

(1) Calculated drawdown at the FH2 bores applies to both FH2-Shallow and FH2-Deep.

(2) MW01-Shallow has been excluded as a compliance bore due to its interpreted perched nature.

(3) Bore location is within pit footprint at Stage 5 and does not represent a usable groundwater level trigger as it will be removed during this stage. A replacement monitoring bore will be required.

The model predicts small groundwater-level effects at the western and eastern compliance boundaries, with drawdown remaining below 0.1 m at both FH1-Shallow New and FH2. A larger response is predicted at GW2N, noting that this bore falls within the quarry footprint under both Stage 1 and Stage 5. The largest drawdown is predicted at MW01; however, this bore is located within the future quarry footprint and therefore does not represent a long-term compliance location.

Prior to the Stage 5 expansion into the MW01 location, a replacement monitoring bore should be installed south of the final quarry extent to maintain suitable monitoring coverage. The final location and design of replacement bores can be determined at a later stage once quarry development plans and monitoring data are further advanced.

At present, the available monitoring record is not considered sufficient to establish absolute groundwater-level trigger values. It is therefore recommended that groundwater levels continue to be monitored to establish a longer baseline record and to better characterise natural seasonal and climatic variability. Once an adequate monitoring record has been established, the modelled drawdowns presented above can be applied to the observed groundwater-level dataset to derive site-specific trigger levels.

The trigger levels should be informed by both the modelled drawdown predictions and the observed range of natural groundwater-level fluctuations. This approach will ensure that trigger values are based on site-specific conditions while allowing refinement of the monitoring and management framework as additional groundwater-level data become available.

6 SUMMARY

A numerical groundwater model was developed to assess the proposed expansion of the existing Clevedon Quarry. The assessment evaluated two pit designs from the proposed staged extraction sequence: the Stage 1 Pit Design and the Stage 5 Pit Design ("Life of Quarry"), each simulated against the calibrated Baseline Model.

The numerical model was calibrated against piezometer groundwater level data and MALF-equivalent stream baseflows derived from the available gauging record. Reasonable calibration was achieved, and the groundwater model is considered suitable for the purposes of this assessment. Additional uncertainty analysis indicated that the principal model conclusions remain stable across plausible recharge and hydraulic conductivity ranges, while a separate analytical assessment using Marinelli and Niccoli (2000) produced a pit inflow estimate that closely matched the numerical model result.

Groundwater drawdown is expected to remain localised within the Quarry catchment and does not extend beyond the Wairoa River, indicating negligible risk to surrounding groundwater users.

The predicted stream depletion effects represent reductions in the groundwater-derived baseflow component only and therefore should be interpreted as reductions in groundwater discharge to the streams, rather than equivalent reductions in total streamflow.

Stream depletion effects under the Stage 1 Pit Design were simulated as baseflow reductions of approximately:

- 1.23 L/s (19%) in Stream 1
- 0.37 L/s (25%) in Stream 2
- Less than 0.0001 L/s in Stream 2A
- 0.01 L/s (0.1%) in Stream 3

Groundwater inflow to the pit was simulated at approximately 162 m^3/day (1.88 L/s) under this scenario.

Stream depletion effects under the Stage 5 Pit Design were simulated as baseflow reductions of approximately:

- 3.10 L/s (48%) in Stream 1
- Stream 2 catchment has been largely removed as a result of the Stage 5 Pit Design
- 0.04 L/s (18%) in Stream 2A
- 1.50 L/s (20%) in Stream 3

Groundwater inflow to the pit was simulated at approximately 544 m^3/day (6.30 L/s), or approximately 199,000 m^3/year, under this scenario.

Groundwater inflow to the proposed pit at Stage 5 exceeds the combined predicted baseflow reductions in Streams 1 and 3 (approximately 4.6 L/s) and provides a potential reliable source for streamflow mitigation. As such, with suitable water treatment measures, there is potential for stream augmentation as a practical mitigation measure for offsetting predicted baseflow reductions in Streams 1 and 3 and maintaining environmental flow conditions downstream. The stream augmentation regime should be informed by the updated Groundwater and Surface Water Monitoring and Contingency Plan. Ongoing groundwater and surface water monitoring would be used to confirm the timing, magnitude and location of any baseflow depletion effects, and to refine augmentation requirements.

The proposed quarry expansion will intercept groundwater from the Hunua Wairoa Greywacke aquifer. The site is not located within a High Use Aquifer Management Area or a Water Supply Management Area, and the intercepted groundwater does not represent an abstraction from a highly allocated groundwater resource. Accordingly, the predicted groundwater inflows are not expected to materially affect groundwater availability for other users.

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8 LIMITATIONS

This hydrogeological assessment has been undertaken in accordance with standard industry practice and is based on the best available information at the time of reporting. However, inherent limitations in the data and modelling approach introduce a degree of uncertainty to the findings, and these should be considered when interpreting the results.

This report has been prepared specifically to assess the potential hydrogeological effects associated with the proposed expansion of Clevedon Quarry. It is intended to inform resource consent applications, support environmental assessments, and guide groundwater management planning related to the Quarry development. The findings, interpretations, and model outputs presented herein are based on the available data and the specific scenarios assessed. As such, this report should not be relied upon for environmental assessments outside the defined study area or scope of work.

The conceptual model developed for this assessment is based on a combination of geological mapping, local borehole logs and site investigations. Some generalisations have been made in defining lithological boundaries, hydraulic units, and aquifer characteristics. These assumptions are typical when constructing a workable conceptual and numerical model but contribute to uncertainty in the modelled outputs.

Spatial data coverage is uneven across the study area, with limited borehole and hydrogeological information available in some zones. This restricts the resolution of the model in these areas and limits confidence in the predicted extent of groundwater drawdown and aquifer responses. Additionally, hydraulic conductivity values assigned to model units are derived from a combination of site-specific testing, literature sources, and calibration results. While these values are considered appropriate at the scale of the numerical model, they may not capture localised heterogeneity that could influence flow patterns and groundwater responses.

The numerical groundwater model was constructed using steady-state conditions to simulate long-term effects of pit deepening and expansion. While this provides a useful indication of potential drawdown extent and magnitude, it does not capture short-term or seasonal fluctuations in groundwater levels, nor does it account for time-dependent changes in aquifer response. To provide additional confidence in the assessment, predictive uncertainty was evaluated through alternative recharge and hydraulic conductivity scenarios, and a separate analytical pit inflow assessment was completed using Marinelli and Niccoli (2000).

APPENDIX A
GROUNDWATER MODEL SETUP AND CALIBRATION



Model Packages

Groundwater Vistas is a graphical user interface used to construct, run and evaluate MODFLOW models. This package utilises a suite of MODFLOW software codes for various purposes. GV Version 9.22 Build 3 Premium was used for the construction of this numerical model.

The groundwater flow code MODFLOW-USG, developed by the US Geological Survey, enables modelling of groundwater flow in layered three-dimensional systems using structured or unstructured grids. This is the base code used for groundwater flow simulation in this project.

The numerical packages available in GV and used to simulate the groundwater flow processes in this model include:

- Basic (BAS)
- Output Control (OC)
- Layer Property Flow (LPF)
- Solver (PCG2)
- Discretisation (DIS)
- River (RIV)
- Recharge (RCH)
- Drain (DRN)

Solver

The PCG2 solver is used as the mathematical solver in this model. The solver parameter settings applied for this modelling process are summarised in Table A1.

Table A1: Solver Parameters

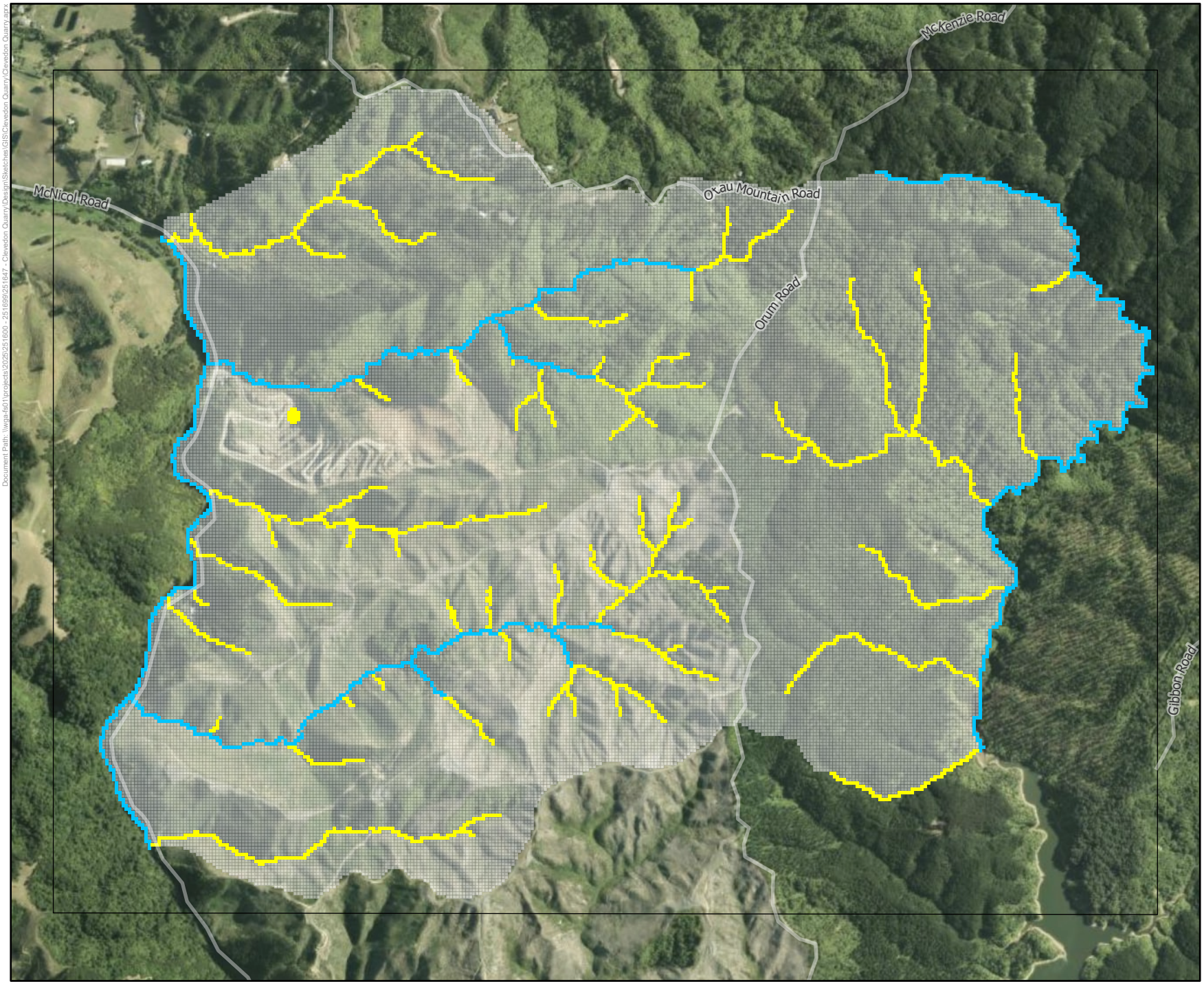
PARAMETER	VALUE
Max outer iterations	100
Max inner iterations	25
Head change criterion	0.001
Residual criterion for convergence	1
Relaxation parameter	1
Matrix preconditioning method	Cholesky
Maximum bound of Eigenvalue	Equal to 2

Model Discretisation

A numerical groundwater model provides an approximation of a complex natural system. Finite difference numerical modelling codes such as MODFLOW require spatial discretisation both horizontally and vertically. Discretisation is achieved by specifying an orthogonal set of rows and columns to form a grid (mesh).

The groundwater model constructed for this project consists of one model layer. The model top is based on the 1 m topographic LIDAR dataset available from LINZ (and merged with pit designs where required).

The single-layer model represents the weathered and fractured greywacke as a single equivalent flow system. It does not explicitly reproduce measured vertical hydraulic gradients or depth-specific responses at paired piezometers. Predictions should therefore be read as bulk-system responses rather than depth-specific drawdown estimates.





LEGEND

- River Cells
- Drain Cells
- Model Grid
- Model Boundary

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **A1**
Model Domain, Grid and Boundary Conditions

Clevedon Quarry

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Any relevance placed on such information shall be at the risk of the user.

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The MODFLOW model domain is rectangular, spanning 2.6 km (N-S) and 3.4 km (E-W), covering an area of 8.84 km2. The model consists of 260 rows and 340 columns (10 m x 10 m cell size). The total model cell count is 88,400, of which 54,294 are active (Figure A1).

Boundary Conditions

Recharge Package (RCH)

Net recharge was applied evenly across the entire model.

River Package (RIV)

The RIV (River) package was selected to represent:

1. The Wairoa River, on the western model boundary
2. An unnamed stream that defines the eastern boundary of the model
3. Streams 1 and 3, on reaches where streamflow was considered permanent

This approach was adopted because it provides a direct means of representing stream-aquifer interactions under varying groundwater conditions. The RIV package calculates flux dynamically based on the difference between groundwater head, river stage, and the hydraulic properties of the riverbed. This allows both groundwater entering a stream (baseflow) and stream leakage to the aquifer (induced infiltration) to be simulated within the same framework.

For assessing stream depletion due to dewatering, this approach is considered useful because it captures localised shifts from natural baseflow contributions to induced losses from a stream, providing a transparent representation of the mechanisms by which dewatering affects streamflow.

River conductance was applied to the model using cell geometry based on satellite imagery and site visit measurements. Stream bed hydraulic conductivity was adjusted during the calibration process.

Drain Package (DRN)

The drain package was used to define the non-permanent segments of Streams 1 and 3, and all additional streams and gully inverts across the model domain. The drain package only simulates the movement of groundwater to surface water, with no capacity for flows in the opposite direction.

Drain conductance was applied to the model using cell geometry based on satellite imagery and site visit measurements. Drain bed hydraulic conductivity was adjusted during the calibration process.

Drain cells were used to simulate the Quarry pit floor and walls. To conservatively assess the effects of the proposed pit designs, drain elevations were assigned to the proposed pit topography in the pit design. As such, all groundwater entering the pit floor and walls is assumed dewatered. Conductance was adopted based on cell geometry (i.e., 10 x 10 m).

Calibration

Introduction

Calibration of groundwater models, or more specifically, inverse modelling, is a process whereby a range of model parameters are adjusted to produce a match between simulated and observed data. The process begins with the initial estimate of parameters (such as hydraulic conductivity, recharge rates and boundary conditions) for each cell in the model domain. The parameters subject to calibration are principally recharge and hydraulic conductivity of the various lithologies.

For this steady-state calibration, an ensemble-based inverse-modelling approach was adopted. Generally, a model realisation is considered acceptable when:

1. The calculated groundwater heads are in 'reasonable' agreement with observed heads.
2. The calculated groundwater discharge fluxes to nearby waterways (base flows) are in 'reasonable' agreement with observed flows.

Pilot-Point Calibration Approach

A pilot-point parameterisation was adopted to represent the complex and spatially heterogeneous hydrogeological conditions across the model domain. The site is underlain predominantly by variably weathered and fractured greywacke, within which groundwater movement is controlled by spatial variations in weathering, fracture density, fracture connectivity and local geological structures. Hydraulic testing at the site returned greywacke hydraulic conductivity values ranging from less than 0.0009 m/day at FH2-Deep to approximately 0.1 m/day at FH2-Shallow, demonstrating considerable local variability within the formation.

These hydraulic characteristics are unlikely to form discrete and laterally continuous units that can be represented reliably using a small number of homogeneous hydraulic-conductivity zones. A conventional zonal approach was not considered suitable for the site and would impose abrupt parameter boundaries that are not supported by the available geological information.

The pilot point calibration process enables horizontal hydraulic conductivity to vary spatially across the model domain. Hydraulic conductivity was adjusted at the pilot-point locations and interpolated between these points to produce a spatially continuous parameter field. This process provides sufficient flexibility to represent localised lower- and higher-permeability areas while maintaining smooth transitions and avoiding artificial boundaries between broad parameter zones.

The resulting cell-by-cell hydraulic-conductivity distribution contains extensive areas of relatively low bulk rock mass conductivity together with localised zones or corridors of higher conductivity. This distribution is consistent with a variably weathered and fractured greywacke aquifer in which groundwater flow may be concentrated through connected fracture networks. The calibrated horizontal hydraulic-conductivity distribution is illustrated in Figure A3. As the model comprises a single layer, vertical hydraulic conductivity is not relevant to the model parameterisation and is not discussed further.

Calibration Using PEST-IES

Model calibration was undertaken using PEST-IES, the Iterative Ensemble Smoother included within the PEST++ software suite. PEST-IES uses an ensemble of parameter realisations and iteratively adjusts these realisations to improve agreement between observed and modelled values. The number of model runs required during each iteration is related to the number of realisations in the ensemble rather than directly to the number of adjustable parameters. This makes the method suitable for highly parameterised models containing many pilot-point parameters.

For this model, PEST-IES was used to adjust the pilot-point hydraulic conductivity and rainfall recharge values within specified parameter bounds while seeking an acceptable combined fit to the groundwater-level and stream-flux observations.

Parameter Ranges

The adjustable model parameters and the ranges adopted for calibration are summarised below in Table A2.

Table A2: Parameter Range and Adopted Values

PARAMETER	LOWER BOUND	UPPER BOUND	ADOPTED VALUE OR BASIS
Horizontal hydraulic conductivity (Kx/Ky)	0.0001 m/day	0.5 m/day	Pilot-point parameter adjusted by PEST-IES
Groundwater recharge	143 mm/year	231 mm/year	180 mm/year adopted

The lower bound of 0.0001 m/day was informed by testing of FH2-Deep, which returned a hydraulic conductivity of less than 0.0009 m/day and was associated with very slow hydraulic recovery in the deep fresh greywacke. A lower pilot-point bound for hydraulic conductivity, approximately one order of magnitude below the lowest test result, was adopted for the calibration process to allow for portions of the model domain that may be less permeable than the discrete interval tested at FH2-Deep. This accommodates very tight, poorly fractured or weakly connected greywacke while retaining a finite conductivity and avoiding unrealistically impermeable model cells.

The upper bound for hydraulic conductivity of 0.5 m/day was informed by the FH2-Shallow test, which returned a hydraulic conductivity of approximately 0.1 m/day within weathered greywacke. The upper calibration bound was set above this measured value to recognise that a local test samples only a limited volume of material and may not intersect the most transmissive connected fractures or weathered pathways present within a model cell. The 0.5 m/day bound enables PEST-IES to represent localised areas that are more transmissive than the tested FH2-Shallow interval without extending into the much higher conductivity range associated with the river alluvium at FH1-Shallow. This distinction is important because the FH1-Shallow result of approximately 4.93 m/day relates to alluvial material and is not representative of the greywacke aquifer.

The adopted conductivity range encompasses the tested greywacke values and provides allowance for unresolved fracture-scale variability of the fresh and weathered greywacke. The bounds were sufficiently wide to avoid unnecessarily constraining the calibration but were narrow enough to prevent compensation through hydraulic conductivity values that are not considered representative of the modelled greywacke domain.

Groundwater Recharge

Groundwater recharge was informed by the baseflow assessment summarised in Table 10, which indicated a recharge-equivalent range of approximately 143 to 231 mm/year. A spatially uniform recharge rate of 180 mm/year, equivalent to approximately 0.000493 m/day, was accepted following the steady-state calibration process.

Groundwater Level Calibration

The steady-state groundwater-level calibration used six observations distributed across the model domain based on the midpoint of the available PDP (2017) groundwater-level range, and from field measurements recorded by WGA (Table A3). The PDP (2017) data were adopted in preference to more recent records because they represent groundwater conditions least affected by quarry activity. This provides a baseline calibration consistent with the steady-state, pre-expansion conditions the model is intended to represent.

The model reproduced the principal groundwater-elevation pattern across the site. The mean residual was +0.79 m, indicating a small overall tendency for modelled heads to be lower than observed heads. The absolute mean residual was 1.62 m and the root mean square error was 2.25 m. The scaled root mean square error was approximately 1.09% of the observed groundwater-level range (Table A4).

Table A3: Modelled Head vs Observed Head

BORE	OBSERVED HEAD (m RL)	MODELLED HEAD (m RL)	RESIDUAL (m)
FH1-Deep	15.77	15.89	-0.12
FH2-Shallow	209.84	209.45	0.39
FH3-Shallow	176.20	174.14	2.06
GW2N	26.23	27.02	-0.79
MW01-Deep	222.56	217.78	4.78
GW1	26.50	28.10	-1.60

Table A4: Head Calibration Targets

STATISTICS	VALUE
Residual Mean (m)	0.79
Absolute Residual Mean (m)	1.62
Residual Std. Deviation (m)	2.11
Sum of Squares	30.49
RMS Error (m)	2.25
Min. Residual (m)	-1.60
Max. Residual (m)	4.78
Number of Observations (#)	6
Range in Observations (m)	206.8
Scaled Residual Std. Deviation (%)	1.0%
Scaled Absolute Residual Mean (%)	0.8%
Scaled RMS Error (%)	1.1%
Scaled Residual Mean (%)	0.4%

According to Barnett et al. (2012), a scaled RMS error of less than 10% is considered an acceptable indicator of model calibration performance. The head calibration satisfies the scaled-RMS guideline at the model-domain scale. However, this statistic is influenced by the large observed head range and small number of calibration targets. Model suitability therefore also depends on the spatial pattern of residuals, the stream-flux calibration and the predictive uncertainty assessment.

Stream-Flux Calibration

Stream-flux calibration targets were based on estimated MALF-equivalent baseflows derived from the available stream-gauging results. MALF-equivalent baseflow was used instead of mean gauged flow because the steady-state calibration was intended to represent sustained low-flow groundwater discharge to the streams.

Modelled groundwater discharge was extracted using ZoneBudget areas corresponding to the stream catchments. For Zone Budgets containing river cells, modelled groundwater discharge was calculated as river outflow minus river inflow, plus drain outflow. River inflow represents movement of water from the river into the groundwater system and was therefore deducted when calculating net groundwater discharge to the stream.

The model generally reproduces the magnitude and spatial distribution of the streamflow targets. While some residual differences remain at Stream 1 US and Stream 2A DS, these are considered reasonable given the uncertainty associated with low-flow gauging and the limited monitoring dataset available. In particular, the Stream 2A DS comparison should be interpreted cautiously due to the very small measured flows and the lower confidence in the flow estimation methodology at this location (Table A5).

Collectively, the flux results indicate that the calibrated model reproduces the magnitude of groundwater discharge to the stream system and provides an acceptable representation of stream-aquifer interaction at the site.

Table A5: Stream Flux Modelled vs Observation

STREAM REPRESENTATION	MODEL COMPONENTS	MODELLED FLUX (m^3/day)	MODELLED FLUX (L/s)	TARGET (L/s)	DIFFERENCE (L/s)
Stream 1 US	Net river discharge plus drains	520.01	6.02	4.5	+1.52
Stream 1 DS (1)	Downstream validation result	557.99	6.46	7.5	-1.04
Stream 2 DS	Drains	124.27	1.44	1.5	-0.06
Stream 2A DS	Drains	13.42	0.16	0.1	+0.06
Stream 3	Net river discharge plus drains	655.57	7.59	7.2	+0.39

Note:

(1) Stream 1 DS was not included directly as a calibration target. It was assessed separately as a validation result.

Mass Balance

The steady-state calibration model exhibits a reasonable mass balance, with total inflows and outflows both equal to approximately 3,170 m^3/day and a negligible numerical error (Table A6).

Table A6: Model-wide Mass Balance

DESCRIPTION	INFLOW (m^3/day)	OUTFLOW (m^3/day)
Recharge	2.68E+03	0.00E+00
River	4.89E+02	1.67E+03
Drain	0.00E+00	1.50E+03
TOTAL	3.17E+03	3.17E+03
ERROR	-0.00000749	

Overall Calibration Model Summary

The steady-state model achieved a satisfactory calibration against both groundwater-level and streamflow observations. Groundwater levels were reproduced with a mean absolute residual of 1.62 m and a scaled RMS error of approximately 1.1% across an observed head range of approximately 207 m. Simulated stream baseflows were generally consistent with the MALF-equivalent calibration targets and the independent downstream validation check. Mass balance error was negligible. On this basis, the model is considered suitable to provide an appropriate representation of the groundwater system for assessment of groundwater levels, stream baseflow and Quarry dewatering effects.

The simulated piezometric heads across the modelled domain of the calibrated baseline model are compared graphically to the groundwater level targets in Figure A2. The resulting distribution of hydraulic conductivity across the modelled domain is presented in Figure A3.

Sensitivity Analysis

A local sensitivity analysis was undertaken by applying multipliers of 0.90, 0.95, 1.00, 1.05 and 1.10 to selected model parameters. The multiplier of 1.00 represents the calibrated model. The calibrated hydraulic-conductivity field and uniform recharge rate were varied model-wide, while river and drain parameters were varied separately for the relevant boundary groups.

For Streams 1 and 3, the river and drain components were assessed separately. Separate river-cell and drain-cell flux observations were established using the corresponding fluxes extracted from the calibrated model. This enabled the response of each boundary component to be examined independently, where the calibration assessment had previously combined these components using the ZoneBudget results. As such, the sensitivity-analysis objective function is the combined weighted objective function for groundwater-head and stream-flux observations, and not directly comparable to the results from Table A4.

Results

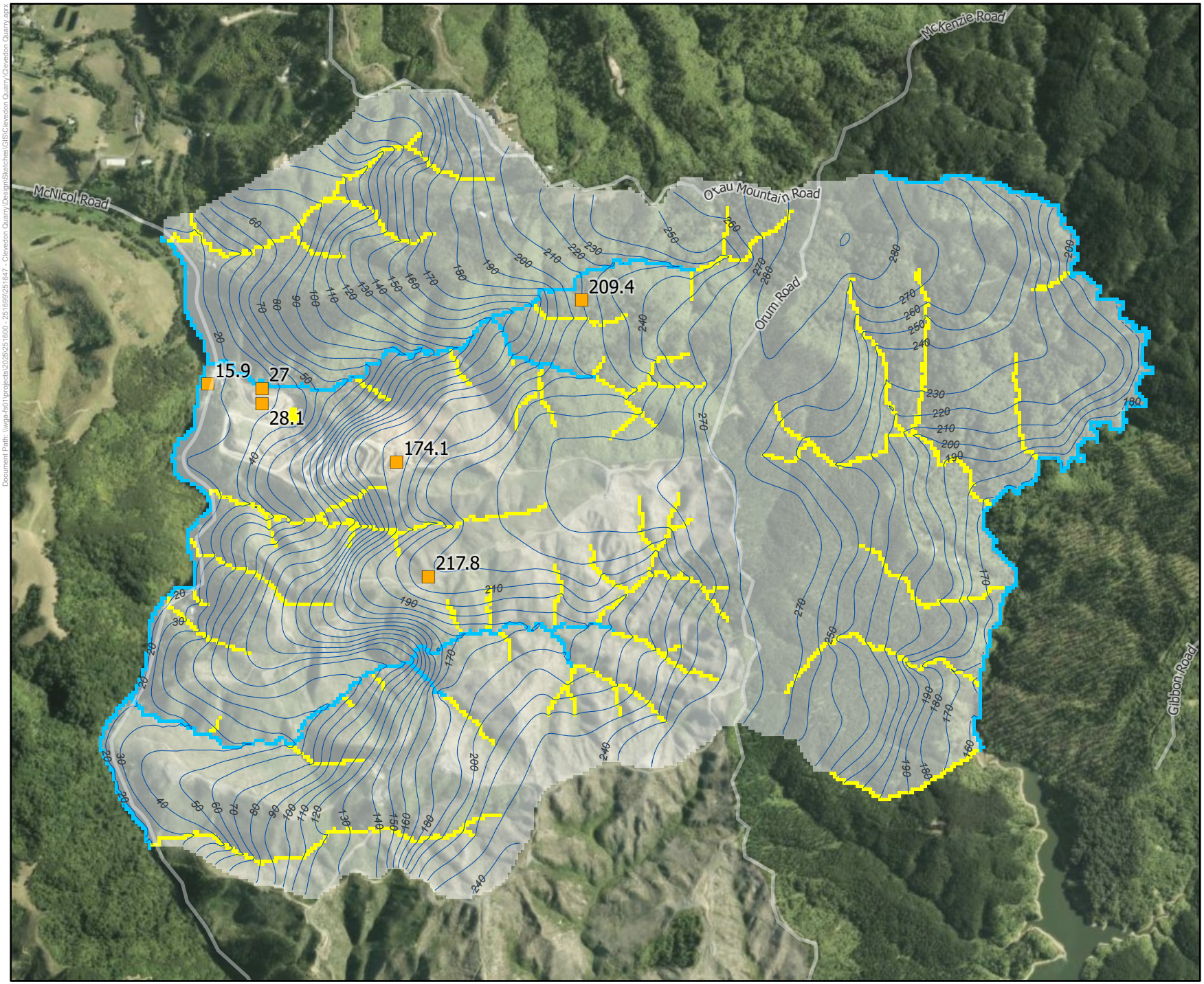
The sensitivity analysis results indicate that the model is most responsive to changes in selected river and drain elevations, followed by recharge. Model-wide hydraulic conductivity and conductance parameters produce smaller responses. Most river and drain conductance parameters produced comparatively small changes.

The results, which are ranked in Figures A4 and A5 and presented numerically in Table A7, indicate that the model is most sensitive to selected river and drain stage elevations, particularly Stream 3, Stream 1, and the eastern boundary. Recharge exhibited moderate sensitivity, while model-wide hydraulic conductivity produced a comparatively smaller response in the bulk calibration statistics. River and drain conductance parameters had negligible influence on calibration performance over the ±10% range tested.

It is important to note that the highest-ranked parameters are stage-based boundary conditions with relatively large absolute elevations. In several locations these stages approach 300 mRL. Consequently, a ±10% sensitivity adjustment represents a substantial physical change in boundary elevation (for example, approximately ±30 m at a 300 mRL boundary). That is, multiplying absolute elevations primarily performs as a diagnostic stress test rather than a physically plausible uncertainty range.

Conductance sensitivity was consistently low, with all river- and drain-conductance parameters producing less than approximately 0.1% change in calibration RSS across the tested range. This indicates that model predictions are primarily controlled by recharge, hydraulic gradients and boundary elevations rather than by uncertainty in conductance values.

