GEOSEARCH
water resource exploration and development

Karl Browne BSc Msc
027 24 24 333

PO Box 43, Oakura 4345
karl@geosearch.co.nz
www.geosearch.co.nz

- **Report**

Assessment of hydrological effects for a proposed expansion of the Whenuku Rd quarry, Normanby, South Taranaki

Prepared for
The Trustees
Horizon Trust
PO Box 414
Whanganui 4541

By
Karl Browne BSc, MSc
Geosearch Limited

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Revision history

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0	Karl Browne	Draft	11 Sep-20
1	Karl Browne	Final	18 Sep-20

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1. Introduction

This report presents an assessment of hydrological effects for a proposed expansion of the Whenuku Rd quarry, South Taranaki (Figure 1). Potential effects from the proposed activities on surface and groundwater levels and flows, and water quality are considered. Section 1 gives background information. Section 2 presents the results of hydrological monitoring carried out to inform this assessment, and Section 3 presents an assessment of effects.

Figure 1 Location of Whenuku Rd quarry

1.1 Proposed excavations

Workings will progress towards the Waingongoro River and northeast parallel to the river (Figure 1). The present quarry covers an area of 5.1 ha. The area proposed for the quarry extension is 6.5 ha to give a total area of 11.6 ha including the present workings.

The site will be opened up in blocks of one hectare at a time. Within each block, strips 25 m wide will be excavated down to a depth of 18 m below the level of the surrounding ground (7 m below the depth of the present pit). Worked out strips will be reinstated before excavating the next, and so on. Excavations will extend below the natural groundwater level and dewatering of the workings will be required.

A buffer zone of untouched natural ground between the workings and the river will be retained. This will serve to protect the quarry from flooding by the river and retard direct effects of dewatering on river flows.

The proposal includes realignment of a small stream (*the tributary*) which runs through the quarry. The estimated minimum life of the quarry is fifteen years. Proposed post quarry reinstatement includes forming a lake and wetland and enhancing the tributary. The reinstated freshwater system will discharge into the Waingongoro River.

1.2 Hydro-geological setting

The quarry is situated in the lower reaches of the Waingongoro catchment, 7 km inland of the sea at an elevation of 70 m. The area receives an average annual rainfall of 1,100 mm. The site is established on an alluvial terrace on the left bank of the Waingongoro River. The river is the dominant hydrological feature and is deeply incised at the quarry. The terrace surface is 11-12 m above the river and underlain by the volcanic alluvium being quarried.

From the river valley, the land rises eastwards to another terrace surface at 110 m elevation. This surface is underlain by bedded marine sand, conglomerate, peat and clay of the cover beds of the Ngarino Terrace. The tributary that flows through the quarry is sourced from springs in Ngarino Terrace (Geosearch 2019).

1.3 Pit geology

The quarried material lies below about 2 m of ash soil cover (Photos 1-3). The deposit is layered with laterally continuous beds of alluvium 1.5-2.5 m thick. The deposit strikes north-east and is bounded by the river. Papa mudstone lies below the alluvium (Figure 4). Quarry materials comprise andesite sands, rounded gravel and boulders in a matrix of silty sand. Sorting within layers is very poor. Materials are tightly packed with interlocking grains that give structural integrity to pit walls. The deposit contains muddy lenses (Photo 2).

Photograph 1 Northwest face. White stick is 2.4 m long. Pit floor is just above the groundwater level exposed in the ring drain (Geosearch 15 May-19)

Photograph 2 Northeast face. White stick is 2.4 m long (Geosearch 15 May-19).

Photograph 3 Whenuku Rd quarry looking northwest with Waingongoro River beyond (Geosearch 15 May-19).

2. Hydrological monitoring

Monitoring of surface and groundwater levels and flows was undertaken to obtain observational data. Groundwater levels were monitored in three purpose-built wells, and water levels, flows and quality at two weirs established in the tributary. Pressure transducer dataloggers were installed at the sites to record water levels. The logging interval was 15-minutes, and covered the period 5 December 2019 to 5 August 2020. The sites were periodically visited for manual gauging's of water levels and flows and maintenance. Monitoring results are presented below.

2.1 Groundwater levels

Wells MW1 to MW3 were installed in November 2019. Well locations are shown in Figure 1. Table 1 gives construction details. Tables 2 to 4 summarise borehole geology. Groundwater level monitoring results are summarised in Table 5 and plotted in Graphs 1 to 3.

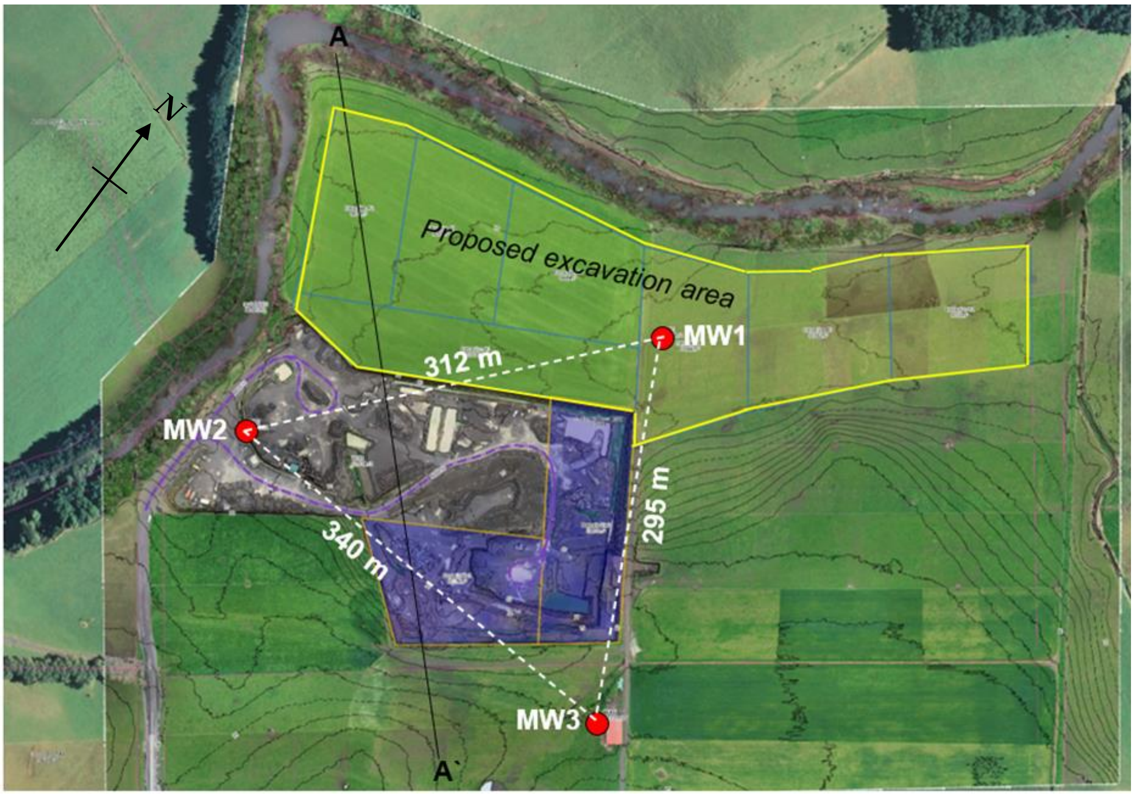


Figure 2 Location of monitoring wells and line of section shown in Figure 4

Table 1 Monitoring well construction

Well ID	Coordinates approx. NZTM		Surveyed ground elevation * m ASL	Total depth m BGL	Diameter mm	PVC screen m BGL (20 thou slot)	
	East	North				From	To
MW1	1706035	5623357	72.538	21	50	9	18
MW2	1705849	5623099	65.552	18	50	8	17
MW3	1706203	5623114	83.237	18	50	10	16

A&C Surveys Ltd, Jul-20.

Table 2 Borehole geology MW1

From	To	Material	Groundwater
0	5.5	Topsoil and clay, incl. 0.5m stone and grit	
5.5	11	Stone and grit in silty clay	Water table
11	11.5	Clay	
11.5	18	Stone and grit in silty clay, peat to 13 m.	
18	21	Papa mudstone.	

Table 3 Borehole geology MW2

From	To	Material	Groundwater
0	2	Fill - stone and grit	
2	5	Fill - stone and grit, peat from 3.5 m	Water table
5	17	Stone, coarse sand and grit in silty clay	
17	18	Papa mudstone.	

Table 4 Borehole geology MW3

From	To	Material	Groundwater
0	4.5	Topsoil and clay, incl. 0.5m stone and grit	
4.5	16	Stone, coarse sand and grit in silty clay	Water table
16	18	Hard sandstone.	

Results

Due to the well partly filling with mud, no logger data was obtained for MW3, only periodic manual measurements. For the other wells continuous logging of water levels was achieved and hence significantly more data obtained.

Graphs 1 and 2 show water levels in metres below ground level (mBGL) for the three wells compared to rainfall and river flows obtained from TRC's Glenn Rd recorder site. Graph 3 shows groundwater levels reduced to metres above sea level (mASL) and shows levels in MW1 and MW3 are elevated well above those in MW2. These elevations establish the slope of the local water table.

