Waikaka Goldmines Ltd. Aquatic Ecology Survey.

Report to Waikaka Goldmines Ltd.

Ross Dungey Consulting Ltd. February 2021

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Executive Summary.

1. Waikaka Stream supports 3 healthy fish populations, Longfin Eel, Brown Trout, and Upland Bully. Gollum galaxiids are present but in low numbers and limited distribution. The Stream supports considerable spawning for the Brown Trout and Upland Bully.
2. Shortfin Eels occupy the small ponds, almost exclusively, perhaps a reflection of high ammonia levels.
3. There is a trend for decline downstream in various invertebrate indices (MCI) indicating effects of nutrient enrichment. Invertebrate densities are higher at the lower sites as chironomids flourish in the algae, and mayfly decline with this change in habitat.
4. The ponds in particular have high levels of Ammonia and nitrates and high conductivity reflecting dissolved nutrients/minerals.
5. Waikaka Stream spikes in E.coli at site 3 below the confluence with the stream draining the Waikaka sewage pond but is otherwise within limits.
6. DRP and DIN exceed the NPS-FW 2020 guidelines in the stream.
7. Critical habitat components on the Waikaka stream include shade from the extensive riparian zone, undercut banks for fish cover, and a coarse substrate for invertebrate and small fish habitat.

Sources of Information

In compiling this report I have conducted the field surveys and sourced information from:

1. An aquatic ecology survey of fish, invertebrates, and habitat at specified locations, throughout the mine area outlined in Figure 1.
2. The New Zealand freshwater fisheries, NZFFD.
3. ES and LAWA water quality information.
4. Local knowledge and anecdotal reports of fish species harvested.

Background.

The L&M mine site in Waikaka Valley is now owned by Waikaka Goldmines Ltd who plan to continue mining the area. The location is approximately 20km NE of Gore in Southland. The proposed mine zone is approximately 144 hectares and involves mining through the Waikaka Stream channel, approximately 2.5km, and several small ponds (4-6) that are old dredge ponds. The existing L&M mining pond is likely to remain in one form or another but the operation will move roughly northwards towards the Chatton-Waikaka Road. The mine therefore has an extensive "Zone of Influence". It is proposed to redirect the stream further to the east so that it more or less flows along the base of the hills. Figure x, Waikaka Goldmines Ltd site plan.

Aim of this study

Ross Dungey Consulting was contracted to provide a report on the aquatic ecological values of the proposed mine site. It describes the current state of the aquatic ecosystems, identifies key habitat components, and establishes some baselines for fish, invertebrates, riparian cover, substrate, aquatic habitat, and water quality.

Methods

Sources of Information

The international literature on freshwater ecology and habitat tolerances and preferences and New Zealand Freshwater Fish Database were searched to provide supporting information for this report. Hydrology and flow records are available on the Environment Southland (ES) website. The National Policy Statement for Freshwater (NPS_FW 2020) was checked for background and standards recently set in place for freshwater resources.

Fish

Electrofishing

Electrofishing was conducted at selected sites in Waikaka River, wetlands/ponds, and drainage ditches. Fish species and fish length were recorded and an assessment of relative abundance made on the basis of electric fishing, trapping, and spotlight counts throughout the proposed mine site. Sample sites are identified in Figure x

Fyke Nets

The large dredge pond was surveyed using a variety of methods including Fyke nets, baited and set overnight. Fyke nets were employed exclusively in the small ponds where water visibility precluded other options.

Minnow Traps

A mix of baited and un-baited minnow traps were set to sample fish in the "Big Pond".

Spotlight

The dredge pond, ditches, and the Waikaka River were surveyed by spotlight in the early evening.

Invertebrates

Surber Samples

For invertebrates three surber samples were collected from each site on the Waikaka Stream to assess invertebrate populations for species present, relative abundance, and density and calculate biotic indices.

Kick samples

Kick samples were collected from pond and ditch sites.

All invertebrate samples were preserved in alcohol and sorted later in the lab. From the counts made of these samples various biotic indices were calculated. These included species composition, density, EPT, MCI, and number of taxa.

Habitat

Habitat was assessed in the Waikaka Stream recording substrate, habitat type, riparian cover, widths and depths according to a modified NZFFD survey card format, appendix 3. A Densiometer was used to assess shading provided by the willow trees in the extensive riparian zone Harding et al (2015) Stream Survey Protocol. This information was recorded to assess habitat but also provide input for the river rehabilitation phase of the operation for the plan to divert the river to the east.

Habitat on Waikaka Stream was visually judged according pool, riffle, and run hydrologic characteristics and the distance of each category measured over the length of the river in the proposed diversion. An assessment of the extent of tree cover was made by measuring the distance along both banks that have tree cover from an aerial photograph. Densiometer readings provided an estimate of canopy cover over the water.

Widths and depths were recorded at each of the main Waikaka Stream survey sites. Of the main survey sites 5 are riffle habitats and 1 (#5) is run habitat. These sites were primarily selected to facilitate electrofishing, invertebrate sampling, and assessment of the "production zones" of the stream. Electrofishing can only be conducted to about 0.7m water depth, this is a safe wading limit. This can be extended to 1m with the reach of the electrofishing electrode wand. The water depth measurement was the deepest point along a width transect.

Substrate.

Substrate in the Waikaka River was measured by randomly selecting 50 particles at each site and measuring the long axis of each particle. The method involves lying a tape along the river bed and selecting the particle that corresponds exactly to the 1m mark and measuring its long axis with a calliper to the nearest millimetre.

Water Quality

Water quality was measured using a handheld YSI meter at sites in all habitat types. Additional samples were collected from a selection of river sites and ponds for more detailed analysis and analysed by Watercare Ltd. Invercargill. Parameters measured were conductivity corrected for temperature-(CT), salinity- (Sal), Total Dissolved Solids-(TDS), Total Suspended Solids-(TSS), ammoniacal nitrogen- (Am-N), Total Nitrogen- (NN), Total phosphorous- (TP), Dissolved reactive phosphorous- (DRP), and E.coli. Dissolved inorganic nitrogen (DIN) was calculated by summing NN and Am-N.

Each site was assessed for all measures on the one visit (November), with the exception of the ponds east of the river that were surveyed at a later date (February). For example, all Water Quality samples collected on the same day, all invertebrates surber samples collected on the same visit, and so on.

Secchi disc readings were taken in the Big Pond in November 2021.

Bathymetry

A bathymetric survey of the L&M dredge pond was conducted. The pond substrate was "sounded" to determine if it was solid or soft bottom along each of 10 transects. (This survey is in a separate report)

Shade.

Canopy cover was assessed using a densiometer, according to the protocol used by Harding et al (2009).

Results

Regional Fish Distribution.

The New Zealand freshwater fisheries database (NZFFD) records fish distribution in New Zealand. There have been 4 salmonids and 2 native fish species recorded in the Waikaka River catchment, table 1, however in the course of this survey we recorded 4 native fish and 1 salmonid (brown trout).

Table 1, fish species and distribution in the Waikaka Stream and associated aquatic habitats and records from NZFFD*. Reported to be in the Waikaka Stream but not recorded on this survey**.

Species	**Scientific Names**	**Distribution**
Brown Trout*	*Salmo trutta*	Stream, Big pond, ditches
Upland Bully	*Gobiomorphus breviceps*	Stream, Big pond, ditches
Shortfin eel	*Anguilla australis*	Small ponds
Longfin eel*	*Anguilla dieffenbachi*	Stream, Big pond, ditches
Galaxiid*	*Galaxias gollomoides*	Stream, Big pond, ditches
Perch	*Perca fluviatilis*	Big Pond & Stream**

The results are presented for each habitat type, so that all the pond, ditch and stream survey results are reported under each of those habitat headings.

Conservation Status of Fish

The conservation status of all New Zealand freshwater fish has been documented by an expert panel and is reviewed regularly. It ranks fish according to threat risks to the populations and considers a range of issues such as loss of habitat, (quality and quantity) and commercial harvest in the case of longfin eels. Two of the fish species present are classified as “at risk and declining, Longfin eels and the galaxiids, Table 2.

Table 2, conservation status of fish species of the Waikaka Catchment.

Common Name	**Conservation Status**
Longfin eel	At risk, declining
Shortfin eel	Not threatened
Gollum Galaxiid	At risk, declining
Upland Bully	Not threatened
Brown trout	Introduced & naturalised
Perch	Introduced & naturalised

Waikaka Stream

Locations of stream survey sites are shown in Figure 1, and GPS co-ordinates provide in table 3. Features common to all sites are a gravelly/cobble substrate, an extensive well vegetated riparian zone, and all but site 5 are riffle habitats.

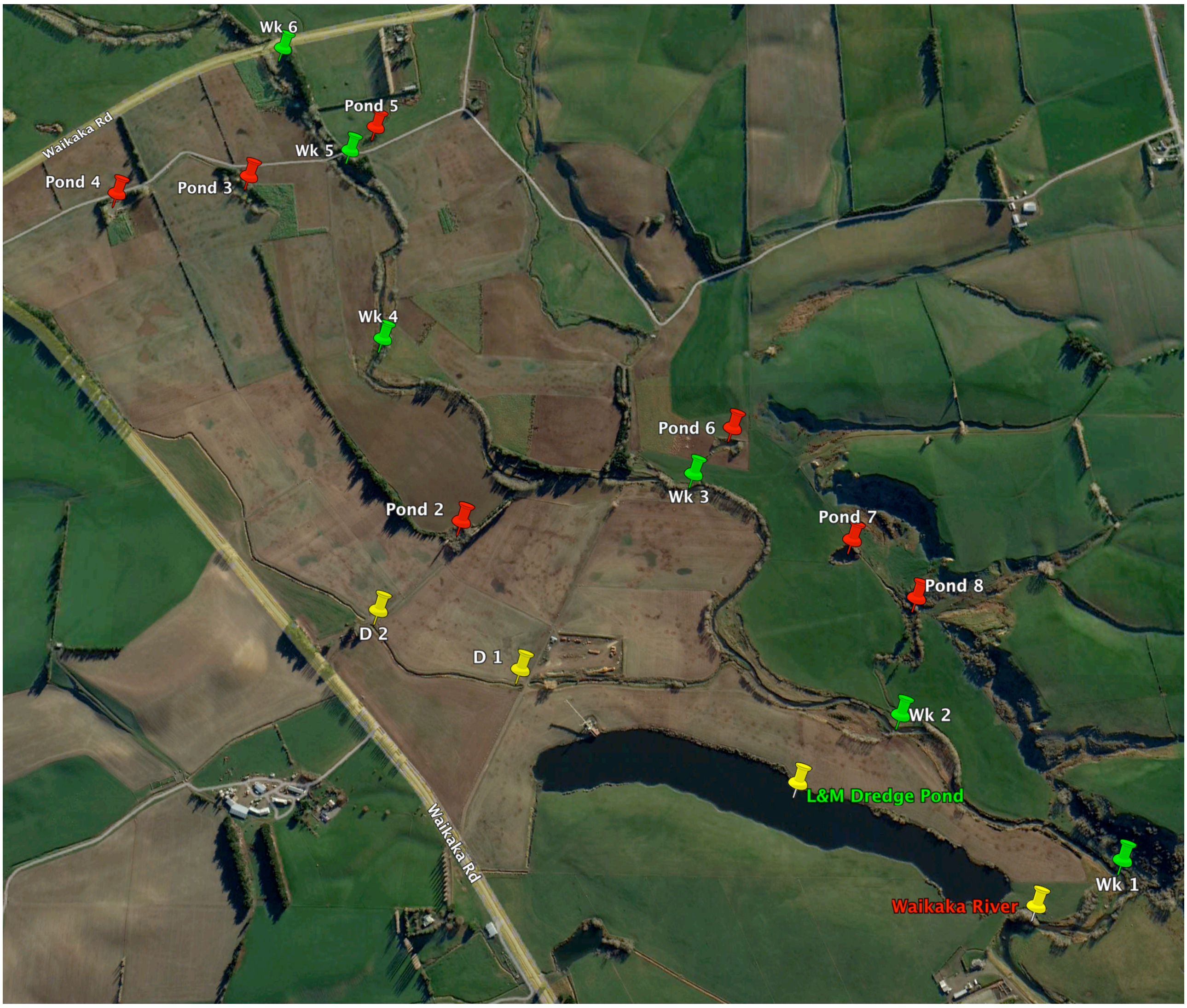

Figure 1, locations of survey sites at the Waikaka Mine Site, Wk= Waikaka Stream, D=ditch.

Site Descriptions.

1. Site 1: the most downstream site with a limited shading and a NW/SE aspect
2. Site 2: very limited shading with E/W aspect.
3. Site 3: heavily shaded by willows on the north bank and an E/W aspect and just below the confluence with the east Waikaka Stream.
4. Site 4: limited shading and a N/S aspect
5. Site 5: Well shaded, gravelly substrate and a run rather than a riffle and N/S aspect.
6. Site 6: just below the bridge, moderate willow shading from morning sun and N/S aspect.
7. Pond 1, The Big Pond is the L&M dredge pond, NW/SE aspect and about 1.1km x 0.1km and up-to 8m deep
8. Pond 2, grey in colour, surrounded by tall trees, very high ammonia.
9. Pond 3,4,7, and 8 clay coloured and surrounded by trees, anoxic mud bottoms.
10. Pond 5 and 6 clear water and macrophyte (*Potamogeton sp*) beds.

Table 3, GPS (NZTM 2000) locations of survey sites.

Site	Northing	Easting	Altitude
Waikaka 1	4903324	1291574	115.2
Waikaka 2	4903634	1291181	115.1
Waikaka 3	494121	1290681	119.9
Waikaka 4	4904370	1290049	120.6
Waikaka 5	4904816	1289914	122.2
Waikaka 6	4905042	1289731	123.9
Big Pond	4903490	1290739	114.5
Pond 2	490380	1290273	na
Pond 3	4904730	1289740	123.7
Pond 4	4904716	1289477	124.0
Pond 5	4904816	1289914	122.2
Pond 6	4904224	1290800	118.1
Pond 7	4904006	1291046	116.9
Pond 8	4903889	1291161	117.3
Ditch 1	4903693	1290354	118.7
Ditch 2	4903798	1290088	120.7

Stream Flows.

