WILLIAMSON
WATER & LAND ADVISORY

Wharekirauponga Downstream Reach Investigations

Waihi North Project

OCEANAGOLD LIMITED

WWLA1002 | Rev. 6

30 August 2024

Wharekirauponga Downstream Reach Investigations

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Project manager:	Josh Mawer
Author(s):	Jaide Derbyshire
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Williamson Water & Land Advisory

P.O. Box 314
Kumeu
New Zealand
www.wwla.kiwi

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Contents

1. Introduction

Williamson Water & Land Advisory (WWLA) was engaged by OceanaGold Limited (OGL) to undertake longitudinal gauging of flows along a reach of the Wharekirauponga Stream (WKP) to assist in verifying potential groundwater discharges to the stream (i.e., gaining reaches).

An assessment of regional hydrogeology undertaken by WWLA in October 2023[1] identified the potential for groundwater discharge to occur along an approximately 1,000 m long reach of the lower WKP Stream. This report details the flow gaugings undertaken to assist in identifying whether such groundwater discharges do in fact occur. The flow gauging events were undertaken in two phases with the first performed by WWLA in February 2024. That initial gauging event identified areas of likely groundwater discharge and OGL field staff undertook gauging and water quality sampling in April 2024 targeting those locations.

The assessment undertaken comprised of the gauging outlined in **Table 1**. The locations of the sites gauged by WWLA are illustrated on **Figure 1** and **Figure 2**. The locations of the flow monitoring and water quality sampling sites undertaken by OGL are shown on **Figure 3**.

Table 1. Gauging summary.

Gauging type	By	Date	Sites
Wading gauging	WWLA	2 February 2024	16 sites – WKP Reach A to Reach M, and the Otahu Upper, Middle, and Lower.
	OGL	9 April 2024	7 sites
Volumetric gauging	WWLA	2 February 2024	4 sites – Reach Trib 2, 3, 5, and 8
Visual flow estimation	WWLA	2 February 2024	6 sites – Reach Trib 1, 4, 6, 7, 9, and 10.

[1] WWLA. 2023. Wharekirauponga Regional Hydrogeological Review Consultancy report prepared for Oceana Gold.

2. Methodology

2.1 Gauging Methodology

Stream flow measurements were taken using two methods: wading gauging with a Sontek FlowTracker, and volumetric gauging. Visual estimates of flow were also made at sites where neither wading gauging nor volumetric gauging could be undertaken.

Wading gauging was undertaken using a Sontek FlowTracker 2. Stream gauging where wading was required aimed to collect at least 24 vertical measurements per cross-section with no vertical measurement representing more than 10% of the flow as per the National Environmental Monitoring Standards (NEMS) for 'Good Quality' flow measurements. Narrower streams where >24 measurements could not accurately be collected were measured at a target of 5 cm increments across the stream. Gauging sites were selected where the streambed was reasonably uniform and as close to laminar flow as reasonably practical (i.e., straight reaches with limited large rocks or deep pools).

Volumetric gauging was undertaken using either a 20 L or 60 L bucket, and a stopwatch in situations where streams were too small to gauge using the FlowTracker, and where flows were toppling over a small ledge and easily catchable. Multiple volumetric measurements were collected and averaged to determine the flow rate for each site. An estimate of losses (i.e., water spilt or not captured in the bucket) was made and added to each volumetric site measurement.

Where sites could not be gauged due to very low flow or unsuitable streambed/terrain, flows were visually estimated based on similar sites where volumetric gauging was completed.

2.2 Site Locations

An approximately 1,000 m long reach of the lower WKP Stream was identified for longitudinal gauging as part of the Regional Hydrogeology Assessment undertaken by WWLA. Based on the findings of this assessment, it was recommended to gauge at intervals of approximately 100 m, with exact locations ultimately dependant on access and profile / cross-section suitability.

The locations of the actual sites gauged are shown in **Figure 1**. Along with the above sites, three sites further downstream were gauged on the Otahu River and are shown in **Figure 2.** The purpose of those gaugings was to assess the discharges from the wider catchment area and validate the NIWA Rivers flow database.

The site gauged and sampled by OGL are shown on **Figure 3** and were targeted within areas of interest identified from the initial gaugings. It is noted that the naming of the tributaries between the WWLA sites and OGL sites do not align, with the exception of the Tributary 1 location.