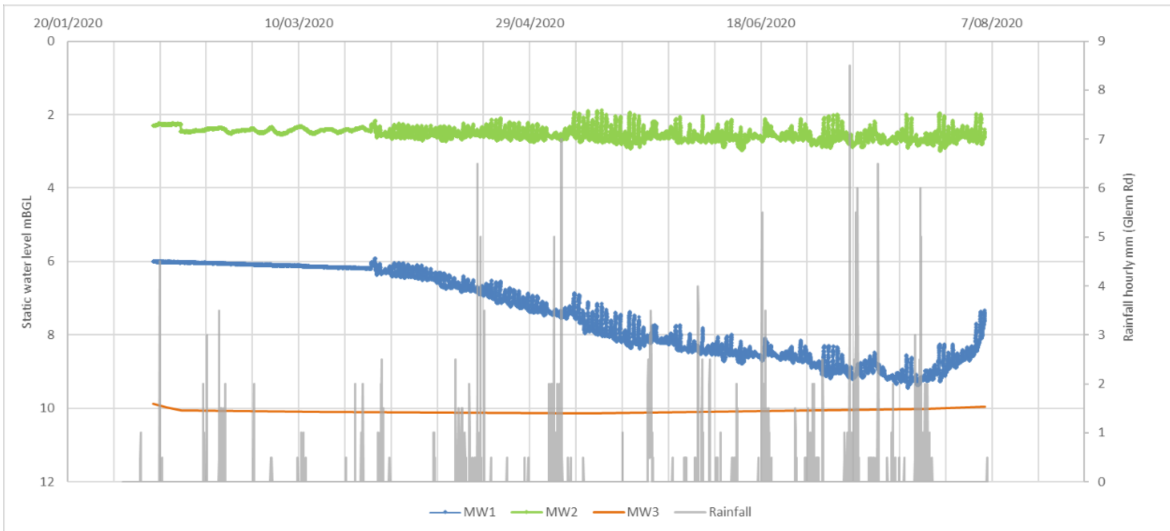
Overall, levels in MW1 declined from February to July 2020, followed by a sharp rise through to the end of the data period in August. MW3 showed similar but muted response. The curve was generally consistent with river flows, in that the decline occurred during low flow and the rise when river flows increased. This observation suggests MW1 has a hydraulic connection with the river. There was insufficient data to say if this was also the case in MW3. Overall, levels in MW2 showed a slight declining trend over the data period with no upswing at the end. The curve suggests there was no connection between this well and the river.

In detail, the curves for MW1 and MW2 show a clear response to rainfall. A similar response would be expected in MW3, but was not observed as there was no logger in this well.

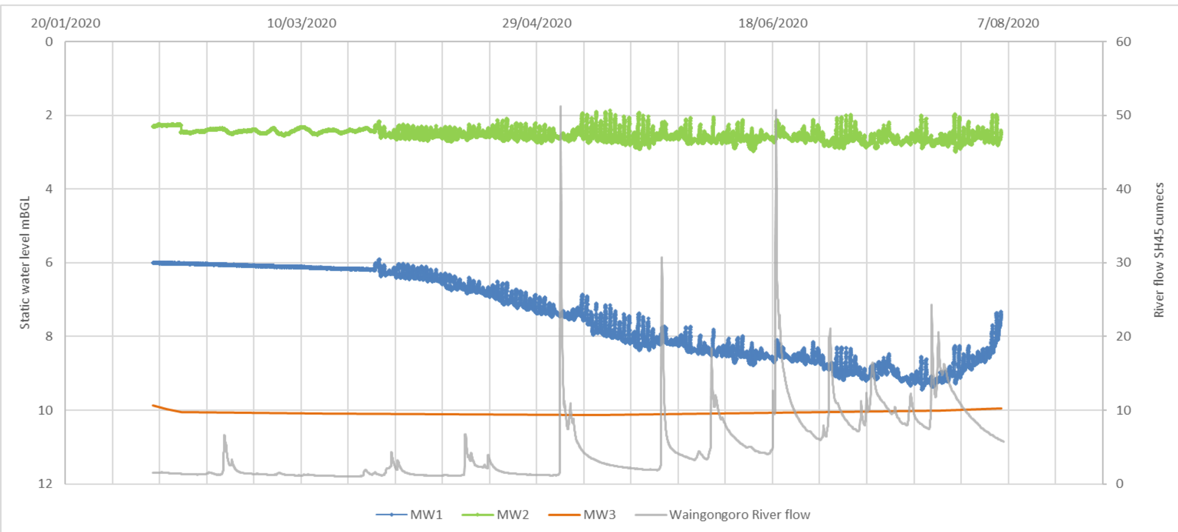
MW1 and MW2 appeared to show a pumping response. A source was not identified, but is likely to be a local abstraction. From 25 March 2020 water levels showed considerably more fluctuation than previously. A similar situation occurred with flows in the tributary (Graphs 4 and 5). It is thought the observed response was related to pumping and obscured by noise in the data, particularly at the weirs.

Table 5 Groundwater levels 7 February to 5 August 2020

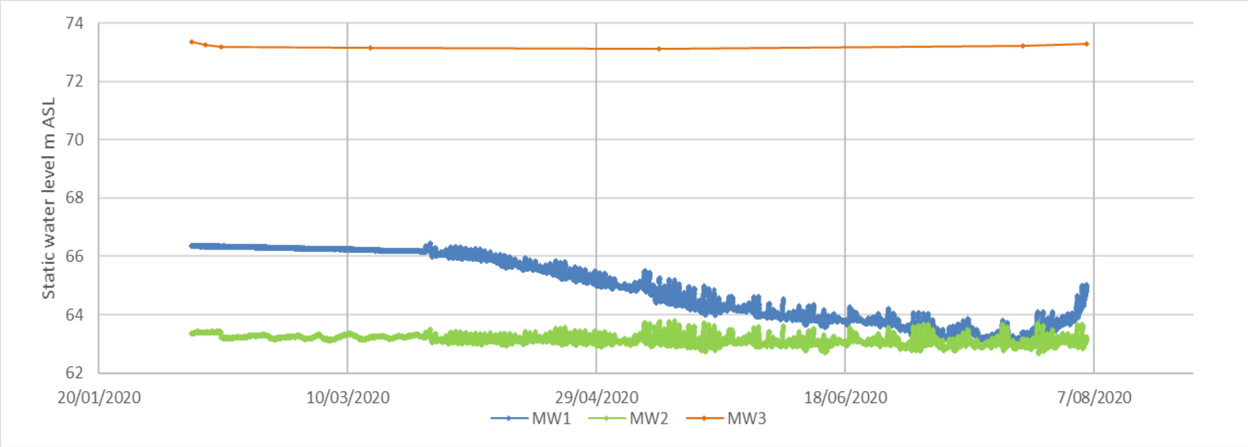
Well	Records	Groundwater levels					
		m ASL			m BGL		
		High	Low	Av.	High	Low	Av.
MW1	17266	66.44	62.91	64.90	5.91	9.45	7.46
MW2	17266	63.79	62.68	63.13	1.87	2.98	2.53
MW3	8	73.36	73.11	73.22	9.87	10.13	10.01



Graph 1 Groundwater levels mBGL and rainfall 7 February to 5 August 2020



Graph 2 Groundwater levels mBGL and river flow 7 February to 5 August 2020



Graph 3 Reduced groundwater levels mASL 7 February to 5 August 2020

2.2 Surface water flows

V-notch weirs, upstream and downstream, were installed in the tributary that flows through the quarry (Figure 3). A stilling well and logger was positioned behind the weir. Weir plates were constructed of 5 mm aluminium sheet with a 90⁰ V-notch cut out. The weirs were firmly seated into the streambed and banks. Minor leaks were experienced, but rectified.

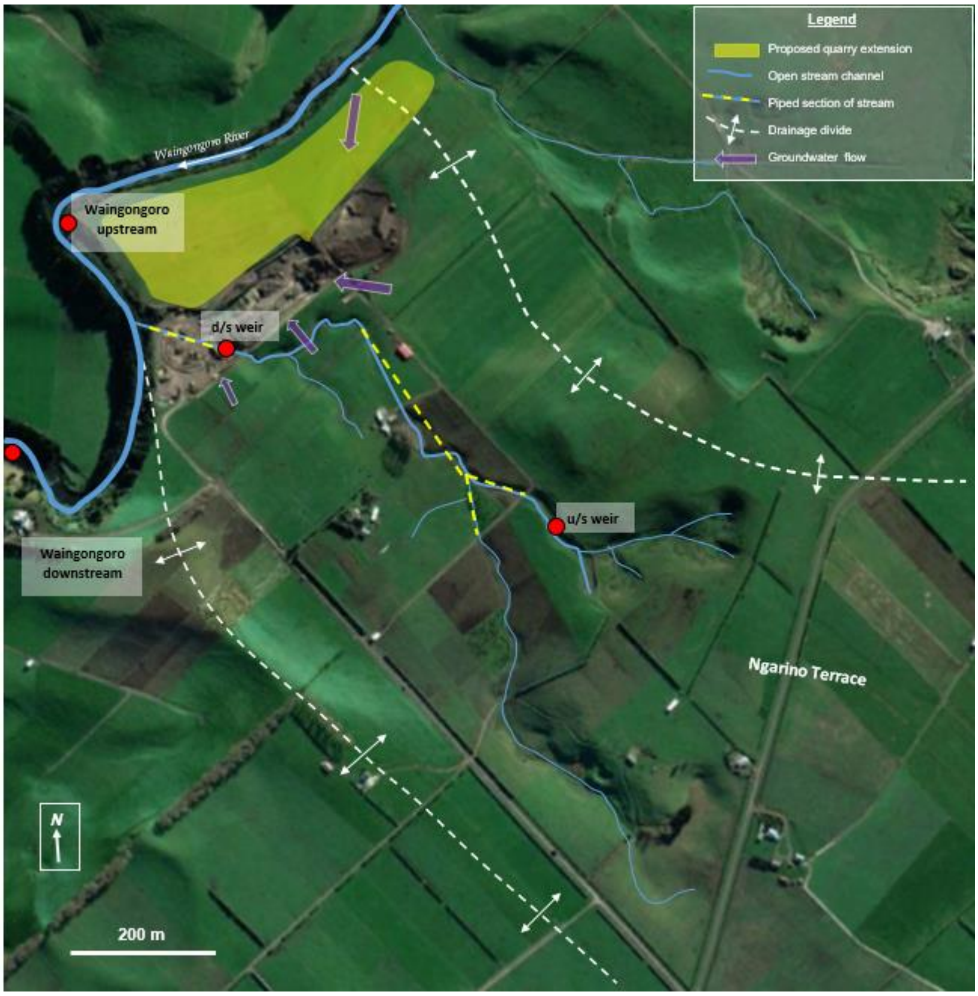


Figure 3 Location of surface water monitoring sites

Results

Stream flow gauging's were carried out, mostly during low flow. Flow data for Waingongoro River was obtained from TRC's Glenn Rd automated recorder site, 4.5 km below the quarry. Equivalent flows at the quarry were estimated using a flow proportioning approach.