Overall, the analysis indicates that the calibrated model is most sensitive to parameters that directly control groundwater gradients and discharge elevations. Recharge remains an important model-wide control, while uncertainty associated with river and drain conductance values is unlikely to materially influence model predictions within the range tested.





LEGEND

- Calibration Target (m RL)
- Groundwater Head (m RL) Calibration Heads
- River Cells
- Drain Cells
- Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

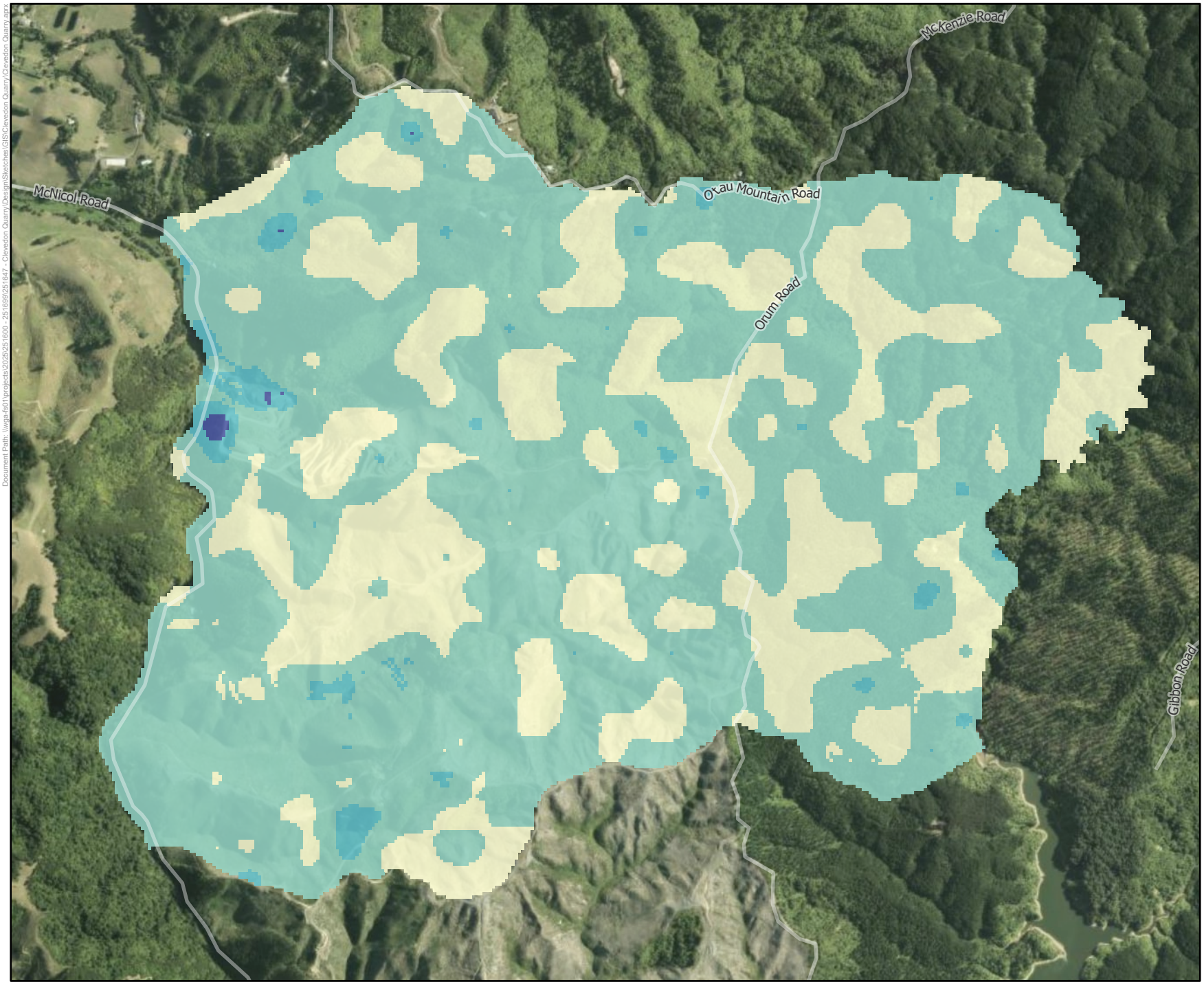
Figure **A2**
Modelled Baseline Heads

Clevedon Quarry

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LEGEND

Kx (m/day)

- 0.0001 - 0.001
- 0.001 - 0.01
- 0.01 - 0.05
- 0.05 - 0.5

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **A3**
Hydraulic Conductivity

Clevedon Quarry

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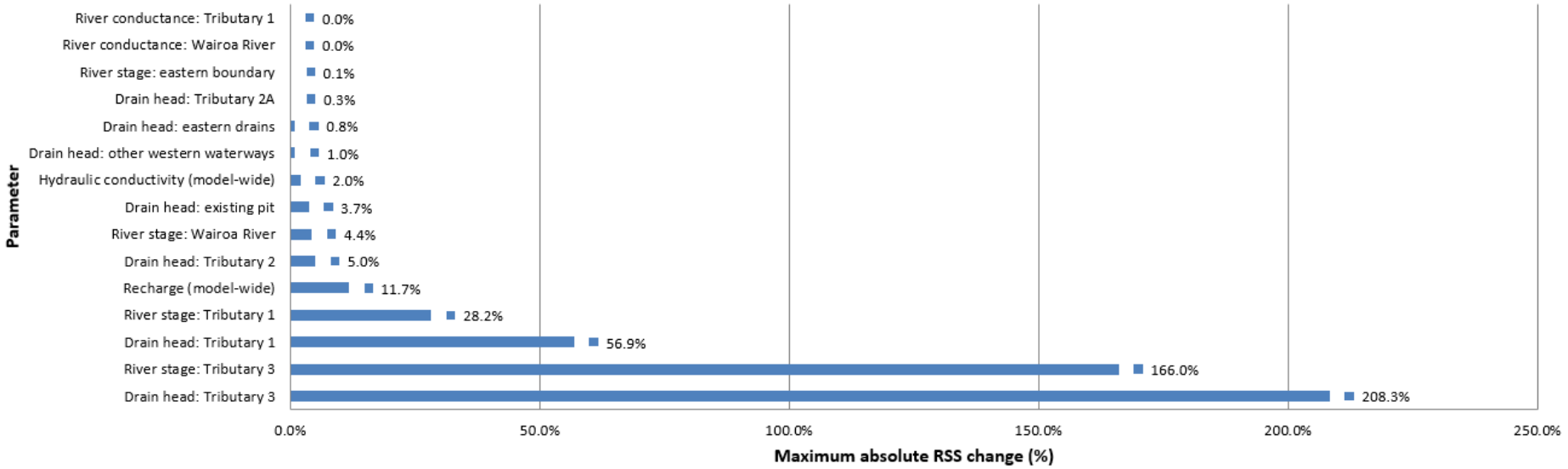


Figure A4: Sensitivity Ranking by Maximum RSS Change

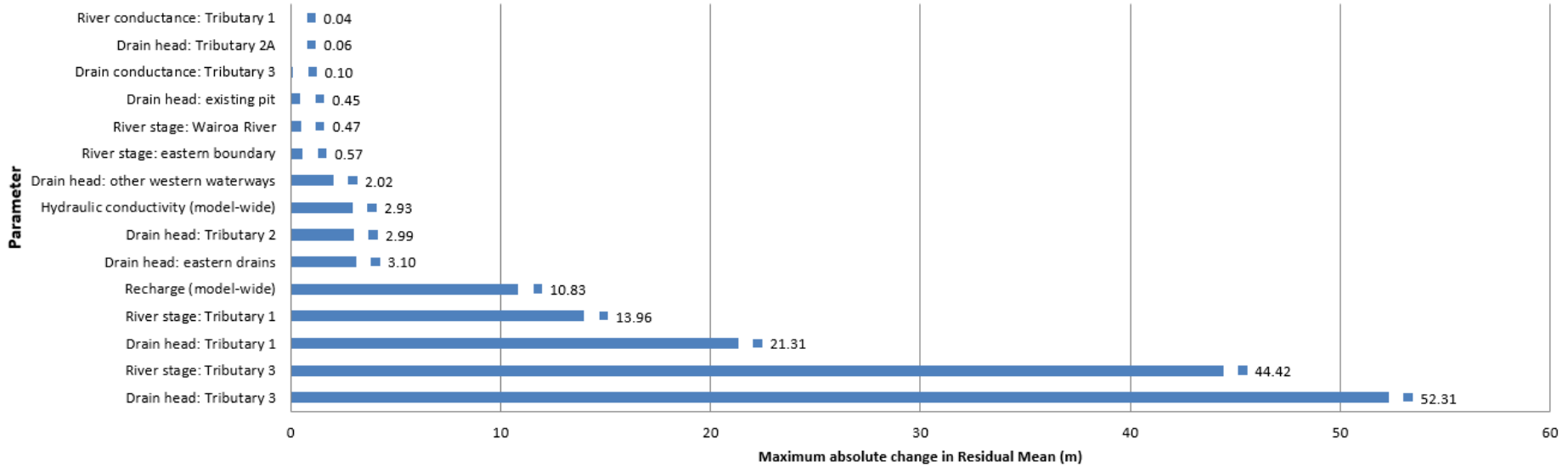


Figure A5: Sensitivity Ranking by Maximum Absolute Change in Residual Mean

Table A7: Sensitivity Analysis Output

PARAMETER	PARAMETER LABEL	MULTIPLIER	SUM OF SQUARES	RESIDUAL MEAN	RESIDUAL STD.	CONVERGED
Kx	Hydraulic conductivity (model-wide)	0.9	72200	32.89	74.89	Yes
Kx	Hydraulic conductivity (model-wide)	0.95	72700	32.29	75.24	Yes
Kx	Hydraulic conductivity (model-wide)	1	73300	32.07	75.66	Yes
Kx	Hydraulic conductivity (model-wide)	1.05	74000	33.56	76.10	Yes
Kx	Hydraulic conductivity (model-wide)	1.1	74800	35.01	76.54	Yes
Recharge	Recharge (model-wide)	0.9	81900	42.90	76.39	Yes
Recharge	Recharge (model-wide)	0.95	76900	37.41	75.73	Yes
Recharge	Recharge (model-wide)	1	73300	32.07	75.66	Yes
Recharge	Recharge (model-wide)	1.05	71300	34.78	76.19	Yes
Recharge	Recharge (model-wide)	1.1	70700	37.68	77.33	Yes
River Conductance	River conductance: Wairoa River	0.9	73300	32.07	75.66	Yes
River Conductance	River conductance: Wairoa River	0.95	73300	32.07	75.66	Yes
River Conductance	River conductance: Wairoa River	1	73300	32.07	75.66	Yes
River Conductance	River conductance: Wairoa River	1.05	73300	32.07	75.66	Yes
River Conductance	River conductance: Wairoa River	1.1	73300	32.07	75.66	Yes
River Conductance	River conductance: Stream 1	0.9	73300	32.11	75.67	Yes
River Conductance	River conductance: Stream 1	0.95	73300	32.09	75.66	Yes
River Conductance	River conductance: Stream 1	1	73300	32.07	75.66	Yes
River Conductance	River conductance: Stream 1	1.05	73300	32.09	75.65	Yes
River Conductance	River conductance: Stream 1	1.1	73300	32.11	75.65	Yes
River Conductance	River conductance: Stream 3	0.9	73300	32.07	75.66	Yes
River Conductance	River conductance: Stream 3	0.95	73300	32.07	75.66	Yes
River Conductance	River conductance: Stream 3	1	73300	32.07	75.66	Yes
River Conductance	River conductance: Stream 3	1.05	73300	32.07	75.66	Yes

PARAMETER	PARAMETER LABEL	MULTIPLIER	SUM OF SQUARES	RESIDUAL MEAN	RESIDUAL STD.	CONVERGED
River Conductance	River conductance: Stream 3	1.1	73300	32.08	75.66	Yes
River Conductance	River conductance: eastern boundary	0.9	73300	32.07	75.66	Yes
River Conductance	River conductance: eastern boundary	0.95	73300	32.07	75.66	Yes
River Conductance	River conductance: eastern boundary	1	73300	32.07	75.66	Yes
River Conductance	River conductance: eastern boundary	1.05	73300	32.07	75.66	Yes
River Conductance	River conductance: eastern boundary	1.1	73300	32.07	75.66	Yes
River Stage	River stage: Wairoa River	0.9	-	-	-	No
River Stage	River stage: Wairoa River	0.95	74900	32.39	76.49	Yes
River Stage	River stage: Wairoa River	1	73300	32.07	75.66	Yes
River Stage	River stage: Wairoa River	1.05	71700	31.85	74.82	Yes
River Stage	River stage: Wairoa River	1.1	70100	31.60	73.97	Yes
River Stage	River stage: Stream 1	0.9	-	-	-	No
River Stage	River stage: Stream 1	0.95	-	-	-	No
River Stage	River stage: Stream 1	1	73300	32.07	75.66	Yes
River Stage	River stage: Stream 1	1.05	77500	38.71	80.34	Yes
River Stage	River stage: Stream 1	1.1	94000	46.03	90.79	Yes
River Stage	River stage: Stream 3	0.9	-	-	-	No
River Stage	River stage: Stream 3	0.95	-	-	-	No
River Stage	River stage: Stream 3	1	73300	32.07	75.66	Yes
River Stage	River stage: Stream 3	1.05	93000	49.97	86.41	Yes
River Stage	River stage: Stream 3	1.1	195000	76.49	129.39	Yes
River Stage	River stage: eastern boundary	0.9	-	-	-	No
River Stage	River stage: eastern boundary	0.95	-	-	-	No
River Stage	River stage: eastern boundary	1	73300	32.07	75.66	Yes
River Stage	River stage: eastern boundary	1.05	73300	32.34	75.77	Yes

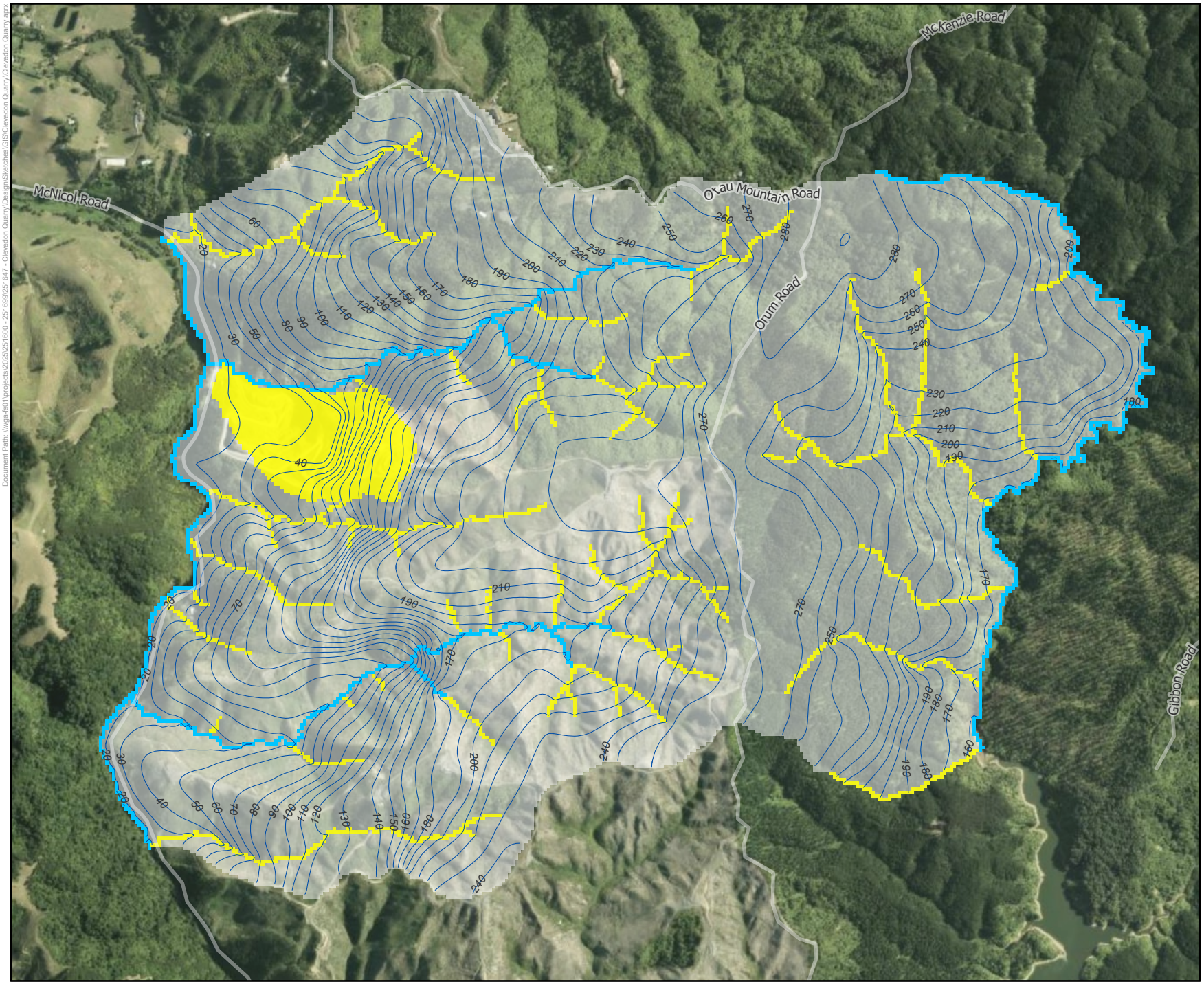
PARAMETER	PARAMETER LABEL	MULTIPLIER	SUM OF SQUARES	RESIDUAL MEAN	RESIDUAL STD.	CONVERGED
River Stage	River stage: eastern boundary	1.1	73400	32.64	75.91	Yes
Drain Conductance	Drain conductance: other western waterways	0.9	73300	32.09	75.66	Yes
Drain Conductance	Drain conductance: other western waterways	0.95	73300	32.08	75.66	Yes
Drain Conductance	Drain conductance: other western waterways	1	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: other western waterways	1.05	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: other western waterways	1.1	73300	32.07	75.65	Yes
Drain Conductance	Drain conductance: Stream 1	0.9	73300	32.10	75.64	Yes
Drain Conductance	Drain conductance: Stream 1	0.95	73300	32.09	75.65	Yes
Drain Conductance	Drain conductance: Stream 1	1	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 1	1.05	73300	32.09	75.66	Yes
Drain Conductance	Drain conductance: Stream 1	1.1	73300	32.11	75.67	Yes
Drain Conductance	Drain conductance: Stream 2	0.9	73300	32.08	75.66	Yes
Drain Conductance	Drain conductance: Stream 2	0.95	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 2	1	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 2	1.05	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 2	1.1	73300	32.07	75.65	Yes
Drain Conductance	Drain conductance: Stream 3	0.9	73300	32.17	75.65	Yes
Drain Conductance	Drain conductance: Stream 3	0.95	73300	32.12	75.65	Yes
Drain Conductance	Drain conductance: Stream 3	1	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 3	1.05	73300	32.08	75.66	Yes
Drain Conductance	Drain conductance: Stream 3	1.1	73300	32.08	75.66	Yes
Drain Conductance	Drain conductance: eastern drains	0.9	73300	32.08	75.66	Yes
Drain Conductance	Drain conductance: eastern drains	0.95	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: eastern drains	1	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: eastern drains	1.05	73300	32.08	75.66	Yes

PARAMETER	PARAMETER LABEL	MULTIPLIER	SUM OF SQUARES	RESIDUAL MEAN	RESIDUAL STD.	CONVERGED
Drain Conductance	Drain conductance: eastern drains	1.1	73300	32.08	75.65	Yes
Drain Conductance	Drain conductance: Stream 2A	0.9	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 2A	0.95	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 2A	1	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 2A	1.05	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: Stream 2A	1.1	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: existing pit	0.9	73300	32.07	75.65	Yes
Drain Conductance	Drain conductance: existing pit	0.95	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: existing pit	1	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: existing pit	1.05	73300	32.07	75.66	Yes
Drain Conductance	Drain conductance: existing pit	1.1	73300	32.07	75.66	Yes
Drain Head	Drain head: other western waterways	0.9	74000	34.09	75.21	Yes
Drain Head	Drain head: other western waterways	0.95	73600	33.03	75.40	Yes
Drain Head	Drain head: other western waterways	1	73300	32.07	75.66	Yes
Drain Head	Drain head: other western waterways	1.05	73100	32.90	75.91	Yes
Drain Head	Drain head: other western waterways	1.1	73000	33.68	76.19	Yes
Drain Head	Drain head: Stream 1	0.9	115000	53.38	101.38	Yes
Drain Head	Drain head: Stream 1	0.95	83800	42.59	84.47	Yes
Drain Head	Drain head: Stream 1	1	73300	32.07	75.66	Yes
Drain Head	Drain head: Stream 1	1.05	78400	39.47	75.79	Yes
Drain Head	Drain head: Stream 1	1.1	90100	45.55	80.14	Yes
Drain Head	Drain head: Stream 2	0.9	69800	32.87	74.44	Yes
Drain Head	Drain head: Stream 2	0.95	71300	32.42	74.89	Yes
Drain Head	Drain head: Stream 2	1	73300	32.07	75.66	Yes
Drain Head	Drain head: Stream 2	1.05	75300	33.49	76.46	Yes

PARAMETER	PARAMETER LABEL	MULTIPLIER	SUM OF SQUARES	RESIDUAL MEAN	RESIDUAL STD.	CONVERGED
Drain Head	Drain head: Stream 2	1.1	77000	35.06	77.09	Yes
Drain Head	Drain head: Stream 3	0.9	226000	84.38	140.47	Yes
Drain Head	Drain head: Stream 3	0.95	101000	54.28	91.20	Yes
Drain Head	Drain head: Stream 3	1	73300	32.07	75.66	Yes
Drain Head	Drain head: Stream 3	1.05	78700	41.91	78.37	Yes
Drain Head	Drain head: Stream 3	1.1	90300	49.31	84.43	Yes
Drain Head	Drain head: eastern drains	0.9	73900	35.17	74.69	Yes
Drain Head	Drain head: eastern drains	0.95	73500	33.62	75.10	Yes
Drain Head	Drain head: eastern drains	1	73300	32.07	75.66	Yes
Drain Head	Drain head: eastern drains	1.05	73400	33.53	76.31	Yes
Drain Head	Drain head: eastern drains	1.1	73800	35.00	77.08	Yes
Drain Head	Drain head: Stream 2A	0.9	73500	32.13	75.71	Yes
Drain Head	Drain head: Stream 2A	0.95	73400	32.10	75.68	Yes
Drain Head	Drain head: Stream 2A	1	73300	32.07	75.66	Yes
Drain Head	Drain head: Stream 2A	1.05	73200	32.04	75.63	Yes
Drain Head	Drain head: Stream 2A	1.1	73200	32.02	75.62	Yes
Drain Head	Drain head: existing pit	0.9	76000	32.52	77.08	Yes
Drain Head	Drain head: existing pit	0.95	74600	32.28	76.32	Yes
Drain Head	Drain head: existing pit	1	73300	32.07	75.66	Yes
Drain Head	Drain head: existing pit	1.05	72200	31.88	75.05	Yes
Drain Head	Drain head: existing pit	1.1	71300	31.73	74.56	Yes

APPENDIX B
PREDICTIVE MODEL RESULTS







LEGEND

- River Cells
- Drain Cells
- Groundwater Head (m RL)
- Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

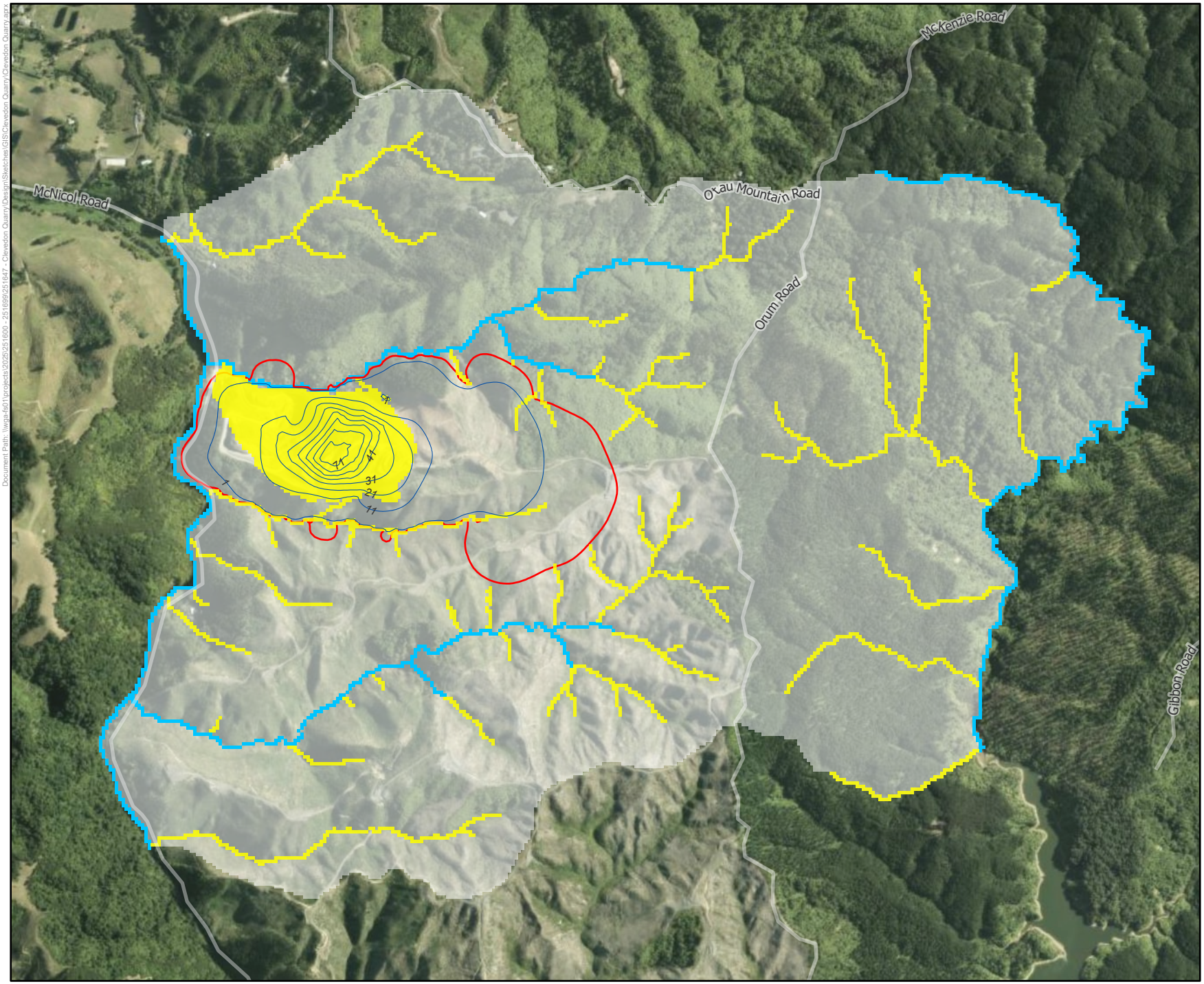
Figure **B1**
Proposed Stage 1 Heads

Clevedon Quarry

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Document Path: \\wga-fs01\projects\2025\251600 - 251699\251647 - Clevedon Quarry\Design\Sketches\GIS\Clevedon Quarry\Clevedon Quarry.aprx





LEGEND

- River Cells
- Drain Cells
- Drawdown (m)
- Zone of Influence (0.25 m drawdown)
- Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

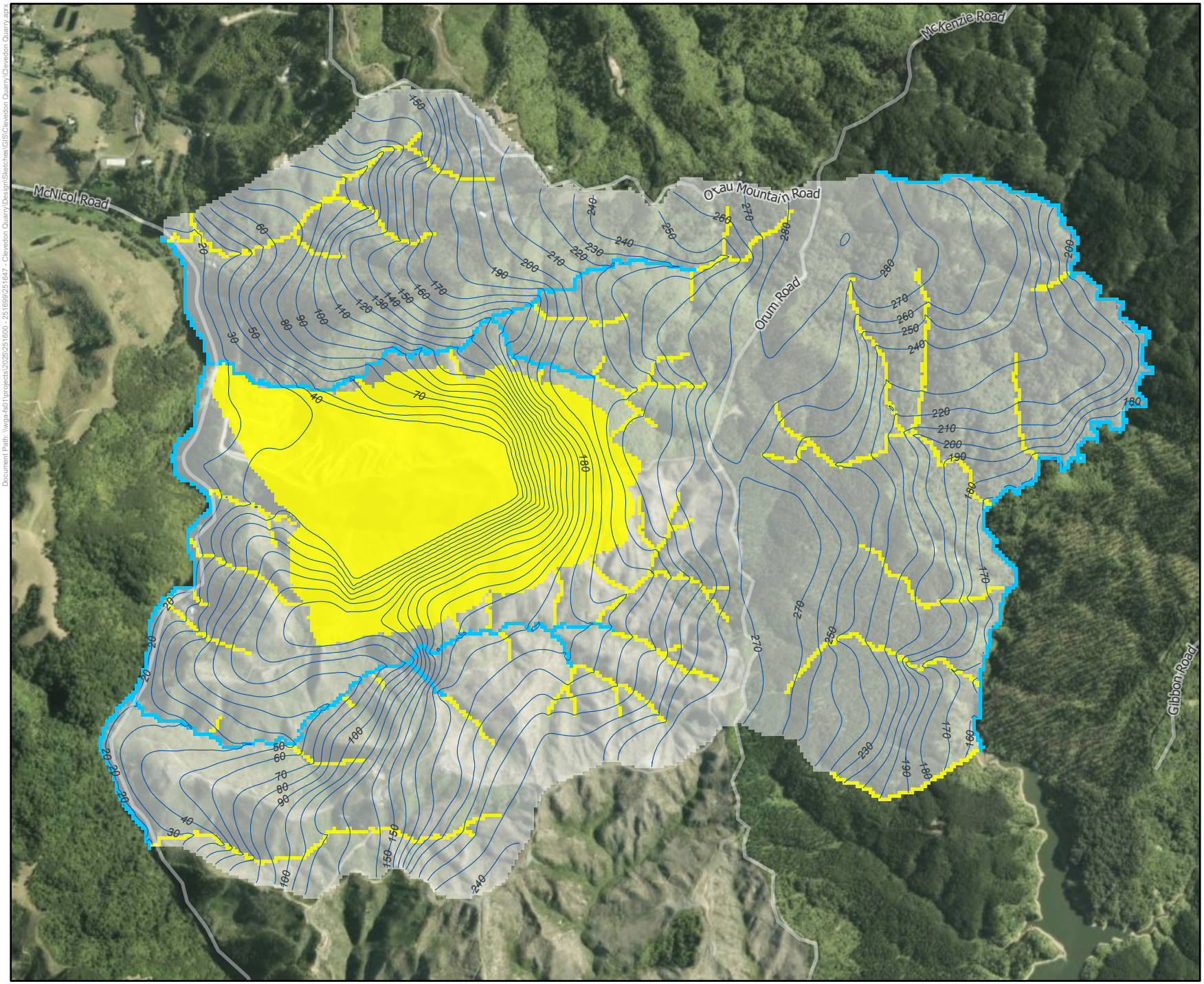
Figure **B2**
Proposed Stage 1 Drawdown

Clevedon Quarry

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Any relevance placed on such information shall be at the risk of the user.