ES's website provides flow data for Waikaka Stream at a measuring site "Hamiltons Flat" near Gore. This is the closest location to monitor and describe flow patterns. Waikaka Goldmines Ltd has established a new site just downstream of the mine site which has been recording since October 2021. The flow records for the days leading up-to and including survey days were noted form the Hamiltons Flat site, appendix 1. Spring and early summer flows are in the order of 2 or 3 cumecs but by mid-summer these have dropped to 500-600L/s and at these low flows the stream is warm, low 20's ^{0}C. Much more of the stream is able to be surveyed at these low water levels allowing some adult trout to be captured and habitat components (for example undercut banks) assessed.

Fish species in the Waikaka Stream

The electric fishing for this survey covered approximately 738m^2 at 9 sites, averaging 82m^2, in November/December 2021. An additional five reaches were spot fished when flows decreased and more of the stream could be accessed (mid January) and this added an additional 1720m^2. These included fishing, in particular, undercut banks, over hanging willows, and areas where boulders line the stream margins, all in areas where higher flow had previously prevented fishing. These sites are mostly Runs (as opposed to riffles), pools were still too deep at low flows to be able to be electro-fished.

Electric fishing was the primary method but this was supplemented by netting and visual observations. This provided more information on size range especially for the adolescent and adult trout. Poor water visibility (murky water) precluded drift diving as a survey technique.

Four survey sites were fished 2 to 3 times to derive a diminishing return in the catch. These sites were all riffle sites, shallow and able to be electro-fished thoroughly enough to derive population statistics.

These sites are primarily focused on small fish such as upland bully, "young of the year" brown trout, and galaxiids. Small fish are concentrated in these locations and spread, as they grow larger, to deeper water. All species are to be found in other habitat types but predator/prey interactions and habitat differences, impact on numbers.

Eel lengths are up-to + or – 100mm but sometimes very accurate where an individual fish relaxed enough to straighten out. Long fin eels are much easier to measure than shortfins as the later will not stop wriggling. Brown trout, upland bully and galaxiids are + or – 1mm. Some adult brown trout were captured and measured, and length for others was estimated. Average size is based on measured fish only.

During the survey of stones in riffles, egg clusters were frequently observed on the underside of cobble size stones and are assumed to be bully egg nests. Large bullies were often electro-fished from these areas and a check on the underside of cobbles from which the fish was drawn, revealed these nests which bullies are known to defend against intruders. Four species of fish were recorded from Waikaka Stream, table 4.

Table 4. Common and scientific names of fish species recorded from the Waikaka Stream and ponds within the mine site.

Common Name	Scientific Name
Longfin eel	*Anguilla diefenbachii*
Shortfin eel	*Anguilla australis*
Upland Bully	*Gobiomorphus brevicepps*
Galaxiid	*Galaxias gollumoides*
Brown trout	*Salmo trutta*

Fish numbers were estimated using the formula (Carle & Strubb 1978) allowing an estimate of fish density to be made based on each species and a total density of fish for each site, table 5.

Table 5, population estimate based on diminishing returns(repeat passes), area fished, fish density fish/m^2, and total site density of 4 riffle areas in the Waikaka Stream. UpB=upland bully, LF=longfin eel, BT=brown trout. Est # = estimated number.

Site		Est #	Area m2	Density	Total Fish Density
3b	LF	3	134	0.02	
	UpB	174		1.3	
	BT	28		0.21	
	Gx	7		0.05	1.58
4a	LF	2	46.9	0.04	
	UpB	88		1.88	
	BT	8		0.17	2.09
4b	UpB	53	69.8	0.76	
	BT	15		0.21	0.97
6	LF	3	108.3	0.03	
	UpB	193		1.78	
	BT	22		0.20	2.01

Three other riffle areas were electro-fished and the same species were present and at similar densities. Based on the proportion captured in the first run at the sites where multiple runs were made, a density estimate at other sites where there was 1 pass with the electrofishing machine, was calculated. That equates to 64% captured on the first run for Upland bully and 75.7% for brown trout. *This provides a pragmatic and conservative estimate of fish density at these locations but lacks the certainty of the diminishing return method. Seasonal and annual natural variations in production are likely to alter these estimates.*

Site 5 is not riffle habitat and therefore supports a different fish community, namely a much lower density of small fish and although no large fish (predators) were captured because of the ease of escape in deeper water, adult trout have been observed feeding at this location. Site 2 is outside the range of densities estimated from the more intense 3 pass survey method but had a large sample of upland bullies. Individual species density and total site density are shown in table 6.

Table 6, the estimated number of fish captured at each site, individual species density and total site density. * outside the range calculated from 3 passes.

Site		Est #	Area m2	Est Density	Site total density
1a	UpB	109.2	74.4	1.47	
	BT	14.3		0.19	1.66
1b	UpB	79.8	135	0.59	
	BT	37.7		0.28	0.87
2	UpB	228.2	81	2.82	
	BT	26		0.32	3.14*
5	BT	5	75	0.09	
	UpB	9		0.17	0.26

For all species combined total fish density in riffle areas ranged from 0.26-3.14 fish/m^2. Upland bully and young of the year brown trout are the dominant species in the riffle areas. Density for Upland bully ranges from 0.17-2.82 and for trout 0.09-0.28 fish/m^2, figure 2

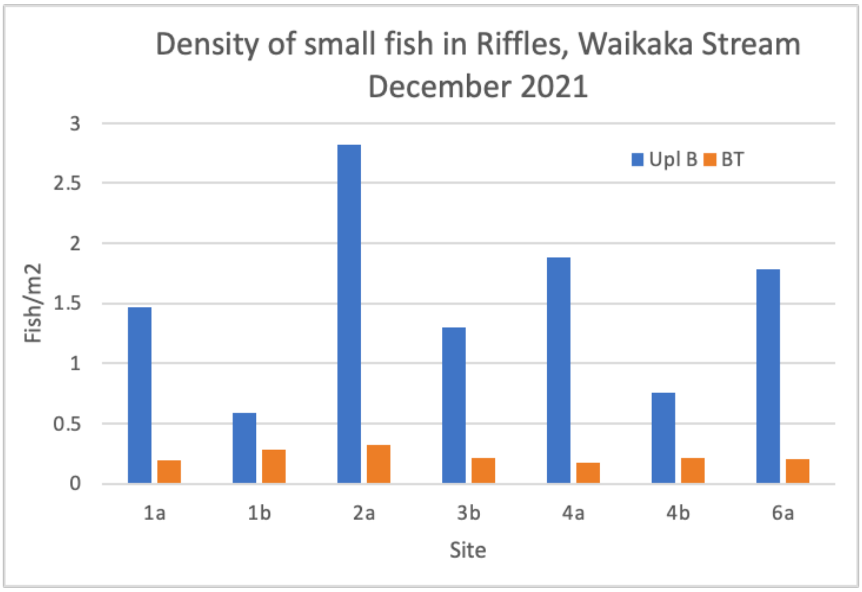

Figure 2, density of small fish in riffle reaches. Upl B=upland bully, BT = brown trout.

Upland bullies were the most common species. Mean length, size range, and sample size were all calculated from the fish sampled and measured at each site. A very small number of other species such as galaxiids and juvenile longfin eels were captured in the riffle areas. Outside the riffle areas, in deeper water, larger fish were occasionally seen but avoided capture, in which case a length was estimated. At lower flows several of these fish were captured and measured.

Fish species captured at the survey sites over a range of samplings included long fin eels, brown trout, upland bully, and galaxiids, table 7. All species are present throughout the Stream except galaxiids which were only located in the vicinity of sites 2 and 3.

Table 7, fish species, number, and (size range, measured) from survey sites.

Site	**Longfin Eel**	**Brown Trout adult**	**Brown Trout juvenile**	**Upland Bully**	**Galaxiid**
Waikaka Stream	61 (98-1000)	7 (231-580)	138 (39-79)	718 (26-76)	18 (26-58)

Trout were observed actively feeding on willow grubs (*Potania pacifica*), which are a major terrestrial food source during summer/hatching. These grubs are the larvae of a sawfly that creates a small gall on the willow leaves, recognisable as a red/brown raised blister. The larvae frequently fall into the water. When adult trout are feeding on these grubs they are very easy to observe, count, and estimate their size. The contribution of overhanging vegetation to providing terrestrial food items has been noted by other researchers, McDowall et al (1996). In the table above the largest and smallest in the adult trout group are all measured fish. Additional electro-fishing at low flows (approximately 0.6cumecs on 18th Jan 2022) allowed the capture of eels and adult trout from water previously to deep to fish.

The count of adult trout is a visual assessment and therefore a conservative estimate of adult trout numbers as the observed fish are an unknown proportion of those actually present. Visual counts of numbers of trout present are from the reach between site 3 and 4, a distance of approximately 800m. The count for this reach is 17 adults in the 350-550mm size class and 11 in the 150-350 size class but most of this later group are approximately 250mm long. This gives a estimate of not less than 21 adult trout/km.

Population structure can be assessed by length frequency plots for the dominant species where a sufficiently large sample size is available.

Eels may live for up-to 70 years prior to migrating to the sea to spawn. Determining year classes from length frequency for such a long life span where a range of habitat factors have an extended period to influence growth is well-nigh impossible. What the length frequency for eels does in this instance is show the range of sizes and usual length of eels supported in this section of the Waikaka Stream, figure x.

Sixty one eels were captured in the Waikaka Stream using electrofishing and fyke nets, figure 3. Catch in nets set overnight varied from no fish in a net to 12 (photo, see appendix 2) in a net. Most eels were captured using electrofishing which has the added advantage of being able to record the habitat the eels were found in whereas a baited netted draws eels from daytime resting habitat, usually deep pools as in the case of 12 eels in 1 net.

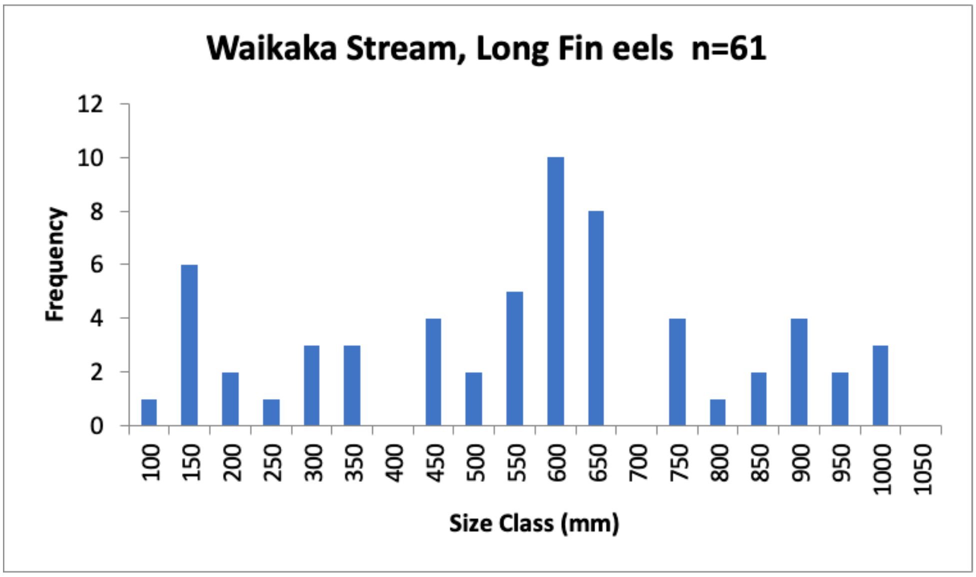

Figure 3, length frequency of Waikaka Stream Longfin eels, December 2021.

Figure 4 below shows the range in size of young of the year brown trout in the Waikaka Stream and the growth that has occurred since hatching at approximately 20mm, since early October. Hatching will be spread over a few weeks and some of the early hatchers have attained a length of 80mm but the majority are around 55mm as at mid December.

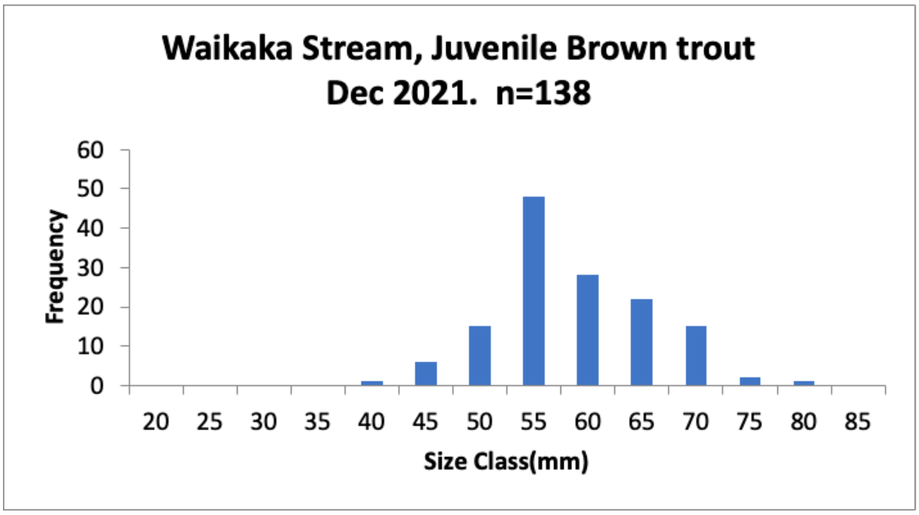

Figure 4, length frequency distribution of young of the year Waikaka Stream brown trout, December 2021.

No larger fish were captured or seen during electrofishing at each of the 6 Waikaka Stream sites which is quite unusual. The next largest fish recorded were observed in pools and estimated to be approximately 200mm. This strongly suggests a distinct lack of the age groups 1+ and 2+ fish that would normally be recorded in the electrofishing surveys conducted at such locations.