Table 6 gives observed and estimated flow data for the tributary and river. The 2019-20 summer and autumn was a very dry period with drought conditions declared over much of the North Island. During the dry, flows in the Waingongoro River fell well below the MALF with a low of 540 l/s recorded at Glenn Rd around 20 March 2020. The March low flow was below the 5-yr return period flow of 597 l/s. Flows in the tributary would also likely have been well below its MALF.

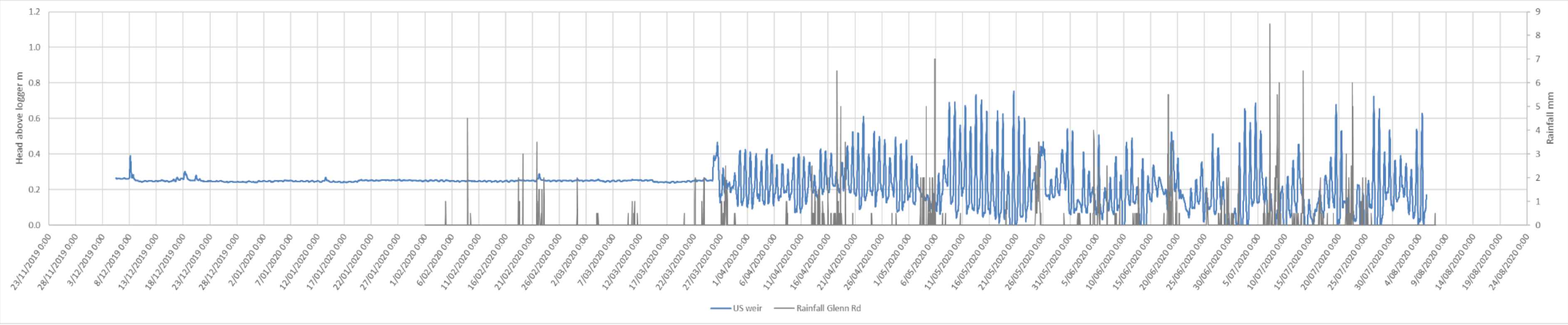
Table 6 Surface water flows

Flow l/s	Location				Notes
	Tributary upstream	Tributary downstream	Waingongoro at quarry	Waingongoro at Glenn Rd	
Low	1.13	1.3	491	540	Observed low flow in tributary 14 Feb-20. Observed low flow at Glenn Rd 20 Mar-20. Low flow at quarry estimated.
MALF (natural)	-	-	1,232	1,354	Natural MALF at Glenn Rd from TRC long term records. Natural MALF at quarry estimated.
Median	31	49	5,150	-	Median flows estimated.
High	>70	>100	58,000	63,740	Observed high flow at Glenn Rd 8 Dec-19. High flow at quarry estimated.

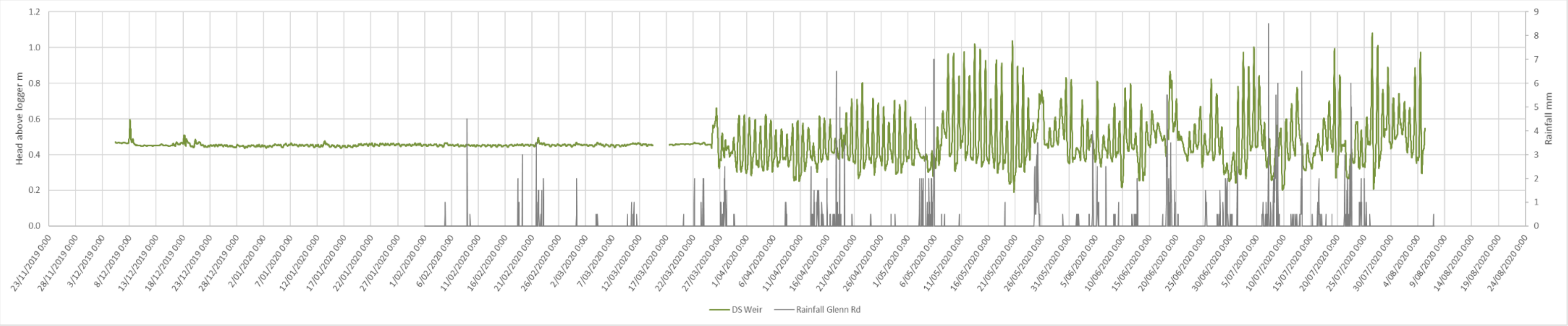
From 25 March 2020, flows at the weirs were considerably more variable than previously. This was also the case for groundwater levels in the wells (Graphs 1 to 3). While the observed response generally coincides with increased rainfall, it also appears to be related to pumping.

Photograph 4 Near low-flow in tributary (2 l/s) at quarry 26 Jan-20

Graph 4 Flows in tributary at weir above quarry 5 Dec-19 to 5 Aug-20



Graph 5 Flows in tributary at the quarry weir 5 Dec-19 to 5 Aug-20



2.3 Surface water quality

Water quality samples were collected from the tributary at the weirs and from the Waingongoro River above and below the quarry. These were dispatched to Hill Laboratories for the analysis of electrical conductivity, pH, turbidity, total suspended solids, and nutrients. Water temperature was measured in the field. Figure 3 shows sampling locations (red dots).

The sampling aimed to characterise the physico-chemical conditions of the waters prior to the proposed quarry extensions. Laboratory results are summarised in Table 7 and 8 and given in full in Appendix II.

Water quality results for the tributary showed that all the parameters tested for increased between the upstream and downstream sites, but the levels observed were of no concern. The trend reflects the effects of farming and quarry activities in the catchment between the two sampling sites. There was reasonable consistency between dry and wet season results and those between the tributary and the river.

Table 7 Water quality results - dry season

Parameter	Units	Tributary		Waingongoro River	
		Above quarry	At quarry	Above quarry	Below quarry
Date/time	-	5 Dec-19 11:40	5 Dec-19 12:15	5 Dec-19 13:10	5 Dec-19 14:00
pH	-	7.2	7.9	7.6	7.7
Temperature	Deg. C	17.7	19.0	18.2	18.4
Electrical conductivity	mS/m	29.0	33.2	15.1	15.1
Turbidity	NTU	1.93	2.4	1.12	1.23
Total suspended solids	g/m^3	<3	7	5	4
Total nitrogen	g/m^3	0.51	2.3	2.2	2.2

Table 8 Water quality results - wet season

Parameter	Units	Tributary		Waingongoro River	
		Above quarry	At quarry	Above quarry	Below quarry
Date/time	-	5 Aug-20 11:00	5 Aug-20 11:50	5 Aug-20 13:00	5 Aug-20 13:45
pH	-	7.2	7.8	7.5	8.0
Temperature	Deg. C	10.3	12.6	10.0	10.6
Electrical conductivity	mS/m	26.3	35.6	18.0	18.0
Turbidity	NTU	1.70	7.4	3.8	3.6
Total suspended solids	g/m^3	<3	4	6	6
Total nitrogen	g/m^3	0.76	2.3	2.8	2.8

3. Assessment of effects

A summary of the proposed quarry excavations is given in Section 1 of this report. The main potential effects of the proposed activities on surface and groundwater are:

- Interception of groundwater flow.
- Lowering of groundwater levels.
- Depletion of surface flows.
- Changes in water quality.

3.1 Groundwater levels

Deepening the pit will take excavations below the groundwater level and trigger the need for dewatering. The maximum rate of dewatering will be limited by *(a)* restrictions around effects on river flows, *(b)* the capacity of the pump and, *(c)* the capacity of the ponds to return treated water to the river to offset the abstraction.

There is only one aquifer to consider, the water table. This is an unconfined aquifer that underlies the alluvial terrace at the quarry and is bounded by the river. Pumping will lower water levels in the pit and form a cone of depression (drawdown) in the surrounding groundwater surface. Water intercepted by the cone of depression will flow towards the pumping centre.

Provision in the consents for dewatering at up to 144 m^3/hr (40 l/s) is suggested given the present uncertainty around the rate of sub-surface flows, although due to the tight nature of the deposit, the actual rate required could be significantly less.

Localised areas of high flow may be encountered in the workings and need to be worked around to control flooding and ground stability. The dewatering rate may need to increase as excavations become deeper and progress closer to the river and northwards.

A brief dewatering trial in July 2020 in a 3 m deep hole in the pit produced rapid drawdown when pumping at a rate of 60 m^3/hr (17 l/s). No effect of this was recognised in any of the monitoring wells, but this may be due to the brevity of the test. Effects on groundwater beyond the quarry may take a longer time frame time to develop.