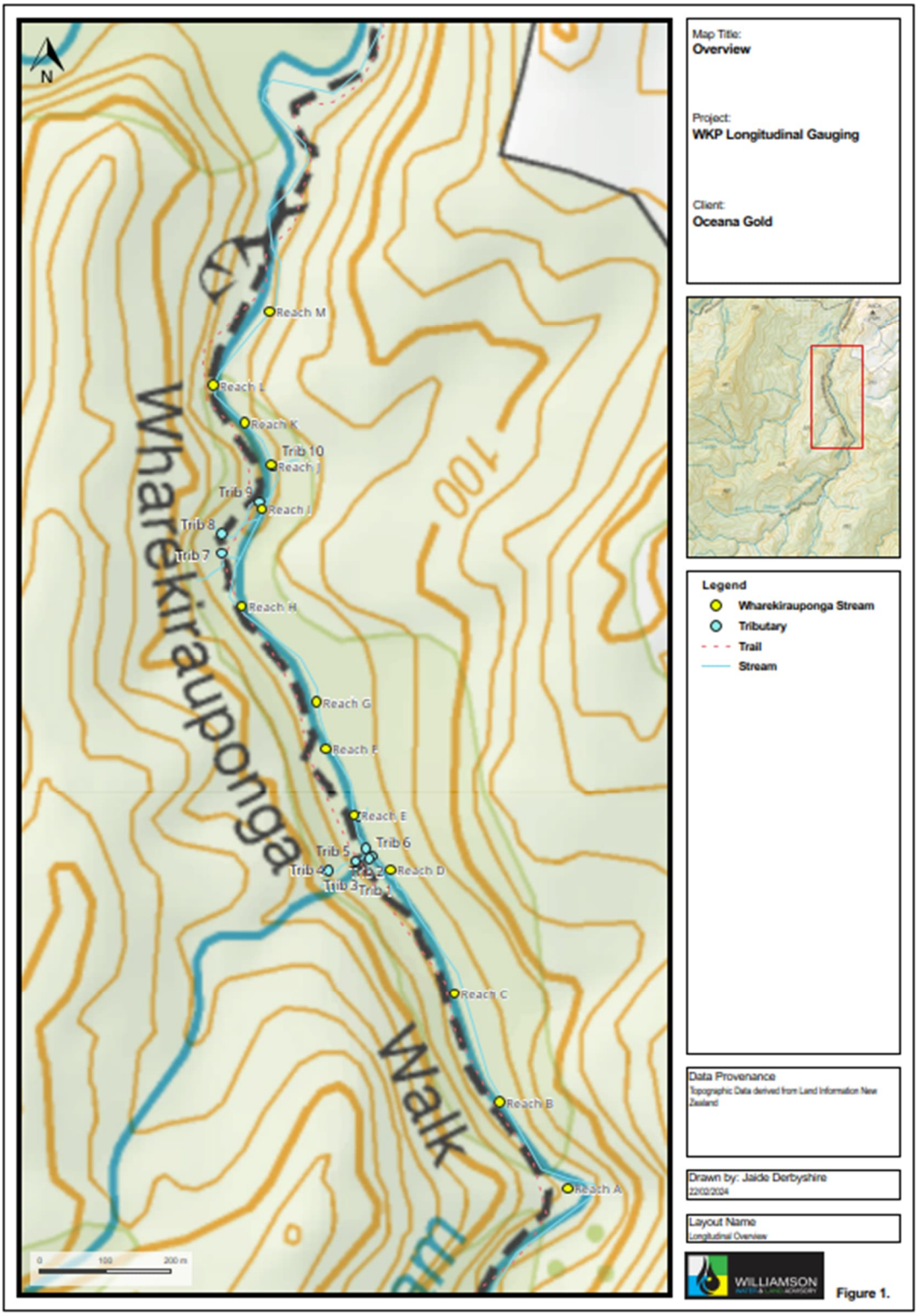


Figure 1. Longitudinal gauging site locations. Replace with A4

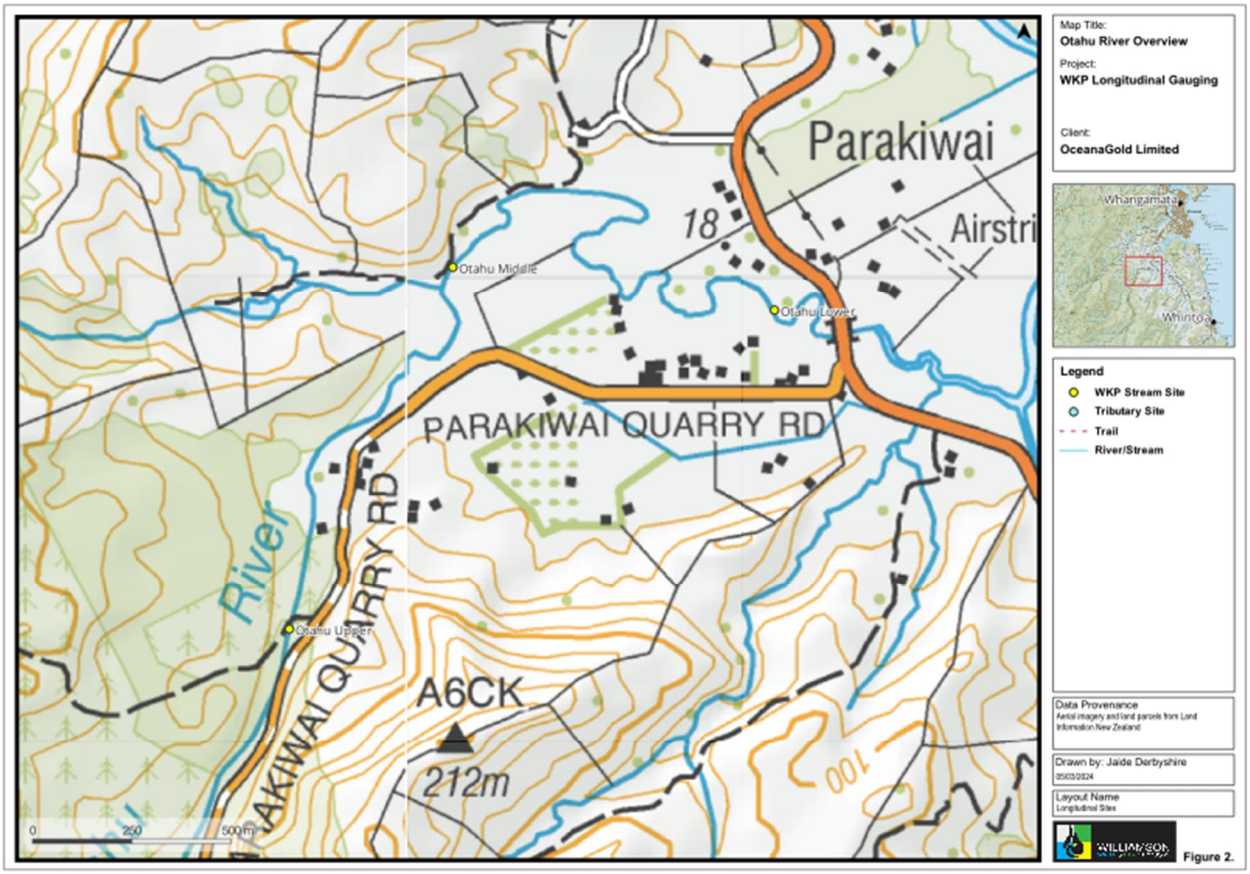


Figure 2. Otahu sites overview.

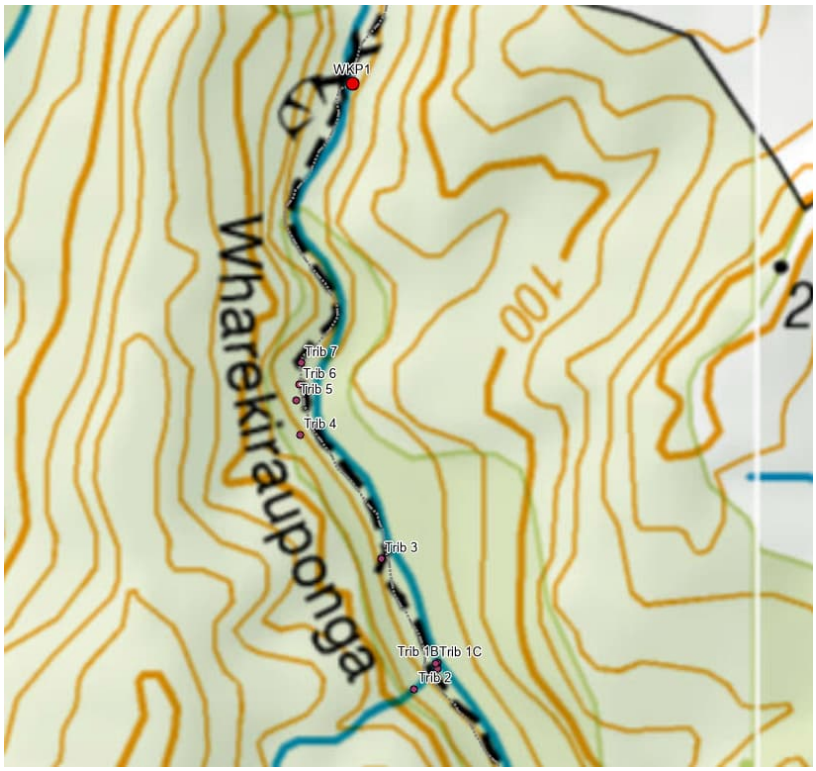


Figure 3. OGL gauging and sampling locations.