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LEGEND

- Groundwater Head (m RL)
- Drain Cells
- River Cells
- Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

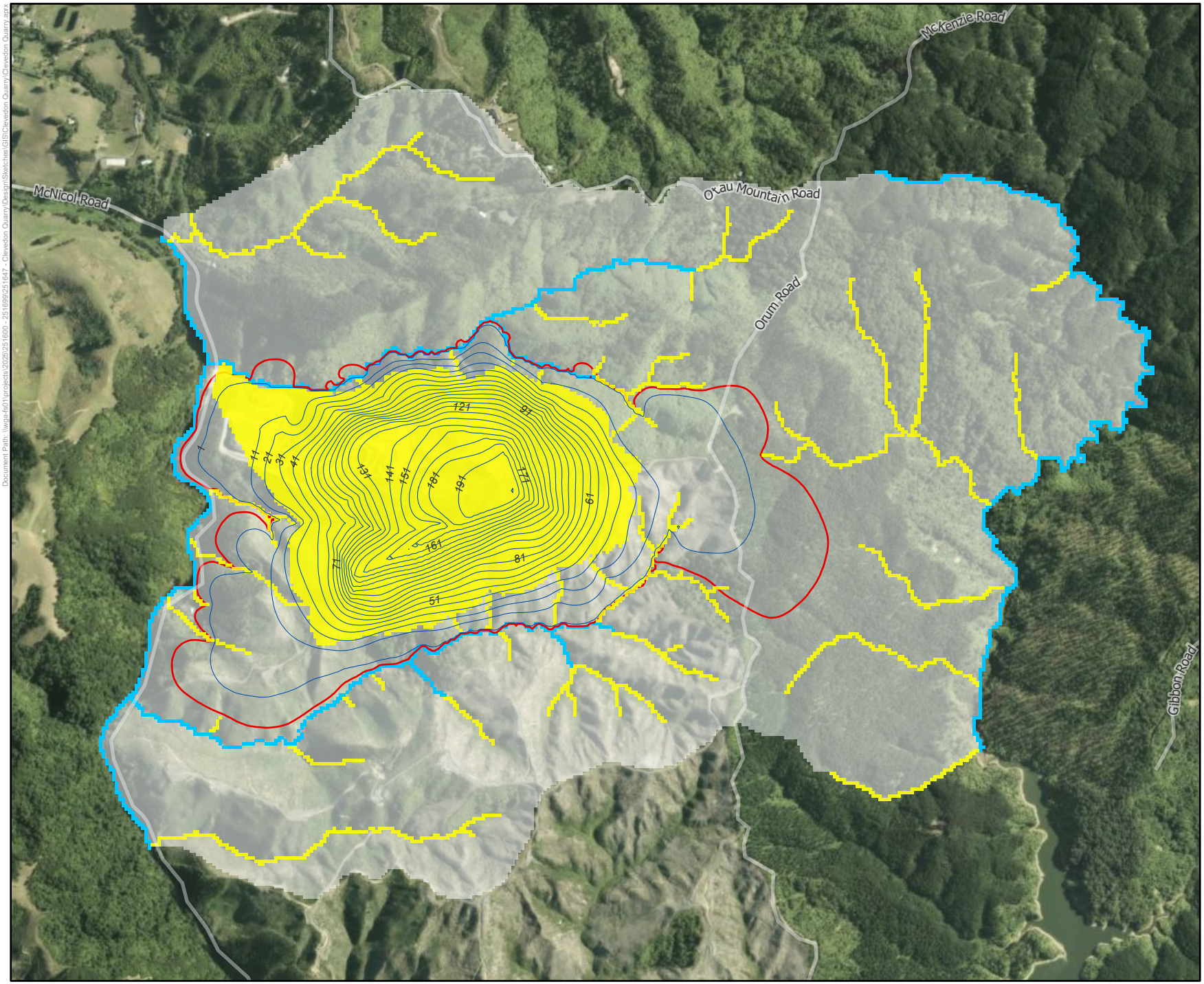
Figure **B3**
Proposed Stage 5 Heads

Clevedon Quarry

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Any relevance placed on such information shall be at the risk of the user.

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LEGEND

- Drawdown (m)
- Zone of Influence (0.25 m drawdown)
- Drain Cells
- River Cells
- Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure **B4**
Proposed Stage 5 Drawdown

Clevedon Quarry

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Any relevance placed on such information shall be at the risk of the user.

Note: The information shown on this map is a copyright of WGA 2026

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Table B1: Stage 1 Pit Design Depletion Rates and Percentage Change

STREAM/REACH	BASELINE NET GAIN (L/S)	STAGE 1 NET GAIN (L/S)	STAGE 1 DEPLETION (L/S)	STAGE 1 DEPLETION (%)
Stream 1	6.45	5.22	1.23	19.0%
Stream 2	1.47	1.10	0.37	25.1%
Stream 2A	0.24	0.24	0.00	0.0%
Stream 3	7.62	7.61	0.01	0.1%

Table B2: Stage 5 Pit Design Depletion Rates and Percentage Change

STREAM/REACH	BASELINE NET GAIN (L/S)	STAGE 5 NET GAIN (L/S)	STAGE 5 DEPLETION (L/S)	STAGE 5 DEPLETION (%)
Stream 1	6.45	3.36	3.10	48.0%
Stream 2 (1)	1.47	0.13	1.34	91.3%
Stream 2A	0.24	0.19	0.04	17.6%
Stream 3	7.62	6.12	1.50	19.6%

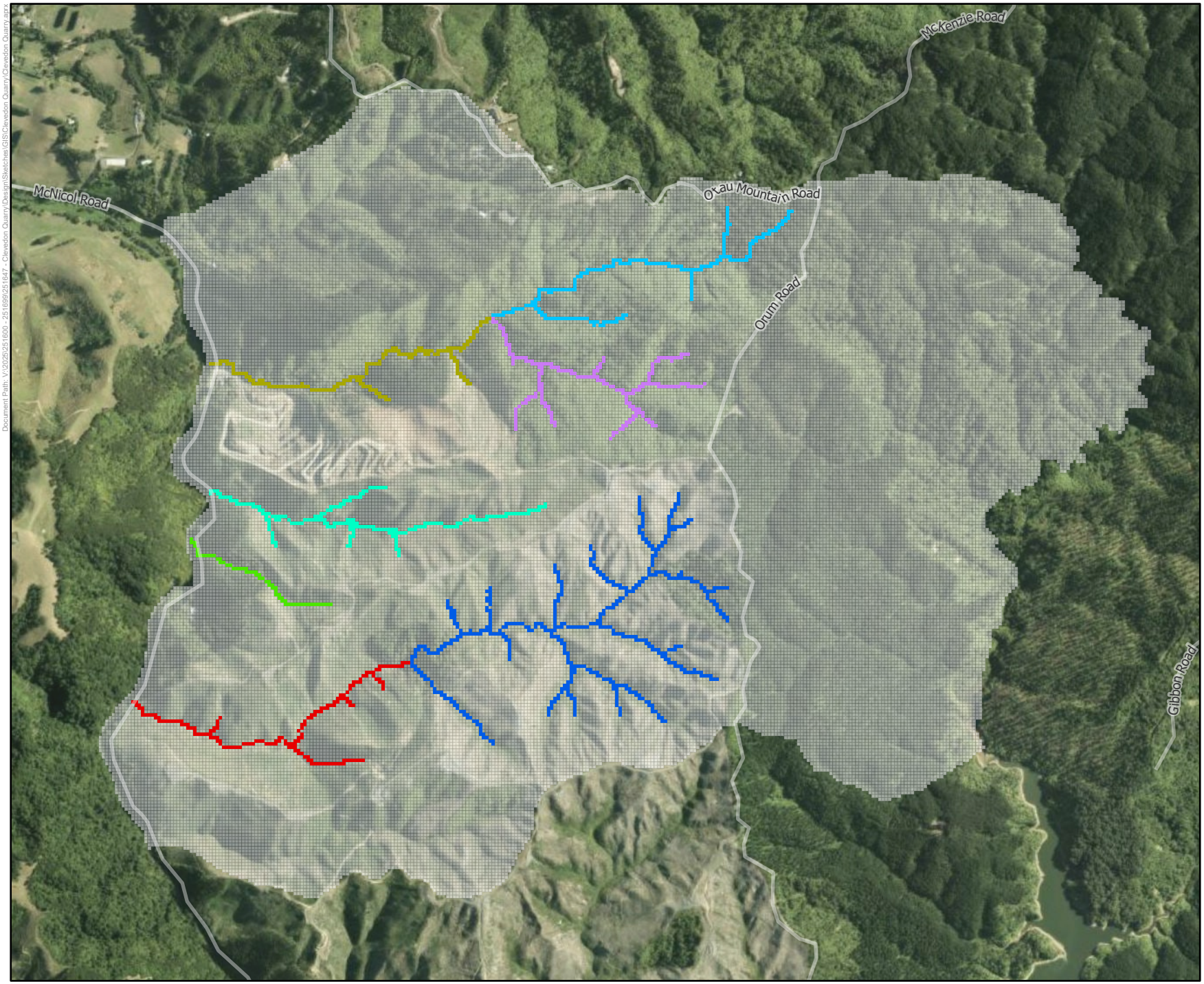
Note:
(1) Under the Stage 5 geometry, most of Stream 2 and its contributing catchment are incorporated into the pit footprint. The modelled reduction of 1.34 L/s therefore primarily reflects removal or interception of the existing drainage system rather than depletion of a fully retained downstream watercourse.

Table B3: Stage 1 and Stage 5 Depletion Rates on Remaining Watercourses

DESCRIPTION	BASELINE (m^3/day)	STAGE 1 (m^3/day)	STAGE 5 (m^3/day)
Wairoa River	172.8	165.8	164.3
Western Streams	370.3	370.3	368.7
Eastern Streams	470.7	470.7	469.2
Eastern boundary river	283.8	283.8	283.8

Table B4: Stage 1 and Stage 5 Pit Inflow

DESCRIPTION	BASELINE (m^3/day)	STAGE 1 (m^3/day)	STAGE 5 (m^3/day)
Pit inflow capture	25	162.1	544.4





LEGEND

Stream Segments

- Trib 1.1
- Trib 1.2
- Trib 1.3
- Trib 2
- Trib 2A
- Trib 3.1
- Trib 3.2

Model Area

N

0 100 200 300 400 m

Scale 1:16,000 @ A4

Coordinate System: NZGD 2000 New Zealand Transverse Mercator

WGA

Figure B**5**
Stream Segments

Clevedon Quarry

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Any relevance placed on such information shall be at the risk of the user.

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Document Path: V:\2026\2516\00 - 251699\2516\47 - Clevedon Quarry\Design\Sketches\GIS\Clevedon Quarry\Clevedon Quarry.aprx

Table B5: Stage 1 Pit Design Depletion Rates and Percentage Change

STREAM/REACH	BASELINE NET GAIN (L/s)	STAGE 1 NET GAIN (L/s)	STAGE 1 DEPLETION (L/s)	STAGE 1 DEPLETION (%)
Stream 1 - Segment 1	2.57	1.35	1.22	47.4%
Stream 1 - Segment 2	2.39	2.39	0.00	0.0%
Stream 1 - Segment 3	1.49	1.48	0.01	0.6%
Stream 2	1.47	1.10	0.37	25.1%
Stream 2A	0.24	0.24	0.00	0.0%
Stream 3 - Segment 1	4.25	4.25	0.00	0.0%
Stream 3 - Segment 2	3.37	3.36	0.01	0.3%

Table B6: Stage 5 Pit Design Depletion Rates and Percentage Change

STREAM/REACH	BASELINE NET GAIN (L/s)	STAGE 5 NET GAIN (L/s)	STAGE 5 DEPLETION (L/s)	STAGE 5 DEPLETION (%)
Stream 1 - Segment 1	2.57	0.27	2.31	89.6%
Stream 1 - Segment 2	2.39	2.38	0.01	0.2%
Stream 1 - Segment 3	1.49	0.71	0.79	52.7%
Stream 2	1.47	0.13	1.34	91.3%
Stream 2A	0.24	0.19	0.04	17.6%
Stream 3 - Segment 1	4.25	4.11	0.14	3.3%
Stream 3 - Segment 2	3.37	2.01	1.35	40.2%

The Stage 1 and Stage 5 simulations achieved excellent mass-balance closure, with numerical errors of less than 0.00001%, indicating stable model convergence and reliable simulation results. As Quarry development progresses, groundwater discharge is progressively redistributed from river boundaries to the Quarry drainage system, consistent with the predicted stream depletion and pit inflow results. These are described below in Table B7 and B8.

Table B7: Stage 1 Model Mass Balance

DESCRIPTION	INFLOW (m^3/day)	OUTFLOW (m^3/day)
Recharge	2.68E+03	0.00E+00
River	5.41E+02	1.62E+03
Drain	0.00E+00	1.60E+03
TOTAL	3.22E+03	3.22E+03
ERROR	-6.26E-06	

Table B8: Stage 5 Model Mass Balance

DESCRIPTION	INFLOW (m^3/day)	OUTFLOW (m^3/day)
Recharge	2.68E+03	0.00E+00
River	5.90E+02	1.49E+03
Drain	0.00E+00	1.78E+03
TOTAL	3.27E+03	3.27E+03
ERROR	-3.47E-07	

Uncertainty Analysis

To quantify predictive uncertainty, a series of paired baseline and Stage 5 simulations were completed using alternative recharge and hydraulic conductivity values representing plausible bounds around the calibrated model. Recharge was varied between 143 mm/year and 231 mm/year, while model-wide hydraulic conductivity was varied by ±10% relative to the calibrated model. The resulting simulations were used to assess the sensitivity of predicted stream depletion and pit inflow to key hydrogeological parameters. The simulations achieved negligible mass-balance errors.

Table B9: Summary of Uncertainty Analysis Results

SCENARIO	STREAM 1 DEPLETION (%)	STREAM 2 DEPLETION (%)	STREAM 2A DEPLETION (%)	STREAM 3 DEPLETION (%)	STAGE 5 PIT INFLOW (L/s)
Calibrated Results	48.0	91.3	17.6	19.6	6.30
Low Recharge (143 mm/year)	56.0	91.9	21.5	21.9	5.54
High Recharge (231 mm/year)	41.2	90.6	16.0	17.6	7.37
Low K (90%)	45.2	91.0	16.8	18.7	6.06
High K (110%)	50.8	91.5	18.7	20.5	6.54

Note: Calculated from paired baseline and Stage 5 ZoneBudget results.

The uncertainty analysis indicates that the principal model predictions remain relatively stable across the tested parameter range. In all simulations, Streams 1 and 3 continue to experience similar depletion rates, as does groundwater inflow to the Quarry pit. The overall pattern of impact therefore remains unchanged regardless of the parameter set adopted.

Recharge uncertainty produced the greatest variation in pit inflow predictions. Stage 5 pit inflow ranged from approximately 479 m^3/day (5.54 L/s) under the low-recharge scenario to 637 m^3/day (7.37 L/s) under the high-recharge scenario, compared with 544 m^3/day (6.30 L/s) for the calibrated model. This represents an uncertainty range of approximately +17% / -12% around the calibrated prediction.

Changes in hydraulic conductivity had a lesser influence on model predictions. Stage 5 pit inflow varied between approximately 524 m^3/day (6.06 L/s) and 565 m^3/day (6.54 L/s) for the 90% and 110% hydraulic conductivity scenarios, respectively. This corresponds to a variation of approximately ±4% relative to the calibrated model.

Overall, the uncertainty analysis demonstrates that while the magnitude of depletion and pit inflow varies depending on the assumed recharge and hydraulic conductivity values, the key conclusions of the assessment remain unchanged. Streams 1 and 3 remain the most affected surface-water receptors, groundwater inflow to the Quarry pit remains substantial, and recharge uncertainty represents the dominant source of predictive uncertainty within the parameter range tested.

APPENDIX C
STREAMFLOW ANALYSIS



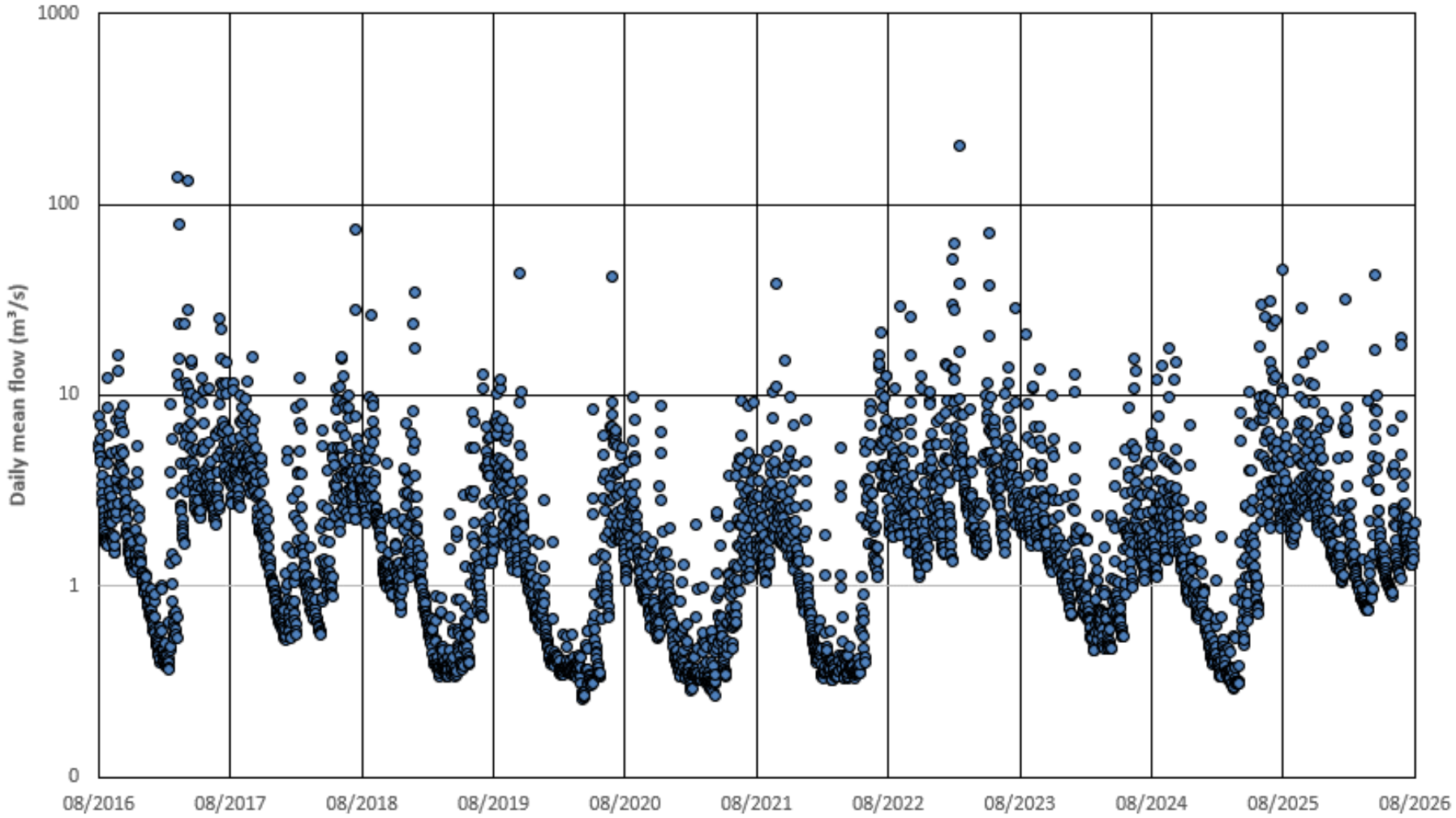


Figure C1: Wairoa River 10-Year Daily Mean Flow (m^3/s)

Table C1: Gauging Assessment and Wairoa River MALF Equivalent

SITE	LOCATION	GAUGING DATE/TIME (NZST)	GAUGED FLOW (L/s)	WAIROA FLOW AT GAUGING (m^3/s)	WAIROA DAILY MEAN (m^3/s)	WAIROA/MALF (AT TIME)	WAIROA/MALF (DAILY)	MALF-EQUIV. BASEFLOW (L/s)
Stream 1	US	11/02/2026 13:25	11.490	1.307	1.392	2.53x	2.69x	4.268
Stream 1	DS	11/02/2026 07:55	18.230	1.347	1.392	2.60x	2.69x	6.772
Stream 1	US	31/03/2026 09:00	10.620	1.193	1.173	2.31x	2.27x	4.683
Stream 1	DS	31/03/2026 09:40	19.310	1.193	1.173	2.31x	2.27x	8.514
Stream 1	US	29/04/2026 10:50	13.920	1.564	1.580	3.02x	3.05x	4.557
Stream 1	DS	29/04/2026 11:40	22.220	1.555	1.580	3.01x	3.05x	7.275
Stream 2	US	19/02/2026 11:15	3.800	1.170	1.178	2.26x	2.28x	1.668
Stream 2	DS	19/02/2026 12:05	2.290	1.163	1.178	2.25x	2.28x	1.005
Stream 2	US	31/03/2026 11:30	4.140	1.170	1.173	2.26x	2.27x	1.825
Stream 2	DS	31/03/2026 12:30	4.210	1.163	1.173	2.25x	2.27x	1.856
Stream 2	US	29/04/2026 15:15	4.360	1.538	1.580	2.97x	3.05x	1.427
Stream 2	DS	29/04/2026 14:00	4.530	1.538	1.580	2.97x	3.05x	1.483
Stream 2A	US	19/02/2026 09:15	0.045	1.185	1.178	2.29x	2.28x	0.020
Stream 2A	DS	19/02/2026 13:50	0.353	1.156	1.178	2.23x	2.28x	0.155
Stream 2A	US	31/03/2026 15:30	0.039	1.245	1.173	2.41x	2.27x	0.017
Stream 2A	DS	31/03/2026 14:20	0.223	1.139	1.173	2.20x	2.27x	0.098
Stream 2A	DS	29/04/2026 13:40	0.501	1.547	1.580	2.99x	3.05x	0.164
Stream 3	DS	11/02/2026 09:35	20.050	1.339	1.392	2.59x	2.69x	7.448
Stream 3	DS	31/03/2026 15:20	13.730	1.139	1.173	2.20x	2.27x	6.054
Stream 3	DS	29/04/2026 12:55	24.390	1.547	1.580	2.99x	3.05x	7.985

APPENDIX D
WATER QUALITY



Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Drill Force New Zealand Limited	**Lab No:**	3278393	IWPv1
Contact:	Kathryn Lawn	**Date Received:**	17-May-2023	
	C/- Drill Force New Zealand Limited	**Date Reported:**	24-May-2023	
	PO Box 72 335	**Quote No:**		
	Papakura 2244	**Order No:**	DF44986	
		Client Reference:	DF20WW234	
		Submitted By:	Kathryn Lawn	

Sample Type: Aqueous

Sample Name:		546 McNicol Road Clevedon 15-May-2023 4:00 pm
Lab Number:		3278393.1
pH	pH Units	9.4
pH_c*	pH Units	9.1
Electrical Conductivity (EC)	mS/m	30.9
Approx Total Dissolved Salts	g/m³	210
Sample Temperature*	°C	20.0
Sodium Absorption Ratio (SAR)*	$(mmol/L)^{0.5}$	10.7
Adjusted Sodium Absorption Ratio*		2.9
Cations		
Total Calcium	g/m³	2.7
Total Copper	g/m³	< 0.00053
Total Iron	g/m³	< 0.021
Total Magnesium	g/m³	0.051
Total Manganese	g/m³	< 0.00053
Total Potassium	g/m³	0.42
Total Sodium	g/m³	65
Total Zinc	g/m³	0.0058
Sum of Cations	meq/L	3.0
Anions		
Total Alkalinity	g/m³ as $CaCO_3$	81
Hydroxide Alkalinity	g/m³ as $CaCO_3$	1.2
Carbonate	g/m³ at 25°C	8.7
Bicarbonate	g/m³ at 25°C	79
Free Carbon Dioxide	g/m³ at 25°C	< 1.0
Chloride	g/m³	36
Sulphate	g/m³	14
Nitrate-N	g/m³	< 0.05
Nitrate	g/m³	< 0.3
Sum of Anions	meq/L	2.9
Langelier Saturation Index		0.3
Total Boron	g/m³	0.053
Total Phosphorus	g/m³	< 0.021

Figure D1: Water Quality Sample Collected from Bore 31427

CERTIFICATE OF ANALYSIS

Work Order	:	**NH2600161**			
Client	:	**WGA NZ Ltd**	Laboratory	:	Environmental Hamilton
Contact	:	Catherine Howell	Contact	:	Customer Services NH
Address	:	10 Bisley Road Hamilton Waikato New Zealand	Address	:	Ruakura Research Centre, 10 Bisley Rd Hamilton WKO New Zealand 3214
Telephone	:	----	Telephone	:	+64 7 974 4740
Project	:	WGA251647	Date Samples Received	:	15-Jan-2026 10:00
Order number	:	----	Date Analysis Commenced	:	16-Jan-2026
C-O-C number	:	----	Issue Date	:	22-Jan-2026 16:47
Sampler	:	Craig Lennon			
Site	:	Clevedon Quarry			
Quote number	:	NH26WGANZL0002			
No. of samples received	:	2			
No. of samples analysed	:	2			

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.
This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below.

Signatories	*Position*	*Accreditation Category*
Amaria Reweti	Section Supervisor - Inorganics	Inorganics, Hamilton, Waikato
Ashley Russell	Client Services Officer	Enviro General, Hamilton, Waikato
Louise Coombridge	Chemist - Inorganics	Inorganics, Hamilton, Waikato
Matt Counsell	Laboratory Manager	Inorganics, Hamilton, Waikato
Rowin Angkico	Chemist - Inorganics	Inorganics, Hamilton, Waikato
Tharanga Samarasinghe	Senior Laboratory Technician	Trace, Hamilton, Waikato

General Comments

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key: CAS Number: CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR: Limit of Reporting (detection limit).

Unit	*Description*
(mS/m)/10	(mS/m)/10
g CaCO3/m3	Grams of calcium carbonate per cubic meter
g eqv. CaCO3/m3	Grams equivalent to calcium carbonate per cubic meter
g/m3	Grams per cubic metre
meq/L	Milliequivalents per litre
pH	pH
uS/cm	uS/cm

>: greater than.
<: less than.
ø: ALS is not IANZ accredited for these tests.
^: This result is computed from individual analyte detections at or above the level of reporting.
~: Indicates an estimated value.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED on SRN or QCI Report, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.

Workorder Comments

Samples were collected by yourselves (or your agent) and analysed as received at ALS NZ (or at the subcontracted laboratories, when applicable). Samples were in acceptable condition unless otherwise noted on this report.