It is estimated that drawdown effects from dewatering could eventually extend several hundred metres radially, including below the river. Effects will diminish with distance away from the quarry.

Drawdown is expected to occur in the monitoring wells, the amount of which will vary depending on the rate and duration of pumping, and the distance between quarry and well. While there is currently no pumping test data available to quantify distance-drawdown effects, the monitoring wells will provide observational data as dewatering proceeds.

Drawdown from dewatering would also be expected in the unidentified well/bore that caused the pumping response observed in the monitoring wells. TRC records show there were no registered abstraction bores within at least 500 m of the quarry. Effects on bores at a distance of 500 m or more from the quarry are expected to be less than minor.

The local groundwater surface slopes to the south-west under the present quarry to the river. This slope suggests the aquifer is receiving recharge from the north, the most likely source of which is the river (Graph 3). This implies there is a connection between the river and the aquifer to the north. As excavations progress northwards, it is likely that groundwater will be encountered at a shallower depth.

Figure 4 is a schematic hydrogeological cross-section through the quarry based on borehole data (Figure 1 shows line of section). Elevations are in metres R.L. (m ASL). The section shows the aquifer under the quarry extends above and below riverbed level, and that the area is underlain by alluvium.

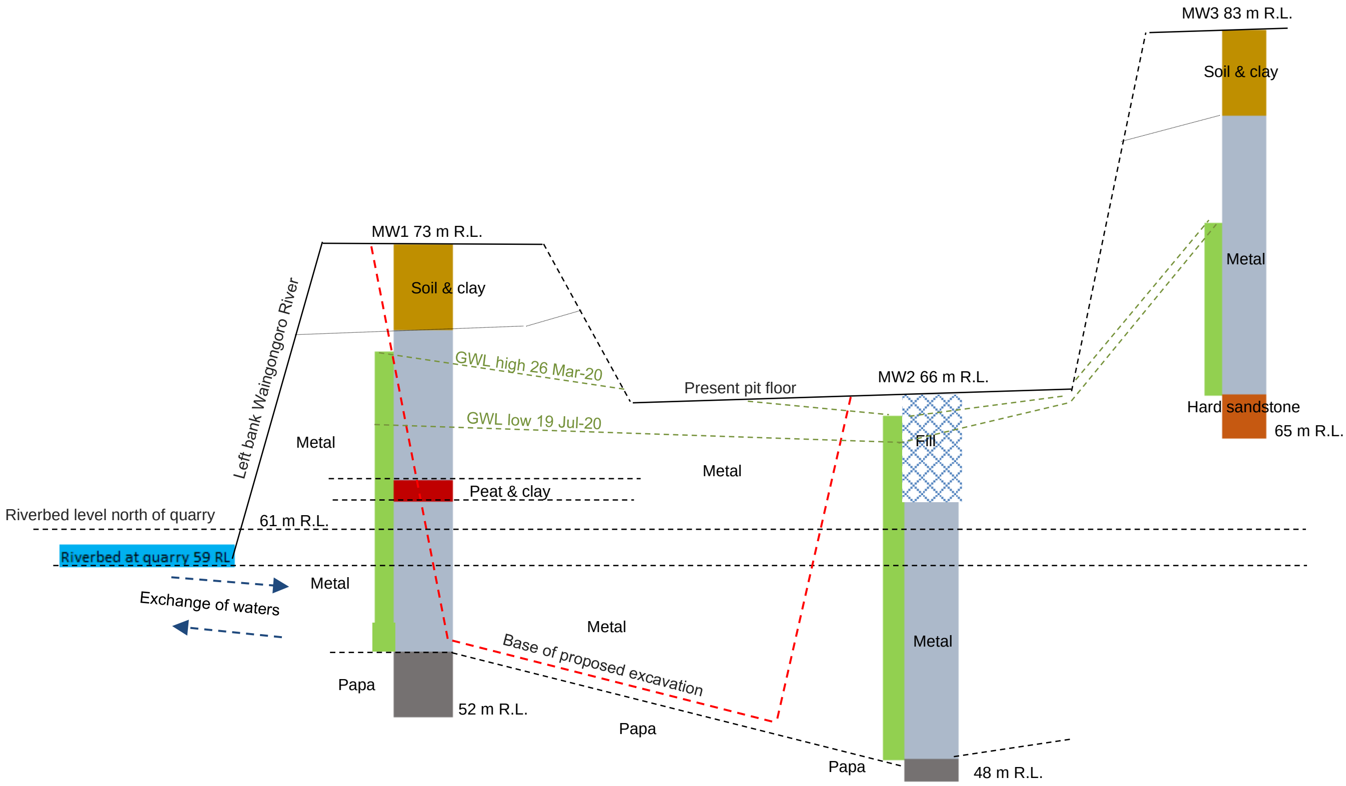


Figure 4 Schematic hydrogeological cross-section A-A` in Figure 1. Shows simplified borehole geology, water table aquifer, bed level for Waingongoro River, and present and proposed depth of excavation. Vertical green bar denotes water table aquifer. Not to scale horizontally.

3.2 Waingongoro River

When the cone of depression from groundwater pumping intercepts the bed of a stream, lake or wetland, or groundwater that would otherwise flow to a these, the pumping can capture surface water flows (stream depletion).

Stream depletion can occur in settings where a surface waterway is above or adjacent to an aquifer that is pumped. Effects are likely if all three of the following conditions apply (ECAN):

(i) *Water can flow between surface water and pumped aquifer.*
(ii) *The rate at which water moves between surface water and the pumped aquifer is under a hydraulic gradient.*
(iii) *The groundwater gradient adjacent to the stream is affected by pumping.*

In this case, all three criteria above are true. The degree of hydraulic connection between an aquifer and surface water body is a key factor in the potential for effects. Main considerations are distances, depth and type of aquifer, rate and duration of pumping, streambed conductance, and the presence of low-permeability layer/s between the pumped aquifer and surface water body. Low permeability layers between the aquifer and riverbed are not indicated (Figure 4).

To the north-east of the pit, the deposit is 12 m thick in MW1. The quarry materials are mostly unconsolidated with an estimated global hydraulic conductivity of 4×10^{-4} m/s. The tight nature of the deposit and high proportion of interstitial fines will retard the flow of water, although this may vary spatially in the workings.

Given the nature and location of the deposit, dewatering is likely to intercept river flows, particularly as excavations progress deeper, northwards, and closer to the river. Deepening the pit below 59 m R.L. would increase the gradient between the riverbed and pit floor, and the potential for dewatering to capture river flows.

A maximum dewatering rate of 40 l/s has been suggested above for the consents. This rate equates to 3.2 % of the estimated natural MALF in the river at the quarry (Table 6). Effects of the abstraction on flows in the river will be partly offset by the return of treated water from the quarry pond system.

A pond discharge rate of 10 l/s would reduce the net effect of the take on the river to 2.4 % of the estimated natural MALF at the quarry. It is noted that irrigation abstractions on the river are required to cease at MALF. This will also help offset any effect of dewatering on flows.

When river flows fall below the MALF the abstraction should be reduced proportionally to ensure effects remain less than minor. The abstraction should cease when the flow in the river at the quarry is at or below 2/3 MALF (est. 821 l/s).

Ceasing dewatering would eventually result in inundation of the workings. The risk of this scenario occurring would be greatest when flow in the river falls below the MALF and restrictions on taking water apply.

In the 2019-20 summer, river flows were above 2/3 MALF for 100 % of the time. Low flows were punctuated by freshes which took flows above the MALF. The risk of restrictions on dewatering could be minimised by keeping the workings above the river level (59 m R.L, Figure 4).

3.3 Tributary

It is proposed to realign and pipe the tributary through the quarry. While this will physically disrupt the natural channel in the affected reach, the stream is already highly modified.

The stream has been heavily impacted by farming activities and while it does offer aquatic habitat, in its present condition is considered to have limited ecological values. Photograph 5 shows the general nature of the tributary above the quarry. Dewatering could potentially deplete flows in the tributary by drawing down the underlying groundwater surface.

The tributary enters into the Waingongoro River at the quarry, therefore depletion of flows in the stream also depletes river flow. Flows in the tributary are not great (Table 6). Depletion of low flows (2.5 l/s) would equate to a 0.2 % loss of flow in the river at MALF. Effects on the river from this would be less than minor. The proposed direction of mining is away from the tributary and the effects on flows on this waterway should diminish as the workings progress northwards.

Photograph 5 General nature of the tributary above the quarry 15 May-19.

3.4 Natural hazards

Floods

The Waingongoro River rises to the upper slopes of Mount Taranaki and has an estimated catchment area above the quarry of 196 km^2. At the quarry, the river has an estimated median flow of 5,150 l/s (Table 6). Flood flows can exceed 60 cumecs and are contained in the river channel. Due to the elevation above the river of the terrace on which the quarry is situated, inundation by flood flows due to the river over topping its banks is not an issue.

However, the thickness and structural integrity of the untouched natural ground that will be retained between the quarry and river will be critical to minimising the risk of erosion and breaches by the river leading to flooding of the quarry.

Volcanism

The river is mostly well incised along its length. Given the river rises to an active volcano, it is a potential conduit for volcanic debris avalanche flows and lahars. The volcano is currently in a state of rest and poses minimal risk at this time.

Seismicity

GNS Science Active Faults Database shows no known active faults near the quarry.

3.5 Competence of geological materials

The quarry deposits are texturally variable, comprising a poorly sorted mixture of silt, sand, and rock fragments ranging in size from pebbles to metre-scale boulders. The different sized materials form a matrix of interlocking grains which give structural integrity to the pit walls.