3. Monitoring Results

3.1 Flow Gauging

The lower Wharekirauponga Stream reach was gauged over 31 January to 2 February 2024. Weather conditions were clear for the majority of the visit, with some cloud cover and light winds. No rain occurred over the three days of gauging.

A summary of all measurements and site notes are presented in **Table 2** and **Table 3** and photos of each site are presented in **Appendix A**. All of the wading gauging sites meet the NEMS system for flow analysis QC 600 'Good Quality' flow measurement zone with uncertainty levels under 5%. A qualitative assessment of gauging quality was also made at each site, taking into account factors such as streambed uniformity and flow conditions (e.g., was there potential for water to be flowing between streambed rocks, were any eddies present etc.) Based on the qualitative assessment all sites were considered to be of fair to good gauging quality.

Table 2. Wading gauging summary.

Hydrology Summary - Wading Gauging									
General	Weather conditions:	Good, clear conditions with some light wind.							
	Flow Tracker Used:	Serial number:	FT2H2043021 and FT2H1550019		Probe number:	FT2P2043012 and FT2P1547004			Two Flow Tracker 2 devices used throughout (one for each team).
Location	**Date**	**Start Time (NZST)**	**End Time (NZST)**	**Flow (L/s)**	**Discharge Uncertainty (ISO)**	**Cross-section Width (m)**	**Cross-section Area (m2)**	**Water Temp (°C)**	**Comments**
Reach A	31/01/2024	10:28	11:45	217	2.7	6.2	3.2	18.8	Gauging was located around 20 m downstream of large bend and around 10 m upstream of large riffle outlet/end. Streambed was mostly rocky with medium sized boulders. Left bank was very rocky and right bank was more sandy. Gauging – fair.
Reach B	31/01/2024	12:12	13:06	181	4.8	7.8	3.7	20.2	Located approximately 10 m downstream of small drop in the river which acted as small waterfall. Streambed was mostly rocky with small to medium boulders. Right bank was rock slab whilst left bank was sandier. There was significant back eddy that caused velocity angle errors which likely reduced the reliability of gauging for this site. Gauging – poor.
Reach C	31/01/2024	13:36	14:19	246	3	5.6	3.0	21.3	Gauged 10 m downstream of riffle. Streambed was rocky with medium sized boulders. Left bank was a rock face. Right bank was rocky with gravel beach. Gauging - fair.
Reach D	1/02/2024	9:09	9:45	258	2.9	4.5	1.3	18.2	Gauged approximately 200 m downstream from Reach C. Between Reach C and Reach D, there were numerous large boulders which made gauging at 100 m intervals difficult. Lots of riffles and turbulent flows upstream and downstream of gauging site. Some high velocity angles. Around 6m upstream and 1-2 m downstream there were riffles. There was large rock on the left bank and small cobbles on the right bank. Slightly higher flows were observed the middle. Gauging - fair.
Reach E	1/02/2024	11:19	12:13	242	2.7	6.3	1.9	19.5	Located 100 m downstream of Reach D. Calm section of water with riffles around 10 m upstream and 5 m downstream. Bed was mostly rocky with some sand. Boulders were cobble to boulder sized. Mostly laminar flows. Gauging - good.
Reach F	1/02/2024	11:37	12:28	280	2.4	11.0	3.2	18.6	Large cross section with small/medium boulders across streambed. There was a large dead tree branch interrupting flows on the left bank, with around 0.3 m of stagnant water not gauged. Otherwise, flows were even across. Gauging - fair.

Reach G	1/02/2024	10:38	11:18	245	2.8	6.1	1.2	18.2	Cross section was fairly uniform, with large boulder intercepts. Flow was able to pass around boulder easily. Large boulders were present both upstream and downstream. Laminar flow across the cross-section. The left bank was very steep. Gauging - fair.
Reach H	1/02/2024	14:52	15:56	245	2.3	9.9	3.8	21.1	Cross section was fairly uniform with the left bank slightly deeper than the right bank. Small boulders were present across the streambed. Uniform flows across. The left bank was a steep rockface with water flowing down into the main stream (1 m upstream of cross section). Unable to gauge the additional flows which were less than 1 L/s. Gauging - good.
Reach I	31/01/2024	13:28	14:12	226	3	7.2	1.5	19.7	Consistent cross section with boulders across the streambed. Upstream there were several large boulders. Gauging - good.
Reach J	1/02/2024	9:29	10:07	259	3	3.7	1.0	18.3	A large boulder island was situated in the main stream, with the majority of flows on the left bank. Water on the right bank was fairly stagnant and not possible to gauge. Some water could have been seeping through the island, but this was not visually observable. The cross-section bed was fairly uniform. Gauging - good.
Reach K	31/01/2024	12:30	13:07	264	2.8	6.6	1.7	18.8	Fairly uniform cross section with a gravel/boulder bed on the left bank. Some flow appeared to be seeping through the bank. Streambed was level (uniform depth?). Around 30 m upstream there was a large gravel island with most flows on the right bank. Gauging - fair.
Reach L	31/01/2024	11:06	12:00	246	2.6	3.7	1.3	18.2	Located approximately 150 m upstream of Reach M. Deeper on left bank with depths around 0.65 m which levelled out across to the right bank. Small boulders across streambed but fairly level. Gauging - fair.
Reach M	31/01/2024	9:31	10:32	266	2.7	7.2	1.4	17.6	Located upstream of WKP1 and bridge. Rocky streambed with varying depths. Larger boulders closer to the left bank. There was a fallen tree about 1 m downstream from right bank. Gauging - Fair.
Otahu Upper	2/02/2024	10:57	11:36	369	2.7	9.4	2.2	19.5	Gauged ~5 m upstream from the low-lying bridge/ford crossing. Uniform cross-section with pebble streambed. Increasing sediment towards the right bank.
Otahu Middle	2/02/2024	09:40	10:20	363	2.6	13.5	5.6	19.6	Located ~20 m downstream of farm trib. Straight run of river about 50 m long. Riffle about 20 m downstream. Bend about 20-30 m upstream. Streambed is rocky with an even depth across. Mostly laminar flows.
Otahu Lower	2/02/2024	09:13	10:30	311*	1.9	11.3	7.8	19.2	Fairly uniform cross section, gauged near to the picnic bench. Log at 45-degree angle in the middle of cross section. Some sediment centrally. It became clear when half way through the gauging that the depth was increasing, and the stream was tidal. Over 30 cm increase in depth when completed.