Upland bullys range in size from 26-76mm, and all of the fish in this sample are at least 1 year old. Eggs were still abundant under many cobbles so at the time of sampling hatching had not begun and no juveniles were present. (McDowall 2000) notes that they live for 3 or 4 years and that the females may have up-to 8 broods in a summer. They mature at 1 year, probably around 30-40mm. Having several broods per summer means there is a wide variation in length of fish making age classes much more difficult to distinguish. The larger individuals, 60-80mm are likely the four year olds, figure 5.

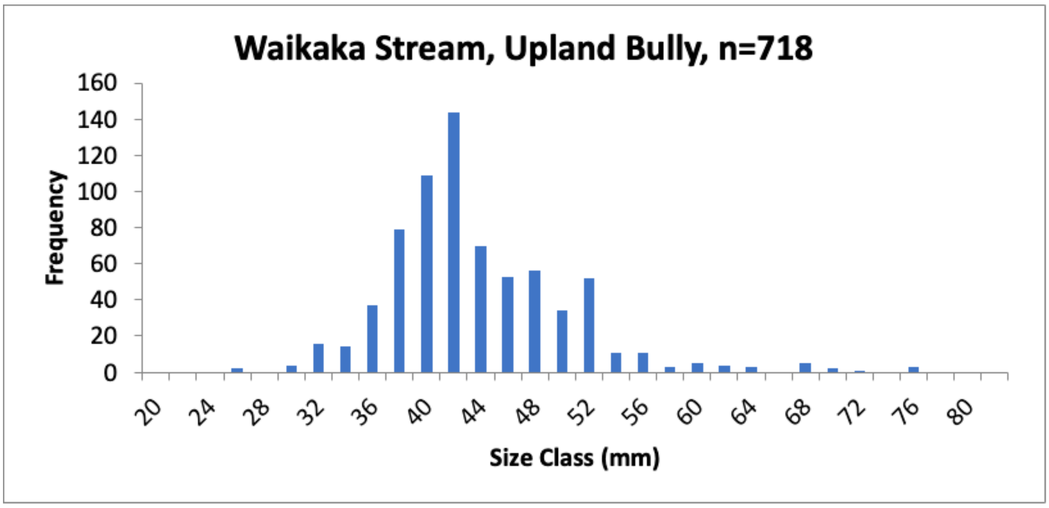

Figure 5, length frequency distribution of Waikaka Stream upland bully populations, December 2021.

Waikaka Stream Invertebrates.

The freshwater lobster *Paranephrops zealandicus* is an invertebrate so is recorded in this section (although it is predominantly about stream insects). One lobster was captured in the Waikaka Stream at site 4 measuring 86mm in length. No freshwater mussels were observed either.

Site 6 is the most upstream site near the bridge on the Waikaka-Chatton Road and site 1 approximately 200m above the outlet of the "Big Pond". Invertebrates were collected by surber sampling and were analysed according to species distribution, Ephemeroptera, plecopteran, trichoptera (EPT score), Macroinvertebrate community index (MCI) score, and density. ES water quality standards list MCI as needing to exceed a score of 90 and SQMCI as needing to exceed 4.5. Based on these scores the Waikaka Stream rates as "fair and good" for MCI and (Semi quantitative) SQMCI scores.

Major invertebrate groups are mayfly, caddis fly and chironomid. There is an association with algal growths and abundant chironomids and conversely a reduction in mayfly and caddisfly. Invertebrate density estimates range from 6550 to 9642/m^2.

The total number of taxa is higher at the downstream site as well but often some species are represented by only 1 or 2 specimens per sampling event. Approximately 1/2 to 2/3 of the taxa present dominate the samples. EPT taxa are 34-50% of the total. Invertebrate population characteristics are listed in table 8.

Table 8, characteristics of invertebrate populations surveyed by surber sampler for the Waikaka River December 2021. Austro=austrosimulium, Del=deleatdium, Pycno=pyncnocentria, potam=potamopyrgus, chiron=chironomid.

	EPT Taxa	Density /m^2	# of Taxa	QMCI score	SQMCI	MCI	Major taxa
Waikaka River 1	5 (43%)	69208	11.7	5.1	3.6	107.7	Mayfly, caddisfly, chironomid.
Waikaka River 2	5 (38%)	8500	13	3.98	3.5	103.1	Chironomid
Waikaka River 3	5 (42%)	7183	12	5.61	4.2	108.3	Mayfly, caddisfly.
Waikaka River 4	4 (34%)	6550	11.7	5.53	4.2	103.1	Mayfly, caddisfly.
Waikaka River 5	6 (43%)	9642	14	6.7	3.3	112.9	Mayfly
Waikaka River 6	7 (50%)	7775	14	6.11	3.5	107.1	Mayfly, caddisfly.

The EPT score is based on the numbers of these taxa, (mayfly, stonefly, and caddis), the higher this score the cleaner more pristine is the habitat. All the mayfly and stonefly species and some of the caddis have very low tolerances to nutrient enrichment. EPT scores could be as high as in the mid 20's in pristine streams (where there are several mayfly and stonefly species) but is more commonly less than 10 in lowland waterways.

EPT scores vary from 4-7 at the Waikaka Stream Sites but only 1 species of mayfly is present and stonefly are absent. There is a slight downstream decline in the EPT scores from site 6 to 1, figure 6.

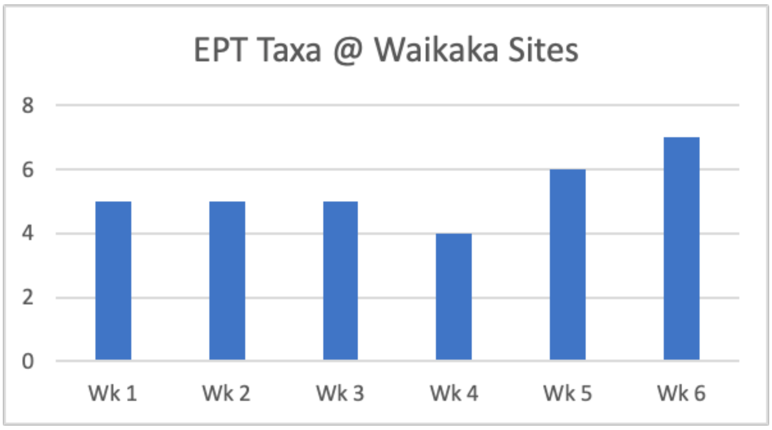

Figure 6, EPT scores for Waikaka Stream invertebrate survey sites.

An analysis based on the percent of each of three dominant groups of the total invertebrate numbers shows a variable proportion of caddis fly over the six sites, a decline in mayfly with distance downstream and an increase in chironomid numbers. Shade is a key habitat difference between sites that appears to limit algae and therefore support invertebrates indicative of better water quality. Figure 7 below shows the relative percent of the 3 main groups of invertebrates in the samples.

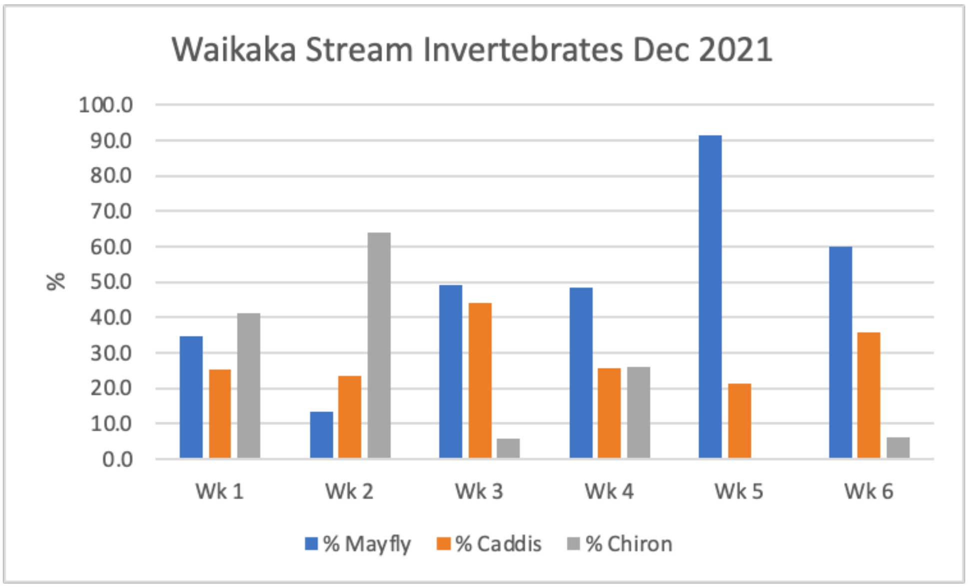

Figure 7, the relative percent of 3 major groups of invertebrates at the 6 Waikaka Stream survey sites.

Mean density of invertebrates at Waikaka Stream sites is 8143m^2 with a range of 6550-9642m^2, figure 8. At the top (most upstream) site mayflies are 60% of the total while at the lower site they are 35% of the total and chironomids dominate.

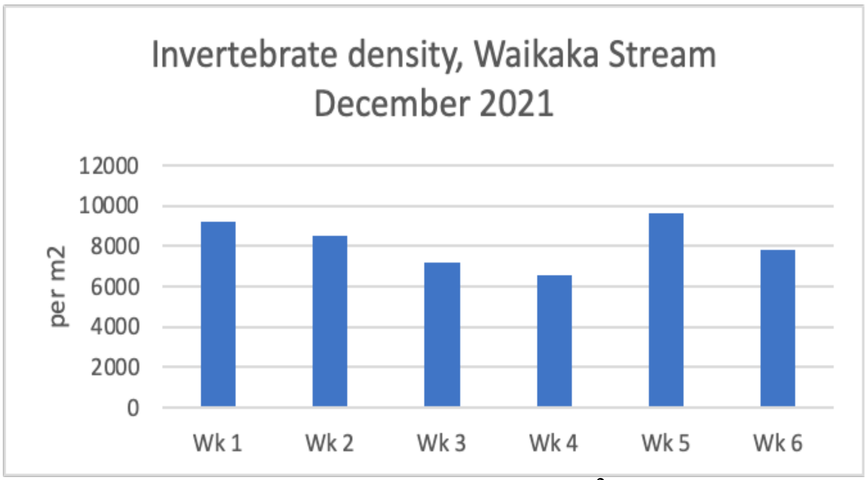

Figure 8, Density of invertebrates (numbers/m^2) at 6 Waikaka Stream sites.

The QMCI biotic index was calculated for each of the Waikaka Sites. This index is the most quantitative measure of the level of enrichment of a waterway and based on the numbers of each species present as well as their tolerance score. However ES standards list MCI and SQMCI, figure 9 so these "more qualitative" indices were calculated as well, table 9. (MCI Good, SQMCI Poor).

Table 9, MCI scores for Waikaka Stream Sites.

	SQMCI	MCI	QMCI
WK1	3.58	107.7	5.1
WK2	3.51	103.1	3.98
WK3	4.18	108.3	5.61
WK4	4.17	103.1	5.53
WK5	3.31	112.9	6.7
WK6	3.5	107.1	6.11
Mean	**3.7**	**107.0**	**5.5**

For Waikaka Stream QMCI values on average rank as "Good", but the two most downstream sites rank as "Fair" and "Good" by a small margin, figure 10. Visible differences at the downstream sites is the algal mats that tend to smother the stream bed, both sites I and 2 are quite open with plenty of light.

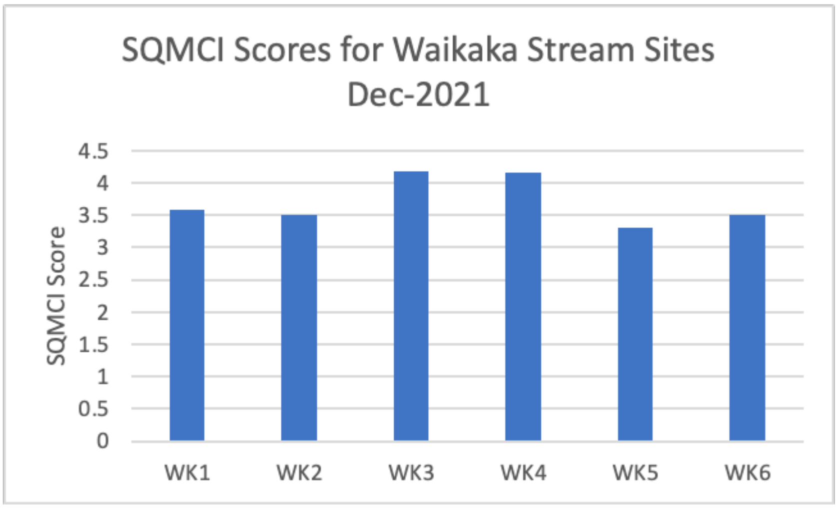

Figure 9, SQMCI scores for Waikaka Stream Sites, December 2021.

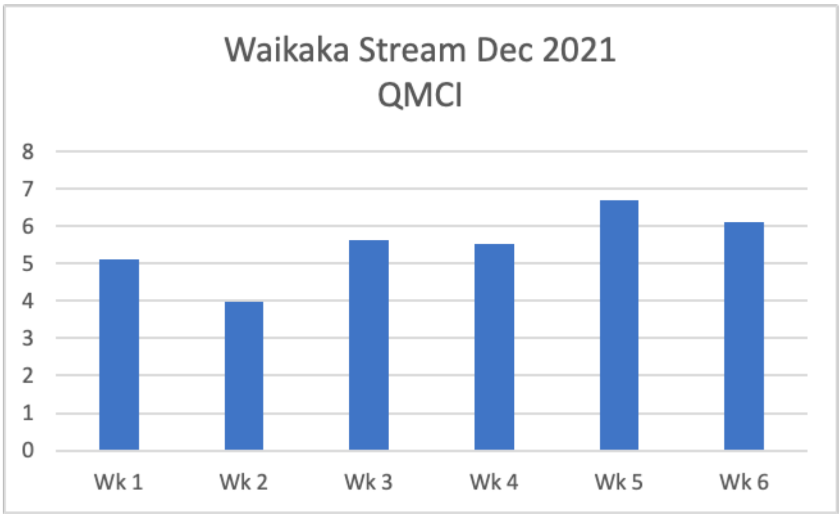

Figure 10, QMCI scores for Waikaka Stream Sites, December 2021.