Evidence of structural integrity is provided by the present sub-vertical pit walls which sustain face heights of 10 m with no slumping. However, the depth of the proposed pit is 18 metres below the ground level of the surrounding land (Figure 4).

Pit wall stability can be compromised loading of slopes above cut faces (i.e. natural slopes, buildings, ponds) and poor management of water flows in and around workings. The existing quarry is well laid out, water flows are well managed and there is no loading of cut slopes. The land surrounding the quarry is flat to gently sloping and there are no obvious erosion issues.

3.6 Water quality

Effects of the abstraction on river flows will be offset in part by the discharge of treated quarry waters. Treatment ponds should be above the water table and appropriately sized and designed to provide adequate settling time. Hay bales or geotextile membrane could be used to filter the waters and speed up treatment.

A proportion of the groundwater abstracted in the dewatering will be used for aggregate washing. Wash water should be treated in a separate pond system and kept apart from cleaner groundwater abstracted which should be able to be treated over a shorter time frame and discharged back into the river.

As the quarry expands, groundwaters of varying quality may be encountered. Waters with different colour, pH and iron and manganese concentrations will reflect different Eh-pH conditions within the aquifer. Groundwater quality in some areas of the workings will likely be influenced by surface water infiltration.

Turbidity

The proposed excavations will extend below the groundwater level and the level of the adjacent river. Once below the groundwater level the excavations will essentially be mining a riparian aquifer. The workings will need to be dewatered by pumping.

Excavation and processing will release mud onto the dewatered ground which could infiltrate directly into the aquifer. The fate of any turbid groundwater will depend on the hydraulic gradient around the quarry. When excavations are above river level, turbid groundwater could potentially migrate through the aquifer into the river and produce a discoloured plume.

However, the aquifer would have a filtering effect and provided sufficient untouched ground is retained between the workings and river turbidity effects in the river are not anticipated. When excavations are below river level the hydraulic gradient would be towards the quarry, essentially eliminating the potential for turbidity effects in the river via the aquifer.

Temperature

Thermal effects on groundwater can result from the infiltration of solar heated water in ponds and drains. The pathway for solar heated waters to enter the river is similar to that of turbidity. The potential for effects will only arise in summer when temperatures are high, but as the ground has a high heat-buffering capacity effects are unlikely.

3.7 Reinstatement

Proposed reinstatement of the quarry is to include a constructed wetland (Figure 5). At the end of the quarry life, the ground will be contoured to accommodate the wetland and dewatering will cease. Groundwater levels are expected to gradually recover over time, and the system will eventually find an equilibrium with the river.

To be viable, the wetland must be constructed below the seasonal groundwater level low and retain sufficient water depth to minimise adverse effects from solar heating. It is noted that evaporation in ponds and lakes less than 2 m deep occurs at a higher rate of than those deeper. Figure 4 gives insight into the reinstated ground levels that would provide sufficient water depth to support a wetland. The present condition of the tributary above the quarry will be enhanced with riparian planting.

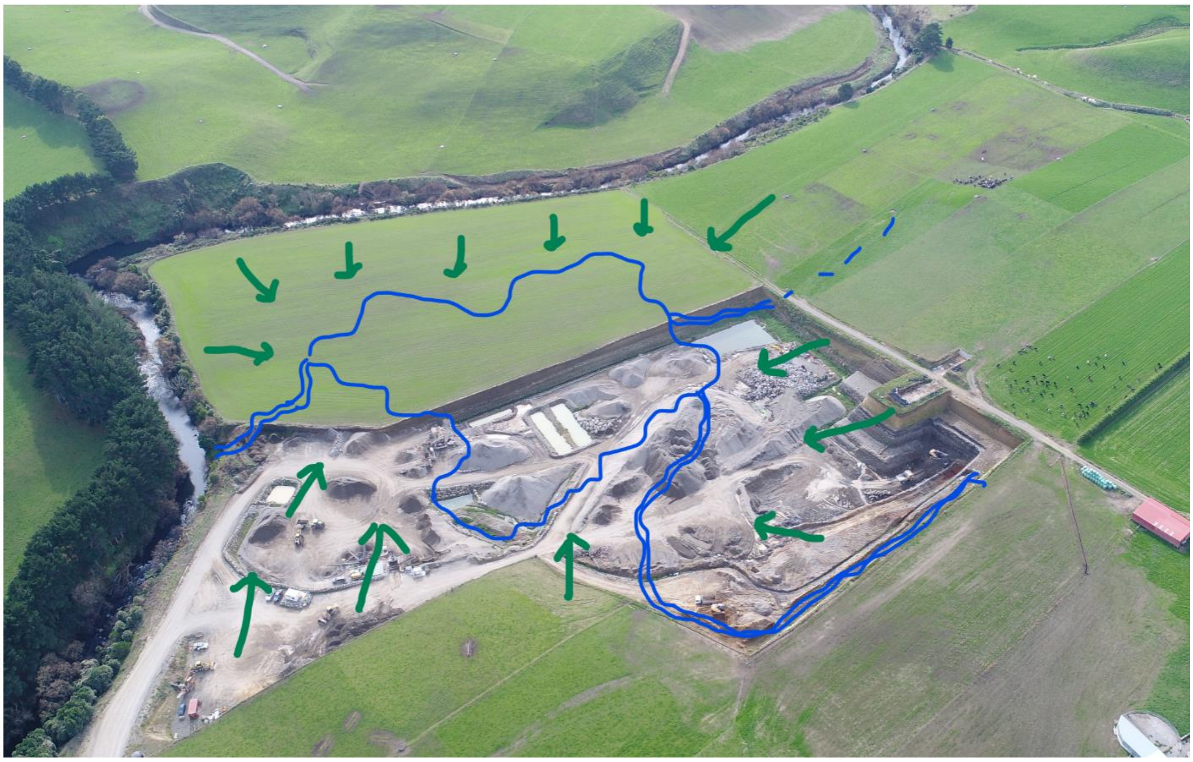


Figure 5 Concept diagram for proposed post-quarry lake and wetland (WSP). Green arrows indicate finished slope directions.

4. Conclusions

This report considers the effects of proposed extensions to the Whenuku Rd quarry on ground and surface water.

The site is underlain by extensive deposits of largely unconsolidated and poorly sorted volcaniclastic materials. The texture and composition of the quarry deposits gives them structural integrity such that the sub-vertical quarry pit walls should be able to sustain face heights of 20 m with little or no slumping. The land surrounding the quarry is flat to gently undulating and there is no loading of quarry sides due to natural slopes.

Preliminary testing has shown groundwater flows in the quarry could potentially be managed by pumping at a rate of 17 l/s (60 m^3/hr), at least initially. However, planning should provide for pumping at up 40 l/s to cover potentially higher flows that may be encountered with depth and as the workings progress closer to the river and northwards. Areas of higher flow may require management to maintain the stability of cut faces.

Dewatering activities will likely result in the depletion of flows in the Waingongoro River and the small tributary which flows through the quarry. Effects will be offset in part by the return of treated water to the river. Provided the rate of dewatering does not exceed 40 l/s and pumping ceases at 2/3 MALF, the effects of flow depletion on the river are expected to be less than minor. To avoid adverse effects on the river the dewatering rate should reduce below MALF and cease at 2/3 MALF.

Provided the quarry is managed carefully effects of the proposed activities on ground and surface water quality are expected to be no more than minor. On-going groundwater level monitoring will provide data to assist with managing effects.

Flooding of the working by the Waingongoro River due to high rainfall events by overtopping of the banks is not considered a risk to the quarry operation.

Appendix I

Monitoring wells logs,

as-builts and photos

Horizons Trust
Whenuku Road, Hawera
Tuesday 26th November 2019 to Wednesday 27th November 2019

Pezo Hole 1, Paddock.

- 7 5/8-inch oilfield casing hammered into a depth of 5.450 metres.
- Drilled hole = 6-inch in diameter.
- Drilled with quarry water and bentonite mud.
- Total depth drilled = 21 metres.
- Total depth of PVC lined hole = 21 metres.
- 50mm PVC, Heavy wall pipe, 700mm Abgl to a depth of 9 metres.
- 50mm PVC slotted Screen, 9 metres to a depth of 18 metres.
- 50mm Heavy wall pipe (Sump) 18 metres to a depth of 21 metres.
- 21 x 1 metre samples collected.
- Back fill around PVC from 21 metres to 2 metres with clean grade 5 chip.
- Back fill from 2 metres to 500mm above G.L with Bentonite chip.
- E
- N
- Elevation =

BORE LOG PEZO HOLE 1
(Measured in metres)