Table 3. WWLA tributary gauging summary.

Hydrology Summary - Tributary Gauging				
General	Weather conditions:	Good, clear conditions with some light wind.		
Location (Gauging Type)	**Date**	**Start Time (NZST)**	**Flow (L/s)**	**Comments**
Reach Trib 1 (Volumetric)	31/01/2024	11:00	0.3	Appeared to be spring fed as dry immediately upstream. Surfaces around 5 m from the left bank, thought to be connected to Reach Trib 2. Gauged in two sections across the cross section. Gauging - good.
Reach Trib 2	31/01/2024	11:30	-	Waterfall (gauged downstream at Reach Trib 3).
Reach Trib 3 (Volumetric)	31/01/2024	11:45	2.3	Volumetrically gauged in two sections. The other three areas of minor flows were estimated. Waterfall is located 10-15 m upstream with a good gauging location, but as trib approaches confluence with the river, the flows appear to decrease. This indicates seepage into the ground. Trib bed is very rocky throughout with large boulders from the waterfall all the way to the confluence. Most rocky areas downstream appear dry but could be flowing underneath. Looks like a watercourse in high flows.
Reach Trib 4 (Visual Estimate)	31/01/2024	13:00	<0.5	Very small trickle, estimated at <0.1 l/s. Immediately downstream of Reach E cross section. Unable to gauge.
Reach Trib 5 (Volumetric)	31/01/2024	13:30	2.3	Gauged at multiple points along the cross section. Measured at the pool close to the main stream.
Reach Trib 6 (Visual Estimate)	31/01/2024	13:40	<0.5	Small trib, just a trickle. Unable to gauge.
Reach Trib 7 (Visual Estimate)	31/01/2024	14:30	1-2	Small stream running along track and into the main river. Flow could not be gauged. Approximately the same flow rate as Reach Trib 8. About 1 m upstream from the confluence, the streamflow disappeared completely into the ground before resurfacing as it joined the main river.
Reach Trib 8 (Volumetric)	31/01/2024	14:23	1-2	Small stream running along the trail path. Flow entered small pipe under track which was volumetrically gauged at the pipe outlet. Gauging - good.
Reach Trib 9 (Visual Estimate)	31/01/2024	14:15	1-2	Small stream flowing into the main stream. Unable to confirm if this is the same streamflow as Reach Trib 8. Unable to gauge.
Reach Trib 10 (Visual Estimate)	1/02/2024	9:30	<0.5	The left bank of the mainstream was a very steep rock face. Water flows down the rock from a tributary. It was not possible to find the exact source of flow, nor gauge the flows.
Reach Trib 11 (Volumetric)	02/02/2024	10:30	6.0	Farm trib located 20 m upstream form the confluence with the Otahu River. Otahu middle is located immediately downstream. Six measurements were taken over the cross section. All flow was captured, and therefore there were no additional losses to account for.

Table 4. OGL tributary gauging summary.

Location (Gauging Type)	Date	Start Time (NZST)	Flow (L/s)	Water Sample	Comments
Trib 1A	9/4/2024	11:45	0.28	1	Pool with upwelling water entering the main river in two flowing sections (gauged here), downstream of Trib 2 (waterfall), sampled at 11:31
Trib 1B	9/4/2024	11:55	0.57	2	Pool flowing towards river, sampled at 11:34
Trib 1C	9/4/2024	12:06	0.47	3	Pool with clear channel upstream, sampled at 11:41, photo at 11:58
Trib 2	9/4/2024	12:30	1.13	4	Gauged at base of waterfall in five branches plus an estimated flow for portion that couldn't be gauged with bucket, losses were approximately an additional 0.02L/s (or 2%), water samples taken approximately 25m downstream of waterfall in a pool at 12:20
Trib 3	9/4/2024	13:12	0.10	5	True left of river, small waterfall running across track.
Trib 4	9/4/2024	13:40	0.16	6	True left of river, waterfall trickling down rocky bank and across the track, sampled from pool on stream side of track. Stream is in 3 branches, just below where branch 1 & 2 join was gauged with a 1L bottle, third branch is approximately 50% of combined flow of branch 1 & 2.
Trib 5	9/4/2024	13:52	0.07	7	Small stream running down channel on true left of main river, pipe under track not flowing. Gauged at confluence with main river, downstream of the pipe running under the track. Gauged in two sections, branch 1 gauged with a bucket and branch 2 estimated at approximately 60% of branch 1.
Trib 6	9/4/2024	14:07	0.07	8	Small stream on true left of main river, flows under track in pipe, sampled from just below pipe, gauged flow from pipe.
Trib 7	9/4/2024	14:14	0.17	9	Stream running off bank above track and along track in drain. Discharges under track towards main river, some water flowing through pipe and some flowing under pipe. Gauged in two sections (left branch Sampled from pool downstream of pipe.

3.2 Water Sampling

Water quality samples were collected for laboratory analysis of cations, anions and heavy metals. The results of those analyses are included in **Attachment B** and show no significant difference between the samples other than nominally lower alkalinity and bicarbonate at Tributary 1 (refer **Figure 5**). Water samples collected were also analysed for Radon to assess the likely contribution of deeper groundwater in the stream waters[2] and the results of those analyses are included in **Table 5**.

Table 5. Measured Radon concentrations in surface water.

Location	Radon Concentration (Bq/L)
Trib 1A	1.57
Trib 1B	1.56
Trib 1C	4.03
Trib 2	0.23
Trib 3	0.05
Trib 4	0.07
Trib 5	0.33
Trib 6	0.11
Trib 7	0.23

[2] The presence of dissolved radon is indicative of groundwater influx, while a lack of radon indicates that the water source is exclusively rainfall. The minimum concentration considered to be indicative of some degree of groundwater contribution is 0.5 BqL^{-1}.

The measured concentrations suggest the waters discharging at Trib 1 have a significantly greater proportion of groundwater (higher Radon results) than at the other locations by comparison.