Analytical Results

Sub-Matrix: CLEAN WATER
(Matrix: WATER)

Compound	CAS Number	LOR	Unit	Client Sample ID	Site 1, Clevedon Q Depth: 0.25	Site 3, Clevedon Q Depth: 0.15	----	----	----
				Client Sampling date / time	14-Jan-2026 16:10	14-Jan-2026 14:55	----	----	----
					NH2600161-001	**NH2600161-002**	**----**	**----**	**----**
					Result	Result	----	----	----
ACB_Calc: Anion/Cation Balance									
ø Total Anions	----	0.01	meq/L		**1.80**	**1.62**	----	----	----
ø Total Cations	----	0.01	meq/L		**1.61**	**1.43**	----	----	----
ø EC/10	----	0.002	(mS/m)/10		**1.93**	**1.77**	----	----	----
Alk_W: Alkalinity									
Alkalinity	----	1	g CaCO3/m3		**42**	**34**	----	----	----
Bicarbonate Alkalinity	----	1	g CaCO3/m3		**42**	**34**	----	----	----
Carbonate Alkalinity	----	1	g CaCO3/m3		<1	<1	----	----	----
Ani_W: Anions by Ion Chromatography									
Chloride	16887-00-6	0.5	g/m3		**23.1**	**26.5**	----	----	----
Sulfate	14808-79-8	0.15	g/m3		**13.1**	**7.91**	----	----	----
COD_W: Chemical Oxygen Demand									
Chemical Oxygen Demand	----	10	g/m3		<10	<10	----	----	----
DRPFIA_W: Dissolved Reactive Phosphorus by Flow Injection Analyser									
Dissolved Reactive Phosphorus as P	----	0.002	g/m3		**0.043**	**0.030**	----	----	----
EC_W: Electrical Conductivity									
Electrical Conductivity	----	10.0	uS/cm		**193**	**177**	----	----	----
Hardness_Calc: Hardness									
Total Hardness	----	0.05	g eqv. CaCO3/m3		**45.0**	**36.2**	----	----	----
ø Calcium Hardness	----	0.05	g eqv. CaCO3/m3		**28.0**	**21.0**	----	----	----
ø Magnesium Hardness	----	0.05	g eqv. CaCO3/m3		**17.1**	**15.3**	----	----	----
HMSol_W: Elements in Water (Soluble)									
Zinc	7440-66-6	0.001	g/m3		<0.001	<0.001	----	----	----
Sodium	7440-23-5	0.01	g/m3		**17.2**	**17.3**	----	----	----
Potassium	7440-09-7	0.05	g/m3		**1.31**	**1.26**	----	----	----
Manganese	7439-96-5	0.0005	g/m3		**0.0009**	**0.0053**	----	----	----
Magnesium	7439-95-4	0.01	g/m3		**3.84**	**3.25**	----	----	----
Lead	7439-92-1	0.00005	g/m3		<0.00005	<0.00005	----	----	----
Iron	7439-89-6	0.005	g/m3		**0.045**	**0.036**	----	----	----

Analytical Results

Sub-Matrix: CLEAN WATER
(Matrix: WATER)

Compound	CAS Number	LOR	Unit	Client Sample ID	Site 1, Clevedon Q Depth: 0.25	Site 3, Clevedon Q Depth: 0.15	----	----	----
				Client Sampling date / time	14-Jan-2026 16:10	14-Jan-2026 14:55	----	----	----
					NH2600161-001	NH2600161-002	----	----	----
					Result	Result	----	----	----
HMSol_W: Elements in Water (Soluble)									
Copper	7440-50-8	0.0002	g/m3		**0.0002**	**0.0005**	----	----	----
Chromium	7440-47-3	0.0002	g/m3		**0.0003**	<0.0002	----	----	----
Calcium	7440-70-2	0.05	g/m3		**10.3**	**7.61**	----	----	----
Cadmium	7440-43-9	0.00002	g/m3		<0.00002	<0.00002	----	----	----
Boron	7440-42-8	0.01	g/m3		**0.03**	**0.03**	----	----	----
Arsenic	7440-38-2	0.0005	g/m3		<0.0005	<0.0005	----	----	----
Aluminium	7429-90-5	0.003	g/m3		**0.016**	**0.016**	----	----	----
NH3NFIA_W: Ammoniacal Nitrogen by Flow Injection Analyser									
Ammoniacal Nitrogen as N	----	0.005	g/m3		<0.005	<0.005	----	----	----
NO2NFIA_W: Nitrite by Flow Injection Analyser									
Nitrite as N	14797-65-0	0.001	g/m3		**0.002**	**0.001**	----	----	----
NO3NFIA_W: Nitrate as N by Calculation									
Nitrate as N	14797-55-8	0.002	g/m3		**0.406**	**0.334**	----	----	----
NOXFIA_W: Total Oxidised Nitrogen by Flow Injection Analyser									
Total Oxidised Nitrogen	----	0.002	g/m3		**0.407**	**0.335**	----	----	----
pH_W: pH in Water									
pH	----	0.01	pH		**7.44**	**7.39**	----	----	----
Subcontracted Analysis									
ø Bromide	24959-67-9	0.05	g/m3		<0.05	**0.10**	----	----	----
TDS_W: Total Dissolved Solids									
Total Dissolved Solids	----	3	g/m3		**136**	**115**	----	----	----
TKN_W: Total Kjeldahl Nitrogen by Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	g/m3		**0.3**	<0.1	----	----	----
TN_Calc: Total Nitrogen by Calculation									
Total Nitrogen	----	0.1	g/m3		**0.7**	**0.3**	----	----	----
TSS_W: Total Suspended Solids									
Total suspended solids	----	3	g/m3		**5**	**16**	----	----	----

Brief Method Summaries

Analytical Methods	Method	Matrix	Method Descriptions
Alkalinity	Alk_W	WATER	Samples analysed as received by potentiometric titration. (APHA 2320 B Online edition). Calculations calculated from pH and Total Alkalinity. (APHA 4500 CO2 D - Online edition).
Ammoniacal Nitrogen as N via Flow Injection Analyser	NH3NFIA_W	WATER	Samples are filtered and measured colourimetrically by flow injection analysis. Results represent total ammonical nitrogen (APHA 4500-NH3 H - Modified - Online edition).
Anion/Cation Balance via Calculation	ACB_Calc	WATER	Sum of milliequivalents/litre of measured Anions/Cations.
Anions in Water	Ani_W	WATER	Analysis by Ion exchange chromatography following sample filtration. (APHA 4110B - Online edition).
Bromide in Water	HILL_W_BROMIDE	WATER	Subcontracted to Hill Laboratories. Sample analysed as received, filtered if required. Ion Chromatography. US EPA Method 300.1 Part B (modified).
Chemical Oxygen Demand in Water	COD_W	WATER	Samples analysed colourimetrically following an acid digestion. (APHA 5220 D - Online edition).
Dissolved Reactive Phosphorus via Flow Injection Analyser	DRPFIA_W	WATER	Samples filtered and measured colourimetrically by flow injection analysis. (APHA 4500-P G - Modified - Online edition)
Electrical Conductivity in Water	EC_W	WATER	Samples analysed as received using a conventional conductivity electrode. (APHA 2510 B - Modified - Auto-titrator - Online edition). Resistivity is calculated from conductivity, 25°C.
Heavy Metals Soluble in Water	HMSol_W	WATER	Samples were analysed as received by the laboratory using ICP-MS following a 0.45µm membrane filtration and acidification (except when field filtered). In house procedure based on US EPA 200.8.
Nitrate as Nitrogen via Calculation	NO3N_Calc	WATER	Calculated from oxidised nitrogen and Nitrite-N, measured colourimetrically by flow injection analysis. (APHA NO3- I. Online edition) - Result reported as Nitrate as nitrogen.
Nitrite as Nitrogen via Flow Injection Analyser	NO2NFIA_W	WATER	Samples analysed colourimetrically by flow injection analysis following filtration. (APHA 4500-NO2 I. Online edition) - Result reported as Nitrite (N2) species.
pH in Water	pH_W	WATER	Samples measured as received using a conventional pH electrode. (APHA 4500 H+ B. Online edition).
Total Dissolved Solids in Water	TDS_W	WATER	Filtration followed by complete drying at 180°C. (APHA 2540 C - Online edition).
Total Hardness in Water via Calculation	TotalHardness_Calc	WATER	Result calculated from Magnesium and Calcium. (APHA 2340B - Online edition)
Total Kjeldahl Nitrogen as N in Water	TKN_W	WATER	Samples analysed colourimetrically following an acid digestion. (APHA 4500-N Org D - Modified - Discrete Analyser - Online edition).
Total Nitrogen as N via Calculation	TN_Calc	WATER	In house: Referenced to APHA 4500 Norg/NO3- Total Nitrogen is determined as the sum of TKN and Oxidised Nitrogen, each determined separately as N.
Total Oxidised Nitrogen via Flow Injection Analyser	NOXFIA_W	WATER	Measurement of Nitrite-N and Nitrate-N determined colourimetrically by flow injection analysis. (APHA NO3- I. Online edition)
Total Suspended Solids	TSS_W	WATER	Total Suspended Solids measured gravimetrically following filtration through glass micro-fibre filters. (APHA 2540 D - Modified - Online edition)

APPENDIX E
STREAM GAUGING REPORT



Stevensons – Clevedon Quarry
Site Summary Report



June 2026

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HYDRO LOGIC NZ LTD - NAPIER – HAMILTON
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Contents

Stream 1 3
Gauging Results 4
Site Notes 4
Water Level Hydrograph 5
Stream 1 Upstream Rating Curve 6
Stream 1 Downstream Rating Table 7
Stream 2 8
Gauging Results 9
Site Notes 9
Water Level Hydrograph 10
Stream 2 Upstream Rating Curve 11
Stream 2 Downstream Rating Curve 12
Stream 2A 13
Gauging Results 14
Site Notes 14
Stream 2A Water Level Hydrograph 15
Stream 2A Upstream Rating Curve 16
Stream 2A Downstream Rating Curve 17
Stream 3 18
Gauging Results 19
Site Notes 19
Stream 3 Water Level Hydrograph 20
Stream 3 Rating Curve 21

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Stream 1



Gauging Results

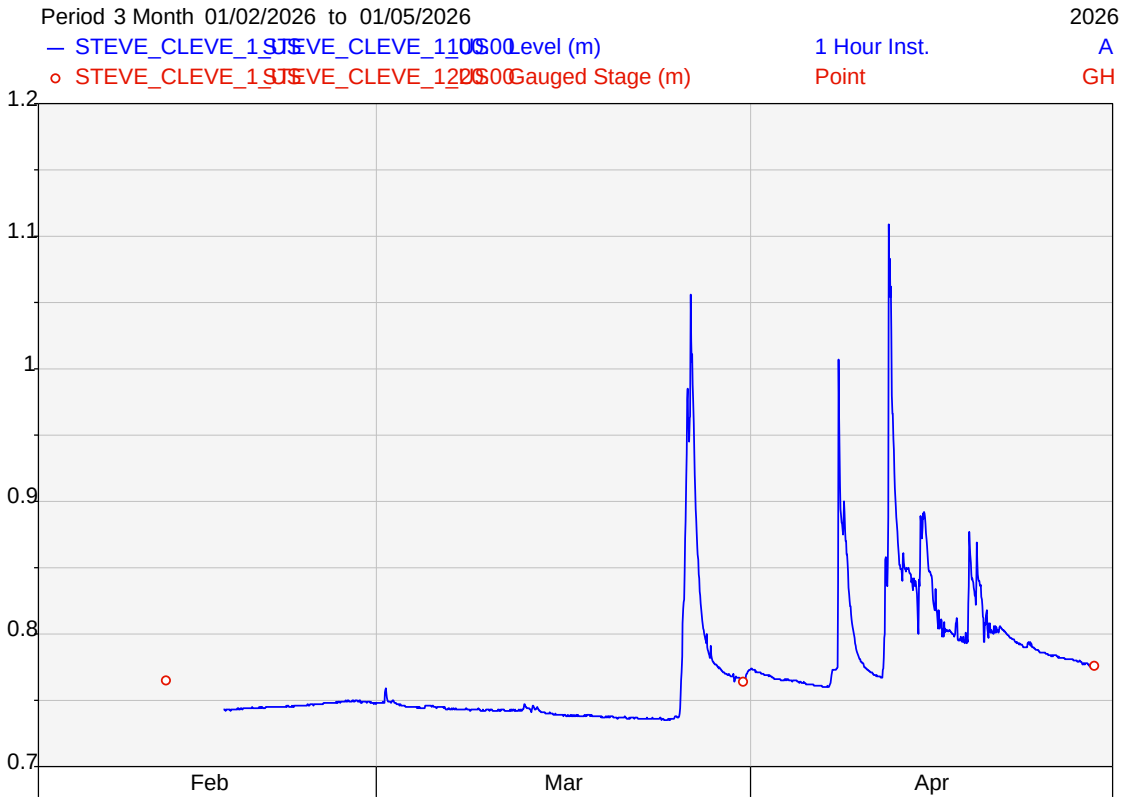
Date	Time (NZST)	ESG	Stream Location	Discharge (l/s)
11/02/2026	13:25	0.765	Upstream	11.49
11/02/2026	07:55	0.765	Downstream	18.23
31/03/2026	09:00	0.764	Upstream	10.62
31/03/2026	09:40	0.764	Downstream	19.31
29/04/2026	10:50	0.776	Upstream	13.92
29/04/2026	11:40	0.776	Downstream	22.22

Site Notes

- The first site (Stream 1) was located on the quarry premises itself in a bushed area upstream of the ponds at -37.02815, 175.07754.
- Flow measurements were done with a calibrated OTT current meter.
- All flow measurement had a measured reference point to the water level.
- Stream 1 has decent flow (10-23 l/s).
- Stream 1 upstream location refers to a measurement done upstream of the ponds.
- Stream 1 downstream location refers to a measurement done downstream of the road culvert.
- Previous owners installed pipes underground, diverting flow. Where this water is entering or exiting the surface flow is unknown.
- Downstream location has significantly more flow than upstream.
- Water level sensor is separate from the gaugings sections, as there is no suitable location that would be suitable for both.
- 2 of the 3 flow measurements are at a similar water level.
- Accurate flow ratings at these sites are possible to construct, but currently lack enough flow measurements to have a high degree of confidence.
- The downstream flow site being further away from the sensor adds further uncertainty with its flow rating.
- Water level hydrograph and data has been corrected to the onsite reference point taken during flow measurements.

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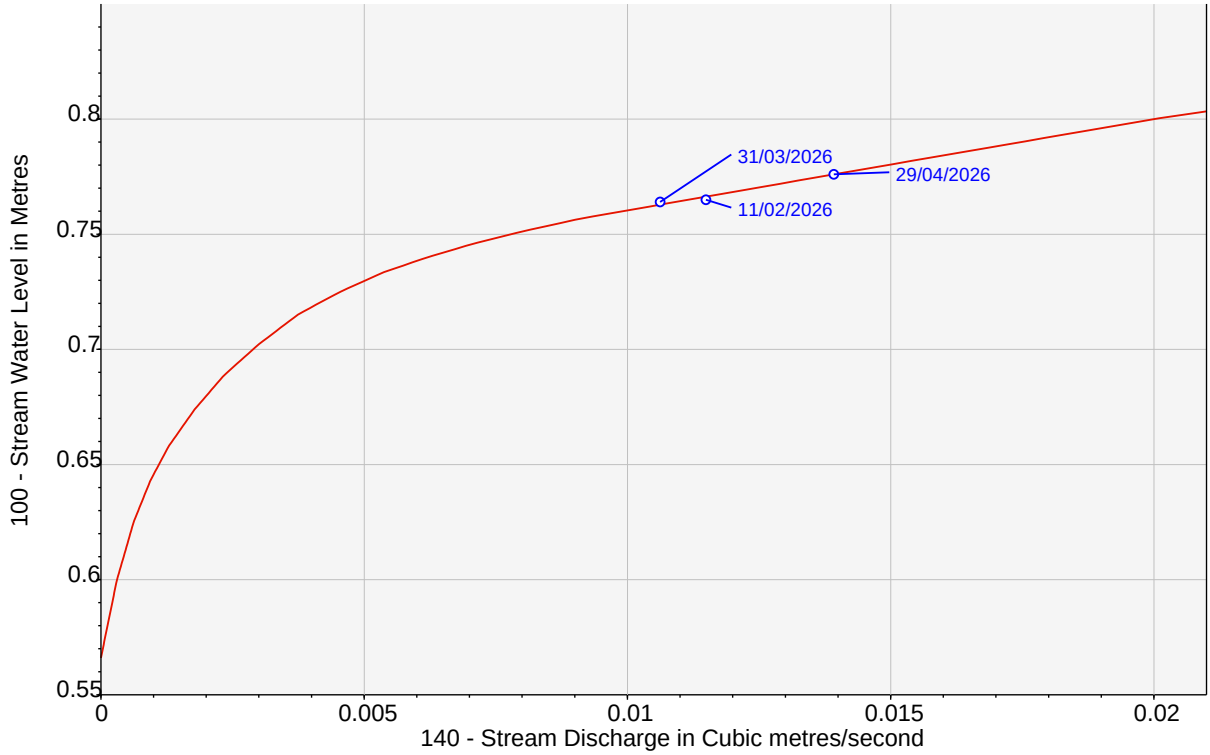
Water Level Hydrograph



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Stream 1 Upstream Rating Curve

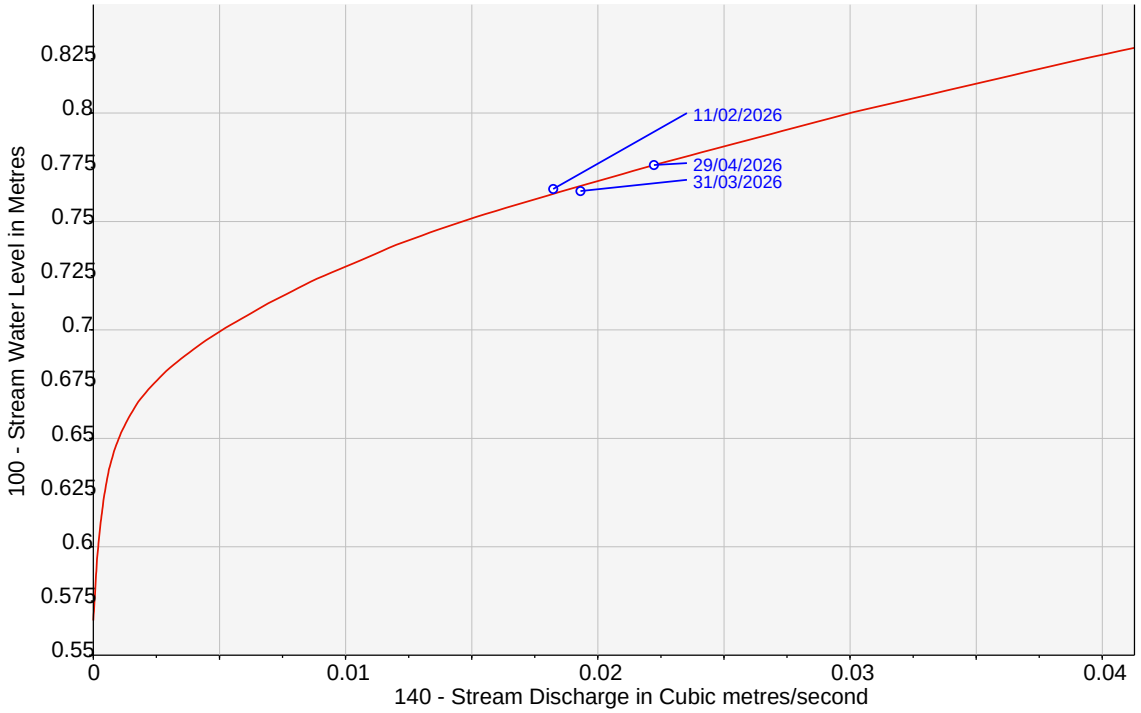
STEVE_CLEVE_1_US STEVENSONS_CLEVEDON - Stream 1 Upstream
Gaugings from 11/02/2026 to 29/04/2026
Rating Table 1.00 SQC_SW1_US 01/01/2026 to Present



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Stream 1 Downstream Rating Table

STEVE_CLEVE_1_DS STEVENSONS_CLEVEDON - Stream 1 Downstream
Gaugings from 11/02/2026 to 29/04/2026
Rating Table 1.00 SQC_SW1_DS 01/01/2026 to Present



HYDRO LOGIC NEW ZEALAND LTD

Stream 2



Gauging Results

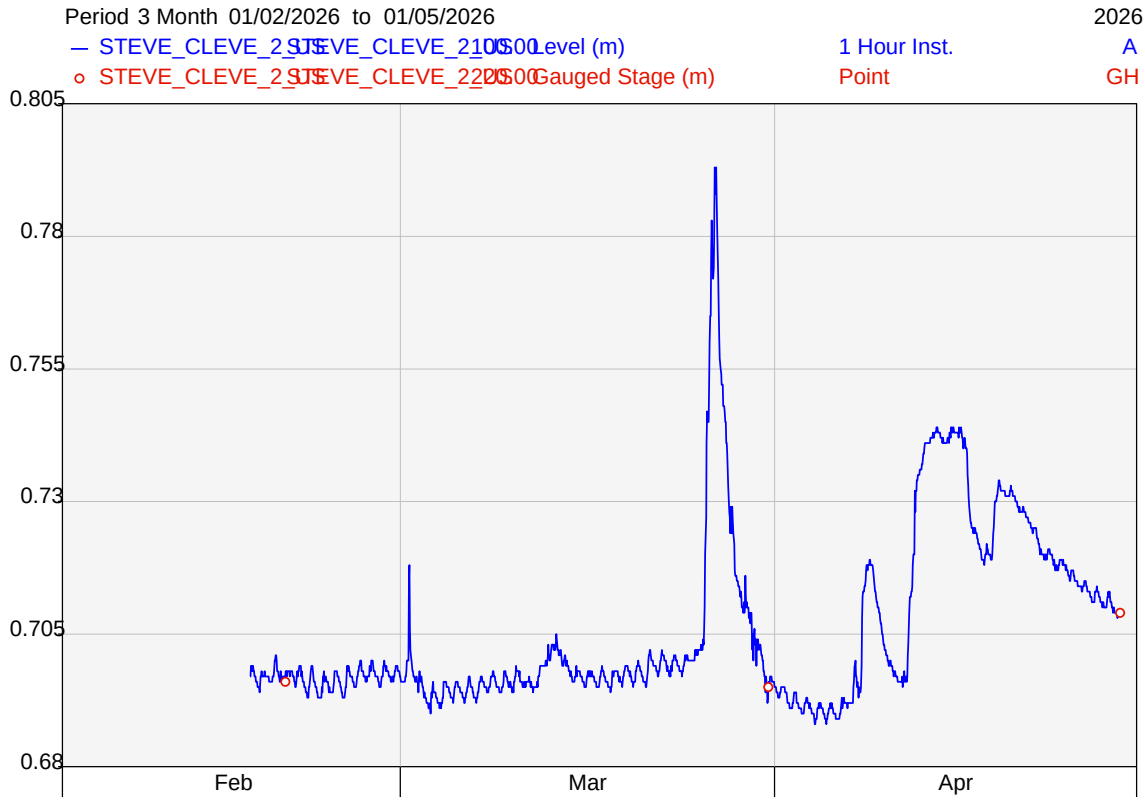
Date	Time (NZST)	ESG	Stream Location	Discharge (l/s)
19/02/2026	11:15	0.696	Upstream	3.80
19/02/2026	12:05	0.696	Downstream	2.29
31/03/2026	11:30	0.695	Upstream	4.14
31/03/2026	12:30	0.695	Downstream	4.21
29/04/2026	15:15	0.709	Upstream	4.36
29/04/2026	14:00	0.709	Downstream	4.53

Site Notes

- The second site (Stream 2) was located off the southern side of the current quarry premises with the downstream gauging location and water level site in a bushed area at -37.03129, 175.07647.
- Stream 2 upstream location refers to a measurement done as close to the proposed boundary of the quarry pit expansion as practical.
- Stream 2 downstream locations refer to a measurement done just above the culverts of McNichol road before the stream discharges into the Wairoa river.
- Possible underground water movement entering or exiting the stream.
- Upstream flow measurements were done with a calibrated OTT current meter and downstream measurements with a volumetric container.
- All flow measurement had a measured reference point to the water level.
- Stream 2 has low flow (2-5 l/s).
- Water level sensor is separate from the gaugings sections, as there is no suitable location that would be suitable for both.
- 2 of the 3 flow measurements are at a similar water level.
- As these sites are low flow, creating an accurate flow rating is extremely difficult. This is due to the very small differences in flow/water level, and an unsteady control that can change with high flushes and debris. These ratings should be used as an estimate only.
- The upstream flow site being further away from the sensor adds further uncertainty with its flow rating.
- Water level hydrograph and data has been corrected to the onsite reference point taken during flow measurements.

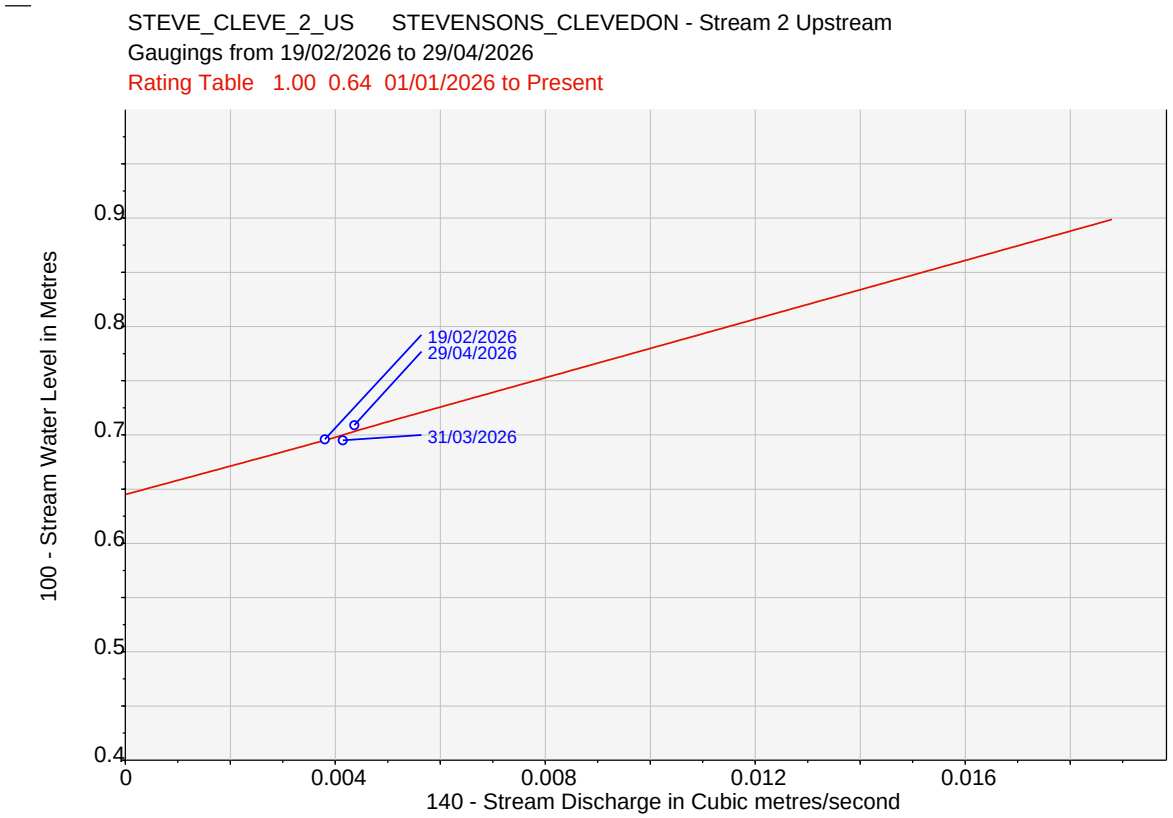
HYDRO LOGIC NEW ZEALAND LTD

Water Level Hydrograph



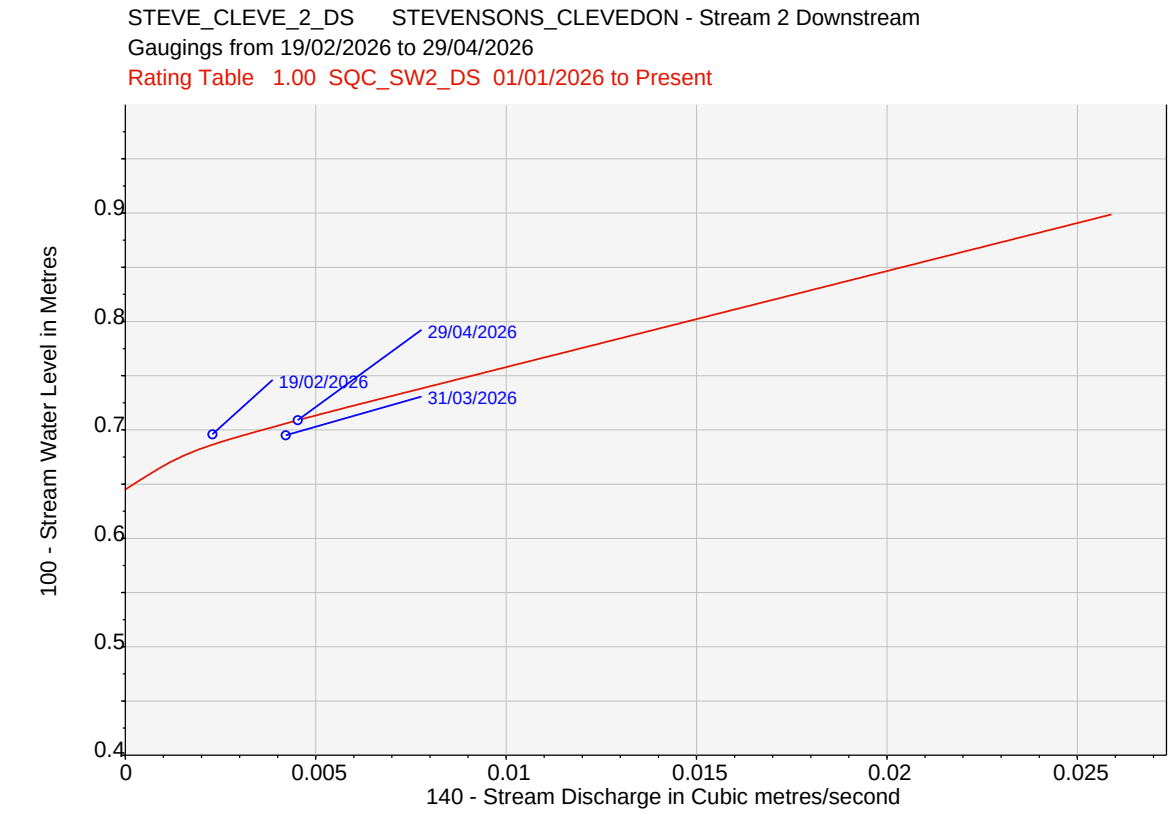
NEW ZEALAND LTD

Stream 2 Upstream Rating Curve



NEW ZEALAND LTD

Stream 2 Downstream Rating Curve



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Stream 2A



Gauging Results

Date	Time (NZST)	ESG	Stream Location	Discharge (l/s)
19/02/2026	09:15	0.974	Upstream	0.045
19/02/2026	13:50	0.974	Downstream	0.353
31/03/2026	03:30	0.965	Upstream	0.039
31/03/2026	14:20	0.965	Downstream	0.223
29/04/2026	*	0.966	Upstream	*
29/04/2026	13:40	0.966	Downstream	0.501

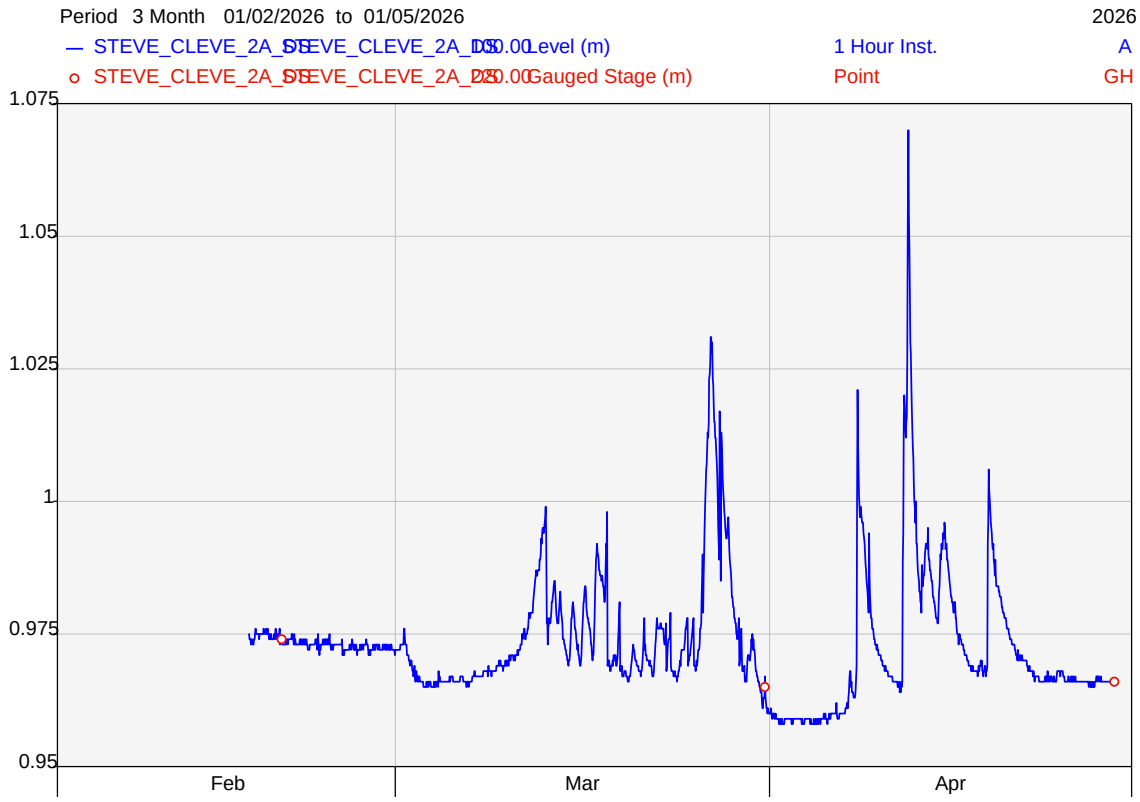
*No site access for flow measurement.