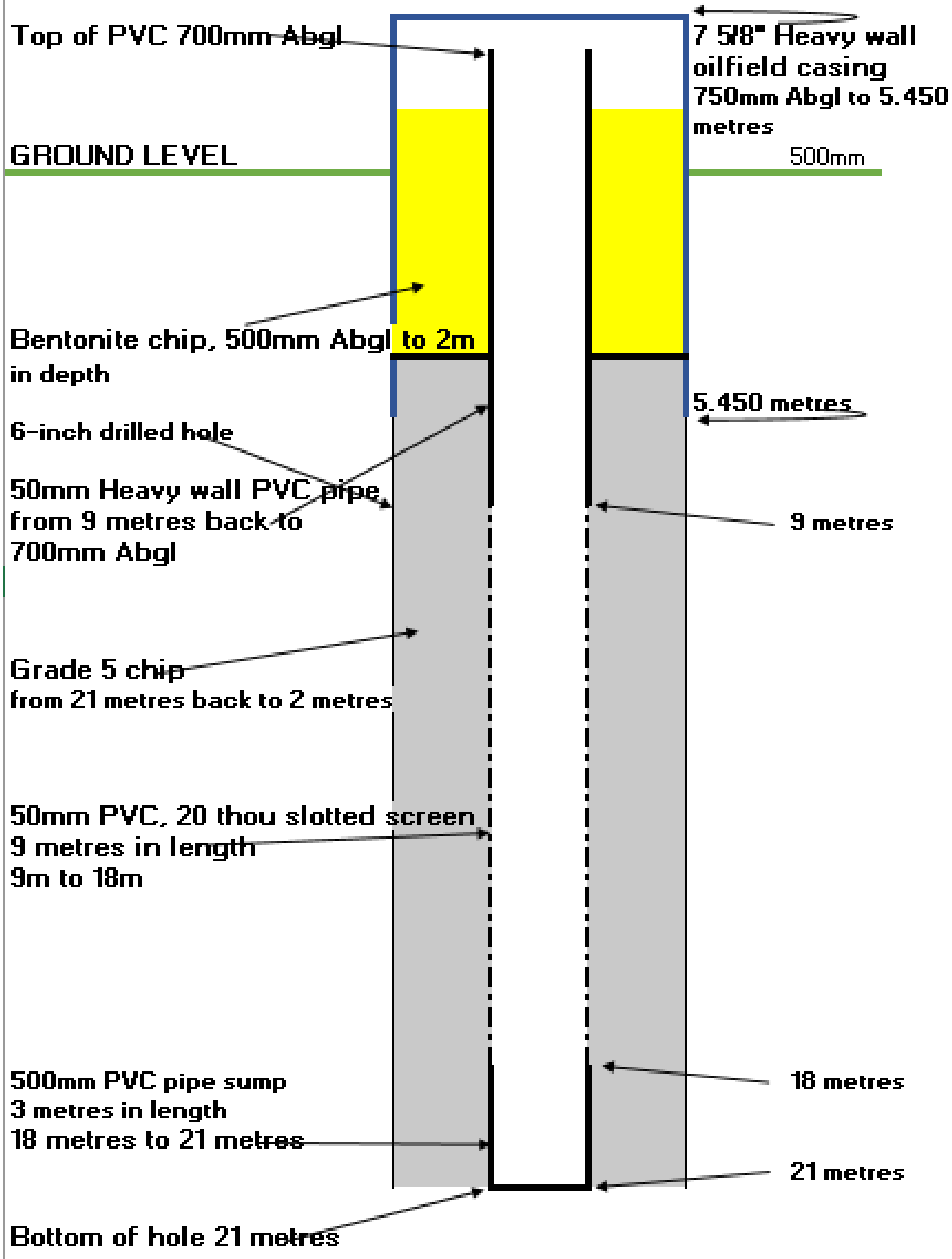
0 – 300MM	Topsoil
300mm – 1.5 m	Brown Clay
1.5 – 2m	Yellow Silty Clay
2m – 2.5m	Small Stone & Grit, Cemented in Brown Silty Clay
2.5m – 5.5m	Yellow Silty Clay
5.5m – 6m	Small Stone & Grit, Cemented in Grey Silty Clay
6m – 11m	Small Stone & Grit, Soft Grey Clay
11m – 11.5m	Grey Clay
11.5m – 13m	Small Stone & Grit, Cemented in Brown Swampy Clay, Traces of wood
13m – 15m	Small Stone & Grit, Traces of Brown Silty Clay
15m – 17.5m	Small Stone, Silty Grey Clay
17.5m – 18m	Stone, Silty Grey Clay
18m – 20.5m	Small Stone & Grit, Traces of Papa
20.5m – 21m	Papa, Traces of Grit
	Still in this when drilling stopped at 21 metres.

Horizon Trust, Hole 1. Whenuku Rd, Hawera. 26.11.19 - 27.11.19

50mm Heavy wall PVC pipe, 700mm Abgl to 9 metres.

50mm Heavy wall PVC screen, 20 thou slot, 9 metres to 18 metres.

50mm Heavy wall PVC pipe, (Sump), 18 metres to 21 metres.



WellDrillers WANGANUI LTD

Horizons Trust
Whenuku Road, Hawera
Wednesday 27th November 2019

Pezo Hole 2, in quarry pit.

- 7 5/8-inch oilfield casing hammered into a depth of 4.340 metres.
- Drilled hole = 6-inch in diameter.
- Drilled with quarry water and bentonite mud.
- Total depth drilled = 18 metres.
- Total depth of PVC lined hole = 18 metres.
- 50mm PVC, Heavy wall pipe, 700mm Abgl to a depth of 8 metres.
- 50mm PVC slotted Screen, 8 metres to a depth of 17 metres.
- 50mm Heavy wall pipe (Sump) 17 metres to a depth of 18 metres.
- 18 x 1 metre samples collected.
- Back fill around PVC from 18 metres to 2 metres with clean grade 5 chip.
- Back fill from 2 metres to 500mm above G.L with Bentonite chip.
- E
- N
- Elevation =

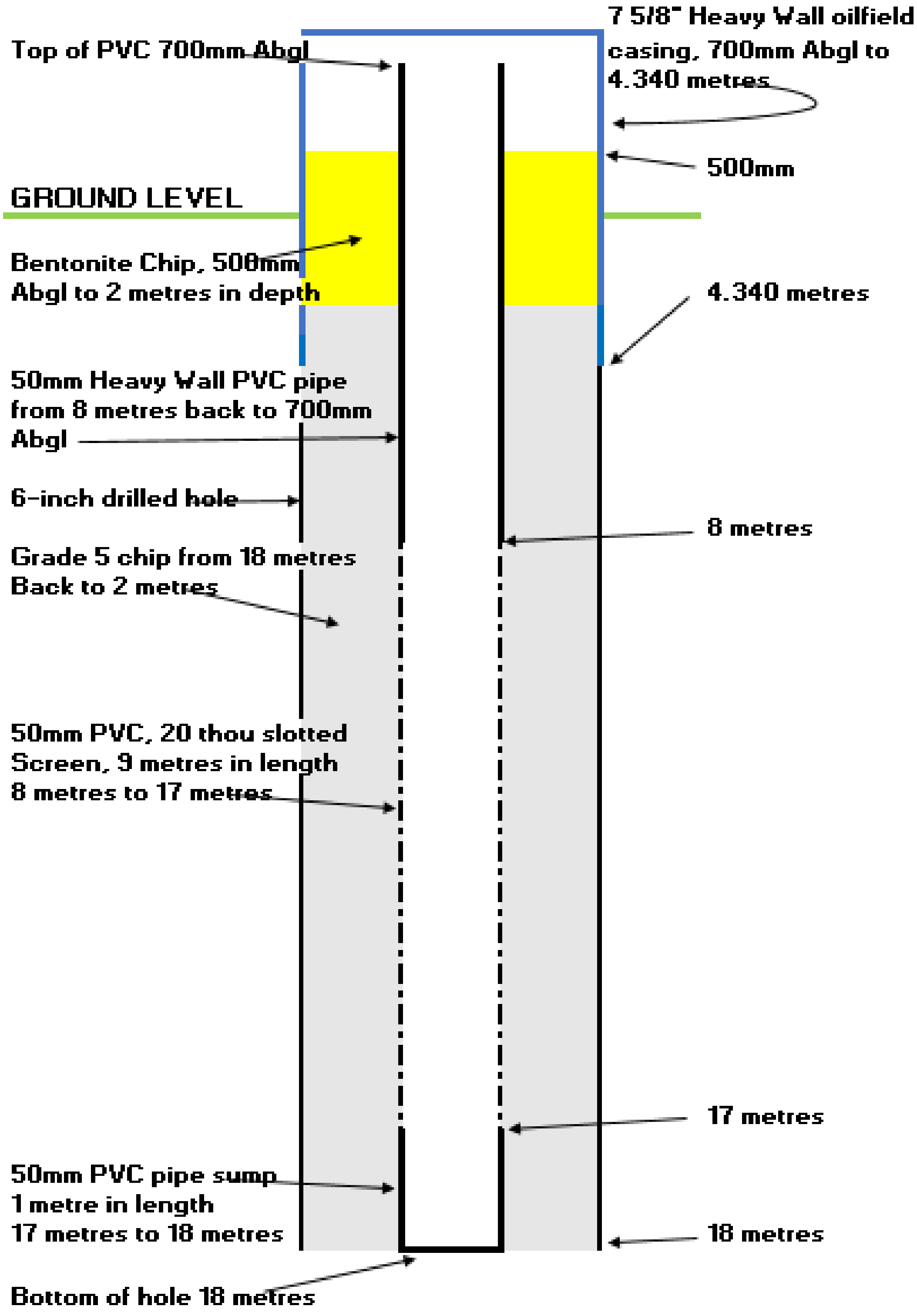
BORE LOG PEZO HOLE 2

(Measured in metres)

0 – 3m	Stone & Grit
3m – 3.5 m	Brown Silty Volcanic Ash, Grit
3.5 – 5m	Swampy Brown Clay, Traces of wood
5m – 6m	Small Stone & Grit, Cemented Brown Clay
6m – 6.5m	Small Stone & Grit, Traces of Brown Clay
6.5m – 8.5m	Stone & Grit
8.5m – 9.5m	Hard Stone
9.5m – 10.5m	Stone & Grit, Traces of Grey Silty Clay
10.5m – 13m	Small Stone & Grit, Traces of Yellow Silty Clay
13m – 15m	Small Stone & Grit, Grey Silt, Traces of Grey Clay
15m – 15.5m	Grit & Coarse Grey Sand
15.5m – 17m	Grit, Coarse Grey Sand, Traces of Papa
17m – 18m	Papa

Still in this when drilling stopped at 18 metres.