Interpretation of MCI.

Sites ranked as "fair to excellent" on the MCI scale, table x. Site 2, the lowest rank has the greatest occurrence of brown algal mats and the bottom fauna is dominated by chironomids. Sites 5 and 6 rank as excellent which it is probably *a little optimistic* as there are definite limitations to habitat even at these sites. The QMCI scores help the sites to be ranked accurately and provide important baseline data to describe the conditions in the Waikaka Stream.

SQMCI and MCI are essentially the same with the QMCI being the more quantitative measure while MCI and SQMCI are the more qualitative (based on presence only) of the semi quantitative (ranked abundance) species present. The QMCI avoids the undue influence of only a few individuals of a particular species being present when the invertebrate community is dominated by other groups who by virtue of their numbers should get greater recognition in the calculation.

The MCI User Guide recommends interpretation of MCI as + or – 5, category boundaries are “blurred” as opposed to distinct. SQMCI and QMCI are progressively more precise, both utilize the same scores.

Table 10, reproduced from Stark et al 2001, MCI score. Based on this the Waikaka stream rates as good for MCI and poor for SQMCI.

Table 6.1 Criteria for aquatic macroinvertebrate health, according to different macroinvertebrate indices (following Stark *et al*., 2001)

Macroinvertebrate index	Poor	Fair	Good	Excellent
MCI	<80	80-99	100-119	>120
SQMCI	<4.00	4-4.99	5-5.99	>6

Environment Southland (ES) Waikaka Stream Hydrology

There is a flow recorder at Hamiltons Park near Gore some 25kms downstream from this study’s survey reach and flows at this site leading up to a sampling program were copied as a record. Hydrology statistics seem to only be available for the Willowbank site (~15kms downstream) but the Willowbank site does not have a constant flow monitoring record available on the ES website. The hydrology statistics for Willowbank, (ES information) are listed in Table 11.

Table 11, ES hydrology statistics, flow in cumecs.

Site	Median	Mean	Max	Q95	7day MALF	Mean Annual Flood
Willowbank	1.783	3.345	184	0.44	0.461	94
	Biggest flood, 4/2/2020 @ ~184cumecs, 2nd ~166m^3/S 27/1/1984					

Water Quality Parameters.

Water quality parameters are mentioned here by way of explanation to assist with interpreting results.

Total suspended solids (TSS) is simply a measure of exactly that while conductivity (corrected for temperature) is a measure of the concentrations of all the ions dissolved in the water.

Conductivity corrected for temperature (CT) is a useful general indicator of nutrient and mineral enrichment but can be effected by local geology(Biggs 2000) CT is an early indicator of change in a water body. Agricultural run-off elevates chloride, phosphate, and nitrate ions. The only input to the Ponds in the mine area is run-off and ground water so they typically have higher levels. The Big Pond has greater dilution which likely reduces conductivity.

Salinity (salts in solution) affects dissolved oxygen solubility, higher salinity equates to less oxygen.

Total dissolved solids (TDS) is the sum of all the ion particles <2microns, minerals, inorganic salts, dissolved metals, and small amounts of organic matter dissolved in the water. To a degree it is a measure of aesthetics but some specific ions that would be picked up in a TDS test maybe harmful such as arsenic, nitrate, aluminium, copper, or lead. TDS values of 2200-3600mg/l have been shown to adversely affect salmonids and perch by reduced hatching and egg survival rates. TDS is significant because of potential sources, run-off and contaminants. More than 1000ppm not suitable for drinking. High TDS water is bitter, metallic, or salty to taste and perhaps malodourous.

Dissolved reactive phosphorous (DRP), is the portion of phosphorous that is dissolved and is readily available to support plant growth. Compared to total P not all of which maybe plant available. Amount is a measure of a Waterbodies potential to support nuisance algal growths and is a key to limiting that event.

Nitrate -nitrogen (NN) is a nutrient but if in excess becomes a toxic substance, highly soluble and one of the most common contaminants in rural areas. Ammoniacal N is converted to Nitrate N in soils. The Stream has low levels of both while the ponds exhibit some very high measurements. Pristine streams will have very low levels of both. This component and DRP are the two with the greatest potential to adversely affect algae and plant growth in water ways.

Water quality measurement units are usually expressed as mg/l = ppm, but the NPS-FW 2020 uses mg/m^3.
An explanation of these is given in appendix 4. The ones measured give a broad description of habitat conditions.

Water Quality Standards.

The ES water quality management unit for the Waikaka Stream is “Lowland Hard Bottom”. For this unit the standards are MCI >90 and SQMCI>4.5 FGA <2cm <30% cover, diatoms <3cm thick and <60% cover. In the sections below the various standards are listed and compared to Waikaka Stream values that were assessed in this study. Some parameters do not have a standard and for others there is no current assessment. Waikaka Stream levels are important because they affect the quality of habitat. Levels of nutrient in the stream will impact on the success of the diversion channel and where they may not be able to be controlled others measures/habitat components will be critical to diversion channel rehabilitation.

The ES general Water Quality Standards;

1. E.coli <1000mpn/100mls,
2. Nov-April filamentous green algae should not exceed, 2cm in length & 30% cover, at <median flow,
3. water clarity should be >1.6m as assessed by Black disc.
4. There should be no fungal or bacterial slimes visible to naked eye,
5. diatoms <3cm thick and <60% cover.
6. DO>80%,
7. pH 6.5-9,
8. chlorophyll a< 120mg/m2,
9. MCI >90 and SQMCI>4.5

The ES Ammonia standard depends on pH & is expressed as mg/m^3, pond 2 exceeds the range (6.5-9) of the limits.

DRP and NN in ponds is less than the detection level. TSS in Stream is less than the detection level except site 1, lowest, where it is 4.2mg/l

Ammoniacal Nitrogen, TSS, and conductivity in the ponds is elevated to quite high levels. Nitrate N is elevated in the ditch.

Temperature data are spot measures only at present but data loggers are installed at 4 sites to describe the temperature regime which can be referenced back to habitat and inform habitat restoration in the diversion channel.

The ORC water plan describes "good water quality" and for riffles and runs it is that they are "free of obvious clay and silt deposits. Walking across a riffle or run should not produce an obvious plume", which Waikaka riffles do, the plume being clay coloured.

MFE and NPS-FW DIN/DRP limits are <250 and $<6mg/m^3$ to limit periphyton growth to less than Biggs (2000) nuisance guideline for aesthetics and angling (<200mm length and <30% cover)

A risk assessment for nuisance periphyton growths is as follows. To keep 85% of biomass below recommended guidelines, DIN and DRP should be within these values, table 12.

Table 12, nutrient levels relative to risk of creating nuisance algae cover, mg/m^3

RISK	DIN	DRP
Low	50	<3
	50-150	3-6
	150-300	6-15
High	>300	>15

At concentrations of more than 20mg/l NN (DIN =sum of NN and NH_4N) can have lethal effects on fish and below that level chronic effects such as adversely affecting their growth.

Table 13 below lists parameters and Environment Southland standards and for those assessed at the mine site, the ones that do not meet current standards.

Table 13, Water Quality standards for "Lowland hard bottom"; ES regional Plan, water, < substituted for "shall not exceed" in the table. NM=Not Measured

Parameter	**ES std**	**Sites that do not meet the std**
NN	No Std	
DRP	No Std	
NH3	180-2570 mg/m^3 (pH dependant)	Pond 2
E.coli MPN/100mls	<1000 (swimming<130)	
Fungal slime	None visible	
Bacterial Slime	None visible	
DO	>80%	NM
FGA	<2cm & 30% cover	
Water clarity	>1.6m @ median flow	Waikaka Stream
pH	6.5-9	NM
Chlorophyll a	<120mg/m2	NM
MCI	>90	
SQMCI	>4.5	Waikaka Stream
Fine sediment (<2mm>)	Change in cover< 10%	
Temperature	<23°C, <11°C trout habitat & spawning	

Water Quality Measurements.

A held hand YSI meter was used to measure some basic water quality parameters; temperature adjusted conductivity, salinity, and total dissolved solids on the November 2021 survey, and later in February 2022 for ponds 5-8, table 14. All sites are presented together for these parameters to demonstrate the comparisons between different water bodies, figure 11, where it can be seen that water quality in the Waikaka Stream is substantially better than the ponds and ditch scoring much lower for the various markers. Conductivity of the Waikaka Stream is 27 % of the average for ponds and ditch and correspondingly TSS is 15%, and while salinity in the stream is 0 the average value for the others is 0.16mg/l. TDS in the Stream is 27% of the average of the other water bodies.

Table 14, Water Quality as measured with YSI meter, temperature adjusted conductivity (microsiemens @ T^{o}C), Temperature, salinity, and Total Dissolved Solids (mg/l, ppm).

	Conductivity	**Salinity**	**Total Dissolved Solids**	**Temp ^{0}C**
Waikaka 1	78.2	0	0.0509	15.9
Waikaka 2	77.6	0	0.0505	16.3
Waikaka 3	73.7	0	0/0477	15.4
Waikaka 4	82.4	0	0.0541	16.6
Waikaka 5	78.8	0	0.0512	18
Waikaka 6	76.6	0	0.0498	8.2
Ditch 1	220.4	0.1	0.1431	13.8
Ditch 2	179.7	0.1	0.1167	13.7
Big Pond	210.6	0.1	0.1370	17.5
Pond 2	318.7	0.2	0.2068	15.8
Pond 3	317.5	0.2	0.2065	12.4
Pond 4	351.8	0.2	0.2289	19.8
Pond 5	157.5	0.1	0.1030	19.4
Pond 6	139.4	0.1	0.0906	12.7
Pond 7	169	0.1	0.1097	13.4
Pond 8	245.2	0.1	0.1602	13.9

Additional sampling for analysis by Watercare Invercargill ltd for nutrients, suspended solids and E.coli are shown in table 16, (page 28) for the 3 sites on Waikaka Stream and a sample of the ponds.

Table 15, Watercare Ltd water quality results, TP (Total phosphate), DRP, (dissolved reactive phosphate), Nitrate nitrogen, NH_3 (Ammonia), TSS (Total Suspended solids), and Ecoli count, summer January 2022 **(mg/l),** Waikaka Stream Sites

	Ammon N	**NN**	**DIN**	**DRP**	**TP**	**TSS**	**Ecoli**
Waikaka River 1	0.07	0.1	0.17	0.007	0.06	4.2	120
Waikaka River 3	0.03	0.08	0.11	0.007	0.05	2	250
Waikaka River 6	0.02	0.07	0.09	0.007	0.06	2	150
Orc sched 15	*.01-.1,*	*.075-.444*		*.005-.033*			*10-260*

All parameters for all sites are summarised in Table 17 at the end of this section. Results of the Water Care Ltd analysis of samples collected from the proposed mine site show the river is clearly very different from the other water bodies, which have a more direct link to surrounding land use impacts, especially with regard to ammonia and nitrate levels.

Ammonia is elevated especially in Pond 2 and NN is high in the Big pond and the ditch but not elsewhere.

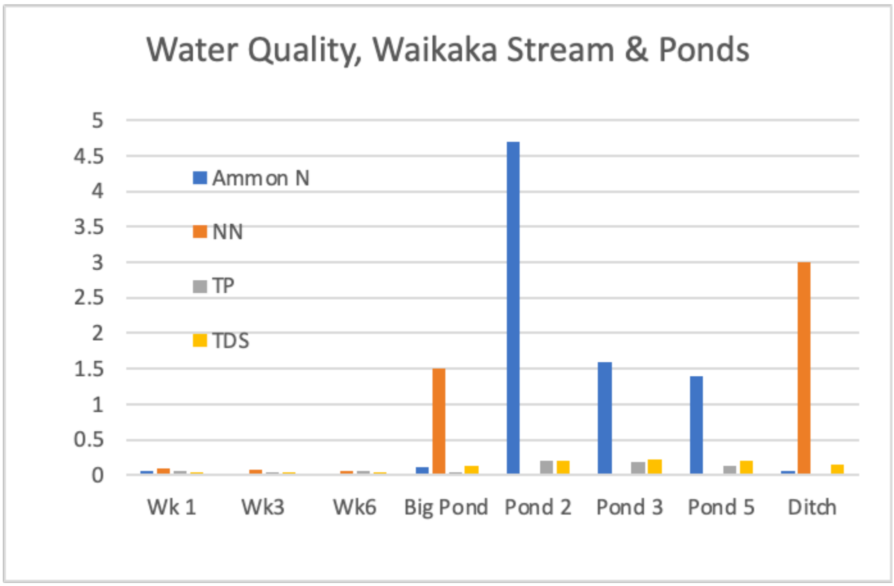

Figure 11, water quality parameters for all sites demonstrating the difference between stream and ponds for Amm-N, NN, TP, TDS.

Figure 11 above shows WQ variation in the different waterbodies on the site but doesn't give satisfactory delineation of parameters in Waikaka Stream. The Stream is separated out in Figure 12 below.