Site Notes

- The third site (Stream 2A) was located further south of Stream 2, again the downstream gauging location and water level site is in a bushed area at -37.03301, 175.07615
- Stream 2A upstream location refers to a measurement done as close to the proposed boundary of the quarry pit expansion as practical.
- Stream 2A downstream locations refer to a measurement done just above the culverts of McNichol road before the stream discharges into the Wairoa river.
- Possible underground water movement entering or exiting the stream.
- Downstream flow measurements were done with a calibrated OTT current meter and upstream measurements with a volumetric container.
- All flow measurement had a measured reference point to the water level.
- Stream 2A has extremely low flow (0-0.5 l/s).
- Water level sensor is separate from the gaugings sections, as there is no suitable location that would be suitable for both.
- 2 of the 3 flow measurements are at a similar water level.
- As these sites are extremely low flow, creating an accurate flow rating is not possible. This is due to the very small differences in flow/water level, and an unsteady control that can change with high flushes and debris. These ratings should be used as an estimate only.
- Water level hydrograph and data has been corrected to the onsite reference point taken during flow measurements.

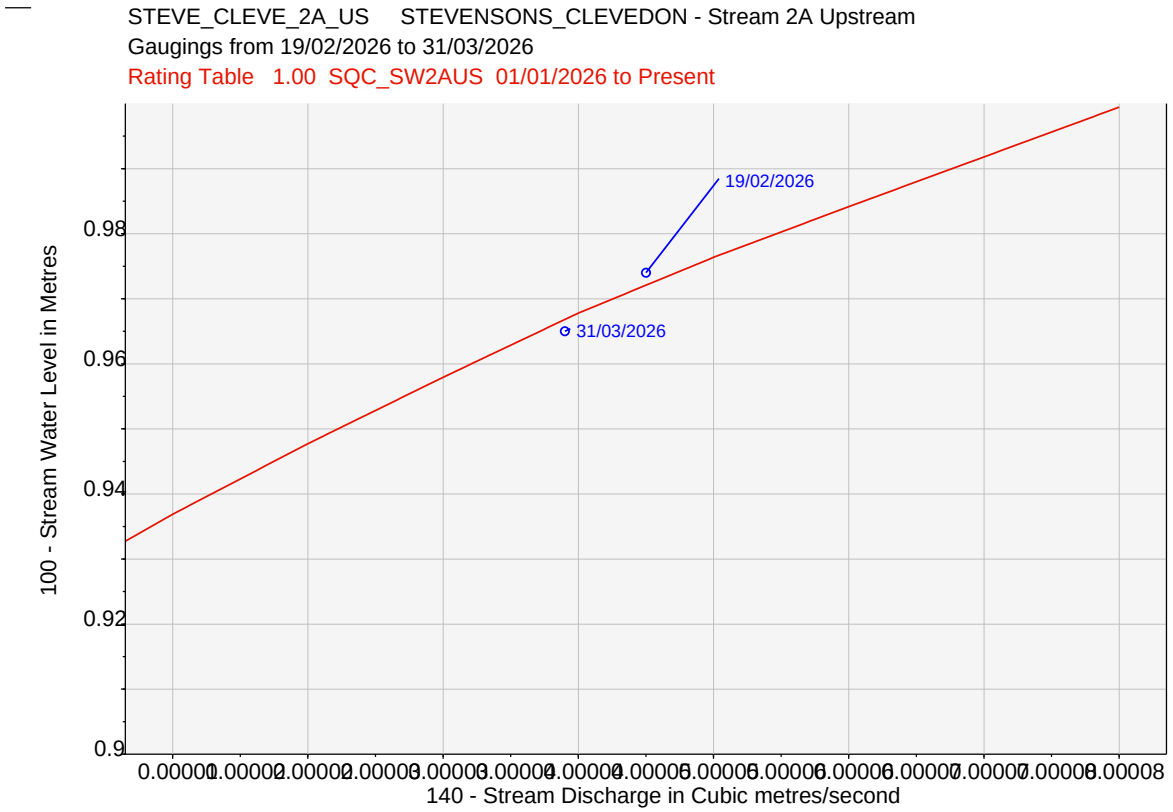
HYDRO LOGIC NEW ZEALAND LTD

Stream 2A Water Level Hydrograph



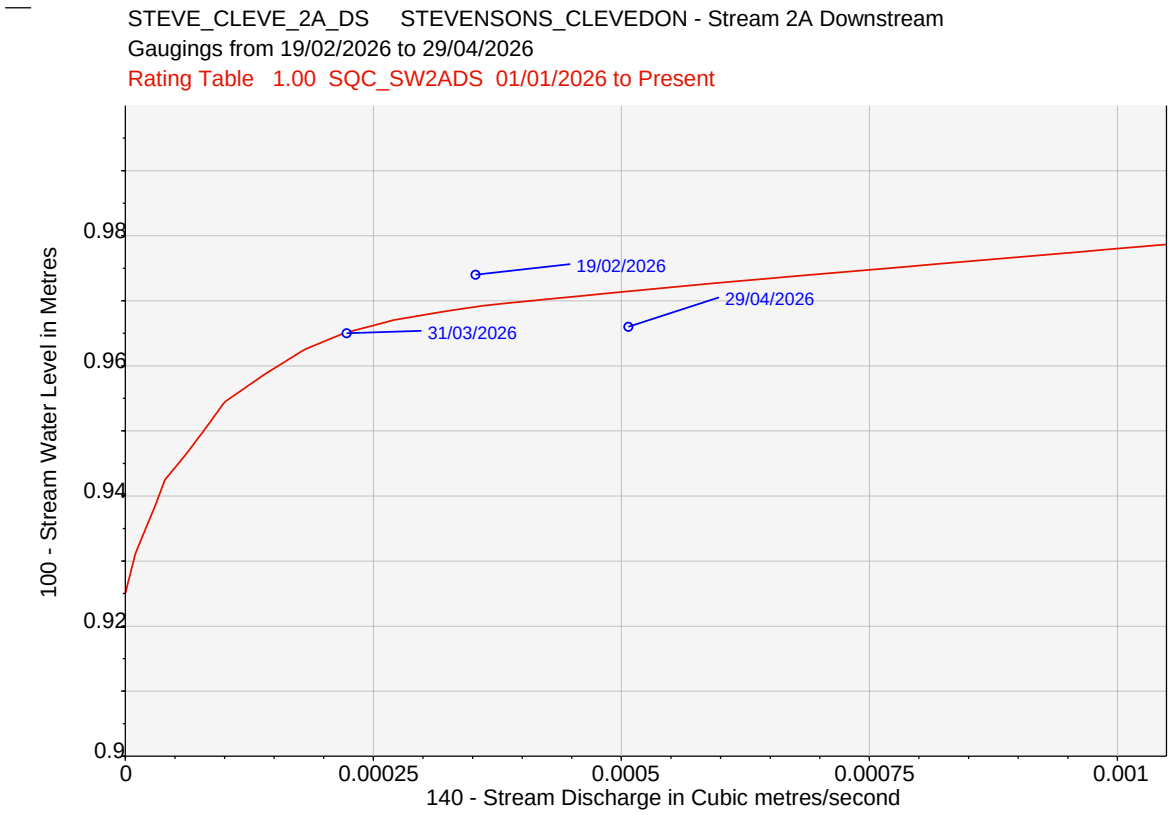
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Stream 2A Upstream Rating Curve



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Stream 2A Downstream Rating Curve



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Stream 3



Gauging Results

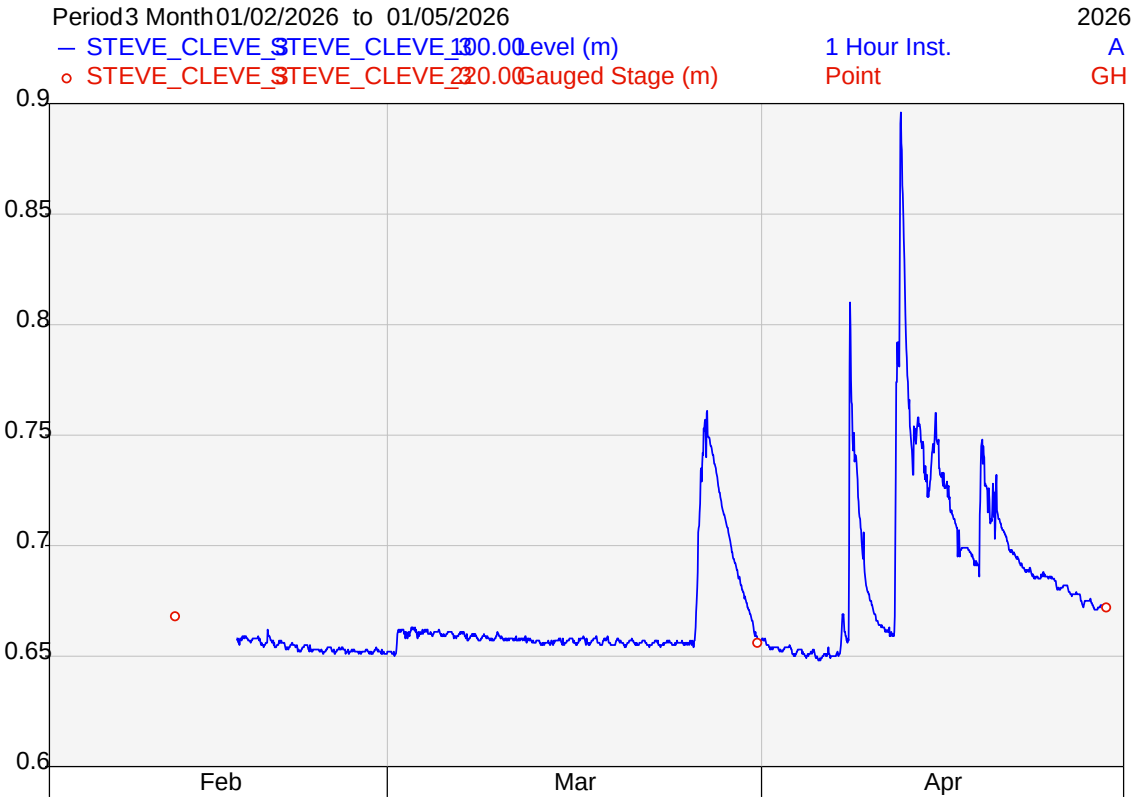
Date	Time (NZST)	ESG	Stream Location	Discharge (l/s)
11/02/2026	09:35	0.668	Downstream	20.05
31/03/2026	15:20	0.656	Downstream	13.73
29/04/2026	12:55	0.672	Downstream	24.39

Site Notes

- The fourth site (Stream 3) was again located further south and accessed via a walking track to the stream before a small walk up the stream to the water level and flow measurement location at -37.03727, 175.07373.
- Flow measurements were done with a calibrated OTT current meter.
- All flow measurement had a measured reference point to the water level.
- Stream 3 has decent flow (13-25 l/s).
- This site is a good location for building an accurate flow rating. More gaugings would be needed to further confirm this relationship.
- Water level hydrograph and data has been corrected to the onsite reference point taken during flow measurements.

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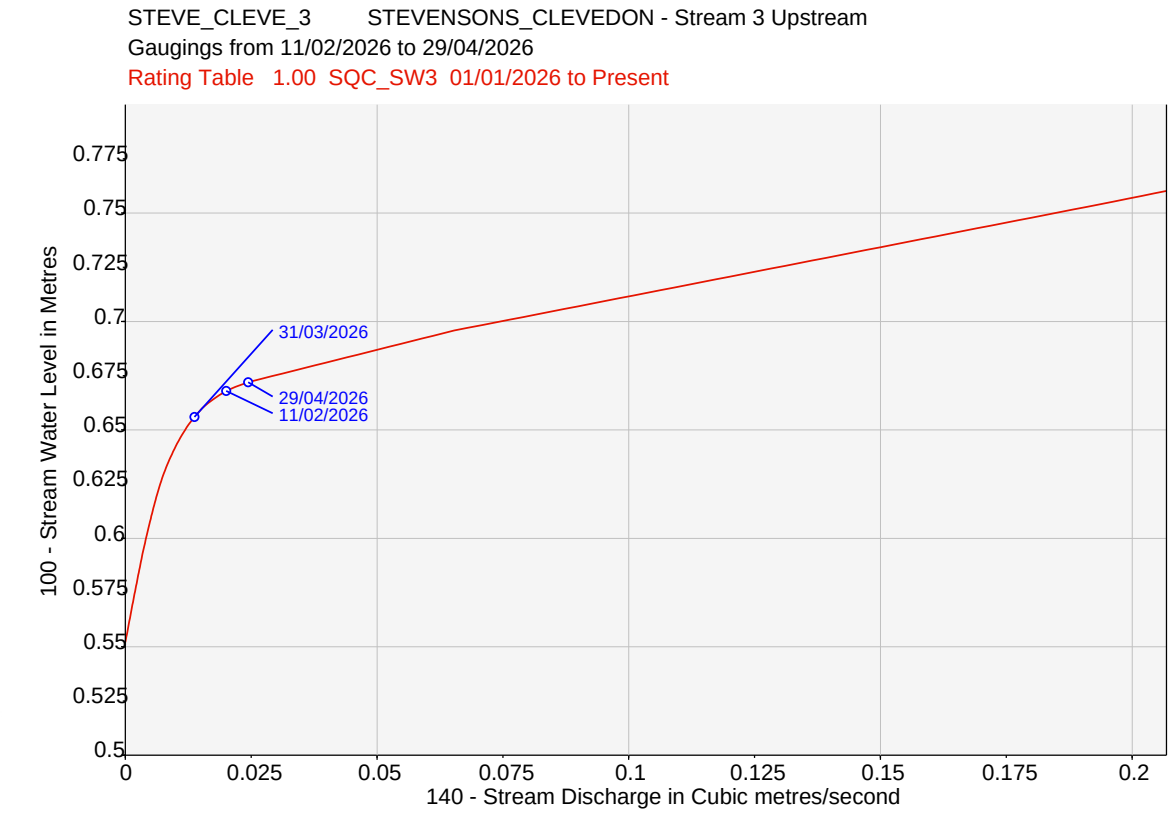
Stream 3 Water Level Hydrograph



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Stream 3 Rating Curve



Report prepared by:	C. Lennon	Hydrologist	10/06/2026
Report checked by:	S. Murdoch	Hydrologist	10/06/2026

APPENDIX F
HYDRAULIC TESTING ANALYSIS SHEETS



Bouwer & Rice (1976) Slug Test Analysis Sheet

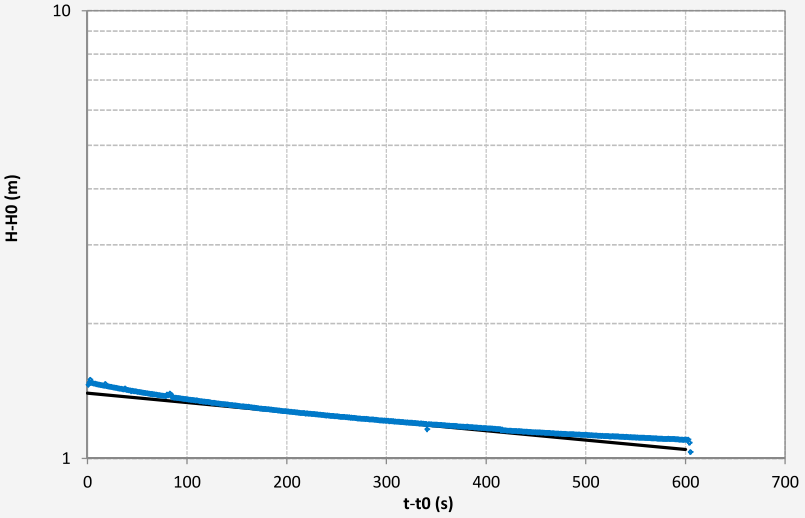
PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH1 Deep

Test date:	10/08/2017	**Bore depth:**	29.92	mBGL	**Slugs used:**	3	
Test time:	10:00	**SWL:**	3.72	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00047	m3
Reviewed by:		**Saturated screen length (Le):**	4	m	**Expected displ:**	0.59	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	100	m	**Obs displacement:**	0.43	m
		Piezo sat. thickness (Lw):	26.2	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Depth to water	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	3.72	**Y-intercept shift:**	1.4	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	4.15	**Hydraulic conductivity (K):**	**2.00E-07**	m/s			
			1.72E-02	m/d	**Test duration:**	600	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	5.181	1.461
2.0	5.199	1.479
3.0	5.220	1.500
4.0	5.197	1.477
5.0	5.194	1.474
6.0	5.193	1.473
7.0	5.191	1.471
8.0	5.190	1.470
9.0	5.187	1.467
10.0	5.186	1.466
11.0	5.184	1.464
12.0	5.183	1.463
13.0	5.182	1.462
14.0	5.179	1.459
15.0	5.178	1.458
16.0	5.177	1.457
17.0	5.174	1.454
18.0	5.189	1.469
19.0	5.171	1.451
20.0	5.171	1.451
21.0	5.169	1.449
22.0	5.168	1.448
23.0	5.168	1.448
24.0	5.166	1.446
25.0	5.164	1.444
26.0	5.162	1.442
27.0	5.162	1.442
28.0	5.160	1.440
29.0	5.159	1.439
30.0	5.157	1.437
31.0	5.156	1.436
32.0	5.154	1.434
33.0	5.154	1.434
34.0	5.151	1.431
35.0	5.151	1.431
36.0	5.149	1.429
37.0	5.148	1.428
38.0	5.154	1.434
39.0	5.145	1.425
40.0	5.144	1.424
41.0	5.142	1.422
42.0	5.141	1.421
43.0	5.140	1.420
44.0	5.134	1.414
45.0	5.138	1.418
46.0	5.136	1.416
47.0	5.134	1.414
48.0	5.134	1.414
49.0	5.135	1.415
50.0	5.131	1.411
51.0	5.130	1.410
52.0	5.128	1.408
53.0	5.128	1.408
54.0	5.126	1.406
55.0	5.125	1.405
56.0	5.124	1.404
57.0	5.123	1.403
58.0	5.121	1.401
59.0	5.120	1.400
60.0	5.120	1.400
61.0	5.118	1.398
62.0	5.117	1.397
63.0	5.116	1.396
64.0	5.114	1.394



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 2 \times 10^{-7} \ m/s$$

Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

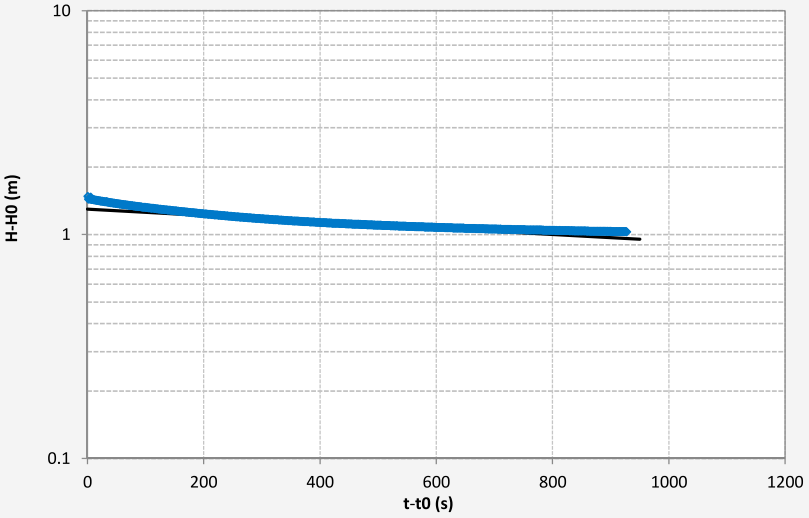
Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH1 Deep

Test date:	10/08/2017	**Bore depth:**	29.92	mBGL	**Slugs used:**	3	
Test time:	10:47	**SWL:**	3.72	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.075	m	**Displacement vol:**	0.00047	m3
Reviewed by:		**Saturated screen length (Le):**	4	m	**Expected displ:**	0.59	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	60	m	**Obs displacement:**	0.43	m
		Piezo sat. thickness (Lw):	26.2	m	**Eff. casing radius:**	0.043	m
					Correct for displacement:	FALSE	

GWL measurement:	Depth to water	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	3.72	**Y-intercept shift:**	1.3	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	4.15	**Hydraulic conductivity (K):**	**2.51E-07**	m/s			
			2.17E-02	m/d	**Test duration:**	950	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	5.2	1.480
2.0	5.1595	1.440
3.0	5.1629	1.443
4.0	5.1613	1.441
5.0	5.1569	1.437
6.0	5.1914	1.471
7.0	5.154	1.434
8.0	5.1547	1.435
9.0	5.1532	1.433
10.0	5.152	1.432
11.0	5.1508	1.431
12.0	5.1481	1.428
13.0	5.1472	1.427
14.0	5.1461	1.426
15.0	5.1441	1.424
16.0	5.1424	1.422
17.0	5.1408	1.421
18.0	5.14	1.420
19.0	5.1377	1.418
20.0	5.1368	1.417
21.0	5.136	1.416
22.0	5.1336	1.414
23.0	5.1319	1.412
24.0	5.1309	1.411
25.0	5.129	1.409
26.0	5.1283	1.408
27.0	5.1264	1.406
28.0	5.1257	1.406
29.0	5.1236	1.404
30.0	5.123	1.403
31.0	5.1209	1.401
32.0	5.1203	1.400
33.0	5.1264	1.406
34.0	5.117	1.397
35.0	5.1158	1.396
36.0	5.114	1.394
37.0	5.1138	1.394
38.0	5.1116	1.392
39.0	5.1106	1.391
40.0	5.1093	1.389
41.0	5.1088	1.389
42.0	5.1068	1.387
43.0	5.1055	1.386
44.0	5.1044	1.384
45.0	5.1037	1.384
46.0	5.1013	1.381
47.0	5.1008	1.381
48.0	5.0997	1.380
49.0	5.0975	1.378
50.0	5.0974	1.377
51.0	5.0962	1.376
52.0	5.0938	1.374
53.0	5.0942	1.374
54.0	5.0915	1.372
55.0	5.0911	1.371
56.0	5.0899	1.370
57.0	5.0883	1.368
58.0	5.0872	1.367
59.0	5.0863	1.366
60.0	5.0843	1.364
61.0	5.0839	1.364
62.0	5.0828	1.363
63.0	5.082	1.362
64.0	5.0812	1.361



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 2.51 \times 10^{-7} \ m/s$$

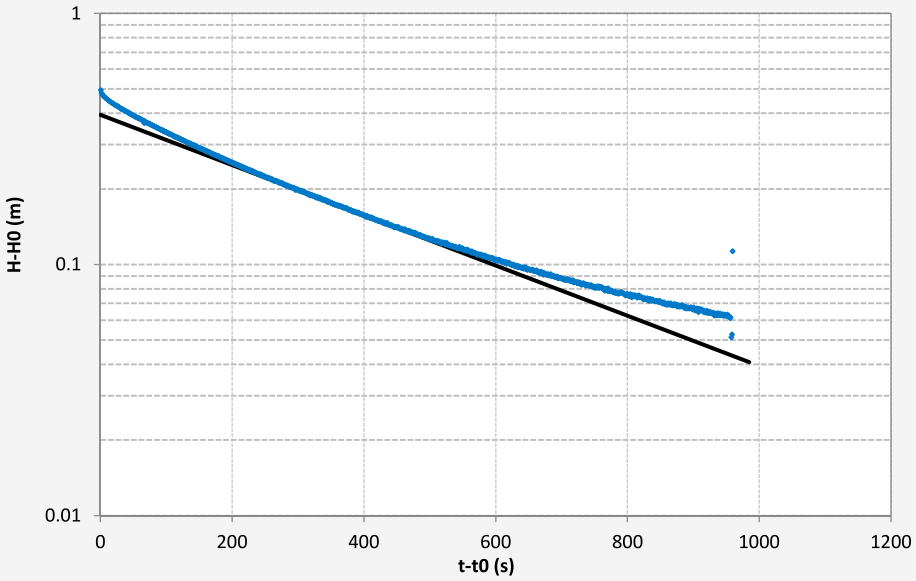
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	Clevedon Quarry	**Job No:**		**Bore ID:**	FH1 Deep		
Test date:	10/08/2017	**Bore depth:**	29.92	mBGL	**Slugs used:**	3	
Test time:	11:03	**SWL:**	3.72	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00047	m3
Reviewed by:		**Saturated screen length (Le):**	8	m	**Expected displ:**	0.59	m
Test type:	Rising head	**Aquifer sat. thickness (h):**	100	m	**Obs displacement:**	0.41	m
		Piezo sat. thickness (Lw):	26.2	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Depth to water	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	4.74	**Y-intercept shift:**	0.395	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	4.329	**Hydraulic conductivity (K):**	**5.25E-07**	m/s			
			4.53E-02	m/d	**Test duration:**	985	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	4.245	0.496
2.0	4.258	0.482
3.0	4.263	0.477
4.0	4.267	0.473
5.0	4.271	0.469
6.0	4.274	0.466
7.0	4.278	0.462
8.0	4.280	0.460
9.0	4.282	0.458
10.0	4.283	0.457
11.0	4.286	0.454
12.0	4.288	0.452
13.0	4.291	0.449
14.0	4.292	0.448
15.0	4.295	0.445
16.0	4.296	0.444
17.0	4.299	0.442
18.0	4.300	0.440
19.0	4.302	0.438
20.0	4.302	0.438
21.0	4.305	0.435
22.0	4.307	0.433
23.0	4.309	0.431
24.0	4.310	0.430
25.0	4.312	0.428
26.0	4.313	0.427
27.0	4.314	0.426
28.0	4.316	0.424
29.0	4.318	0.422
30.0	4.319	0.421
31.0	4.321	0.419
32.0	4.323	0.417
33.0	4.324	0.417
34.0	4.325	0.415
35.0	4.326	0.414
36.0	4.328	0.412
37.0	4.330	0.410
38.0	4.331	0.409
39.0	4.332	0.408
40.0	4.333	0.407
41.0	4.335	0.406
42.0	4.337	0.403
43.0	4.338	0.402
44.0	4.339	0.401
45.0	4.341	0.399
46.0	4.343	0.398
47.0	4.343	0.397
48.0	4.345	0.395
49.0	4.346	0.394
50.0	4.347	0.393
51.0	4.349	0.391
52.0	4.350	0.390
53.0	4.352	0.388
54.0	4.352	0.388
55.0	4.353	0.387



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 5.25 \times 10^{-7} \quad m/s$$

Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	Clevedon Quarry	**Job No:**	C02806205	**Bore ID:**	FH1Deep

Test date:	10/08/2017	**Bore depth:**	29.92	mBGL	**Slugs used:**	3	
Test time:	10:00	**SWL:**	3.72	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00047	m3
Reviewed by:	KG	**Saturated screen length (Le):**	4	m	**Expected displ:**	0.59	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	100	m	**Obs displacement:**	0.43	m
		Piezo sat. thickness (Lw):	26.2	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Depth to water	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	3.72	**Y-intercept shift:**	0.37	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	4.15	**Hydraulic conductivity (K):**	**7.41E-07**	m/s			
			6.40E-02	m/d	**Test duration:**	765	s

Observed data

t (s)	GWL (m)	H-H0 (m)
30.0	4.090	0.370
60.0	4.070	0.350
75.0	4.050	0.330
90.0	4.030	0.310
120.0	4.030	0.310
135.0	4.020	0.300
150.0	4.010	0.290
165.0	4.000	0.280
180.0	3.990	0.270
210.0	3.975	0.255
240.0	3.960	0.240
270.0	3.975	0.255
300.0	3.930	0.210
330.0	3.920	0.200
360.0	3.910	0.190
390.0	3.900	0.180
420.0	3.890	0.170
480.0	3.875	0.155
540.0	3.860	0.140
600.0	3.850	0.130
660.0	3.830	0.110
720.0	3.820	0.100
		#N/A
		#N/A
		#N/A