Horizon Trust, Hole 2. Whenuku Rd, Hawrea. 27.11.19
50mm Heavy Wall PVC pipe, 700mm Abgl to 8 metres.
50mm Heavy Wall PVC Screen, 20 thou slot, 8 metres to 17 metres.
50mm Heavy Wall PVC pipe, (Sump), 17 metres to 18 metres.



WellDrillers WANGANUI LTD

Horizons Trust
Whenuku Road, Hawera
Thursday 28th November 2019

Pezo Hole 3, by red hay shed.

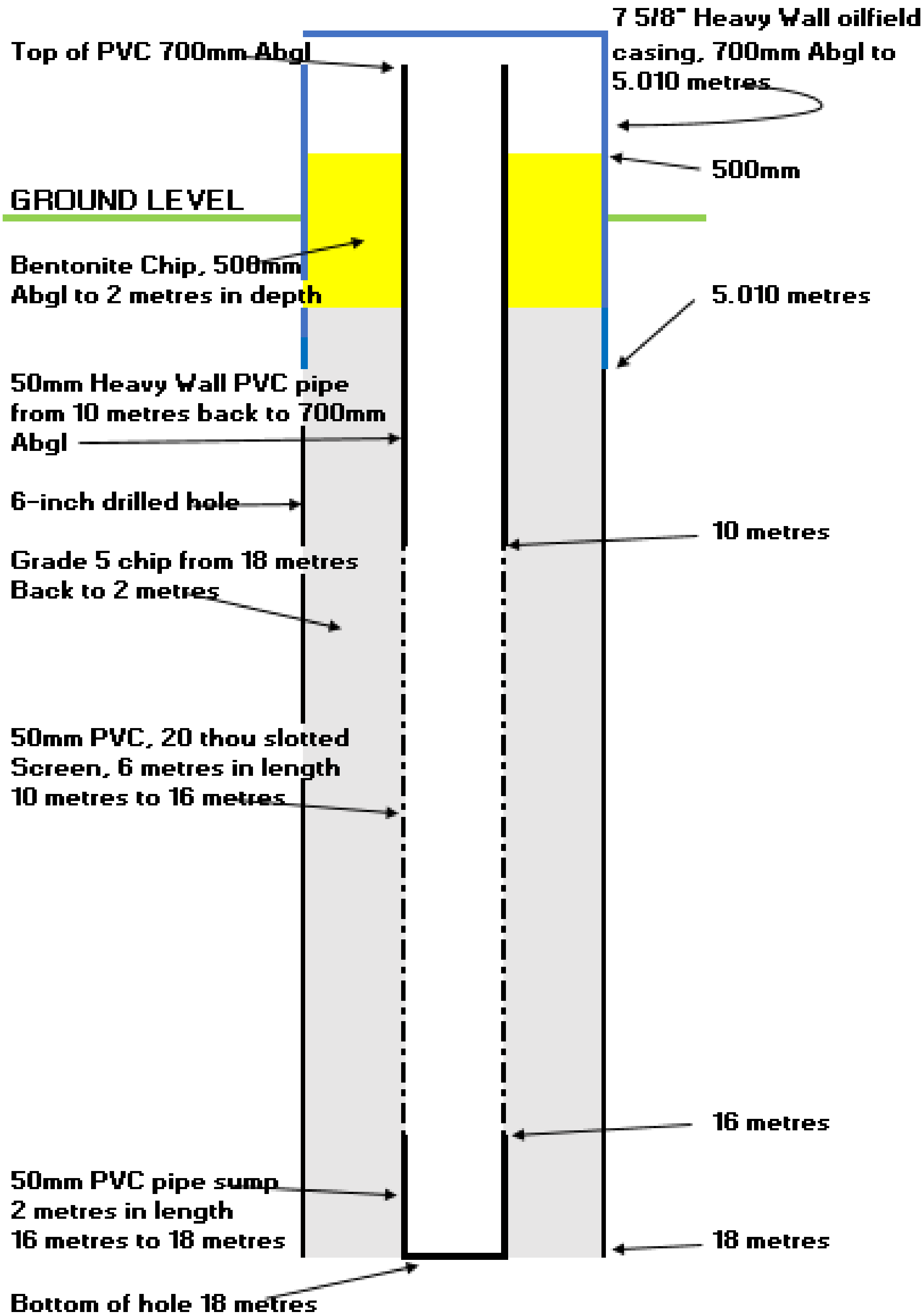
- 7 5/8-inch oilfield casing hammered into a depth of 5.010 metres.
- Drilled hole = 6-inch in diameter.
- Drilled with quarry water and bentonite mud.
- Total depth drilled = 18 metres.
- Total depth of PVC lined hole = 18 metres.
- 50mm PVC, Heavy wall pipe, 700mm Abgl to a depth of 10 metres.
- 50mm PVC slotted Screen, 10 metres to a depth of 16 metres.
- 50mm Heavy wall pipe (Sump) 16 metres to a depth of 18 metres.
- 18 x 1 metre samples collected.
- Back fill around PVC from 18 metres to 2 metres with clean grade 5 chip.
- Back fill from 2 metres to 500mm above G.L with Bentonite chip.
- E
- N
- Elevation =

BORE LOG PEZO HOLE 3
(Measured in metres)

0 – 300mm	Topsoil
300mm – 1.5 m	Brown Volcanic Ash
1.5 – 4.5m	Brown Silty Clay, Traces of Small Grit
4.5m – 5.5m	Small Stone & Grit, Cemented Yellow Silty Clay
5.5m – 7.5m	Small Stone & Grit, Yellow Silt
7.5m – 9m	Small Stone & Grit, Yellow Silt, Traces of Yellow Clay
9m – 9.5m	Small Stone & Grit, Yellow Silty Clay
9.5m – 10m	Stone & Grit, Coarse Grey Sand
10m – 12.5m	Small Stone & Grit, Coarse Grey Sand, Traces of Yellow Silty Clay
12.5m – 16m	Stone & Grit, Coarse Grey Sand
16m – 18m	Hard Sand Stone

Still in this when drilling stopped at 18 metres.

Horizon Trust, Hole 3. Whenuku Rd, Hawrea. 28.11.19
50mm Heavy Wall PVC pipe, 700mm Abgl to 10 metres.
50mm Heavy Wall PVC Screen, 20 thou slot, 10 metres to 16 metres.
50mm Heavy Wall PVC pipe, (Sump), 16 metres to 18 metres.




MW1


MW2


MW3

Appendix II

Surface water quality

laboratory results and field notes

GEOSEARCH
water resource exploration and development

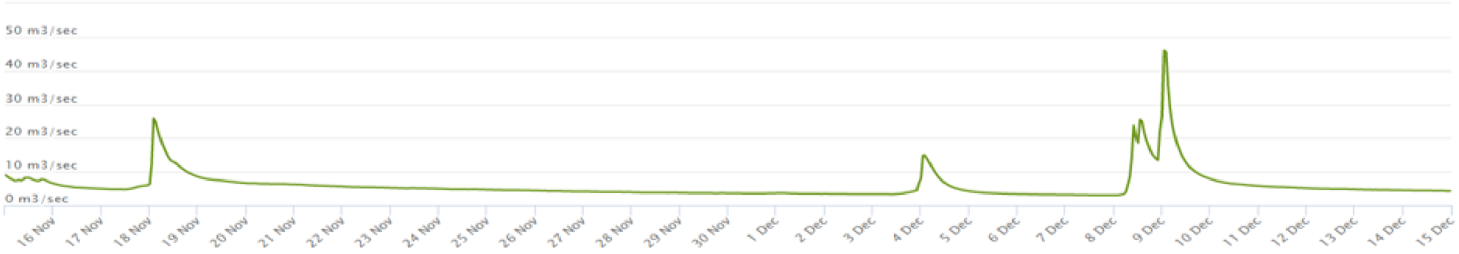
Surface water quality

Hill Labs job number relating to these samples: 2288287

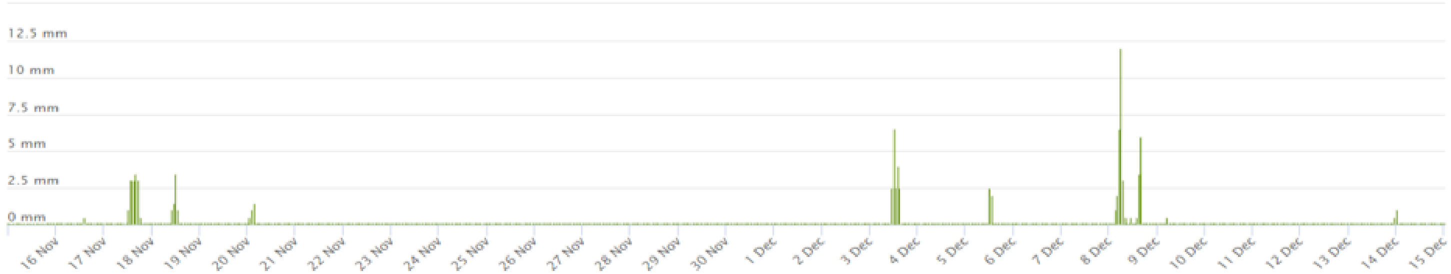
Weather: Humid sunny, minor rain around
Date last rain: 4 Dec-19
Amount last rain: 5 mm

Sample site id	Location Photo-located			Sampling date/time	Water clarity	Odour	Water temp @ 20 cm Deg. C	Sampler	comments
	E	N	Elev. m ASL						
Upstream tributary Whenuku quarry	1706450	5622870	88	5 Dec-19 11:40	Could see bottom	nil	17.7	KWB	Water slightly murky.
Downstream tributary Whenuku quarry	1705939	5623119	63	5 Dec-19 12:15	Could see bottom	nil	19.0	KWB	Water slightly murky. Works upstream stripping cover.
Waingongoro upstream	1705710	5623286	65	5 Dec-19 13:10	Could see bottom	nil	18.2	KWB	Water clean & clear.
Waingongoro downstream	1705552	5622978	62	5 Dec-19 14:00	Could see bottom	nil	18.4	KWB	Water clean & clear.