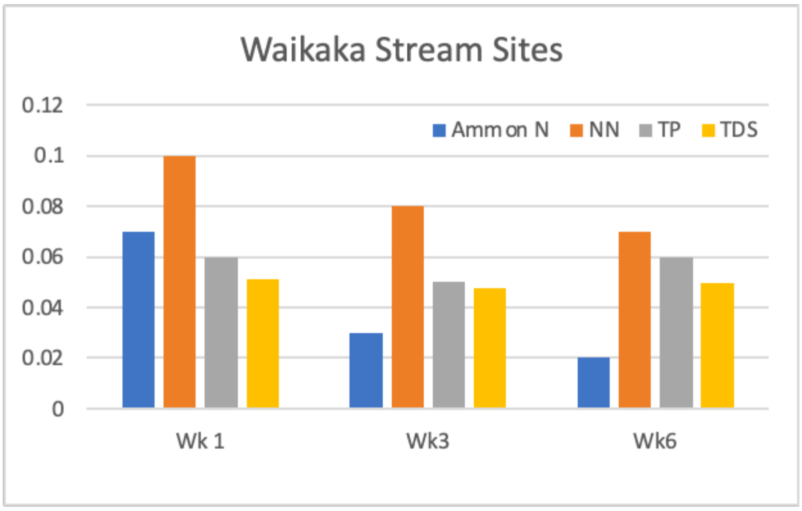

Figure 12, Total Phosphorous values for summer 2021-22. Wk=Waikaka.

From upstream to downstream Wk6-Wk1, there is a general increase for ammonia and nitrates, a slight increase for TDS, but no trend is evident for TP.

Conductivity is elevated for all pond samples and the western ditch that specifically drains surrounding farmland, figure 13.

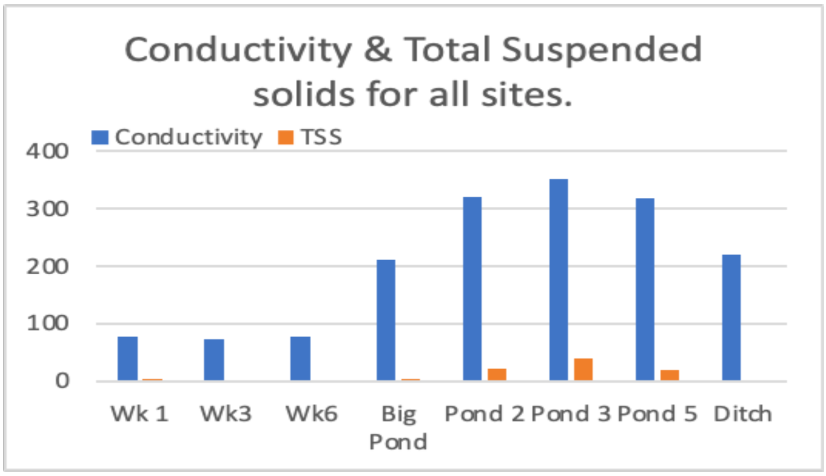

Figure 13, Temperature corrected conductivity and Total Suspended Solids for all sites.

DRP is at high levels in the Waikaka Stream and especially pond 2, figure 14.

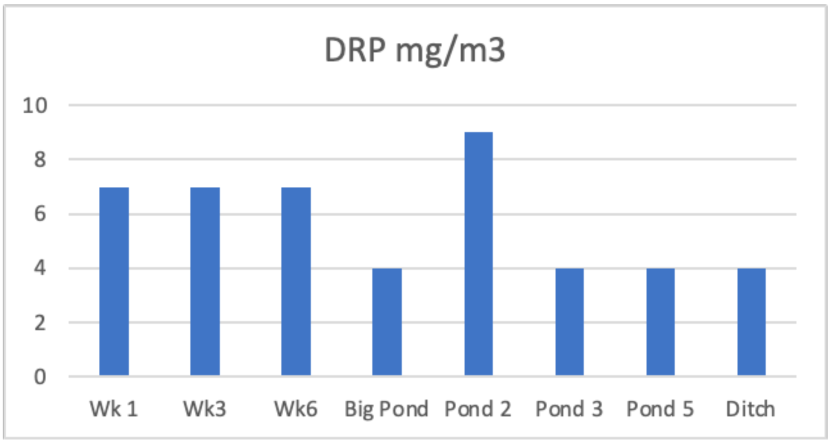

Figure 14, DRP loadings on water ways within the mine area.

DIN is low in the Waikaka Stream but particularly high in Pond 2 and the ditch, figure 15.

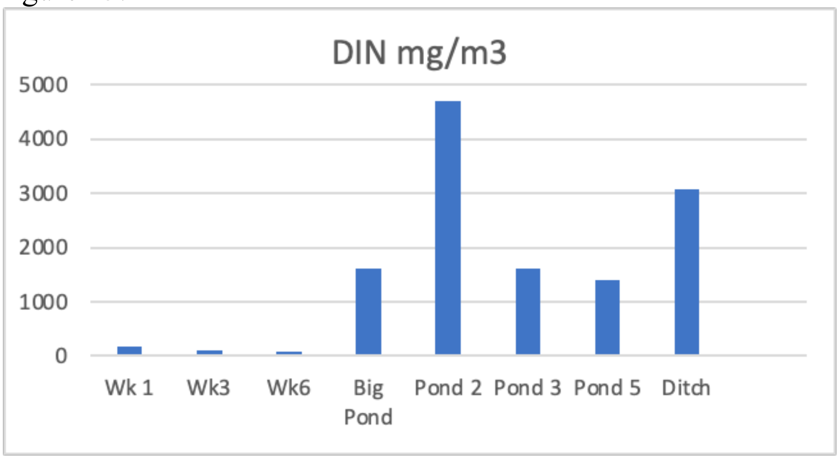

Figure 15, DIN loadings on water ways within the mine area.

Table 16, DIN and DRP values mg/m^3 for Waikaka Mine Site waterbodies.

	Wk 1	Wk 3	Wk 6	Big Pond	Pond 2	Pond 3	Pond 5	Ditch
DIN	170	110	90	1610	4710	1610	1410	3070
DRP	7	7	7	4	9	4	4	4

MFE NPS FW Standards list DIN<250 and DRP<6 mg/m^3 to limit filamentous cover to <30%. So the Waikaka Stream and Pond 2 exceed the NPS-FW DRP recommendations but the effect in the stream is limited by shading at most sites but not site 2 and site 1 where there is insufficient shade to restrict the algal mats observed at these sites. This is important information for the rehabilitation channel because only shade can be manipulated and not water quality in the stream diversion.

The E.coli trend is for low levels throughout the mine area but there is a spike where the stream (Shepherds Creek) draining the Waikaka sewage pond enters the Waikaka Stream at site 3 and a spike in Pond 3, figure 16.

All the water quality measurements were taken at a time when stock was absent from the area and had been for several months as the proposed mine area is currently a dairy wintering block.

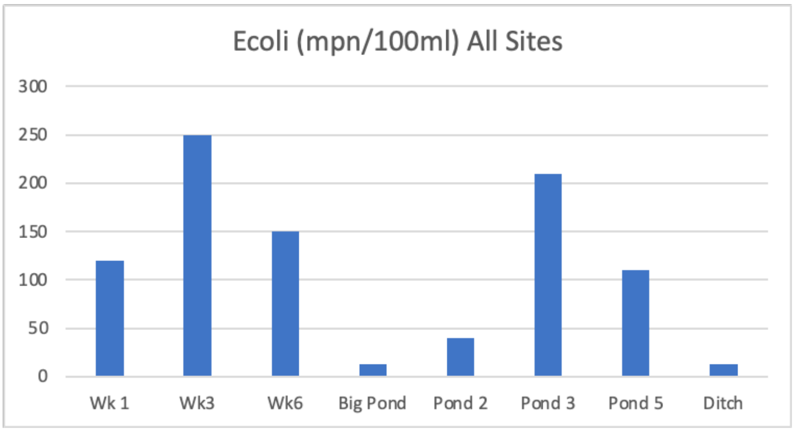

Figure 16, E.coli count all sites, detection limit 1 MPN/100ml, Watercare Invercargill.

Table 17, Summary of water quality parameters for all survey sites and both methods (handheld & laboratory analysis). Wk=Waikaka.

mg/l	Wk 1	Wk3	Wk6	Big Pond	Pond 2	Pond 3	Pond 5	Ditch
Ammon N	0.07	0.03	0.02	0.11	4.7	1.6	1.4	0.07
NN	0.1	0.08	0.07	1.5	<.01	<.01	<.01	3
DIN	0.17	0.11	0.09	1.61	4.71	1.61	1.41	3.07
DRP	0.007	0.007	0.007	0.004	0.009	0.004	0.004	0.004
TP	0.06	0.05	0.06	0.05	0.2	0.19	0.14	0.03
TSS	4.2	2	2	4.6	21	40	19	2
E.coli	120	250	150	13	40	210	110	13
Conductivity	64.7	60.6	66.4	179.6	262.7	267	285.4	174.3
Cond/Temp	78.2	73.7	76.6	210.2	318.7	351.8	317.5	220.4
Sal	0	0	0	0.1	0.2	0.2	0.2	0.1
TDS	0.0509	0.0477	0.0498	0.1367	0.2068	0.2289	0.2065	0.1431
Temperature	15.9	15.4	18.1	17.4	15.8	12.4	19.8	13.8

Habitat

Stream dimensions

Mean width of survey sites was 8.15m, mean depth of survey sites (a typical riffle area including part of the pool tail above and running into a pool below) 0.632m at the time of conducting surveys when stream flow was approximately 1.5 cumecs at Hamiltons Flat near Gore. The range in depths at each site was 200-1450mm. Pools usually exceed 1m and up-to an estimated 2.0m. The riffles are generally 100-250mm deep, but depending on the flow.

Riparian Zone

The Waikaka Stream has an unusually extensive riparian zone that provides shade and cover for the aquatic fauna and almost certainly limits nuisance algal growths. In addition to providing a buffer from adjacent activities the trees also provide erosion resistance from the extensive root mats that bind the bank and allow for undercut banks and overhanging vegetation all of which are critical habitat components. The erosion resistance provided by willow root mass allows the channel to be incised and therefore maintain a deeper rather than broad channel that mitigates against elevated water temperatures. Control of temperature and incident light are key habitat components.

Vegetation overhang can be measured in metres, for example one third of the channel has overhanging willows for approximately 100m (between sites 3 and 4) and there are stretches of stream totally enclosed by trees on both banks. In these locations the stream bed is clean gravel with no algal mats.

Undercut banks have up-to 0.8m overhang and extend for 20 to 75% of the survey sites. They are more extensive in the pool and run habitats creating important eel and trout habitat.

ORC Water plan Schedule 15, lists functional riparian margins as a key characteristic of "good water quality" for Otago lakes and rivers and this a strong feature of the Waikaka Stream (in Southland).

Shade

Shade was recorded as the percent of canopy cover and by visual assessment according to the stream survey card format. The stream survey card lists several categories of fish cover of which bank vegetation is one. Trees on the river bank may not register in the canopy cover assessment and only provide shade from certain angles of the sun.

Some willows overhang the stream and provide extensive shade. This canopy cover was measured with a densiometer to give a percent canopy cover, figure 17 and Table 18. This varies from 0% to 100%, photographs x and y. It is very noticeable that in the areas with moderate to heavy shading there is no algal mat that tends to smother the streambed at unshaded sites.

Table 18, shade canopy cover (densiometer) and vegetation fish cover component on Waikaka Stream summer 2021-22.

Waikaka Stream	%Canopy Cover	Est % Veg Cover
Site 1	0	10
Site 2	0	60
Site 3a	32.2	40
Site 3b	42.7	80
Site 3c	90.3	100
Site 4b	0	20
Site 5	99.5	90
Site 6a	34.9	70
Site 6b	25.1	80

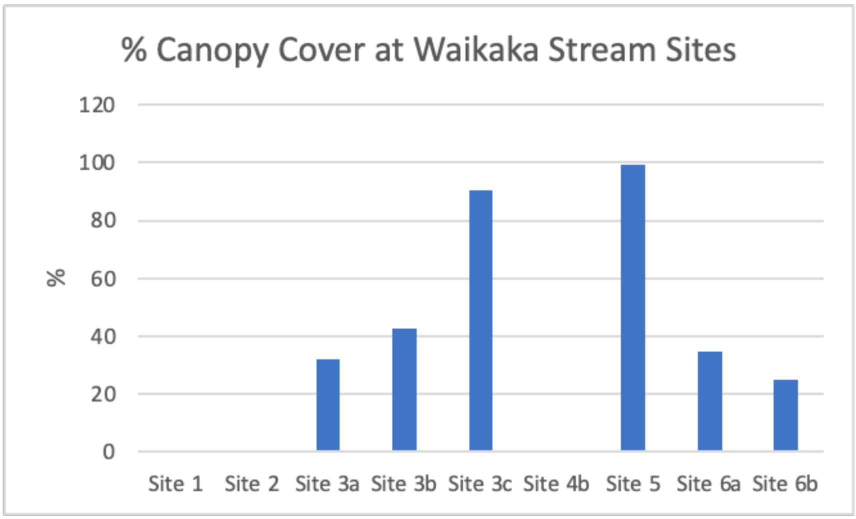

Figure 17, the percent canopy cover at Waikaka Stream sites as measured with a Densiometer.

The total length of stream is approximately 3.3km multiplied by 2 to give total length of stream bank is 6.6km. Of this approximately 1.6km (24%) is not tree lined. A high proportion therefore is providing the benefits that come with trees, shade (temperature regulation), bank stability, food, fish cover.

Substrate

Riffle substrates were assessed as part of the habitat assessment of Waikaka Stream and they rank as coarse gravel on the Wentworth Scale.

Riffle areas at all sites tends to be coarse gravel but with a trend to slightly finer with distance downstream. Pools tend to be areas of "settling" as velocity reduces and they are typically much finer sediment, fine gravel through to mud forming the bed. Pool substrate was not specifically measured because they could not be seen in the initial surveys. As water levels receded and clarity improved the fine gravel to mud assessment was visually confirmed for pools.

Mean substrate and particle sizes are presented in figure 18, and table 19 below.