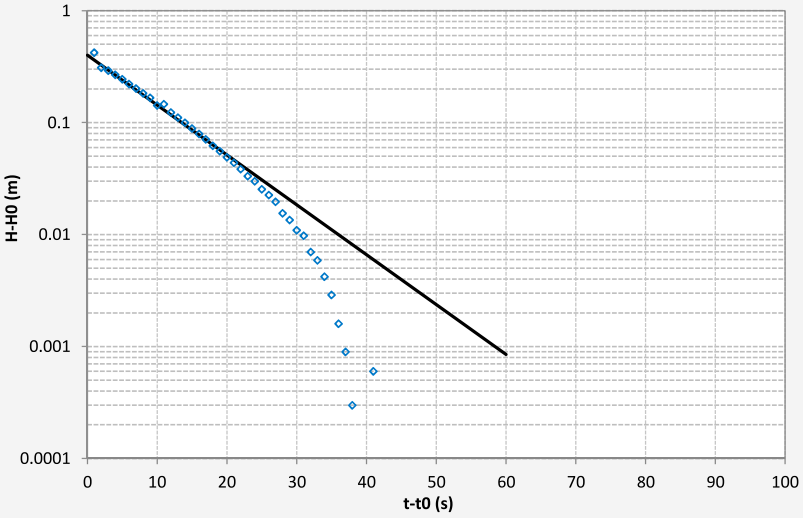
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH1 Shallow		
Test date:	10/08/2017	**Bore depth:**	11.4	mBGL	**Slugs used:**	3	
Test time:	11:25	**SWL:**	3.91	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00047	m3
Reviewed by:		**Saturated screen length (Le):**	4	m	**Expected displ:**	0.59	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	8	m	**Obs displacement:**	0.50	m
		Piezo sat. thickness (Lw):	7.49	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	4.6	**Y-intercept shift:**	0.4	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	5.1	**Hydraulic conductivity (K):**	**4.17E-05**	m/s			
			3.60E+00	m/d	**Test duration:**	60	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	5.020	0.420
2.0	4.910	0.310
3.0	4.892	0.292
4.0	4.867	0.267
5.0	4.843	0.243
6.0	4.822	0.222
7.0	4.801	0.201
8.0	4.782	0.182
9.0	4.766	0.166
10.0	4.742	0.142
11.0	4.746	0.146
12.0	4.723	0.123
13.0	4.711	0.111
14.0	4.700	0.100
15.0	4.689	0.089
16.0	4.679	0.079
17.0	4.671	0.071
18.0	4.662	0.062
19.0	4.655	0.055
20.0	4.649	0.049
21.0	4.644	0.044
22.0	4.638	0.038
23.0	4.633	0.033
24.0	4.630	0.030
25.0	4.625	0.025
26.0	4.623	0.023
27.0	4.620	0.020
28.0	4.616	0.016
29.0	4.614	0.014
30.0	4.611	0.011
31.0	4.610	0.010
32.0	4.607	0.007
33.0	4.606	0.006
34.0	4.604	0.004
35.0	4.603	0.003
36.0	4.602	0.002
37.0	4.601	0.001
38.0	4.600	0.000
39.0	4.599	#N/A
40.0	4.599	#N/A
41.0	4.601	0.001
42.0	4.598	#N/A
43.0	4.597	#N/A
44.0	4.597	#N/A
45.0	4.596	#N/A
46.0	4.597	#N/A
47.0	4.595	#N/A
48.0	4.594	#N/A
49.0	4.595	#N/A
50.0	4.594	#N/A
51.0	4.594	#N/A
52.0	4.594	#N/A
53.0	4.595	#N/A
54.0	4.594	#N/A
55.0	4.588	#N/A
56.0	4.593	#N/A
57.0	4.593	#N/A
58.0	4.593	#N/A
59.0	4.592	#N/A
60.0	4.593	#N/A
61.0	4.593	#N/A
62.0	4.593	#N/A
63.0	4.593	#N/A
64.0	4.592	#N/A



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 4.17 \times 10^{-5} \ m/s$$

Bouwer & Rice (1976) Slug Test Analysis Sheet

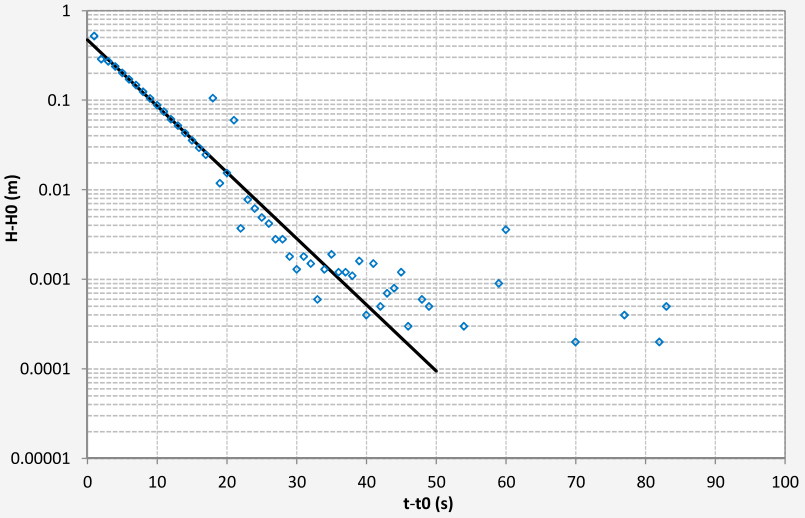
PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH1 Shallow

Test date:	10/08/2017	**Bore depth:**	11.4	mBGL	**Slugs used:**	3	
Test time:	11:35	**SWL:**	3.91	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00047	m3
Reviewed by:	PN	**Saturated screen length (Le):**	4	m	**Expected displ:**	0.59	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	8	m	**Obs displacement:**	0.52	m
		Piezo sat. thickness (Lw):	7.49	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	4.58	**Y-intercept shift:**	0.47	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	5.1	**Hydraulic conductivity (K):**	**6.92E-05**	m/s			
			5.98E+00	m/d	**Test duration:**	50	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	5.100	0.520
2.0	4.868	0.288
3.0	4.851	0.271
4.0	4.817	0.237
5.0	4.783	0.203
6.0	4.752	0.172
7.0	4.727	0.147
8.0	4.704	0.124
9.0	4.685	0.105
10.0	4.668	0.088
11.0	4.654	0.074
12.0	4.642	0.061
13.0	4.632	0.052
14.0	4.623	0.043
15.0	4.616	0.035
16.0	4.610	0.029
17.0	4.605	0.024
18.0	4.685	0.105
19.0	4.592	0.012
20.0	4.595	0.015
21.0	4.640	0.060
22.0	4.584	0.004
23.0	4.588	0.008
24.0	4.586	0.006
25.0	4.585	0.005
26.0	4.584	0.004
27.0	4.583	0.003
28.0	4.583	0.003
29.0	4.582	0.002
30.0	4.581	0.001
31.0	4.582	0.002
32.0	4.582	0.002
33.0	4.581	0.001
34.0	4.581	0.001
35.0	4.582	0.002
36.0	4.581	0.001
37.0	4.581	0.001
38.0	4.581	0.001
39.0	4.582	0.002
40.0	4.580	0.000
41.0	4.582	0.002
42.0	4.581	0.000
43.0	4.581	0.001
44.0	4.581	0.001
45.0	4.581	0.001
46.0	4.580	0.000
47.0	4.580	#N/A
48.0	4.581	0.001
49.0	4.581	0.000
50.0	4.580	#N/A
51.0	4.580	#N/A
52.0	4.580	#N/A
53.0	4.580	#N/A
54.0	4.580	0.000
55.0	4.580	#N/A
56.0	4.580	#N/A
57.0	4.579	#N/A
58.0	4.580	#N/A
59.0	4.581	0.001
60.0	4.584	0.004
61.0	4.579	#N/A
62.0	4.579	#N/A
63.0	4.579	#N/A
64.0	4.579	#N/A



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 6.92 \times 10^{-5} \ m/s$$

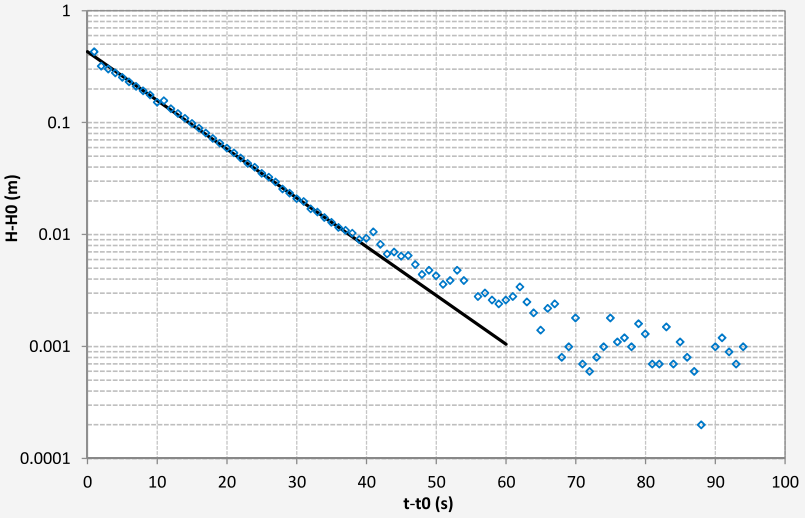
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH1 Shallow		
Test date:	10/08/2017	**Bore depth:**	11.4	mBGL	**Slugs used:**	3	
Test time:	11:31	**SWL:**	3.91	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00047	m3
Reviewed by:	PN	**Saturated screen length (Le):**	4	m	**Expected displ:**	0.59	m
Test type:	Rising head	**Aquifer sat. thickness (h):**	8	m	**Obs displacement:**	0.51	m
		Piezo sat. thickness (Lw):	7.49	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	4.59	**Y-intercept shift:**	0.43	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	5.1	**Hydraulic conductivity (K):**	**4.07E-05**	m/s			
			3.52E+00	m/d	**Test duration:**	60	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	5.020	0.430
2.0	4.910	0.320
3.0	4.892	0.302
4.0	4.867	0.277
5.0	4.843	0.253
6.0	4.822	0.232
7.0	4.801	0.211
8.0	4.782	0.192
9.0	4.766	0.176
10.0	4.742	0.152
11.0	4.746	0.156
12.0	4.723	0.133
13.0	4.711	0.121
14.0	4.700	0.110
15.0	4.689	0.099
16.0	4.679	0.089
17.0	4.671	0.081
18.0	4.662	0.072
19.0	4.655	0.065
20.0	4.649	0.059
21.0	4.644	0.054
22.0	4.638	0.048
23.0	4.633	0.043
24.0	4.630	0.040
25.0	4.625	0.035
26.0	4.623	0.032
27.0	4.620	0.030
28.0	4.616	0.026
29.0	4.614	0.024
30.0	4.611	0.021
31.0	4.610	0.020
32.0	4.607	0.017
33.0	4.606	0.016
34.0	4.604	0.014
35.0	4.603	0.013
36.0	4.602	0.012
37.0	4.601	0.011
38.0	4.600	0.010
39.0	4.599	0.009
40.0	4.599	0.009
41.0	4.601	0.011
42.0	4.598	0.008
43.0	4.597	0.007
44.0	4.597	0.007
45.0	4.596	0.006
46.0	4.597	0.006
47.0	4.595	0.005
48.0	4.594	0.004
49.0	4.595	0.005
50.0	4.594	0.004
51.0	4.594	0.004
52.0	4.594	0.004
53.0	4.595	0.005
54.0	4.594	0.004
55.0	4.588	#N/A
56.0	4.593	0.003
57.0	4.593	0.003
58.0	4.593	0.003
59.0	4.592	0.002
60.0	4.593	0.003
61.0	4.593	0.003
62.0	4.593	0.003
63.0	4.593	0.003
64.0	4.592	0.002



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 4.07 \times 10^{-5} \ m/s$$

Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

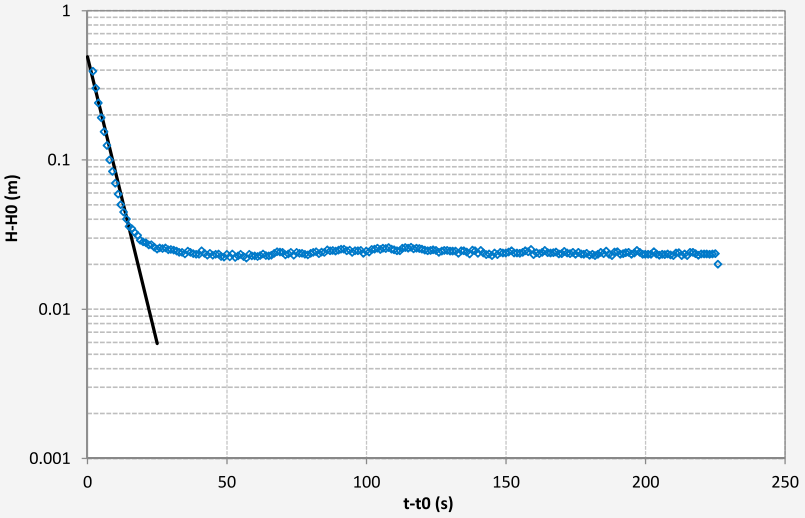
Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH1 Shallow

Test date:	10/08/2017	**Bore depth:**	11.4	mBGL	**Slugs used:**	3	
Test time:	11:31	**SWL:**	4.6	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00047	m3
Reviewed by:	PN	**Saturated screen length (Le):**	4	m	**Expected displ:**	0.59	m
Test type:	Rising head	**Aquifer sat. thickness (h):**	8	m	**Obs displacement:**	0.40	m
		Piezo sat. thickness (Lw):	6.8	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	

GWL measurement:	Depth to water	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	4.6	**Y-intercept shift:**	0.49	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	4.2	**Hydraulic conductivity (K):**	**6.92E-05**	m/s			
			5.98E+00	m/d	**Test duration:**	25	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	4.2077	#N/A
2.0	4.2983	0.392
3.0	4.3592	0.302
4.0	4.4083	0.241
5.0	4.4456	0.192
6.0	4.4752	0.154
7.0	4.4997	0.125
8.0	4.5164	0.100
9.0	4.5303	0.084
10.0	4.5409	0.070
11.0	4.5498	0.059
12.0	4.5553	0.050
13.0	4.5599	0.045
14.0	4.5641	0.040
15.0	4.5654	0.036
16.0	4.5673	0.035
17.0	4.5687	0.033
18.0	4.571	0.031
19.0	4.5717	0.029
20.0	4.5721	0.028
21.0	4.5731	0.028
22.0	4.5729	0.027
23.0	4.574	0.027
24.0	4.5747	0.026
25.0	4.5742	0.025
26.0	4.5745	0.026
27.0	4.5742	0.026
28.0	4.575	0.026
29.0	4.5749	0.025
30.0	4.5751	0.025
31.0	4.5755	0.025
32.0	4.576	0.024
33.0	4.576	0.024
34.0	4.5765	0.024
35.0	4.5755	0.023
36.0	4.5759	0.024
37.0	4.5764	0.024
38.0	4.5766	0.024
39.0	4.5766	0.023
40.0	4.5754	0.023
41.0	4.5763	0.025
42.0	4.577	0.024
43.0	4.5763	0.023
44.0	4.577	0.024
45.0	4.5766	0.023
46.0	4.5765	0.023
47.0	4.5775	0.023
48.0	4.5777	0.023
49.0	4.5766	0.022
50.0	4.5776	0.023
51.0	4.5765	0.022
52.0	4.5778	0.023
53.0	4.5772	0.022
54.0	4.5766	0.023
55.0	4.5775	0.023
56.0	4.578	0.023
57.0	4.5767	0.022
58.0	4.5772	0.023
59.0	4.5772	0.023
60.0	4.5774	0.023
61.0	4.5771	0.023
62.0	4.5765	0.023
63.0	4.5771	0.023
64.0	4.5772	0.023



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 6.92 \times 10^{-5} \ m/s$$

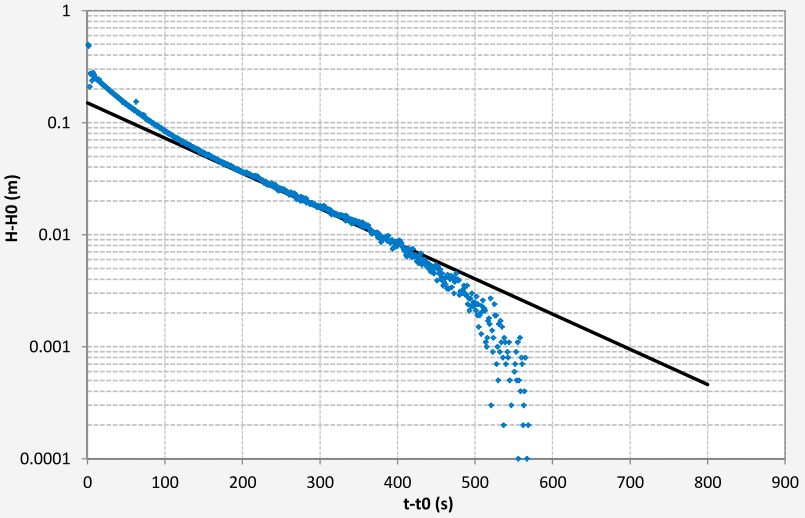
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH2-Shallow		
Test date:	10/08/2017	**Bore depth:**	35.81	mBGL	**Slugs used:**	1	
Test time:	10:00	**SWL:**	23.06	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00016	m3
Reviewed by:		**Saturated screen length (Le):**	10	m	**Expected displ:**	0.20	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	50	m	**Obs displacement:**	0.49	m
		Piezo sat. thickness (Lw):	12.75	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	5.0886	**Y-intercept shift:**	0.15	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	5.58	**Hydraulic conductivity (K):**	**1.26E-06**	m/s			
			1.09E-01	m/d	**Test duration:**	800	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	5.585	0.496
2.0	5.572	0.484
3.0	5.299	0.210
4.0	5.364	0.275
5.0	5.360	0.272
6.0	5.326	0.238
7.0	5.368	0.280
8.0	5.351	0.262
9.0	5.356	0.267
10.0	5.343	0.254
11.0	5.338	0.249
12.0	5.334	0.246
13.0	5.331	0.243
14.0	5.328	0.240
15.0	5.332	0.243
16.0	5.321	0.232
17.0	5.318	0.230
18.0	5.314	0.225
19.0	5.311	0.223
20.0	5.308	0.220
21.0	5.306	0.217
22.0	5.302	0.214
23.0	5.299	0.211
24.0	5.297	0.208
25.0	5.294	0.205
26.0	5.290	0.202
27.0	5.289	0.200
28.0	5.285	0.196
29.0	5.283	0.194
30.0	5.280	0.191
31.0	5.277	0.189
32.0	5.275	0.186
33.0	5.273	0.184
34.0	5.270	0.181
35.0	5.268	0.179
36.0	5.266	0.177
37.0	5.263	0.174
38.0	5.260	0.172
39.0	5.258	0.170
40.0	5.255	0.167
41.0	5.254	0.165
42.0	5.252	0.164
43.0	5.251	0.162
44.0	5.248	0.159
45.0	5.243	0.154
46.0	5.244	0.155
47.0	5.243	0.154
48.0	5.240	0.151
49.0	5.237	0.149
50.0	5.236	0.148
51.0	5.235	0.146
52.0	5.232	0.143
53.0	5.231	0.142
54.0	5.229	0.141
55.0	5.229	0.140
56.0	5.227	0.138
57.0	5.225	0.136
58.0	5.222	0.134
59.0	5.222	0.134
60.0	5.219	0.130
61.0	5.219	0.131
62.0	5.218	0.129
63.0	5.242	0.154
64.0	5.214	0.125



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 1.26 \times 10^{-6} \ m/s$$

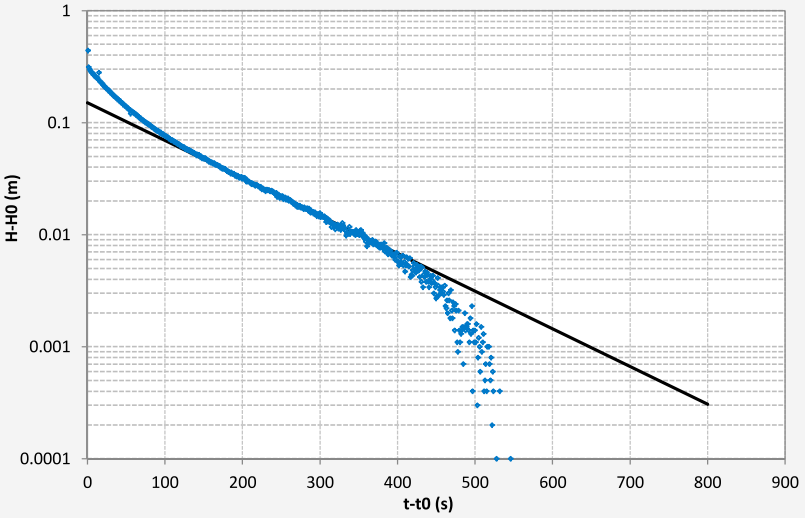
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH2 Shallow		
Test date:	10/08/2017	**Bore depth:**	35.81	mBGL	**Slugs used:**	1	
Test time:	10:00	**SWL:**	23.06	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00016	m3
Reviewed by:		**Saturated screen length (Le):**	10	m	**Expected displ:**	0.20	m
Test type:	Rising head	**Aquifer sat. thickness (h):**	50	m	**Obs displacement:**	0.44	m
		Piezo sat. thickness (Lw):	12.75	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	5.07	**Y-intercept shift:**	0.15	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	4.63	**Hydraulic conductivity (K):**	**1.35E-06**	m/s			
			1.17E-01	m/d	**Test duration:**	800	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	4.630	0.440
2.0	4.757	0.313
3.0	4.771	0.300
4.0	4.778	0.292
5.0	4.788	0.282
6.0	4.790	0.280
7.0	4.793	0.277
8.0	4.801	0.269
9.0	4.806	0.264
10.0	4.810	0.260
11.0	4.813	0.257
12.0	4.816	0.254
13.0	4.819	0.251
14.0	4.828	0.242
15.0	4.790	0.280
16.0	4.834	0.236
17.0	4.839	0.231
18.0	4.843	0.227
19.0	4.846	0.224
20.0	4.851	0.219
21.0	4.855	0.215
22.0	4.858	0.212
23.0	4.861	0.209
24.0	4.866	0.204
25.0	4.868	0.202
26.0	4.871	0.199
27.0	4.875	0.195
28.0	4.877	0.194
29.0	4.880	0.190
30.0	4.883	0.187
31.0	4.886	0.184
32.0	4.890	0.180
33.0	4.893	0.177
34.0	4.895	0.175
35.0	4.897	0.173
36.0	4.900	0.170
37.0	4.902	0.168
38.0	4.905	0.165
39.0	4.908	0.163
40.0	4.909	0.161
41.0	4.912	0.158
42.0	4.915	0.156
43.0	4.916	0.154
44.0	4.918	0.152
45.0	4.920	0.150
46.0	4.924	0.147
47.0	4.924	0.146
48.0	4.927	0.143
49.0	4.929	0.141
50.0	4.930	0.140
51.0	4.933	0.137
52.0	4.935	0.135
53.0	4.936	0.134
54.0	4.939	0.131
55.0	4.940	0.130
56.0	4.949	0.121
57.0	4.945	0.125
58.0	4.943	0.127
59.0	4.946	0.124
60.0	4.947	0.123
61.0	4.949	0.121
62.0	4.950	0.120
63.0	4.953	0.117
64.0	4.953	0.117



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 1.35 \times 10^{-6} \ m/s$$

Bouwer & Rice (1976) Slug Test Analysis Sheet

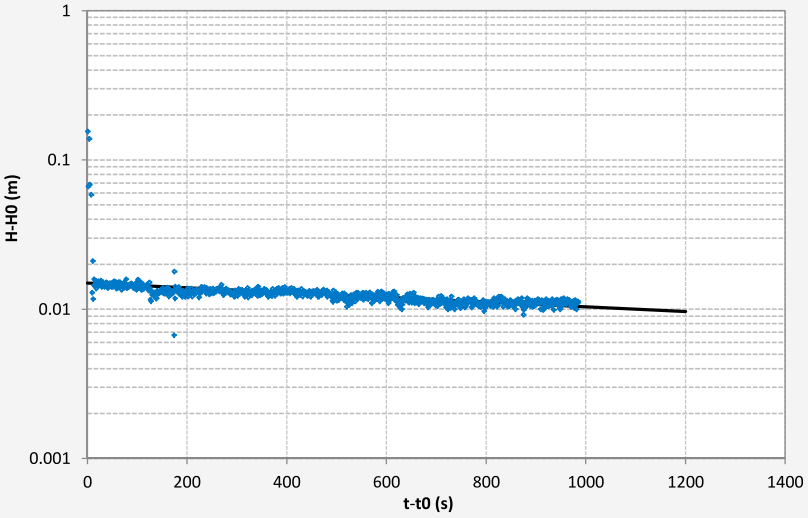
PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH3 Deep

Test date:	10/08/2017	**Bore depth:**	120	mBGL	**Slugs used:**	1	
Test time:	10:00	**SWL:**	41.97	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00016	m3
Reviewed by:		**Saturated screen length (Le):**	6	m	**Expected displ:**	0.20	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	200	m	**Obs displacement:**	0.16	m
		Piezo sat. thickness (Lw):	78.03	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	17.45	**Y-intercept shift:**	0.015	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	17.605	**Hydraulic conductivity (K):**	**1.17E-07**	m/s			
			1.02E-02	m/d	**Test duration:**	1200	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	17.605	0.155
2.0	17.517	0.067
3.0	17.431	#N/A
4.0	17.589	0.139
5.0	17.519	0.069
6.0	17.119	#N/A
7.0	17.430	#N/A
8.0	17.509	0.059
9.0	17.444	#N/A
10.0	17.463	0.013
11.0	17.471	0.021
12.0	17.462	0.012
13.0	17.465	0.015
14.0	17.466	0.016
15.0	17.464	0.014
16.0	17.465	0.015
17.0	17.464	0.014
18.0	17.464	0.014
19.0	17.465	0.015
20.0	17.465	0.015
21.0	17.465	0.015
22.0	17.465	0.015
23.0	17.465	0.015
24.0	17.465	0.015
25.0	17.465	0.015
26.0	17.465	0.015
27.0	17.466	0.016
28.0	17.465	0.015
29.0	17.464	0.014
30.0	17.465	0.015
31.0	17.465	0.015
32.0	17.465	0.015
33.0	17.464	0.014
34.0	17.465	0.015
35.0	17.464	0.014
36.0	17.464	0.014
37.0	17.464	0.014
38.0	17.465	0.015
39.0	17.465	0.015
40.0	17.465	0.015
41.0	17.464	0.014
42.0	17.464	0.014
43.0	17.464	0.014
44.0	17.464	0.014
45.0	17.465	0.015
46.0	17.465	0.015
47.0	17.464	0.014
48.0	17.465	0.015
49.0	17.464	0.014
50.0	17.464	0.014
51.0	17.465	0.015
52.0	17.464	0.014
53.0	17.464	0.014
54.0	17.465	0.015
55.0	17.465	0.015
56.0	17.464	0.014
57.0	17.465	0.015
58.0	17.465	0.015
59.0	17.464	0.014
60.0	17.465	0.015
61.0	17.464	0.014
62.0	17.464	0.014
63.0	17.465	0.015
64.0	17.464	0.014



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 1.17 \times 10^{-7} \quad m/s$$

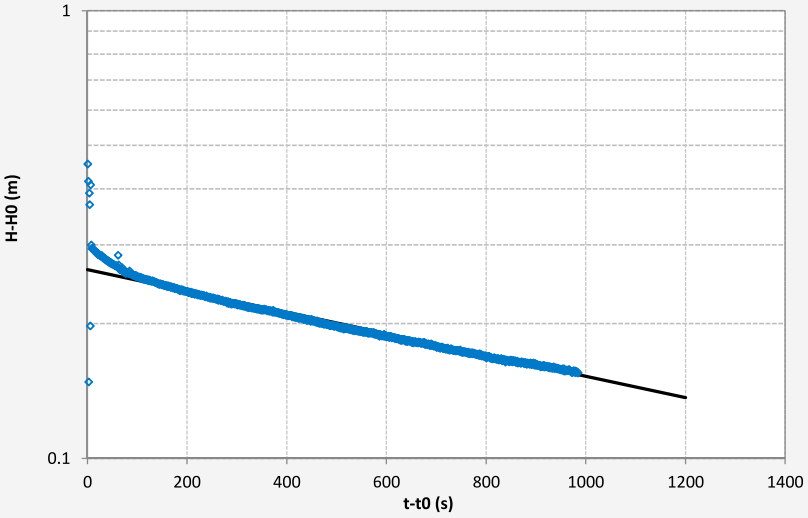
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH3 Shallow		
Test date:	10/08/2017	**Bore depth:**	40	mBGL	**Slugs used:**	2	
Test time:	10:00	**SWL:**	29.27	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00031	m3
Reviewed by:		**Saturated screen length (Le):**	6	m	**Expected displ:**	0.39	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	11	m	**Obs displacement:**	0.45	m
		Piezo sat. thickness (Lw):	10.73	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	8.68	**Y-intercept shift:**	0.264	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	9.13	**Hydraulic conductivity (K):**	**1.66E-07**	m/s			
			1.43E-02	m/d	**Test duration:**	1200	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	9.135	0.455
2.0	9.096	0.416
3.0	8.828	0.148
4.0	9.071	0.391
5.0	9.049	0.369
6.0	8.878	0.198
7.0	9.088	0.408
8.0	8.980	0.300
9.0	8.974	0.294
10.0	8.974	0.294
11.0	8.974	0.294
12.0	8.973	0.293
13.0	8.972	0.292
14.0	8.971	0.291
15.0	8.971	0.291
16.0	8.970	0.290
17.0	8.969	0.289
18.0	8.968	0.288
19.0	8.968	0.288
20.0	8.968	0.288
21.0	8.967	0.287
22.0	8.965	0.285
23.0	8.966	0.286
24.0	8.965	0.285
25.0	8.964	0.284
26.0	8.964	0.284
27.0	8.963	0.283
28.0	8.963	0.283
29.0	8.964	0.284
30.0	8.962	0.282
31.0	8.961	0.281
32.0	8.961	0.281
33.0	8.960	0.280
34.0	8.960	0.280
35.0	8.959	0.279
36.0	8.959	0.279
37.0	8.958	0.278
38.0	8.958	0.278
39.0	8.957	0.277
40.0	8.957	0.277
41.0	8.956	0.276
42.0	8.956	0.276
43.0	8.956	0.276
44.0	8.954	0.274
45.0	8.954	0.274
46.0	8.954	0.274
47.0	8.953	0.273
48.0	8.954	0.274
49.0	8.952	0.272
50.0	8.952	0.272
51.0	8.952	0.272
52.0	8.951	0.271
53.0	8.952	0.272
54.0	8.950	0.270
55.0	8.950	0.270
56.0	8.950	0.270
57.0	8.950	0.270
58.0	8.950	0.270
59.0	8.950	0.270
60.0	8.949	0.269
61.0	8.948	0.268
62.0	8.964	0.284
63.0	8.951	0.271
64.0	8.946	0.266