Hourly average river flow, Waingongoro at SH45 15/11/2019 - 15/12/2019



Hourly total rainfall, Kaupokonui at Glenn Rd 15/11/2019 - 15/12/2019



GEOSEARCH
water resource exploration and development

Surface water quality

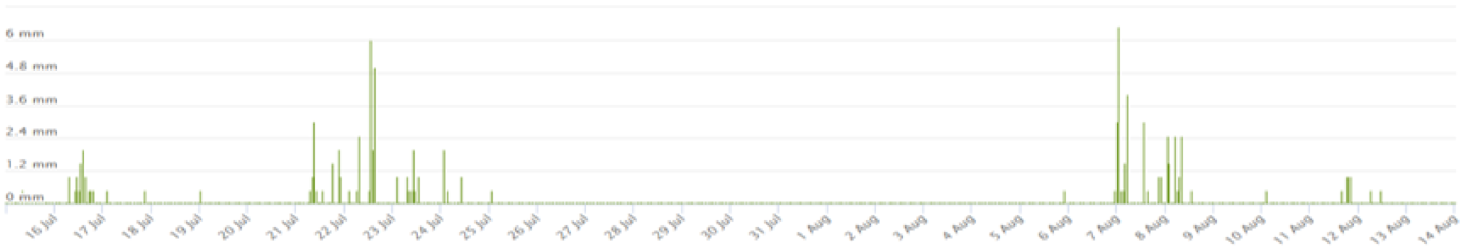
Hill Labs job number relating to these samples: 2413889

Weather: Settled
Date last rain: 25 Jul-20
Amount last rain: 0.5mm

Sample site id	Location Photo-located			Sampling date/time	Water clarity	Odour	Water temp @ 20 cm Deg. C	Sampler	comments
	E	N	Elev. m ASL						
Upstream tributary Whenuku quarry	1706450	5622870	88	5 Aug-20 11:00	Can see bottom	nil	10.3	JT	
Downstream tributary Whenuku quarry	1705939	5623119	63	5 Dec-19 11:50	Murky cannot see bottom	nil	12.6	JT	Works upstream.
Waingongoro upstream	1705710	5623286	65	5 Dec-19 13:00	Can see bottom	nil	10.0	JT	
Waingongoro downstream	1705552	5622978	62	5 Dec-19 13:45	Can see bottom	nil	10.6	JT	

Hourly average river flow, Kaupokonui at Glenn Rd 15/07/2020 - 14/08/2020

Hourly total rainfall, Kaupokonui at Glenn Rd 15/07/2020 - 14/08/2020



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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

SPv1

Client:	Geosearch Limited	**Lab No:**	2288287
Contact:	Karl Browne	**Date Received:**	06-Dec-2019
	C/- Geosearch Limited	**Date Reported:**	13-Dec-2019
	PO Box 43	**Quote No:**	93210
	Oakura 4345	**Order No:**	
	TARANAKI	**Client Reference:**	Lake Water Quality
		Submitted By:	Karl Browne

Sample Type: Aqueous

Sample Name:		Upstream trib Whenua quarry 05-Dec-2019 11:40 am	Downstream trib Whenua quarry 05-Dec-2019 12:15 pm	Waingongaro upstream 05-Dec-2019 1:10 pm	Waingongaro downstream 05-Dec-2019 2:00 pm	
Lab Number:		2288287.1	2288287.2	2288287.3	2288287.4	
Individual Tests						
Turbidity	NTU	1.93	2.4	1.12	1.23	-
pH	pH Units	7.2	7.9	7.6	7.7	-
Electrical Conductivity (EC)	mS/m	29.0	33.2	15.1	15.1	-
Total Suspended Solids	g/m³	< 3	7	5	4	-
Sample Temperature*	°C	17.7	19.0	18.2	18.4	-
Total Potassium	g/m³	3.7	3.6	5.9	5.9	-
Total Nitrogen	g/m³	0.51	2.3	2.2	2.2	-
Total Kjeldahl Nitrogen (TKN)	g/m³	0.22	0.22	0.36	0.35	-
Nutrient Profile						
Total Ammoniacal-N	g/m³	0.019	0.023	0.024	0.019	-
Nitrite-N	g/m³	0.003	0.006	0.022	0.022	-
Nitrate-N	g/m³	0.28	2.1	1.83	1.79	-
Nitrate-N + Nitrite-N	g/m³	0.29	2.1	1.85	1.82	-
Dissolved Reactive Phosphorus	g/m³	< 0.004	0.005	0.053	0.045	-

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	**Method Description**	**Default Detection Limit**	**Sample No**
Nutrient Profile		0.0010 - 0.010 g/m³	1-4
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-4
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-4
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 23rd ed. 2017.	0.05 NTU	1-4
pH	pH meter. APHA 4500-H+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-4
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1-4
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m³	1-4
Sample Temperature*	Supplied by customer, otherwise 20°C.	0.1 °C	1-4

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m³	1-4
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m³ is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m³, the Default Detection Limit for Total Nitrogen will be 0.11 g/m³.	0.05 g/m³	1-4
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m³	1-4
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1-4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-4
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m³	1-4
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m³	1-4
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m³	1-4

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Dates of testing are available on request. Please contact the laboratory for more information.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

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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

SPv1

Client:	Geosearch Limited	Lab No:	2413889
Contact:	Karl Browne	Date Received:	06-Aug-2020
	C/- Geosearch Limited	Date Reported:	11-Aug-2020
	PO Box 43	Quote No:	93210
	Oakura 4345	Order No:	
	TARANAKI	Client Reference:	Lake Water Quality
		Submitted By:	Karl Browne

Sample Type: Aqueous

Sample Name:		Upstream Trib Whenuku Quarry 05-Aug-2020 11:00 am	Downstream Trib Whenuku Quarry 05-Aug-2020 11:50 am	Waingongoro Upstream 05-Aug-2020 1:00 pm	Waingongoro Downstream 05-Aug-2020 1:45 pm	
Lab Number:		2413889.1	2413889.2	2413889.3	2413889.4	
Individual Tests						
Turbidity	NTU	1.70	7.4	3.8	3.6	-
pH	pH Units	7.2	7.8	7.5	8.0	-
Electrical Conductivity (EC)	mS/m	26.3	35.6	18.0	18.0	-
Total Suspended Solids	g/m³	< 3	4	6	6	-
Sample Temperature*†	°C	10.3	12.6	10.0	10.5	-
Total Potassium	g/m³	1.81	4.1	5.4	5.2	-
Total Nitrogen	g/m³	0.76	2.3	2.8	2.8	-
Total Kjeldahl Nitrogen (TKN)	g/m³	0.15	0.23	0.15	0.16	-
Nutrient Profile						
Total Ammoniacal-N	g/m³	0.065	0.094	0.018	0.014	-
Nitrite-N	g/m³	< 0.002	0.016	0.040	0.040	-
Nitrate-N	g/m³	0.60	2.0	2.6	2.6	-
Nitrate-N + Nitrite-N	g/m³	0.61	2.0	2.6	2.6	-
Dissolved Reactive Phosphorus	g/m³	0.007	0.064	0.034	0.030	-

Analyst's Comments

† Customer supplied data. Please note: Hill Laboratories cannot be held responsible for the validity of this customer supplied data, or any subsequent calculations that rely on this information.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Nutrient Profile		0.0010 - 0.010 g/m³	1-4
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-4
Total Digestion	Nitric acid digestion. APHA 3030 E (modified) 23rd ed. 2017.	-	1-4
Turbidity	Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 23rd ed. 2017 (modified).	0.05 NTU	1-4
pH	pH meter. APHA 4500-H+ B 23rd ed. 2017. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field. Samples and Standards are analysed at an equivalent laboratory temperature (typically 18 to 22 °C). Temperature compensation is used.	0.1 pH Units	1-4
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 23rd ed. 2017.	0.1 mS/m	1-4

IANZ ACCREDITED LABORATORY

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Suspended Solids	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5μm), gravimetric determination. APHA 2540 D (modified) 23rd ed. 2017.	3 g/m^3	1-4
Sample Temperature*	Temperature of the sample at the time of sampling, supplied by customer.	0.1 °C	1-4
Total Potassium	Nitric acid digestion, ICP-MS, trace level. APHA 3125 B 23rd ed. 2017.	0.053 g/m^3	1-4
Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1-4
Total Ammoniacal-N	Phenol/hypochlorite colourimetry. Flow injection analyser. (NH_4-N = NH_4^+-N + NH_3-N). APHA 4500-NH_3 H (modified) 23rd ed. 2017.	0.010 g/m^3	1-4
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-4
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (modified) 23rd ed. 2017.	0.002 g/m^3	1-4
Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D (modified) 4500 NH_3 F (modified) 23rd ed. 2017.	0.10 g/m^3	1-4
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colourimetry. Flow injection analyser. APHA 4500-P G (modified) 23rd ed. 2017.	0.004 g/m^3	1-4

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Dates of testing are available on request. Please contact the laboratory for more information.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Appendix III

Photos of weirs in tributary

Upstream weir
14 Mar-20

Downstream weir
21 Jul-20

m 027 2424 333

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m 027 2424 333