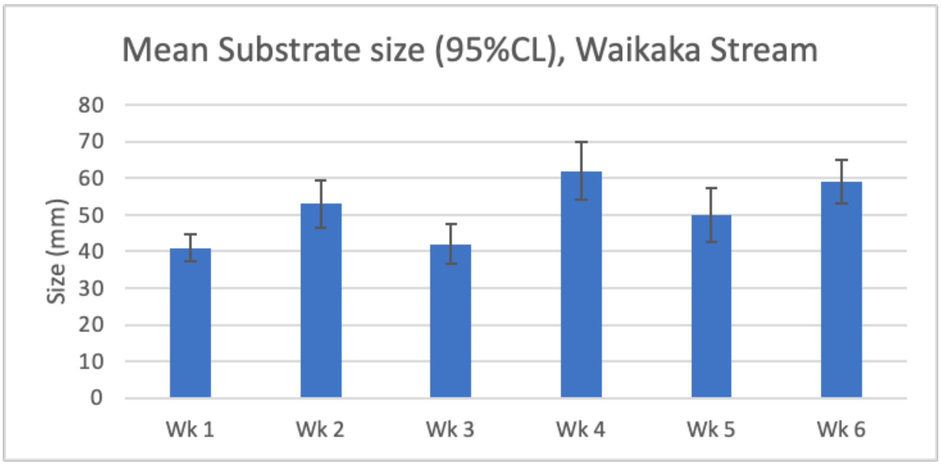

Figure 18, mean substrate size at Waikaka riffle sites, 1-4, and 6 and 1 run site 5.

Table 19, mean particle size at riffle survey sites, except site 5* which is a run with lower water velocity and settling of finer particles.

Site	**Mean Size (mm)**	**Range (mm)**
Wk 1	41.3	11-115
Wk 2	53.1	12-170
Wk 3	42.3	4-144
Wk 4	62.3	12-212
Wk 5*	50.4	8-195
Wk 6	58.6	13-240

A length frequency analysis shows particle distribution in a different format and the range of sizes. There are finer particles but these are somewhat buried but have not blocked all the interstitial spaces, figure 19.

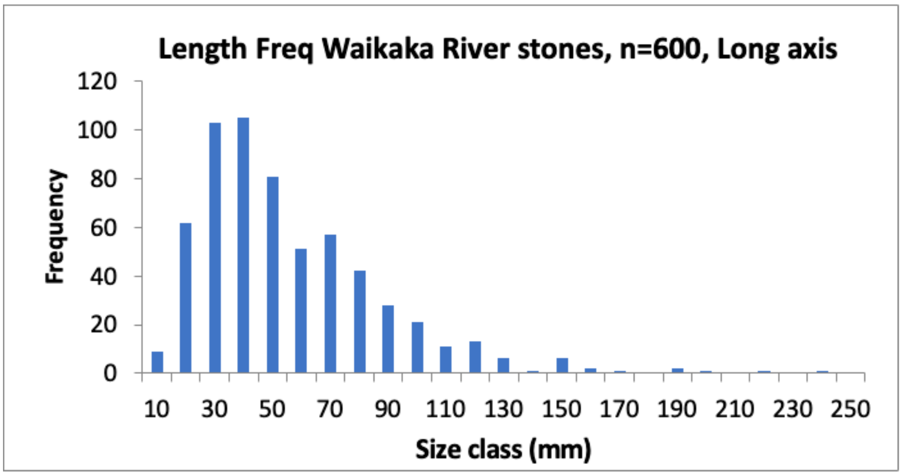

Figure 19, length frequency of substrate particle size (mm) at riffle survey sites, Waikaka Stream, November 2021.

Ponds.

Fish

Six of the eight small ponds (Figure 1) supports a significant short fin eel population with a range of fish sizes indicating stable habitat over several decades. Fish captured were in good condition and appeared to be thriving in-spite of the apparent poor water quality. Pond 6 is the only 1 with both species of eel present so for. The little ponds were only sampled by fyke nets and minnow traps because the lack of clear water precluded any other techniques that are dependent on being able to see into the water. Size of fish captured in nets is very dependent on the mesh size. A return visit to pond 4 using a smaller mesh resulted in the capture of shortfin eels only 290mm long extending the size range significantly and indicating what is likely to be present in any of the ponds.

The “Big pond” was netted with 12 sets of 2 minnow traps combined with 1 lobster pot. Two fyke nets were deployed in shallow margins near where eels were observed in the spotlight. Locals were also spoken to for their knowledge of fish species present. Perch were captured from the “Big Pond” at a rate of 0.11fish/hr. Only small perch were captured in these traps but anglers report catching much larger specimens.

Longfin eels, perch, brown trout and lobsters are reported by anglers to be in the Big Pond. Trout were not captured during this survey although anglers frequent the pond and report some large trout (2.5kgs). Perch are the dominant species in the “big pond” and are known to have higher temperature tolerances than brown trout who likely seek refuge in the deeper water or where cooler groundwater inflows are located. The high water temperatures and the oxygen levels associated with the algal bloom in the Big Pond meant that netting for larger trout was likely to cause fish mortality related to the stresses of being netted. To avoid this I have relied on anecdotal evidence for the presence of trout as it is not in contention that they are present and provide a small localised fishery.

Only shortfin eels were captured in the small ponds and they were not found anywhere else. No other species were found in these ponds using the practical methods of assessment, namely netting. Galaxiids maybe present in the ditches that connect the small ponds to the Waikaka Stream but these waterways are ephemeral and therefore not permanent habitat.

Fish species, number and size range are presented below in table 20.

Table 20, fish species, number, and (size range mm) from pond survey sites.

Site	Longfin Eel	Shortfin Eel	Perch	Lobster
Big Pond	5 (510-650)		18 (125-163)	5
Pond 2		7 (400-850)		
Pond 3		7 (310-750)		
Pond 4		9 (290-600)		
Big 5	No fish			
Pond 6	1(1100)	2 (660 &780)		
Pond 7		3 (390-920)		
Pond 8	No fish			

The shortfin eels were mostly around 500mm with the largest specimen being 850mm in length, figure 20. Mean catch rate for short fin eels was 0.18 fish per hour in nets but varied from 0.032-0.29.

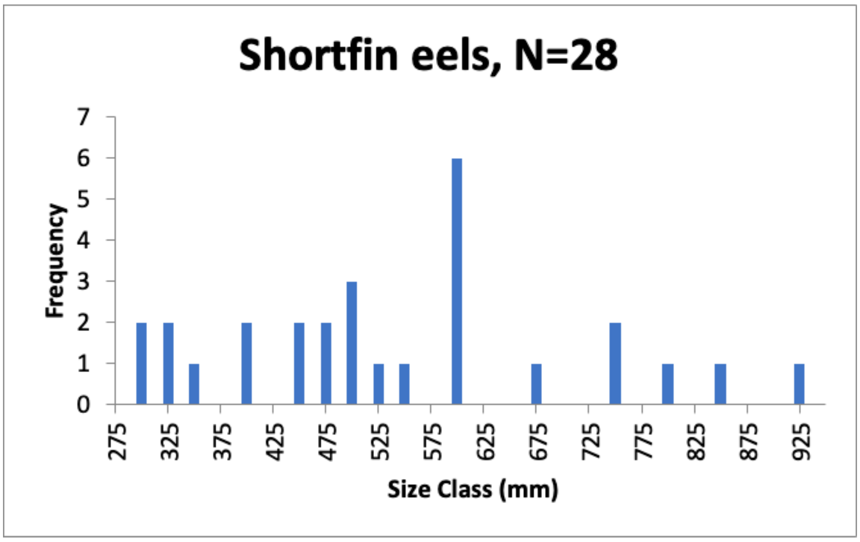

Figure 20, short fin eel length frequency captured in small ponds 2, 3, 4,6,7.

Invertebrates of Ponds.

The ponds and ditches have serious habitat limitations consequent on rampant plant growth and poor water visibility (limited light penetration) in the case of the ponds. The invertebrate fauna are sparse and limited as expected in the habitat available. Invertebrate population characteristics are presented below in table 21.

Table 21, characteristics of invertebrate populations surveyed by kick sampler for the Waikaka Ponds November 2021.

	EPT Taxa	# of Taxa	Major taxa
Ditches (3)	0	3	*Potamopyrgus* (snail)
Ponds (8)	0	2	Water boatmen, Snail.
Big Pond	0	2	Water boatmen, Snail.

Water Quality

The three small ponds have dubious water quality and a very high sediment loading so that water visibility is zero. A lack of light limits primary production and therefore limited capacity to support aquatic life. Conductivity is generally very high as is TDS, an indication of high concentrations of dissolved materials, table 22. Pond 2 has unusually high concentrations of ammonia and ponds 3 and 5 are also quite high.

The small ponds have much higher C, TDS, Sal, and Ammonia, compared to the Big Pond, ditch and stream.

Table 22, water quality parameters in Ponds and the ditch in Proposed Mine path. Mg/l and microsiemens for Conductivity.*=YSI meter only

	Ammon	DRP	NN	TP	TSS	Cond(T)	Sal	TDS	Colour
Pond 1 (Big)	0.11	.004	1.5	0.05	4.6	179.6	0.1	.1367	Clear
Pond 2	4.7	.009	.01	0.2	21	262.7	0.2	.2068	Grey
Pond 3	1.6	.004	.01	0.19	40	267	0.2	.2289	Clay
Pond 4	1.4	.004	.01	0.14	19	285	0.2	.2065	Clay
Pond 5*						176.6	0.1	.1153	Clear
Pond 6*						139.4	0.1	.0906	Clear
Pond 7*						169.0	0.1	.1097	Clay
Pond 8*						245.2	0.1	.1602	Clay
Ditch	.07	.004	3	0.03	2	174.3	0.1	.1431	Clear

Ammoniacal N, contributes to eutrophication and can be a toxic pollutant, two forms of N, ammonia and ammonium- are likely from animal waste. NITRATE N is NO_3N and as pH increases so does its toxicity.

NPS-FW standards list DRP and DIN as key parameters to maintaining freshwater values and in particular controlling nuisance algal proliferations, NPS limits are DIN<250 and DRP<6 mg/m^3.

Table 23, DIN and DRP levels in the various waterways of the proposed mine area, NPS limits are DIN<250 and DRP<6 mg/m^3 .

	Wk 1	Wk 3	Wk 6	Big Pond	Pond 2	Pond 3	Pond 5	Ditch
DIN	170	110	90	1610	4710	1610	1410	3070
DRP	7	7	7	4	9	4	4	4

The Waikaka Stream sites and Pond 2 all exceed the recommended levels for DRP of 6 mg/m^3. The Ponds and the ditch exceed the DIN limits substantially, table 23. Figure 21 shows DRP levels for all sites tested in the Watercare Ltd laboratory.

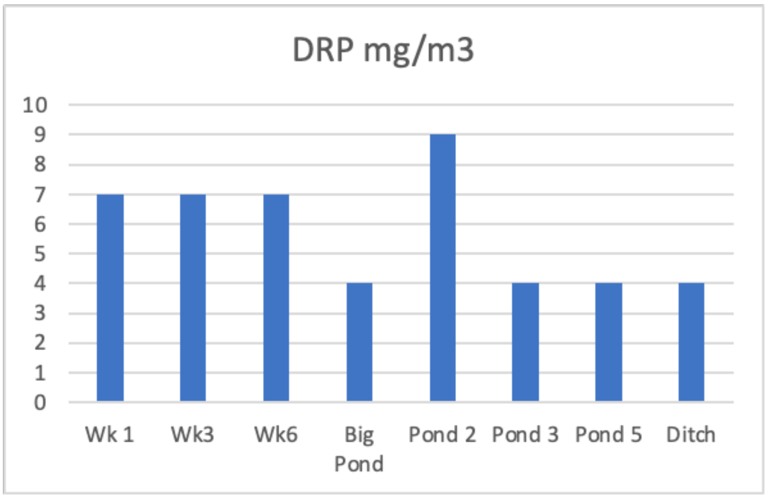

Figure 21, DRP levels 27/1/22, at all sites.

The ponds and the ditch sites all exceed the recommended DIN levels of 250 mg/m^3, figure 22.

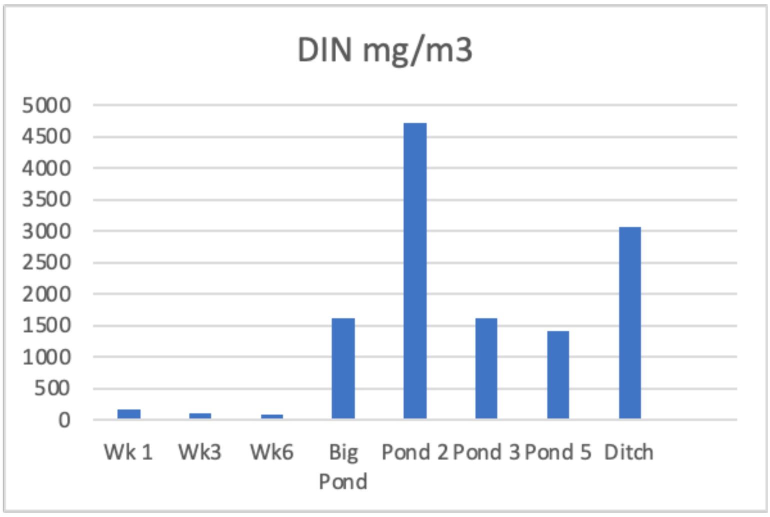

Figure 22, DIN levels 27/1/22, all sites.

Secchi disc, water visibility, recordings in the Big Pond gave readings of 0.8 and 1m 25/11/21.

Habitat

Most of the ponds have extensive riparian cover (assorted tall willows and other trees) which also adds to the shading effects that limit small plant/shrub growth. The small ponds have ephemeral connections to the Waikaka Stream and have dried out over the course of this summer. Ponds 5 and 7 has a “trickle” inflow and perhaps as a consequence relatively clear water. In times of flood connections to the main stream are likely to be available.

Aquatic Vegetation.

In the large pond there are abundant weed beds as well as an algal bloom that gives the pond a soupy appearance. Weed beds are depth limited and found in water approximately less than 3m deep. Various wetland plant species including carex, raupo, and assorted rushes are found around and within the ponds. The Big Pond has extensive macropyhte beds of *Potamogeton sp* and *Myriophylum sp* .

Wildlife.