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 1.66 \times 10^{-7} \ m/s$$

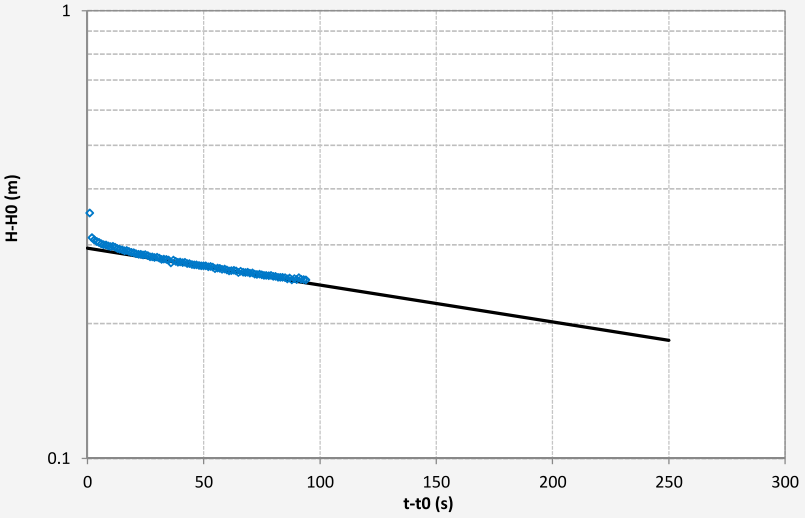
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	FH3 Shallow		
Test date:	10/08/2017	**Bore depth:**	40	mBGL	**Slugs used:**	2	
Test time:	11:31	**SWL:**	29.27	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00031	m3
Reviewed by:		**Saturated screen length (Le):**	6	m	**Expected displ:**	0.39	m
Test type:	Rising head	**Aquifer sat. thickness (h):**	11	m	**Obs displacement:**	0.36	m
		Piezo sat. thickness (Lw):	10.73	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	8.8	**Y-intercept shift:**	0.295	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	8.44	**Hydraulic conductivity (K):**	**5.75E-07**	m/s			
			4.97E-02	m/d	**Test duration:**	250	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	8.446	0.354
2.0	8.489	0.311
3.0	8.492	0.308
4.0	8.495	0.305
5.0	8.496	0.304
6.0	8.498	0.302
7.0	8.500	0.300
8.0	8.500	0.300
9.0	8.502	0.298
10.0	8.503	0.297
11.0	8.502	0.298
12.0	8.504	0.296
13.0	8.505	0.295
14.0	8.507	0.294
15.0	8.507	0.293
16.0	8.509	0.291
17.0	8.509	0.291
18.0	8.510	0.290
19.0	8.511	0.289
20.0	8.512	0.288
21.0	8.513	0.287
22.0	8.514	0.286
23.0	8.514	0.286
24.0	8.515	0.285
25.0	8.515	0.285
26.0	8.516	0.284
27.0	8.518	0.282
28.0	8.518	0.282
29.0	8.519	0.281
30.0	8.519	0.282
31.0	8.520	0.280
32.0	8.522	0.279
33.0	8.521	0.279
34.0	8.522	0.278
35.0	8.522	0.278
36.0	8.527	0.274
37.0	8.523	0.277
38.0	8.524	0.276
39.0	8.526	0.275
40.0	8.525	0.275
41.0	8.526	0.274
42.0	8.526	0.274
43.0	8.528	0.273
44.0	8.528	0.272
45.0	8.529	0.271
46.0	8.529	0.271
47.0	8.529	0.271
48.0	8.530	0.270
49.0	8.531	0.269
50.0	8.531	0.269
51.0	8.531	0.269
52.0	8.532	0.268
53.0	8.531	0.269
54.0	8.532	0.268
55.0	8.535	0.265
56.0	8.534	0.266
57.0	8.534	0.266
58.0	8.535	0.265
59.0	8.535	0.265
60.0	8.536	0.264
61.0	8.538	0.263
62.0	8.537	0.263
63.0	8.537	0.263
64.0	8.538	0.262



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 5.75 \times 10^{-7} \ m/s$$

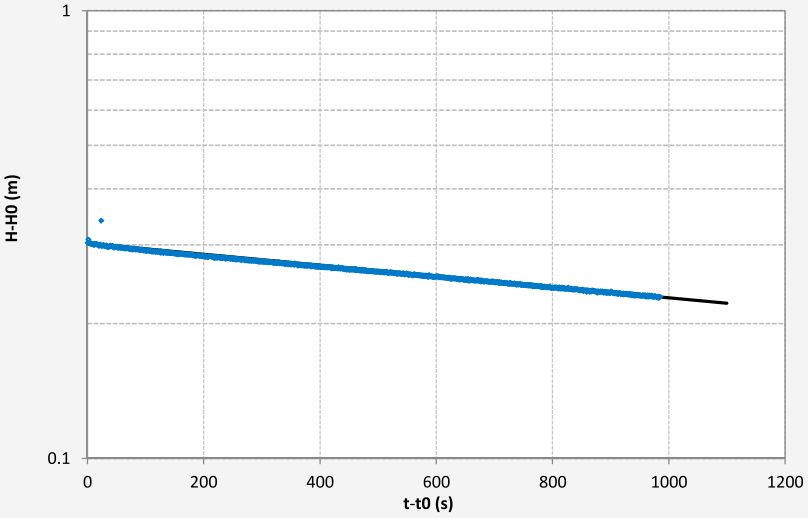
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	CLEVEDON QUARRY	**Job No:**		**Bore ID:**	Quarry Bore		
Test date:	10/08/2017	**Bore depth:**	30	mBGL	**Slugs used:**	2	
Test time:	11:59	**SWL:**	0.35	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00031	m3
Reviewed by:		**Saturated screen length (Le):**	78	m	**Expected displ:**	0.39	m
Test type:	Falling head	**Aquifer sat. thickness (h):**	200	m	**Obs displacement:**	0.30	m
		Piezo sat. thickness (Lw):	29.65	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	9.94	**Y-intercept shift:**	0.302	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	10.243	**Hydraulic conductivity (K):**	**8.51E-09**	m/s			
			7.35E-04	m/d	**Test duration:**	1100	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	10.243	0.303
2.0	10.248	0.308
3.0	10.243	0.303
4.0	10.243	0.303
5.0	10.242	0.302
6.0	10.242	0.302
7.0	10.242	0.302
8.0	10.242	0.302
9.0	10.241	0.301
10.0	10.241	0.301
11.0	10.241	0.301
12.0	10.240	0.300
13.0	10.242	0.302
14.0	10.241	0.301
15.0	10.241	0.301
16.0	10.241	0.301
17.0	10.241	0.301
18.0	10.241	0.301
19.0	10.240	0.300
20.0	10.239	0.299
21.0	10.239	0.299
22.0	10.241	0.301
23.0	10.240	0.300
24.0	10.280	0.340
25.0	10.239	0.299
26.0	10.239	0.299
27.0	10.239	0.299
28.0	10.240	0.300
29.0	10.239	0.299
30.0	10.239	0.299
31.0	10.238	0.298
32.0	10.239	0.299
33.0	10.239	0.299
34.0	10.238	0.298
35.0	10.236	0.296
36.0	10.237	0.297
37.0	10.237	0.297
38.0	10.238	0.298
39.0	10.237	0.297
40.0	10.239	0.299
41.0	10.238	0.298
42.0	10.238	0.298
43.0	10.239	0.299
44.0	10.237	0.297
45.0	10.238	0.298
46.0	10.236	0.296
47.0	10.237	0.297
48.0	10.237	0.297
49.0	10.237	0.297
50.0	10.237	0.297
51.0	10.237	0.297
52.0	10.237	0.297
53.0	10.235	0.295
54.0	10.236	0.296
55.0	10.236	0.296
56.0	10.237	0.297
57.0	10.236	0.296
58.0	10.236	0.296
59.0	10.235	0.295
60.0	10.236	0.296
61.0	10.236	0.296
62.0	10.235	0.295
63.0	10.235	0.295
64.0	10.236	0.296



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 8.51 \times 10^{-9} \ m/s$$

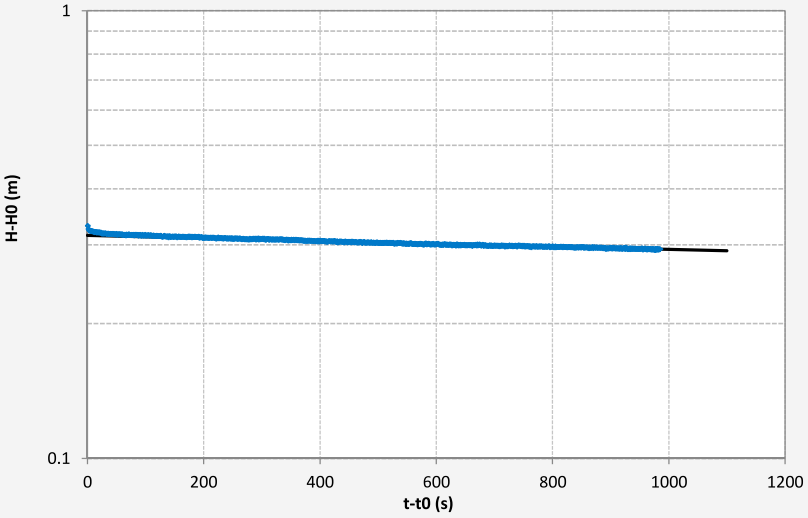
Bouwer & Rice (1976) Slug Test Analysis Sheet

PATTLE DELAMORE PARTNERS

Project:	Clevedon Quarry		**Job No:**			**Bore ID:**	FH1 Deep
Test date:	10/08/2017	**Bore depth:**	30	mBGL	**Slugs used:**	2	
Test time:	0:24	**SWL:**	0.35	mBGL	**Slug length:**	0.5	m
Performed by:	DS	**Screen radius (rc):**	0.016	m	**Slug radius:**	0.01	m
Analysed by:	DS	**Borehole radius (Re):**	0.05	m	**Displacement vol:**	0.00031	m3
Reviewed by:		**Saturated screen length (Le):**	8	m	**Expected displ:**	0.39	m
Test type:	Rising head	**Aquifer sat. thickness (h):**	200	m	**Obs displacement:**	0.34	m
		Piezo sat. thickness (Lw):	29.65	m	**Eff. casing radius:**	0.030	m
					Correct for displacement:	FALSE	
GWL measurement:	Water depth	**Curve fitting:**			**Well screened across water table:**	TRUE	
Static GWL (m):	10.15	**Y-intercept shift:**	0.315	m	**Filter pack porosity:**	0.3	
Displaced GWL (m):	9.81	**Hydraulic conductivity (K):**	**1.62E-08**	m/s			
			1.40E-03	m/d	**Test duration:**	1100	s

Observed data

t (s)	GWL (m)	H-H0 (m)
1.0	9.819	0.331
2.0	9.825	0.326
3.0	9.827	0.324
4.0	9.827	0.323
5.0	9.828	0.322
6.0	9.827	0.323
7.0	9.828	0.322
8.0	9.828	0.322
9.0	9.828	0.322
10.0	9.829	0.321
11.0	9.829	0.321
12.0	9.829	0.321
13.0	9.830	0.320
14.0	9.830	0.321
15.0	9.829	0.321
16.0	9.830	0.320
17.0	9.831	0.320
18.0	9.830	0.320
19.0	9.830	0.320
20.0	9.831	0.319
21.0	9.830	0.320
22.0	9.830	0.320
23.0	9.831	0.319
24.0	9.831	0.320
25.0	9.832	0.318
26.0	9.832	0.318
27.0	9.832	0.319
28.0	9.832	0.318
29.0	9.832	0.318
30.0	9.832	0.318
31.0	9.832	0.318
32.0	9.832	0.318
33.0	9.832	0.318
34.0	9.832	0.318
35.0	9.833	0.317
36.0	9.832	0.318
37.0	9.833	0.317
38.0	9.833	0.317
39.0	9.833	0.317
40.0	9.833	0.317
41.0	9.833	0.317
42.0	9.833	0.317
43.0	9.833	0.317
44.0	9.832	0.318
45.0	9.833	0.317
46.0	9.833	0.318
47.0	9.833	0.317
48.0	9.833	0.317
49.0	9.833	0.317
50.0	9.834	0.317
51.0	9.833	0.318
52.0	9.834	0.316
53.0	9.834	0.316
54.0	9.833	0.317
55.0	9.833	0.317
56.0	9.834	0.316
57.0	9.834	0.316
58.0	9.833	0.317
59.0	9.834	0.316
60.0	9.833	0.317
61.0	9.834	0.316
62.0	9.834	0.316
63.0	9.834	0.316
64.0	9.834	0.316



Notes:

Well is screened across the water table. K calculation corrected for expected displacement within the filter pack (Eq. 6.10 in Butler, 1996). Curve fitting focussed on latter part of drawdown data.

$$K = 1.62 \times 10^{-8} \ m/s$$

APPENDIX G
BORE LOGS



PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH1-Shallow**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 10-02-2017
END DATE: 10-02-2017
COORDINATES: 1784636E 5899983N
TOTAL DEPTH: 11.6 m
LOGGED BY: DS
SHEET 1 OF 2

GROUND LEVEL: 21 m RL
TOP OF CASING: 21 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
ALLUVIUM	Clayey SILT with some gravel. Light brown. Soft, moist. Gravel is light grey, sub-rounded to angular greywacke (5-10 mm). [RIVER ALLUVIUM]		0	21	10 Feb			Cement
			1	20				
			2	19				Bentonite
			3	18				uPVC Casing (32 mm)
	Sandy SILT with some clay and gravel. Light brownish yellow. Soft, moist. Gravel is light grey, sub-rounded to angular greywacke (5-10 mm). [RIVER ALLUVIUM]		4	17				Blinding Sand
			5	16				

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: PQ
Method:
Datum:

Filename: A03091701B001_FH1_Shallow

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

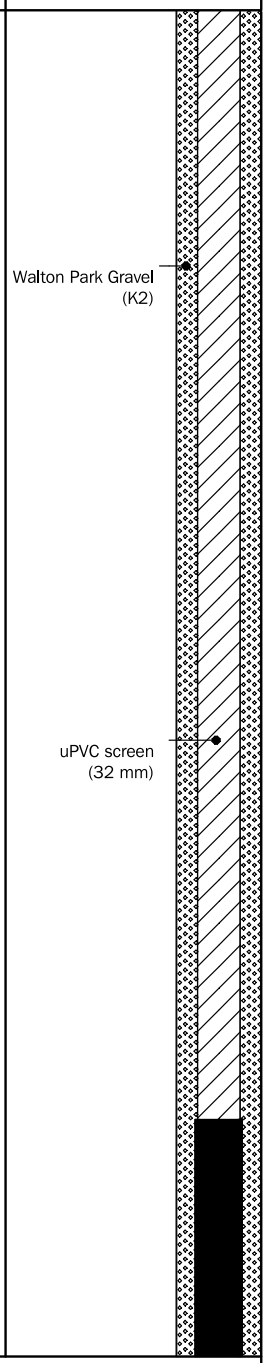
HOLE NO. **FH1-Shallow**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 10-02-2017
END DATE: 10-02-2017
COORDINATES: 1784636E 5899983N
TOTAL DEPTH: 11.6 m
LOGGED BY: DS
SHEET 2 OF 2

GROUND LEVEL: 21 m RL
TOP OF CASING: 21 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	DEPTH (m)	RL (m)
ALLUVIUM	Sandy SILT with some clay and gravel. Light brownish yellow. Soft, moist. Gravel is light grey, sub-rounded to angular greywacke (5-10 mm). [RIVER ALLUVIUM]	6	15
	Sandy SILT with some clay. Light yellowish orange. Soft, wet. [RIVER ALLUVIUM]	7	14
		8	13
GREYWACKE BASEMENT	Silty SAND with minor clay. Light greyish blue. Firm, wet. [COMPLETELY WEATHERED GREYWACKE]		
	Sandy CLAY with some gravel. Light grey. Firm, wet. Gravel is dark grey, sub-angular greywacke (5 mm). [COMPLETELY WEATHERED GREYWACKE]. Organic matter, dark brownish black with fragments of wood at 9.45 m.	9	12
	Sandy GRAVEL with some silt and clay. Light grey. Firm, wet. Gravel is grey with iron oxide staining, sub-angular to angular greywacke (3-15 mm). [COMPLETELY WEATHERED GREYWACKE]	10	11
	GRAVEL. Dark to light grey with iron oxide staining. Weak, friable, angular greywacke. [COMPLETELY WEATHERED GREYWACKE]		
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with iron oxide staining, calcite and quartz veins. Weak, laminated, angular greywacke. [MODERATELY TO HIGHLY WEATHERED GREYWACKE]	11	10



END OF BOREHOLE AT 11.6 m.

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: PQ
Method:
Datum:

Filename: A03091701B001_FH1_Shallow

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH1-Deep**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 15-02-2017
END DATE: 16-02-2017
COORDINATES: 1784636E 5899983N
TOTAL DEPTH: 36 m bgl
LOGGED BY: DS
SHEET 1 OF 2

GROUND LEVEL: 21.00 m RL
TOP OF CASING: 21.00 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
GREYWACKE BASEMENT	No recovery.
	Sandy GRAVEL. Light greyish brown. [EXTREMELY TO COMPLETELY WEATHERED GREYWACKE]
	Interbedded SANDSTONE/MUDSTONE. Light grey with iron oxide staining. Highly fractured. Fractures are open, rough, infilled with calcite (5-100 mm spacing). [HIGHLY WEATHERED GREYWACKE]
	Fine Interbedded SANDSTONE/MUDSTONE. Dark grey with iron oxide staining. Fractured, laminated. Fractures are open, rough, infilled with calcite (10-200 mm spacing). [MODERATELY WEATHERED GREYWACKE]
	Fine Interbedded SANDSTONE/MUDSTONE. Light to dark grey. Hard with some fractures, laminated. Fractures are open, rough, infilled with calcite and quartz (50-300 mm spacing). Dense quartz veins, closed (<5 mm thick). [SLIGHTLY WEATHERED TO FRESH GREYWACKE]. Greywacke becomes indurated, fresh at 17.0 m. Quartz vein, closed (~15 mm thick) at 20.6 m.
	Highly fractured, open, rough, infilled with white calcite and quartz (10-200 mm spacing).

GRAPHIC LOG | DEPTH (m) | RL (m) | DRILLING DEPTH / DATE | WATER LEVEL GAIN / LOSS | SAMPLES / TESTS | INSTALLATION

DEPTH (m): 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29
RL (m): 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8

DRILLING DEPTH / DATE: 15 Feb; 16 Feb

INSTALLATION: uPVC Casing (32 mm); Bentonite; Blinding Sand

Notes:
For top 11.6 m see FH1-Shallow.

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B002_FH1_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH1-Deep**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 15-02-2017
END DATE: 16-02-2017
COORDINATES: 1784636E 5899983N
TOTAL DEPTH: 36 m bgl
LOGGED BY: DS
SHEET 2 OF 2

GROUND LEVEL: 21.00 m RL
TOP OF CASING: 21.00 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine Interbedded SANDSTONE/MUDSTONE. Light to dark grey. Hard with some fractures, laminated. Fractures are open, rough, infilled with calcite and quartz (50-300 mm spacing). Dense quartz veins, closed (<5 mm thick). [SLIGHTLY WEATHERED TO FRESH GREYWACKE]. Greywacke becomes indurated, fresh at 17.0 m. Quartz vein, closed (~15 mm thick) at 20.6 m.		30 31 32 33 34 35 36	-9 -10 -11 -12 -13 -14 -15				Walton Park Gravel (K2) uPVC screen (32 mm)

END OF BOREHOLE AT 36 m

Notes: For top 11.6 m see FH1-Shallow.

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B002_FH1_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH2-Shallow**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 16-02-2017
END DATE: 16-02-2017
COORDINATES: 1785787E 5900241N
TOTAL DEPTH: 35 m
LOGGED BY: DS
SHEET 1 OF 2

GROUND LEVEL: 233.00 m RL
TOP OF CASING: 233.49 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with iron oxide staining, calcite and quartz veins. Weak, laminated, angular greywacke. [MODERATELY TO HIGHLY WEATHERED GREYWACKE]		0	233	16 Feb			
			1	232				
			2	231				
			3	230				
			4	229				
			5	228				
			6	227				
			7	226				
			8	225				
			9	224				
			10	223				
			11	222				
			12	221				
			13	220				
			14	219				
			15	218				
			16	217				
			17	216				
			18	215				
			19	214				

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B003_FH2_Shallow

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH2-Shallow**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 16-02-2017
END DATE: 16-02-2017
COORDINATES: 1785787E 5900241N
TOTAL DEPTH: 35 m
LOGGED BY: DS
SHEET 2 OF 2

GROUND LEVEL: 233.00 m RL
TOP OF CASING: 233.49 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with iron oxide staining, calcite and quartz veins. Weak, laminated, angular greywacke. [MODERATELY TO HIGHLY WEATHERED GREYWACKE]		20	213				uPVC Casing (32 mm)
			21	212				
			22	211				
			23	210				
			24	209				
			25	208				
			26	207				Bentonite
			27	206				Blinding Sand
			28	205				
			29	204				
			30	203				
			31	202				uPVC screen (32 mm)
			32	201				
			33	200				Walton Park Gravel (K2)
			34	199				
			35	198				
	END OF BOREHOLE AT 35 m.							

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B003_FH2_Shallow

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH2-Deep**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 16-02-2017
END DATE: 16-02-2017
COORDINATES: 1785787E 5900241N
TOTAL DEPTH: 234 m
LOGGED BY: DS
SHEET 1 OF 4

GROUND LEVEL: 233.00 m RL
TOP OF CASING: 233.66 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with some quartz veining. Greywacke is indurated, laminated, fractured, open, rough, infilled with calcite and minor quartz. [UNWEATHERED GREYWACKE]		35	198	16 Feb			
			36	197				
			37	196				
			38	195				
			39	194				
			40	193				
			41	192				
			42	191				
			43	190				
			44	189				
			45	188				
			46	187				
			47	186				
			48	185				
			49	184				
			50	183				
			51	182				
			52	181				
			53	180				
			54	179				
			55	178				
			56	177				
			57	176				
			58	175				
			59	174				
			60	173				
			61	172				
			62	171				
			63	170				
			64	169				
			65	168				
			66	167				
			67	166				
			68	165				
			69	164				
			70	163				
			71	162				
			72	161				
			73	160				
			74	159				
			75	158				
			76	157				
			77	156				
			78	155				
			79	154				
			80	153				
			81	152				
			82	151				
			83	150				
			84	149				
			85	148				
			86	147				
			87	146				
			88	145				
			89	144				
			90	143				
			91	142				
			92	141				
			93	140				
			94	139				

Notes:
For top 35 m see FH2-Shallow.

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B004_FH2_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH2-Deep**

JOB NO: A03091701

CLIENT: Fulton Hogan

LOCATION: Clevedon

START DATE: 16-02-2017
END DATE: 16-02-2017

COORDINATES: 1785787E 5900241N

TOTAL DEPTH: 234 m

LOGGED BY: DS

SHEET 2 OF 4

GROUND LEVEL: 233.00 m RL
TOP OF CASING: 233.66 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with some quartz veining. Greywacke is indurated, laminated, fractured, open, rough, infilled with calcite and minor quartz. [UNWEATHERED GREYWACKE]		95 – 153	138 – 80				

Notes:
For top 35 m see FH2-Shallow.

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B004_FH2_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH2-Deep**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 16-02-2017
END DATE: 16-02-2017
COORDINATES: 1785787E 5900241N
TOTAL DEPTH: 234 m
LOGGED BY: DS
SHEET 3 OF 4

GROUND LEVEL: 233.00 m RL
TOP OF CASING: 233.66 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with some quartz veining. Greywacke is indurated, laminated, fractured, open, rough, infilled with calcite and minor quartz. [UNWEATHERED GREYWACKE]		154	79				
			155	78				
			156	77				
			157	76				
			158	75				
			159	74				
			160	73				
			161	72				
			162	71				
			163	70				
			164	69				
			165	68				
			166	67				
			167	66				
			168	65				
			169	64				
			170	63				
			171	62				
			172	61				
			173	60				
			174	59				
			175	58				
			176	57				
			177	56				
			178	55				
			179	54				
			180	53				
			181	52				
			182	51				
			183	50				
			184	49				
			185	48				
			186	47				
			187	46				
			188	45				
			189	44				
			190	43				
			191	42				
			192	41				
			193	40				
			194	39				
			195	38				
			196	37				
			197	36				
			198	35				
			199	34				
			200	33				
			201	32				
			202	31				
			203	30				
			204	29				
			205	28				
			206	27				
			207	26				
			208	25				
			209	24				
			210	23				
			211	22				
			212	21				

Notes:
For top 35 m see FH2-Shallow.

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B004_FH2_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH2-Deep**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 16-02-2017
END DATE: 16-02-2017
COORDINATES: 1785787E 5900241N
TOTAL DEPTH: 234 m
LOGGED BY: DS
SHEET 4 OF 4

GROUND LEVEL: 233.00 m RL
TOP OF CASING: 233.66 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with some quartz veining. Greywacke is indurated, laminated, fractured, open, rough, infilled with calcite and minor quartz. [UNWEATHERED GREYWACKE]		213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234	20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1				uPVC Casing (32 mm); Bentonite; Blinding Sand; Walton Park Gravel (K2); uPVC screen (32 mm)

END OF BOREHOLE AT 234 m.

Notes: For top 35 m see FH2-Shallow.

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B004_FH2_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH3-Shallow**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 23-02-2017
END DATE: 27-02-2017
COORDINATES: 1785217E 5899743N
TOTAL DEPTH: 60 m
LOGGED BY: DS
SHEET 1 OF 2

GROUND LEVEL: 204.50 m RL
TOP OF CASING: 205.14 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	No return.
GREYWACKE BASEMENT	Sandy GRAVEL. Greyish brown. Gravel is very angular (crushed/broken GREYWACKE), very weak, friable, damp with iron oxide staining throughout. [EXTREMELY TO COMPLETELY WEATHERED GREYWACKE]
	GRAVEL. Grey, light brown. Moist. Gravel is very angular, densely fractured (broken GREYWACKE). Fractures are open, rough, with infilling of soft (2-4 mm thick) iron oxide. [HIGHLY WEATHERED GREYWACKE]
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with dense cemented quartz veins. Greywacke is moderately weak, laminated, fractured, open, rough, infilled with iron oxide and calcite. [MODERATELY WEATHERED GREYWACKE]
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with cemented quartz veins. Greywacke is indurated, laminated, highly fractured (25-100 mm spacing), open, rough, infilled with iron oxide (1 mm coating) and trace calcite. [SLIGHTLY WEATHERED GREYWACKE]
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey. Greywacke is indurated, laminated, moderately fractured (100-200 mm spacing), open, very rough with minor infilling of iron oxide (1 mm coating) and trace calcite. [SLIGHTLY WEATHERED GREYWACKE]
	Fine interbedded SANDSTONE/MUDSTONE. Dark grey with moderate (100 mm spacing) quartz veining (45°). Greywacke is indurated, laminated, fractured (50-200 mm spacing; 10-45°), open, smooth, infilled with thin coating of calcite. [UNWEATHERED GREYWACKE]

GRAPHIC LOG

DEPTH (m)	RL (m)
0	204
1	203
2	202
3	201
4	200
5	199
6	198
7	197
8	196
9	195
10	194
11	193
12	192
13	191
14	190
15	189
16	188
17	187
18	186
19	185
20	184
21	183
22	182
23	181
24	180
25	179
26	178
27	177
28	176
29	175
30	174
31	173
32	172
33	171
34	170
35	169
36	168
37	167
38	166
39	165
40	164
41	163

DRILLING DEPTH / DATE: 23 Feb; 24 Feb

WATER LEVEL GAIN / LOSS

SAMPLES / TESTS

INSTALLATION

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B005_FH3_Shallow

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH3-Shallow**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

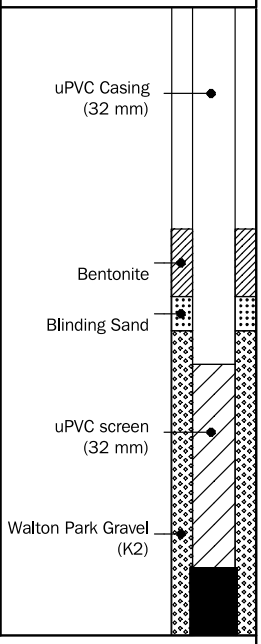
START DATE: 23-02-2017
END DATE: 27-02-2017
COORDINATES: 1785217E 5899743N
TOTAL DEPTH: 60 m
LOGGED BY: DS
SHEET 2 OF 2

GROUND LEVEL: 204.50 m RL
TOP OF CASING: 205.14 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark grey with moderate (100 mm spacing) quartz veining (45°). Greywacke is indurated, laminated, fractured (50-200 mm spacing; 10-45°), open, smooth, infilled with thin coating of calcite. [UNWEATHERED GREYWACKE]
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with closely spaced (50-100 mm) quartz veining (30-60°). Greywacke is indurated, laminated, moderately fractured (50-100 mm spacing), open, smooth, infilled with thin coating of calcite and minor quartz. [UNWEATHERED GREYWACKE]

GRAPHIC LOG | DEPTH (m) | RL (m) | DRILLING DEPTH / DATE | WATER LEVEL GAIN / LOSS | SAMPLES / TESTS | INSTALLATION

DEPTH (m): 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60
RL (m): 162, 161, 160, 159, 158, 157, 156, 155, 154, 153, 152, 151, 150, 149, 148, 147, 146, 145
DRILLING DEPTH / DATE: 25 Feb



END OF BOREHOLE AT 60 m.