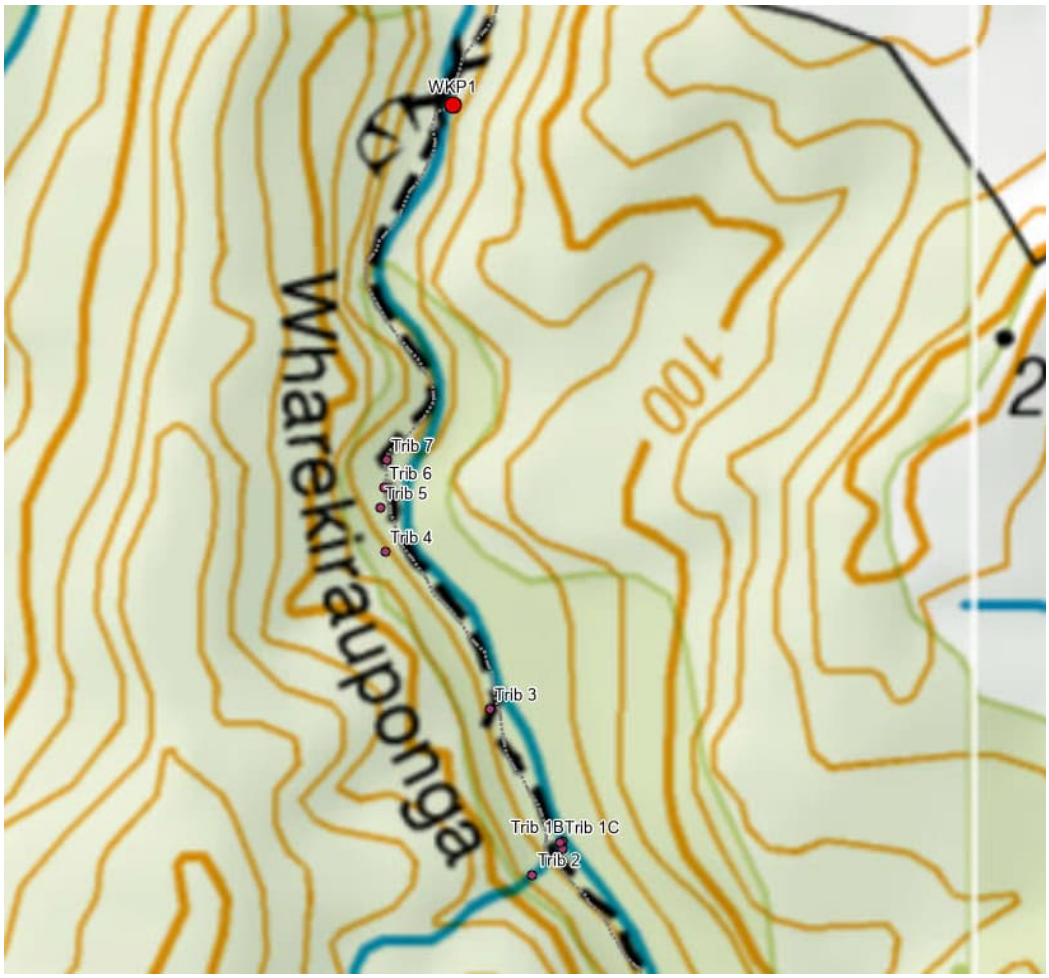


Figure 4. Location of flow gaugings and water quality samples (April 2024).

4. Discussion

4.1 Summary of Results

The change in flow with increasing distance along the lower reach of the Wharekirauponga Stream is illustrated in **Figure 5**. Typically, you would expect progressively increasing streamflow with increasing distance downstream. When a decrease in flow from upstream to downstream is observed it indicates a potential loss of flow (i.e., loss to groundwater) (depending on the reliability of the gauging). Conversely, a sudden increase in flow indicates a gain in flow (a groundwater spring, surface water tributary).

A decrease in flow was observed from Site A to Site B. The gauging at Site B was considered 'Fair' based on the qualitative assessment of gauging quality. At this point in time (based on the data collected to date) we are uncertain whether this represents an actual location of loss to groundwater, or whether the perceived decrease in flow is a function of gauging uncertainty due to site conditions. The later is expected to be more likely.

Flows between Site C and Site E were fairly consistent. However, the gaugings indicated a small decrease in flow between Site D and Site E. This is unexpected as at least two tributaries were identified as entering along this reach which would be adding to the flow. Based on the volumetric gauging and visual estimates of these inflows, an increase of around 5 L/s would have been expected. Similar to above, it is not currently possible to determine whether this decrease in flow represents an actual loss or is a function of gauging uncertainty of the rocky streambeds.

Applying the theory that there should be a consistent gain along the reach, the results indicate possible losses at sites E, I and L and a gain at site F.

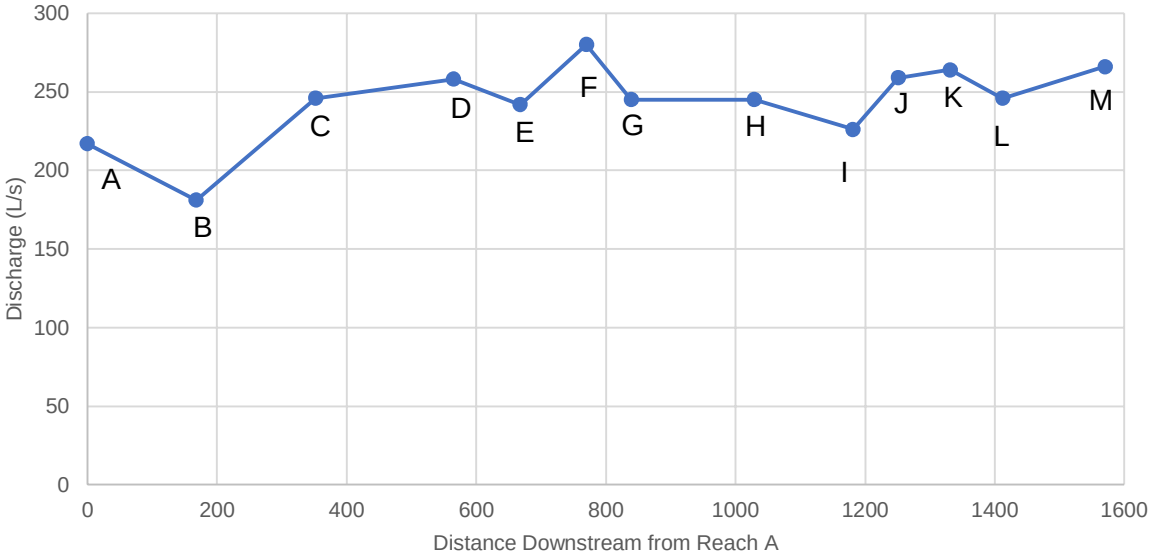


Figure 5. Change in flow along the WKP reach with increasing distance downstream.