Mallard and Teal ducks were present on the ponds at each visit and at least for summer are permanent residents. They are likely there all year and certainly during the duck shooting season. Several ponds have maimais present. On the Big Pond there are in addition to the mallards, Canada geese and paradise shelduck. Additional species of wading birds such as pied stilt, oyster catchers, and occasionally herons are also in residence.

Pond Dimensions.

The ponds range in surface area from an estimated 600m^2 to 2250m^2 for ponds 6 and 3 respectively, with an average of 1500m^2.

Ditches

Fish of the Ditches

Spotlight, netting, and electrofishing recorded long fin eel, upland bully, galaxiid, and brown trout from the drainage ditch to the west of the mine area. The more central ditch that connects the 3 small ponds to the river is an ephemeral stream and lacked sufficient water to be able to electro-fish or net. In the western ditch galaxiid larvae and adults were abundant, trout and bullies rare in the stretch they were located in, perhaps influenced by the presence of a relatively large eel at the same site. The ditches are narrow and shallow and a large predator such as the eel is likely to have a considerable toll on small fish present. Fish species in the ditches are summarised below in table 24.

Table 24, fish species, number, and (size range mm) from ditch survey sites.

Site	Longfin Eel	Brown Trout	Upland Bully	Galaxiid
Ditches	3 (200-650)	1 (44)	1 (45)	24 (54-76)

Invertebrates

The invertebrate fauna in the ditch is largely limited to snails and water boatmen.

Table 25, characteristics of invertebrate populations surveyed by kick sampler for the Waikaka Ponds November 2021.

	EPT Taxa	# of Taxa	Major taxa
Ditches	0	3	*Potamopyrgus* (snail)

Water Quality

In the ditch water quality is characterised by elevated conductivity, high NN and salinity levels, low Ammonia and TP, tables 26 and 27.

Table 26, Water Quality as measured with YSI meter, temperature adjusted conductivity (microsiemens @ T^{o}C), Temperature, salinity, and Total Dissolved Solids (ppm).

	Conductivity	Salinity	Total Dissolved Solids	Temp 0^{c}
Ditch 1	220.4	0.1	0.1431	13.8
Ditch 2	179.7	0.1	0.1167	13.7

Table 27, water quality parameters in the ditch in Proposed Mine path. Mg/l and microsiemens for Conductivity, Watercare Invercargill Ltd analysis.

	Ammon	DRP	NN	TP	TSS	Sal	TDS	Colour
Ditch 1	.07	.004	3	0.03	2	0.1	.1431	Clear

Habitat.

The ditches are excavated channels largely fed by tile drains. They are steep sided and approximately 3m deep and an average of 0.7m wide at the bottom. Water depth is usually less than 0.3m deep but occasional pools are about 0.7m deep. Substrate is typically mud up to 0.25m deep but sometimes overlain with a thin layer of fine gravel (<16mm). Riparian vegetation is almost entirely grasses providing an abundance of overhanging cover along the banks.

Habitat in the ditches is compromised by rampant plant growth (grasses and water cress) and by mid-summer this has obscured almost all visible surface water. The ditches provide a considerable amount of galaxiid habitat and the presence of a small trout indicates some spawning is occurring but both trout and upland bully numbers are very low.

Discussion.

Fish

Conservation threat Status.

Two of the fish species encountered are classified as "at risk and declining", according to the NZ threat classification series 24, Dunn et al (2019).

1. Longfin eels are classified as "At risk, declining".
2. Gollum galaxiids are classified as "At risk, declining".
3. Shortfin eels are not threatened.
4. Upland Bully not threatened.
5. Brown Trout are introduced and naturalised.
6. Perch are introduced and naturalised.

This report covers fish surveys conducted to support consent applications for Waikaka Goldmines Ltd. The results of the surveys provide the species present and estimates of numbers present rather absolute values. Using the qualitative categories of abundant, common, occasional, and rare, the following is a summary of fish populations in the Waikaka Stream;

1. Longfin eels are present and *common* at adolescent and adult life stages
2. Brown trout are *abundant* as juveniles but *common* at older life stages
3. Upland bullies are *abundant* at all life stages
4. Galaxiids are present and *common* as juveniles and *occasional* as adults
5. Perch are *abundant* in the "Big Pond"
6. Lobsters are *rare*.

Focusing on areas that can be surveyed thoroughly and from which the most accurate estimates can be derived, allows one to use such sites for monitoring and rehabilitation channel design features. The more accurate the survey (minimal sources of variation) the more useful any observed changes are for determining the success or otherwise of measures put in place to maintain or enhance aquatic habitats. The most useful sites are therefore shallow that can be fished/sampled the most thoroughly, that is riffles. These are also the productive hub (food production zones) of the stream ecosystem supporting the greatest variety and numbers of fish and invertebrates and are the preferred sites for ecological monitoring throughout NZ.

Conducting repeat runs to establish a diminishing return allows a population estimate to be calculated and with the area of the site known, a density (Fish/m^2) to be derived.

There is a thriving population of upland bullies in Waikaka Stream. They are likely a major source of food for larger fish, eels and trout. There are also large numbers of juvenile trout indicating the use of the stream reach for spawning and recruitment. These are also likely a major source of food for larger fish, eels in particular. Gollum galaxiids are common in the ditches and occasional in the Waikaka Stream. Though abundant as larvae (in little eddies and backwaters) they are much less obvious as adults in the mainstem.

The longfin eel is an apex predator and therefore exerts controlling influences on other species lower in the food chain. They are also opportunistic scavengers, (Jellyman 2012). The long fin eel population is very strong in the Waikaka Stream, there are eels of all size classes from juveniles of 100mm to large adults of 1.1m. At a rough estimate the adult longfin eels out-number the brown trout by approximately 1.3:1, probably much more than this as trout are easier to observe by virtue of their feeding strategy and the eels are much more secretive and therefore likely to be under-estimated. Eels were rarely seen in the daytime and when electro-fished always drawn out from under the bank or amongst boulders.

The capture of 12 eels at one location, Site 1, over 1 night, suggests large numbers at least in some locations. It is likely that eels exert a considerable predation pressure on the trout especially as the juvenile trout move from riffle habitat into deeper quieter water. This is especially the case during low flows.

With regard to brown trout there is an unusual size class distribution with a noticeable lack of adolescent/young adult trout. There are abundant “young of the year” ie those hatching out in spring, but a surprising lack of fish in the size range of 100-250mm, one and two year olds. Even when flow conditions were low enough to allow fishing over most of the stream channel (at least in some sections) fish in this size group were much more scarce than is to be expected. The lack of intermediate size fish, 100-350mm requires some consideration.

The scarcity of trout in the size range 100-350mm, a vulnerable size range, suggests trout make a major contribution to supporting the eel population, an effect well documented in NZ as far back as 1960’s, Selwyn river study (Burnett 1968). While his study was in a lake Jellyman (1996), recorded that eels fed on snails and dragonfly larvae but that the most important item by weight, was fish, with upland bully being the main component for eels <500mm and brown trout the most important for eels>700mm. Jellyman (1996), also found that larger eels had a more varied diet. Both these size classes of eel and fish prey species are to be found in the Waikaka Stream and juvenile trout are a much more readily available food item because of their proximity to spawning grounds and a diminished predator avoidance capability at such a young age.

Adult trout density is frequently assessed by drift diving but this method is dependant on adequate visibility underwater. The Waikaka is murky at the best of times and this method could not be used. Another method is to conduct counts of spawning fish when they are typically in shallow water and therefore much more visible, but the spawning season is March/April. A count by a bank observer is another, though less satisfactory method, as any fish under the banks or overhanging vegetation cannot be seen. This method (bank observation) also depends on fish behaviour, they are visible when out feeding but not when they are resting in cover. These limitations might indicate that we have missed the trout in the middle size range during our surveys.

Using a variety of methods to assess the trout population it seems there are abundant juveniles and therefore good recruitment of brown trout. There are good numbers of adult trout based on surface observations (likely conservative) that coincide with moderate to high levels of fish feeding activity, estimated at approximately 20/km.

As well as this predation pressure there is the impacts of the large February 2020 Mataura flood. The Waikaka catchment was also flooded. ES list the flood as a 1:20 year event. Floods of this nature are major events and may scour the river bed disrupting primary production and can lead to high mortality rates in small fish that cannot withstand the stresses of prolonged large flow events. Trout are visual feeders so a prolonged period of dirty water, when they cannot see food items, leads to starvation stresses further reducing their ability to withstand a flood event.

A major flood in the Mataura River in 1978 was recorded by (Witherow & Scott 1984) who noted that as a consequence of the flooding there were major gaps in year classes of trout in subsequent years relating to high levels of mortality in juvenile fish. It is feasible that the age class distribution observed in the Waikaka Stream is real and the combined effects of flood and predation have depressed numbers of "middle" sized trout.

Brown trout are "cool-water stenotherms" which means their metabolism operates within a narrow range of cool temperatures, optimum growth occurs at around 14^{0}C with no growth below 2^{0}C or above 19^{0}C, (Elliot & Hurley 1999). Before these levels are reached fish are under stress so optimum and low stress levels are within that range. The hydrology and climate of Waikaka Stream produce temperatures at the upper limit (at least 19^{o}C) in mid summer so mitigating features such as shade are elevated in importance.

The large pond created by L&M mining contains brown trout, perch, and longfin eels. All but two of the other ponds, that have a noticeably different water quality, support only short fin eels. There was cross over between eel species only in pond number 6 where water quality was noticeably better than is usual for the ponds west of the Stream. It was generally longfin in the big pond, ditches, and stream and shortfin in the small ponds 2-7. It was noted in Dunn et al (2019), that " declining water quality in many areas has resulted in shortfin eel occupying habitat formerly occupied by longfin eel". This may well be the case here as the small ponds have relatively poor water quality as assessed by several measures.

It is possible that galaxiids are also in the small ponds but were not recorded. Only fyke nets were used in the small ponds because eels got into the minnow traps initially set and would likely have taken the opportunity to dine on captured smaller fish. Proof of this would have required killing the eels and this was avoided.

Ammonia can be acutely toxic to fish, affecting the Central Nervous System, and producing a suite of adverse effects. There is differing susceptibility according to species, life stage, and exposure which can lead to death or sublethal effects, like delayed development.

Richardson (1997), in a study of Ammonia toxicity to native fish noted the differing susceptibility according to species. This may well explain the fish distribution between the small ponds, with high Ammonia levels, and the Stream and Big Pond. Richardson's study recorded the LC50 for Shortfin eel as >5.1mg/l and Longfin eel as >1.80, indicating that shortfins are more tolerant of adverse conditions which fits with the elevated ammonia levels in the Ponds and the observed fish distribution.

Invertebrates

MCI scores give an indication of habitat available and the invertebrates response. Invertebrate populations were dominated by mayfly in the river especially in those areas with shade that limited the growth of algal mats that tend to smother the stream bed. Where algal mats develop chironomids became the dominate fauna. Caddis and mayfly are somewhat incompatible with chironomids largely based on habitat differences that provide for differences in algal loading.

Reasons for patterns of distribution.

1. Incident light, aspect, shading, and consequent algae growths.
2. Algae modifies habitat and creates conditions more suited to chironomids than algae film grazers such as mayfly
3. Site 2 is completely exposed, has heavy algal growth and dominated by chironomids
4. Site 3 heavy shading thus limiting algae and has a higher % mayfly
5. Site 5 shaded and a gravelly run not a riffle, no algae mats, abundant mayfly and very few chironomids.

The significance of invertebrate distribution is in what species are supported and how they contribute to fish habitat. Mayfly are large, and readily available/accessible, as fish food. Mayfly drift in the current and are conspicuous to the trout, as they are visual feeders. Eels fossick around amongst the cobbles and gravel in the riffles and pick up insects as they "scurry away" to seek refuge. Chironomids in comparison which although numerous, are small, much less mobile, residing in the algal, mat rather than drifting in the water column, and are therefore much less accessible to fish and are a smaller ration.

Biotic indices, for example the MCI and its variants, EPT, and measures such as density, allow useful comparisons between different habitats where changes in species composition and numbers may occur in response to habitat changes. In this case, where river diversion is planned, these indices will act as a yardstick to measure the success of the stream diversion in replacing existing habitat and supporting a similar aquatic community.

Water Quality

The water quality measured closely reflects adjacent land-use and drainage patterns. Conductivity is high reflecting the amount of dissolved nutrients. N_N loadings in the Big Pond and ditch reflect drainage patterns from relatively intensely used adjacent land. High ammonia levels in the ponds are related to nutrient rich run off and long residence times of the water in these ponds. In streams these nutrient rich waters can lead to nuisance algal growths that smother the stream bed and compromise ecological and aesthetic values.

With regard to nutrients the NPS-FW 2020 sets concentration limits and exceedance criteria for DIN and DRP to achieve periphyton targets (limits) for various waterbodies, and sets limits on land-use activities to meet the exceedance criteria.

In the NPS guidelines for setting nutrient criteria, DIN is sum of ammoniacal N and Nitrate -nitrogen. The (NPS) sets DIN limits between 120-200mg/m^2, depending on habitat values to be protected, and DRP at <6mg/m^3. Periphyton is recognised as "a primary symptom of excessive nutrient input with deleterious effects on ecological, cultural, and socio-economic values", NPSFW(2020). MFE NPS FW Standards list DIN<250 and DRP<6 mg/m3 to limit filamentous cover to <30%. So the Waikaka Stream and Pond 2 exceed the NPS-FW DRP recommendations but the effect in the stream is limited by shading at most sites but not site 2 and site 1 where there is insufficient shade to restrict the algal mats observed at these sites. This is important information for the rehabilitation channel because only shade can be manipulated and not water quality in the stream diversion.

Our assessment was to provide baseline information and characterize existing water quality and identify potential issues relating to mixing of waters, discharge to the stream and stream health indicators for the rehabilitation project. There are some very interesting water quality features of the river and the ponds and a fish distribution that reflects differing tolerances to this habitat component.