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B005_FH3_Shallow

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH3-Deep**

JOB NO: A03091701

CLIENT: Fulton Hogan

LOCATION: Clevedon

START DATE: 27-02-2017
END DATE: 24-03-2017

COORDINATES: 1785217E 5899743N

TOTAL DEPTH: 216 m

LOGGED BY: DS

SHEET 1 OF 4

GROUND LEVEL: 204.50 m RL
TOP OF CASING: 205.30 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	No return.		60–101	144–103	27 Feb; 28 Feb; 1 Mar			
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey. Greywacke is indurated, laminated, fractured (150-600 mm spacing), open, smooth, infilled with thin coating of calcite and minor quartz (30-60°). [UNWEATHERED GREYWACKE]							

Notes:
For top 60 m see FH3-Shallow

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B006_FH3_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH3-Deep**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 27-02-2017
END DATE: 24-03-2017
COORDINATES: 1785217E 5899743N
TOTAL DEPTH: 216 m
LOGGED BY: DS
SHEET 2 OF 4

GROUND LEVEL: 204.50 m RL
TOP OF CASING: 205.30 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey. Greywacke is indurated, laminated, fractured (150-600 mm spacing), open, smooth, infilled with thin coating of calcite and minor quartz (30-60°). [UNWEATHERED GREYWACKE]		102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122	102 101 100 99 98 97 96 95 94 93 92 91 90 89 88 87 86 85 84 83 82	2 Mar			
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with closely spaced (50-100 mm) quartz veining (30-60°). Greywacke is indurated, laminated, moderately fractured (30-50 mm spacing), open, rough, infilled with thin coating of calcite, minor quartz and trace pyrite. [UNWEATHERED GREYWACKE]		123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143	81 80 79 78 77 76 75 74 73 72 71 70 69 68 67 66 65 64 63 62	3 Mar			

Notes: For top 60 m see FH3-Shallow

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B006_FH3_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH3-Deep**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 27-02-2017
END DATE: 24-03-2017
COORDINATES: 1785217E 5899743N
TOTAL DEPTH: 216 m
LOGGED BY: DS
SHEET 3 OF 4

GROUND LEVEL: 204.50 m RL
TOP OF CASING: 205.30 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with closely spaced (50-100 mm) quartz veining (30-60°). Greywacke is indurated, laminated, moderately fractured (30-50 mm spacing), open, rough, infilled with thin coating of calcite, minor quartz and trace pyrite. [UNWEATHERED GREYWACKE]		144 145 146 147 148 149 150 151 152	61 60 59 58 57 56 55 54 53 52	6 Mar			
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with some quartz veining. Greywacke is indurated, laminated, fractured (20-60 mm spacing; 30-70°), open, rough, infilled with calcite and minor quartz. [UNWEATHERED GREYWACKE]		153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184	51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20	7 Mar 16 Mar			

Notes:
For top 60 m see FH3-Shallow

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B006_FH3_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **FH3-Deep**
JOB NO: A03091701

CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: 27-02-2017
END DATE: 24-03-2017
COORDINATES: 1785217E 5899743N
TOTAL DEPTH: 216 m
LOGGED BY: DS
SHEET 4 OF 4

GROUND LEVEL: 204.50 m RL
TOP OF CASING: 205.30 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)	GRAPHIC LOG	DEPTH (m)	RL (m)	DRILLING DEPTH / DATE	WATER LEVEL GAIN / LOSS	SAMPLES / TESTS	INSTALLATION
GREYWACKE BASEMENT	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey with some quartz veining. Greywacke is indurated, laminated, fractured (20-60 mm spacing; 30-70°), open, rough, infilled with calcite and minor quartz. [UNWEATHERED GREYWACKE]		185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216	19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11	17 Mar 20 Mar			uPVC Casing (32 mm) Bentonite Blinding Sand Walton Park Gravel (K2) uPVC screen (32 mm)

END OF BOREHOLE AT 216 m.

Notes: For top 60 m see FH3-Shallow

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Alton Drilling Ltd
Diameter: HQ
Method:
Datum:

Filename: A03091701B006_FH3_Deep

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **GW2N**
JOB NO: A03091701

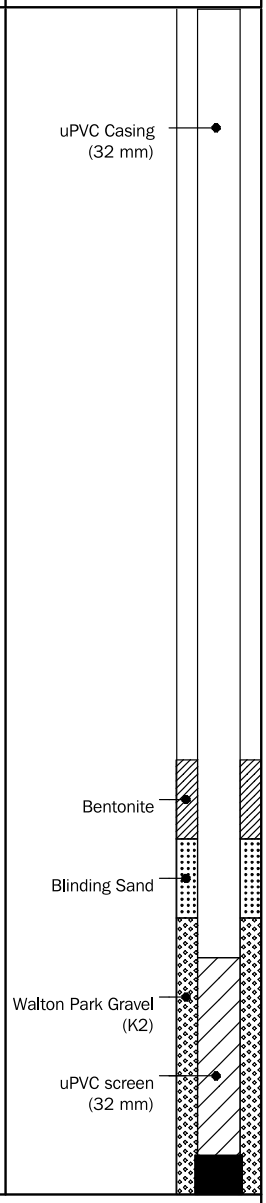
CLIENT: Fulton Hogan
LOCATION: Clevedon

START DATE: Unknown
END DATE: Unknown
COORDINATES: 1784803E 5899969N
TOTAL DEPTH: 30 m
LOGGED BY: DS
SHEET 1 OF 1

GROUND LEVEL: 26.50 m RL
TOP OF CASING: 26.80 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
GREYWACKE BASEMENT	Interbedded SANDSTONE/MUDSTONE. [EXPOSED GREYWACKE]
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey. Greywacke is indurated, moderately fractured (100-200 mm spacing). Fractures are open, very rough, with minor infilling of iron oxide (1mm coating) and trace calcite. [MODERATELY WEATHERED GREYWACKE]
	Fine interbedded SANDSTONE/MUDSTONE. Dark to light grey. Greywacke is indurated with moderate (100 mm spacing) quartz veining (~30°). Some fracturing (300-500 mm spacing, ~10-45°); open, smooth, infilled with thin coating of calcite. [UNWEATHERED GREYWACKE]
	Fine interbedded SANDSTONE/MUDSTONE. Dark grey. Greywacke is indurated with some fracturing (~500 mm spacing, ~10-45°); closed, smooth, no infilling. [UNWEATHERED GREYWACKE]

GRAPHIC LOG | DEPTH (m) | RL (m) | DRILLING DEPTH / DATE | WATER LEVEL GAIN / LOSS | SAMPLES / TESTS | INSTALLATION



END OF BOREHOLE AT 30 m.

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Unknown
Diameter:
Method:
Datum:

Filename: A03091701B007_GW2N

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

PATTLE DELAMORE PARTNERS LTD

LOG OF BOREHOLE
Clevedon Quarry

HOLE NO. **GW1**

JOB NO: A03091701

CLIENT: Fulton Hogan

LOCATION: Clevedon

START DATE: Unknown
END DATE: Unknown

COORDINATES: 1784803E 5899922N

TOTAL DEPTH: 45.8 m

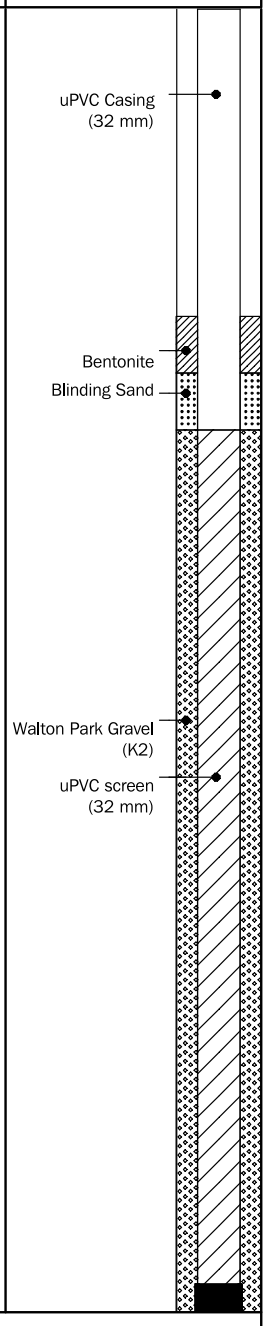
LOGGED BY: DS

SHEET 1 OF 1

GROUND LEVEL: 27.80 m RL
TOP OF CASING: 28.65 m RL

INTERPRETATION	DESCRIPTION OF SOIL / ROCK (based on cuttings etc.)
	No log available

GRAPHIC LOG | DEPTH (m) | RL (m) | DRILLING DEPTH / DATE | WATER LEVEL GAIN / LOSS | SAMPLES / TESTS | INSTALLATION



END OF BOREHOLE AT 45.8 m.

Notes:

KEY
- Groundwater Level
- Water Gain
- Water Loss
- Grab sample

Drilled By: Unknown
Diameter:
Method:
Datum:

Filename: A03091701B008_GW1

Logs based on New Zealand Geomechanics Society Field Description Guidelines (2005)

APPENDIX H
COMPLIANCE GROUNDWATER LEVEL RECORD



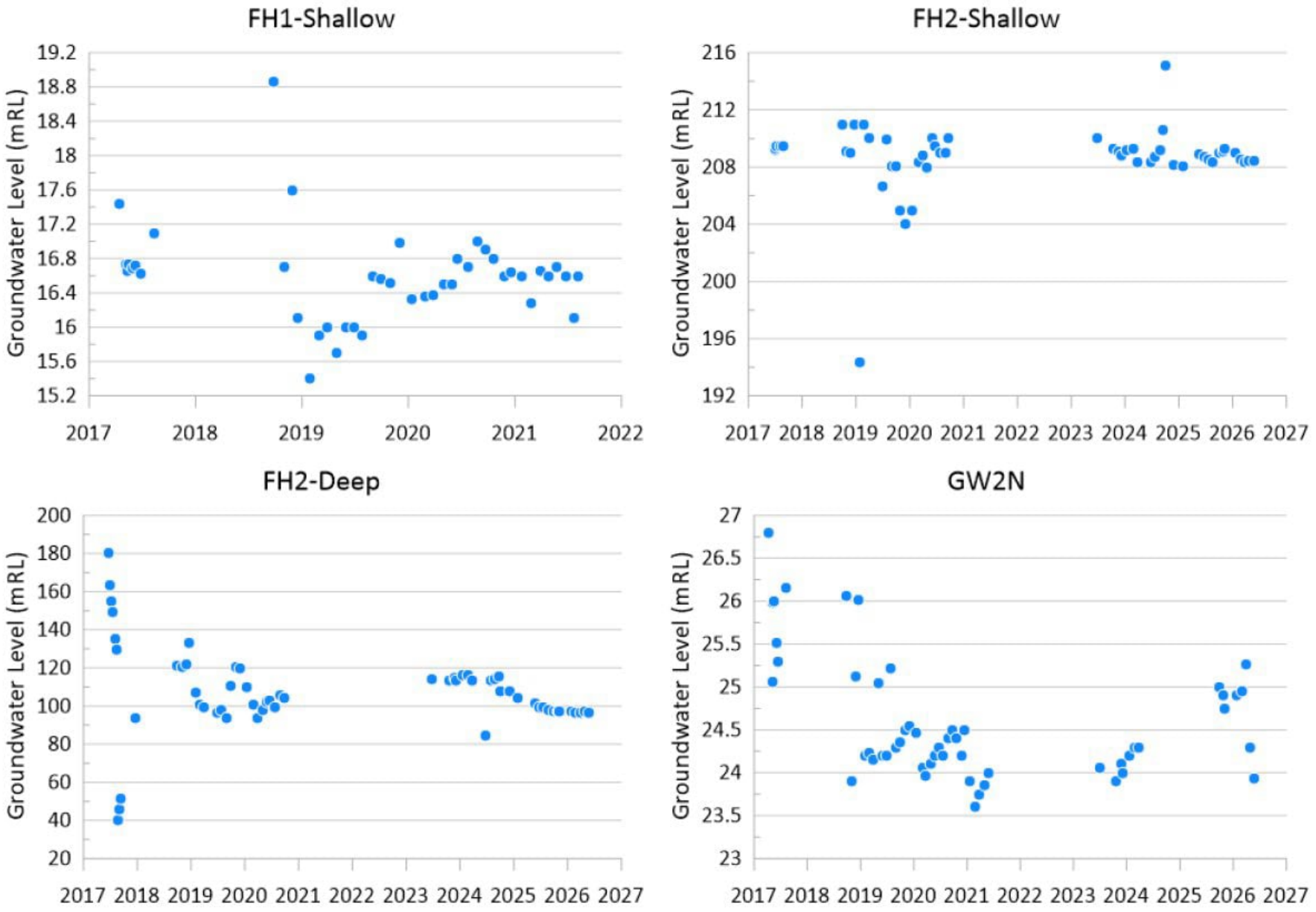


Figure H1: Groundwater Level Records from Compliance Monitoring Bores

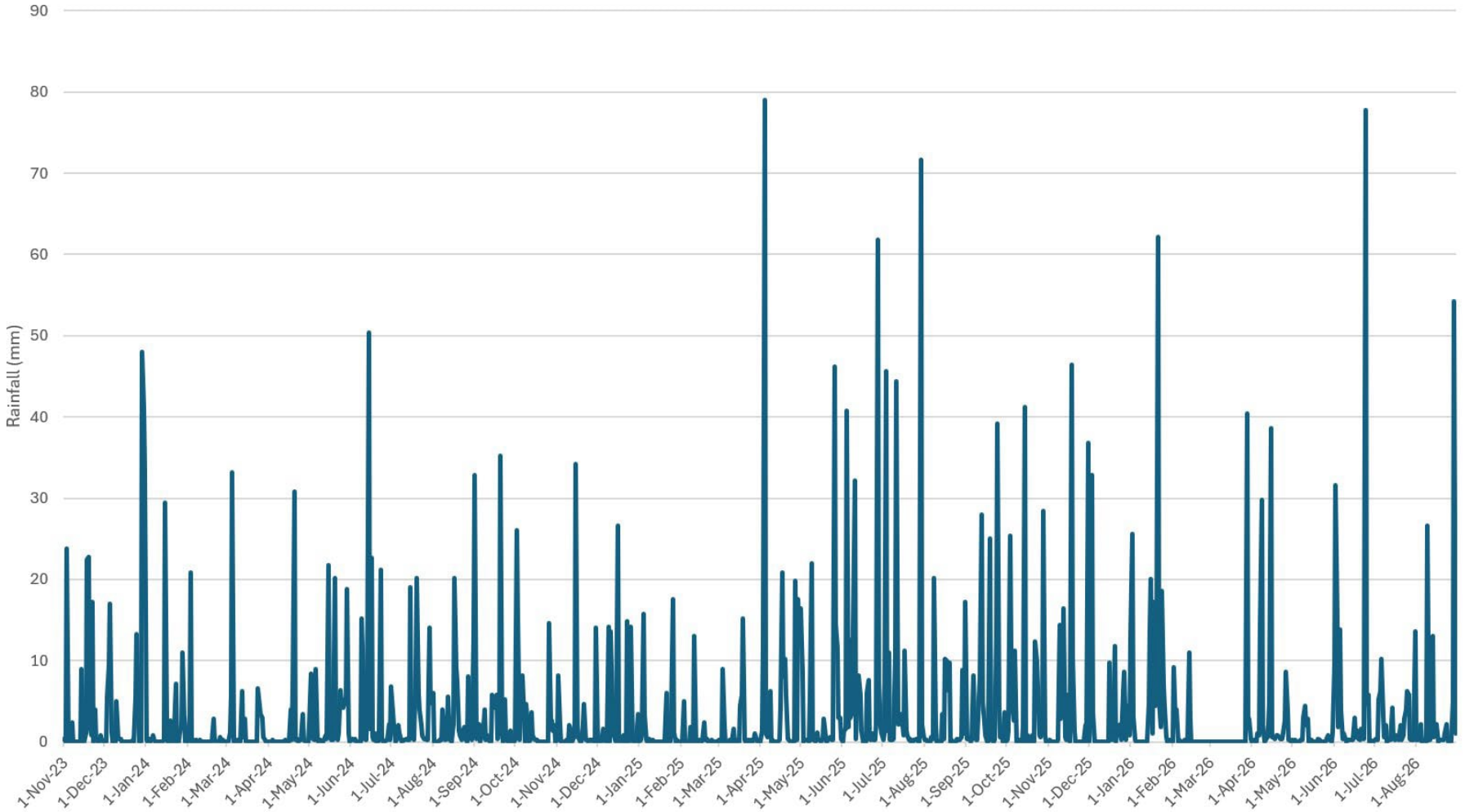
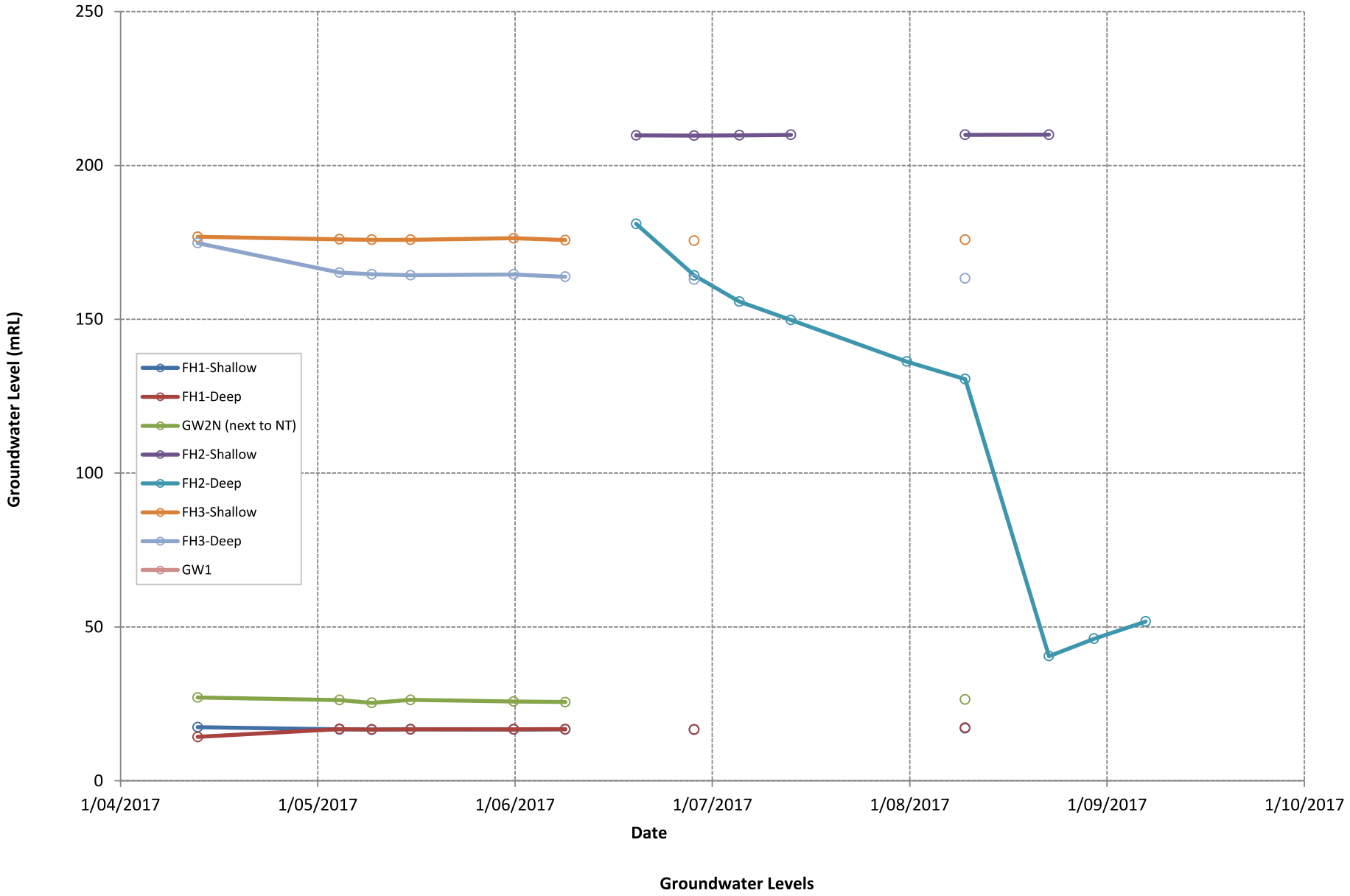


Figure H2: Daily Rainfall at Clevedon Quarry

Clevedon Quarry - A03091701



Groundwater Levels

PATTLE DELAMORE PARTNERS

APPENDIX I
ANALYTICAL PIT MODEL



Analytical Pit Model

A separate analytical assessment of groundwater inflow to the proposed Stage 5 Quarry excavation was undertaken using the conceptual model and equations described by Marinelli and Niccoli (2000). The analytical assessment was completed as a high-level validation check on the numerical groundwater model and provides an estimate of potential pit inflow based on simplified hydrogeological assumptions.

Method

The analytical approach conceptualises groundwater inflow to an open pit as originating from two separate flow domains. The first flow domain (Zone 1) represents horizontal groundwater inflow from the surrounding aquifer toward the pit walls, driven by recharge to the water table. The second flow domain (Zone 2) represents upward groundwater flow through the pit floor. A conceptual model is provided in the documentation sheets provided in the following page.

The method assumes steady-state groundwater conditions, homogeneous hydraulic properties within each flow zone, and radial groundwater flow towards an equivalent circular excavation. The calculations therefore represent a simplified approximation of groundwater behaviour and do not account for the spatial variability in hydraulic conductivity, complex topography, stream-aquifer interactions, or other boundary conditions represented in the numerical groundwater model.

Results

The analytical assessment was configured using hydrogeological parameters developed during calibration of the numerical groundwater model. Recharge was set at 180 mm/year, and hydraulic conductivity of 0.0024 m/day was adopted for both flow zones. An effective pit radius of 190 m was adopted. The saturated thickness above the conceptual base of Zone 1 was set at 201 m. This was calculated based on the modelled head in the calibration model at the eastern side of the pit. The model solved for a radius of influence of approximately 557 m.

The analytical model predicted groundwater inflow to the excavation of approximately 425 m^3/day from Zone 1 and 115 m^3/day from Zone 2 as a result of the Stage 5 design, giving a total estimated groundwater inflow of approximately 540 m^3/day.

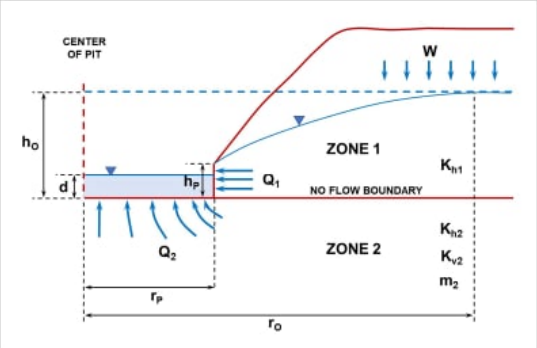
For comparison, the calibrated numerical groundwater model predicted a Stage 5 groundwater inflow of approximately 544 m^3/day. The close agreement between the analytical estimate and the numerical model prediction provides an indication that the simulated pit inflow is of a reasonable magnitude.

The analytical assessment should be regarded as an independent validation of the order of magnitude of groundwater inflow rather than a substitute for the numerical groundwater model. The numerical model remains the primary assessment tool because it explicitly represents site topography, stream-aquifer interactions, spatially variable hydrogeological conditions and the geometry of the proposed excavation.

INFLOW TO OPEN PIT - APPROXIMATION

WGA

CLIENT:	SAL
PROJECT:	Clevedon Quarry Expansion
Project #:	WGA251647
Location:	Clevedon Quarry
Date:	2 August 2026
Document #:	WGA251647-RP-HG-0005



A $$h_o = \sqrt{h_p^{\,2} + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \frac{\left(r_o^2 - r_p^2\right)}{2}\right]},$$

B $$Q_1 = W\pi\left(r_o^2 - r_p^2\right),$$

C $$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)\left(h_0 - d\right),$$

D $$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$

W	5.71E-09	**m/s**	recharge flux
K_{h1}	2.78E-08	**m/s**	horizontal hydraulic conductivity in Zone 1
K_{h2}	2.78E-08	**m/s**	horizontal hydraulic conductivity in Zone 2
K_{v2}	2.78E-09	**m/s**	vertical hydraulic conductivity in Zone 2
h_o	201	**m**	initial saturated thickness above the base of Zone 1
h_p	1	**m**	saturated thickness at the pit wall
r_p	190	**m**	effective pit radius
d	1	**m**	depth of the pit lake

r_o is the radius of influence measured from the center of the pit beyond which groundwater drawdown is nil.

Inflow from Zone 1

Radius of influence r_o calculated by iterating equation A	557	m
Known h_O	201	m
h_O calculated using Equation A	201.0	m
Q_1	4.9E-03	m^3/s
	4.25E+02	m^3/day

Inflow from Zone 2

Anisotropy parameter calculated using equation D	3.162278	
Q_2	1.3E-03	m^3/s
	1.2E+02	m^3/day

Total Pit Inflow	**Q_{TOT}**	6.3E-03 m^3/s
		5.4E+02 m^3/day

Reference: Marinelli, F. & Niccoli W. L. 2000. Simple analytical equations for estimating ground water inflow to a mine pit. Ground Water 38, no. 2: 311-314.

Analysed by: W Dench 27/08/2026
Checked by: B Sinclair 27/08/2026

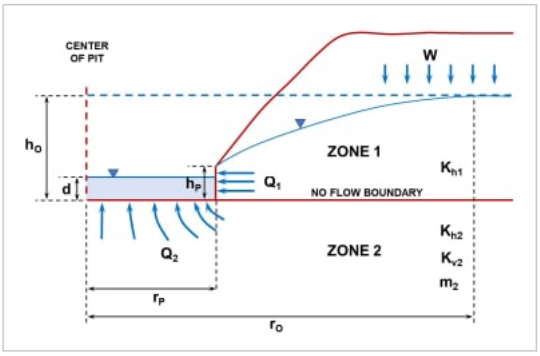
Notes:

Figure I1: Marinelli and Niccoli (2000) Pit Inflow Calculation

GROUNDWATER DRAWDOWN AROUND OPEN PIT - APPROXIMATION

WGA

CLIENT:	SAL
PROJECT:	Clevedon Quarry Expansion
Project #:	WGA251647
Location:	Clevedon Quarry
Date:	2 August 2026
Document #:	WGA251647-RP-HG-0005



$$dH_{Zone\,1} = h_0 - \sqrt{h_p^2 + \frac{W}{k_{h1}}\left[r_0^2 Ln\left(\frac{r}{r_p}\right) - \frac{\left(r^2 - r_p^2\right)}{2}\right]}$$

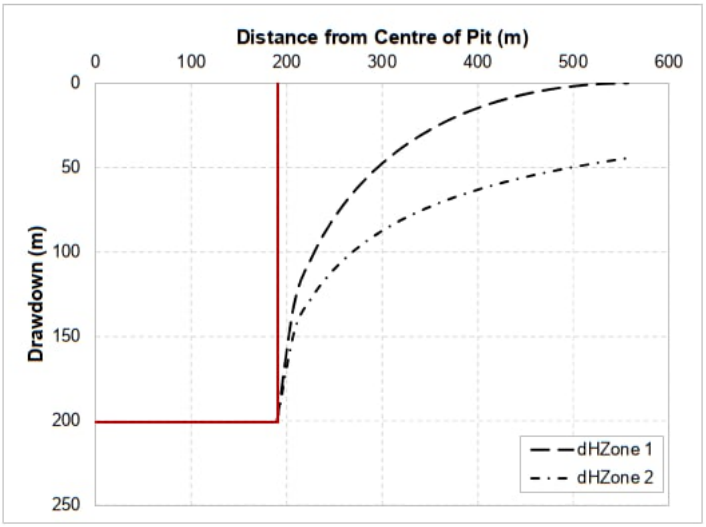
$$dH_{Zone2} = \frac{2(h_0 - d)}{\pi} sin^{-1}\left(\frac{r_p}{r}\right)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$

W	5.71E-09	**m/s**	recharge flux
K_{h1}	2.78E-08	**m/s**	horizontal hydraulic conductivity in Zone 1
K_{h2}	2.78E-08	**m/s**	horizontal hydraulic conductivity in Zone 2
K_{v2}	2.78E-09	**m/s**	vertical hydraulic conductivity in Zone 2
h_o	201	**m**	initial saturated thickness above the base of Zone 1
h_p	1	**m**	saturated thickness at the pit wall
r_p	190	**m**	effective pit radius
d	1	**m**	depth of the pit lake

r_O is the radius of influence measured from the center of the pit beyond which groundwater drawdown is nil.

Radius of influence r_o calculated by iterating equation A in analysis sheet 1 557 m



Drawdown curves

r	$dH_{Zone\,1}$	$dH_{Zone\,2}$
190	200	200.1
208.4	129.4	146.2
226.7	102.6	126.6
245.1	83.7	113.0
263.4	69.1	102.6
281.8	57.2	94.3
300.1	47.4	87.3
318.5	39.1	81.4
336.8	32.0	76.4
355.2	26.0	71.9
373.5	20.8	68.0
391.9	16.4	64.5
410.2	12.6	61.3
428.6	9.44	58.5
446.9	6.79	55.9
465.3	4.63	53.6
483.6	2.91	51.4
502.0	1.61	49.5
520.3	0.71	47.6
538.7	0.18	45.9
557.0	0.00	44.3

Reference: Marinelli, F. & Niccoli W. L. 2000. Simple analytical equations for estimating ground water inflow to a mine pit. Ground Water 38, no. 2: 311-314.

Analysed by: W Dench 27/08/2026
Checked by: B Sinclair 27/08/2026

Notes: The drawdown curves apply along the no-flow boundary line at an elevation equivalent to the base of the pit.
The dH_{Zone2} line does not take into account recharge from above.
Drawdown projections are initial approximations only.

Figure I2: Marinelli and Niccoli (2000) Pit Inflow Calculation and Distance-Drawdown

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