The spatial distribution of the gauging points and noted losses and gains are illustrated on **Figure 6**. The results show observed areas of gains associated with tributaries 1-5 and 7-9 with an immediate downstream loss noted. Along the entire length of the reach gauged there is an overall gain of 40 L/s.

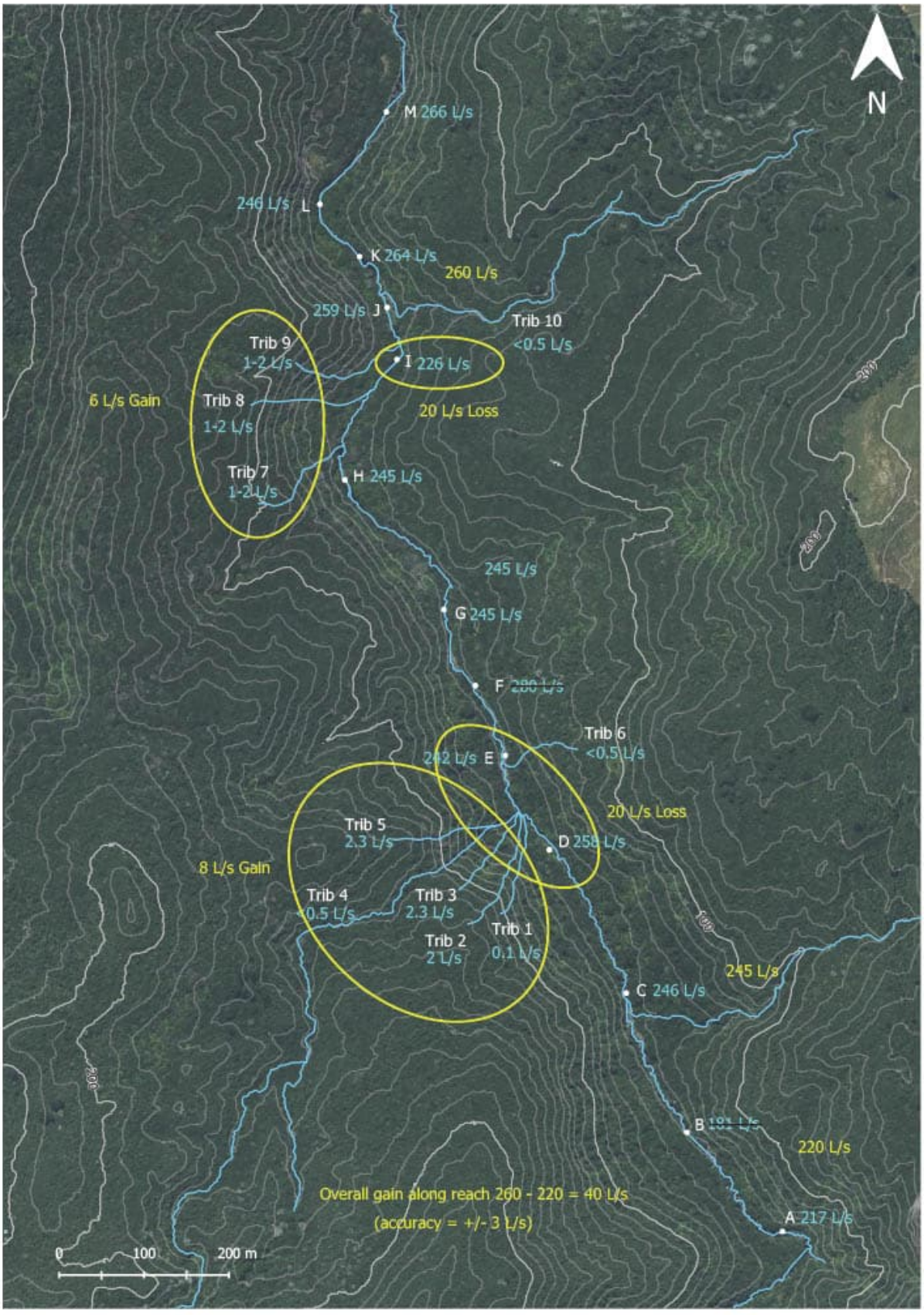


Figure 6. Flow gauging locations and results (WWLA, May 2024).

Targeted investigations were undertaken by OGL that focused on the locations between reach D to E, and H to J. The results of those investigations indicate that, while the flows may be small, the water discharging at the Trib 1 location (between D and E on **Figure 5**) comprises a greater proportion of groundwater than at the other locations sampled.

That observation adds weight to the working hypothesis that this zone of groundwater discharge may relate to the underlying geologic structure (more particular, the northern strike extension of the main EG vein). While the geologic mapping of that stream reach has shown only andesite in exposed outcrop, it could be interpreted that the unit is thin and overlies rhyolite volcanics that hosts the vein mineralisation. Comparison of the radon concentrations in water samples measured from the shallow groundwater system at WKP01D/S and WKP02D/S of 2.0-5.6 Bq/L to those measured at Trib 1 of 1.6 to 4.0 Bq/L indicates a similar range. In our opinion, those results support the working hypotheses and indicate that the lower Wharkirauponga Stream reach receives some groundwater discharging from the shallow groundwater system. The direct stream gain associated with the extension of the structure where the radon concentrations are highest is in the order of 5 L/s.

4.2 Recommendations

There are limited options remaining to further confirm whether and/or how much groundwater discharges to surface waters within the Wharekirauponga catchment or outside of the catchment. These recommendations are as follows.

- Conduct a tracer test by injecting a dye or chemical tracer into to the groundwater system via existing monitoring piezometers or exploratory bores and monitoring potential discharge locations.

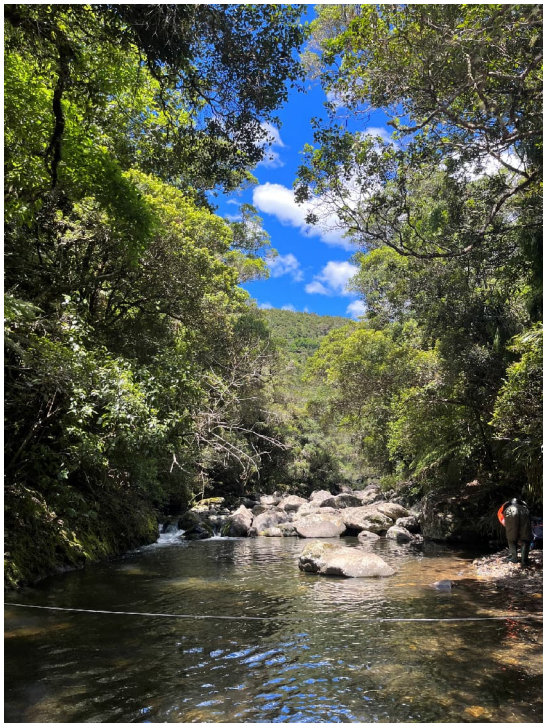
- Undertake drilling investigations at the locations of interest to confirm the interpretation of the geological and hydrogeological conditions.

Appendix A. Flow Gauging Photos

Reach A	
 Cross Section	
 Upstream	 Downstream

Reach B

Cross Section



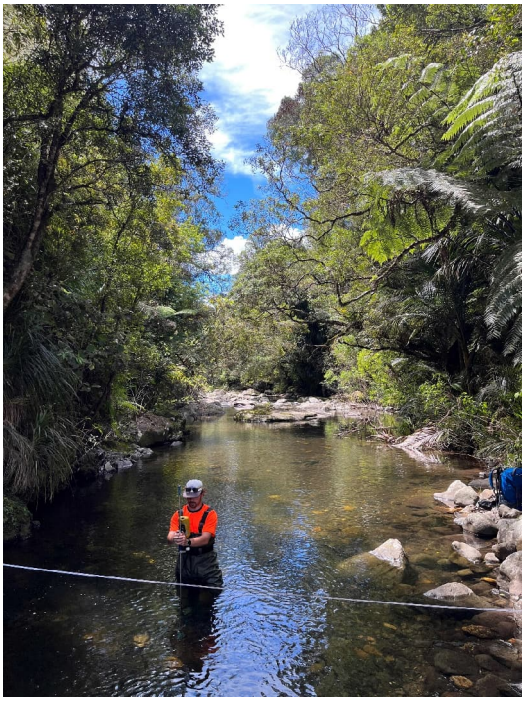
Upstream

Downstream

Reach C

Cross Section

Upstream



Downstream

Reach D	
 Cross Section	 Trib 2 Waterfall (downstream of Reach D)
 Upstream	 Downstream

Reach E

Cross Section

Upstream

Downstream

Reach F

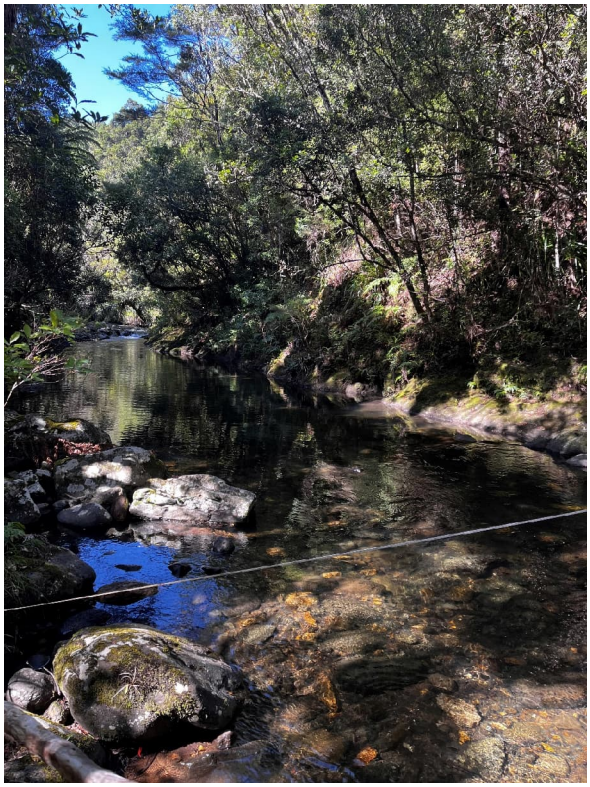
Cross Section

Upstream

Downstream

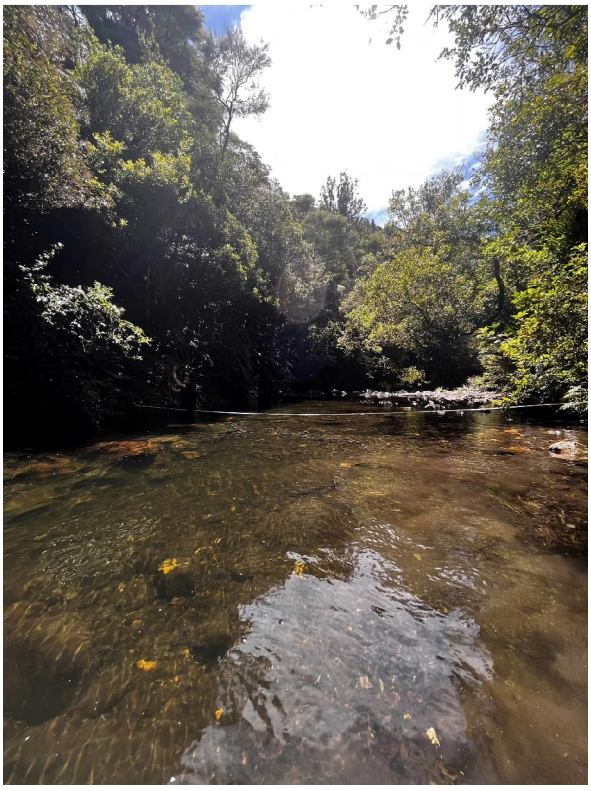
Reach G

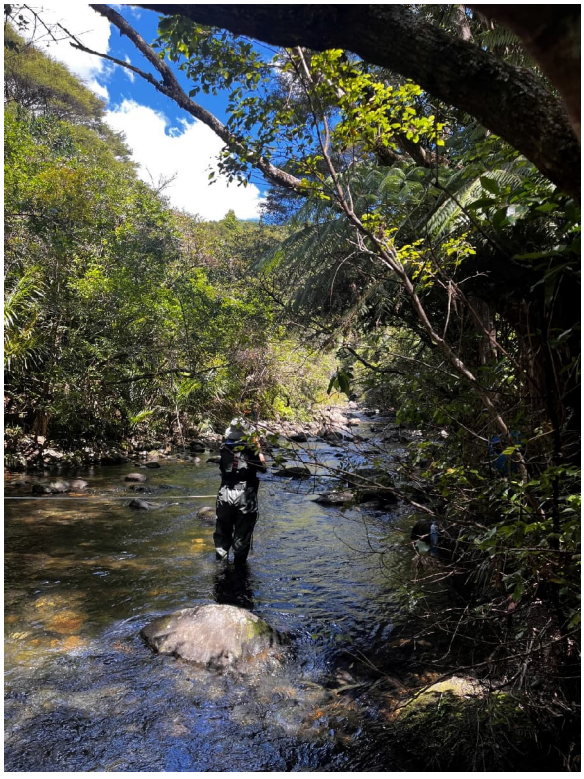
Cross Section



Upstream

Downstream

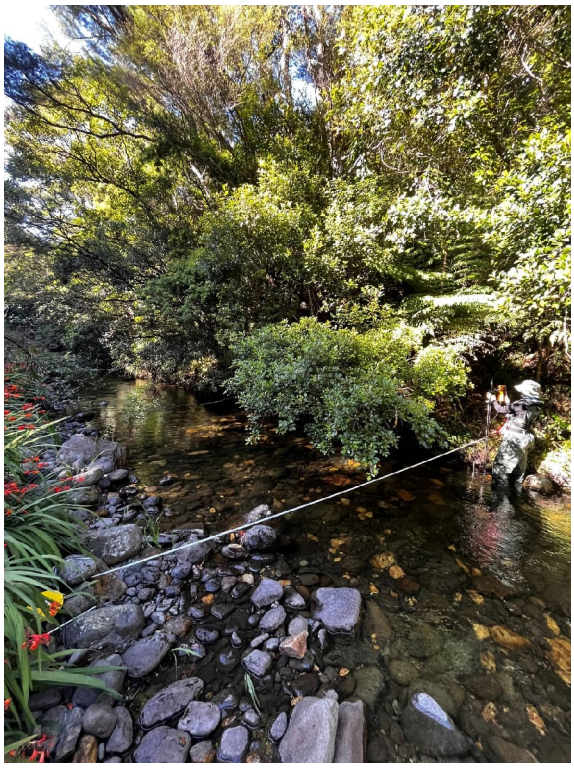
Reach H	
	
Cross Section	Trib 7 (downstream of Reach H)
	
Upstream	Downstream

Reach I	
	
Cross Section	Trib 8 (upstream of Reach I)
	
Upstream	Downstream

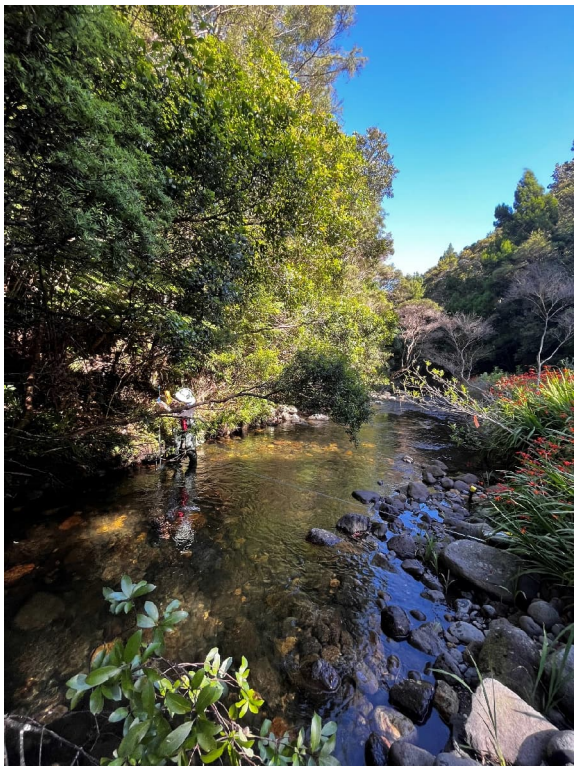
Reach J

Cross Section

Stagnant water on other side of boulder island



Upstream



Downstream

Reach K

Cross Section

Fractures on left bank

Upstream

Downstream

Reach L

Cross Section

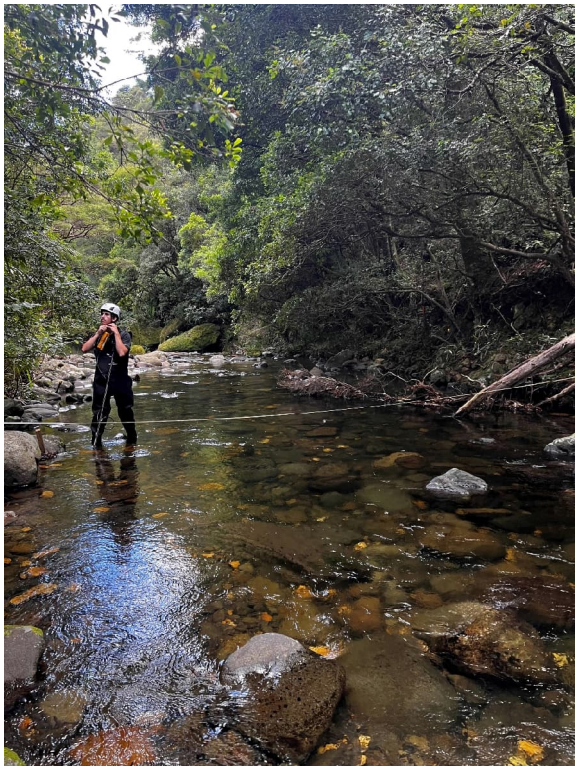
Upstream

Downstream

Reach M

Cross Section

Upstream



Downstream

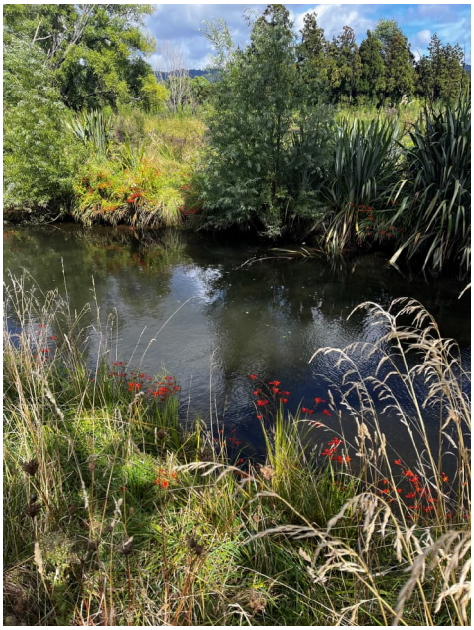
Otahu Upper

Cross Section

Upstream

Downstream

Otahu Middle	
 Cross Section	 Farm Trib culvert
 Upstream	 Downstream

Otahu Lower	
 Cross Section	
 Upstream	 Downstream

Appendix B. Surface Water Quality Results