Longfin and shortfin eels are both found onsite but with a clear separation of habitat as only shortfins are found in most of the smaller ponds. Longfins are present in the large pond so the question is why are they absent from the smaller ponds. Water clarity is a visually obvious difference but analysis of water samples high-light some major differences in water quality, namely Ammoniacal nitrogen. Research (Richardson J 1997) into ammonia toxicity has recorded a greater tolerance by shortfin eels to ammonia and this may explain the distribution.

Ammonia toxicity manifests with a variety of effects, morphological (fin erosion, gill injury) physiological (kidney and liver stress, immune suppression) and behavioural (feeding and reproductive success) effects. These provide a lethal combination and at many levels including species and life stage differences.

When mining, mixing of waters maybe involved as the mine passes through existing water bodies. Care needs to be taken with mixing waters as elevated ammonia levels for example, could be toxic and possibly result in fish kills.

Habitat

Riparian Zone

The riparian zone is extensive and contributes major features that maintain the fish populations present and limit algal growths that would otherwise compromise habitat. Local knowledge suggests it was established about 20 years ago. It is a relatively easy habitat component to establish with planting and protection from stock.

"Shade plays an important role in the regulation of stream light and temperature and with profound effects on instream plant growth, ecosystem metabolism, and the relative suitability of habitat for differing biota" Hicks & Reeves (1994). This si a key feature of the Waikaka Stream aquatic ecology.

Substrate.

Cobbles and coarse gravel provide good habitat for food production, small fish habitat, as long as algae and fine sediment is limited and interstitial spaces maintained. The size of particle is important because of the interstitial spaces provided and the consequent habitat for invertebrates, small fish, and spawning opportunities for brown trout. If these interstitial spaces become clogged with fine sediment this habitat is compromised and the "life supporting capacity" of the stream reduced by among other things, compromised food production, recruitment, and rearing habitat. It was noticeable that the water was easily discoloured even in riffle areas when the bed was disturbed by footfall so there is fine sediment already present compromising riffle habitats.

Shade

Shade is a very important factor in the control of light and temperature with major effects on plant (algae/macropyhte) growth, and habitat suitability for fish and invertebrates. Shade is recognised in the water quality standards as a means to mitigate high nutrient loads which would otherwise lead to nuisance algae growths. The habitat preferences for various fish species has been extensively studied in NZ, for example (Glova 1999), recorded the importance of daytime cover and shade for Longfin eels. Its contribution to a range of species and life stages is well recognised.

Stream Rehabilitation.

Stream rehabilitation is an established and well researched process particularly in North America. It can be problematical with rehabilitation channels varying from the original often in subtle ways that don't always preserve the species or life stage community found in the original stream section. Subtle changes can alter the balance which is important if a species is in decline or has high conservation values, Hicks & Reeves, NIWA Restoration Guide (1994).

Guidelines in the literature list three main systems for providing "channel structure and instream cover" as;

1. Bank placements especially on the outside of corners
2. Weirs across the channel to create dammed pools upstream and scour pools below
3. Mid channel placements of materials to create scour holes and velocity refuges.

There are some examples of this, in the extensive riparian zone on The Waikaka Stream, that have been constructed and some of the large woody debris (LWD) have been made by tying fallen willows to the bank where they have provided habitat and erosion protection/resistance.

While the best option is not to disturb habitat the mining operation on the Waikaka site requires the stream to be relocated to the east. Fundamental to the success of this relocation will be the mimicking of the key habitat features of the Waikaka stream channel.

These are identified based on where fish have been located during the above survey,

1. Trout are seen as juveniles in cobbly/gravelly riffles and
2. Adult trout are in pools with abundant shade and undercut banks
3. Eels are located in pools with heavy shade cover, log jams, overhanging willows, undercut banks, and boulders used for crossings and erosion control, during daylight. At night they migrate to riffles to feed.
4. Upland bully are located in shallower pools, small backwaters, and riffles.

Key habitat features then are;

1. Riffles with coarse gravel and cobbles
2. Undercut banks
3. Overhanging vegetation-grasses, shrubs, willows
4. Large woody debris (LWD)
5. Deep pools
6. Boulder clusters

Of the above features all are relatively easy to create except the undercut banks that have developed in an incised channel where willow root masses stabilize the banks against erosion. LWD is a recognised habitat feature in streams and a major component in stream rehabilitation. The Waikaka riparian zone was established some 20 years ago but in that time has established some very stable and productive habitat.

Undercut banks would be quite difficult to create but there is an alternative in using boulder banks and riprap as a substitute. Where ever these features are located fish of varying species and life stages are usually to be found. Eels are seldom seen in daylight but as shown by electric-fishing are abundant particularly tucked away under the banks and log jams. Adult trout are particularly active in willow lined pools, probably partly in response the shade they provide but also because of the food source the willows provide.

The temperature of the water over summer indicates that it is generally at or near the upper levels of trout tolerance and consequently fish activity declines as the day advances and water temperatures rise. Basing rehabilitation on the species with the lowest tolerance for a particular habitat feature ensures that the habitat requirements of other species are conservatively provided for. In addition it preserves inter-specific relationships such as predator/prey interactions. Small trout and upland bully are likely a major food source for longfin eels for example.

Observations on algal growths also highlight the importance of shade in limiting these to less than “nuisance” levels given the relatively high nutrient levels in the water. This potential issue is recognised by ES and NPS-FW 2020 water quality standards for the waterways in general, with restrictions on filament length and percent cover beyond which some remedial action is required.

There is a definite need to understand these issues because they will define the success of attempts to rehabilitate the stream after diversion. Success is more likely when current limitations and mitigating features are identified so they can be incorporated into the new channel design.

Diversion Channel Habitat.

If want to create "a little more" to mitigate adverse effects of the diversion:

Opportunities to enhance habitat particularly as compensation for losses during diversion include;

1. Large woody debris, LWD, cover for fish
2. Extra length via sinuosity, equates to more habitat
3. Additional shading, control of periphyton and temperature.
4. More coarse substrate, interstitial spaces for invertebrate and fish habitat.
5. Some cobbles/boulders, to provide habitat features, increase variety of habitat, create edge effects, provide cover for small fish.

Markers of the success of rehabilitation will be;

1. the same fish species present with similar size distribution and density
2. a similar invertebrate community with regard to density and perhaps with an improvement in "good water quality" indicating species
3. maintenance of, or improvement in water quality

Summary.

The fish, invertebrates, and water quality monitoring indicate a healthy fish population but water temperatures, some algae growths, and some invertebrates suggest that without specific mitigating features (trees in the riparian zone) these values would be compromised.

The change in dominant invertebrates from mayfly to chironomid, high water temperatures recorded even before flows were low, and the background levels of some nutrients indicates potential to compromise stream ecology with stressful temperatures, smothering nuisance algal growths, and perhaps toxic levels of run-off products.

It is particularly important to be aware of these limitations as they have the potential to limit chances of success in the rehabilitation of the proposed new channel.

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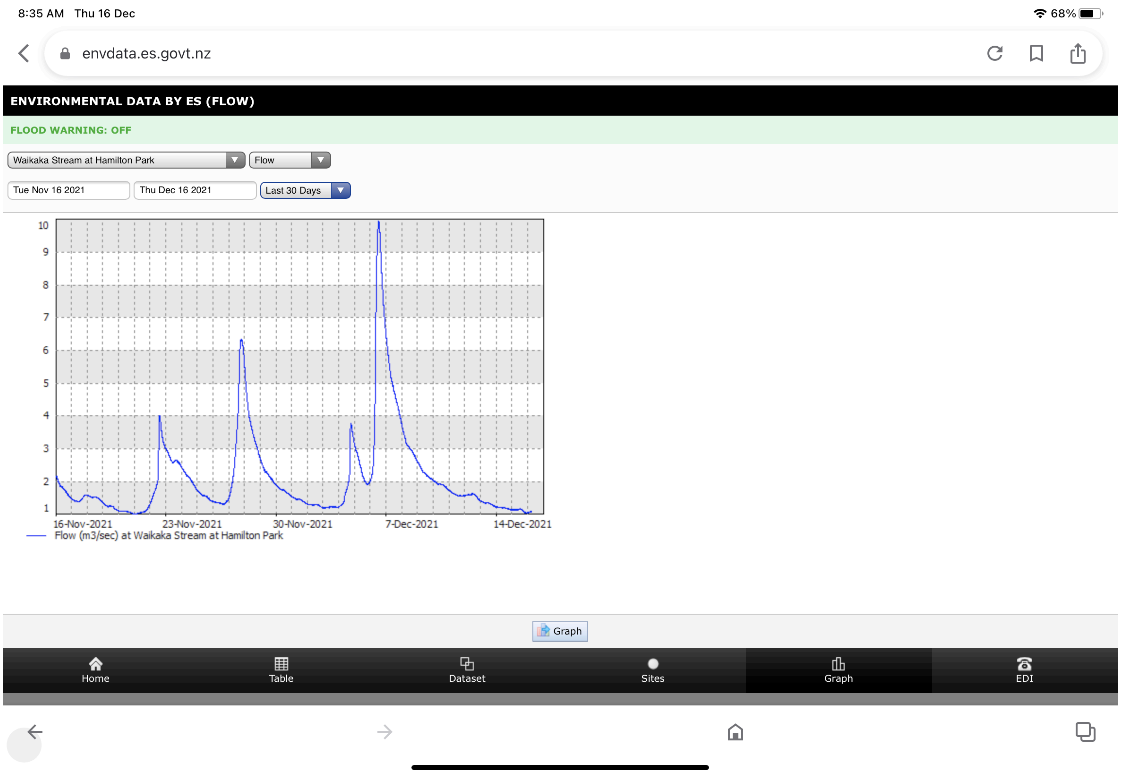
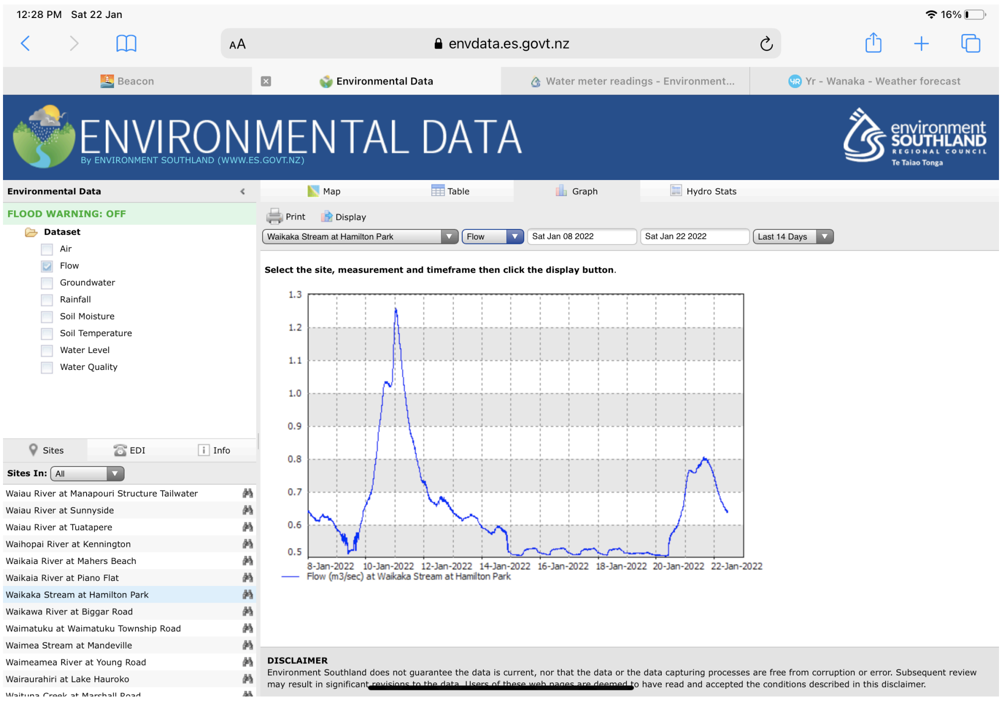
Ross Dungey
February 2021

Appendices

1. Environment Southland Flow Records



Survey conducted 12/12/21



Survey conducted 18/1/2022

2. Photographs

3. Stream survey card

Fish Data Form					**No.**		
Date	Stream						
Time	Sampling Locality						
Observer							
Map No	Coord					Elapsed T	
Fishing Method	Dist.m		No. Passes			Total Time	
HABITAT DATA						Film/Photo#	
WATER	Permanent Water; Y N ?		Habitat Description				
	Colour; blue, green, tea, uncoloured, other				**Clarity**; clear, milky, dirty		
	Av. width (m)		Av. depth (m)		Max. depth (m)		T°C
Habitat Type %	Still	Backwater	Pool	Run	Riffle	Rapid	Cascade
Substrate Type %	Mud	Sand	Fine gr.	Coarse gr.	Cobble	Boulder	Bedrock
Fish Cover %	Substr.	Weed	Instm deb.	Bank Veg.	Un/cut bank	O.H shade	Other
Riparian Veg. %	Native forest.	Exotic forest	Grass tsck	Exposed bed	Scrub will	Raupo flax	Other
Previously Fished	Y/N	**20 stones long axis**					
Water Level. Lo Norm Hi ?				Downstream Blockage. Y N ?			
Bottom Fauna; Abundance. Lo Mod Hi ?					Conductivity (L/V)		
Predominant Species Group. Stonefly, mayfly, caddis, snail, other.							
Bug Notes							
FISH DATA							

Species and Life Stage	Abundance	**Length Data**		

General Comments About Site or Fish	Width (m)	Depth (m)

C → → → CT .... SAL → → ..... TDS

Waikaia Gold, Revised Diversion Plan
Waikaka Stream Mine.

Comments on the effects of this revision on aquatic habitat and habitat rehabilitation components..

Fish Salvage.

The original plan was to include a substantial stream diversion of about 2km. The revised plan is for a staged approach where 3 diversions would occur starting in year 3 (470m) of the project, another in year 4 of 630m, and finally in year 6 a diversion of 1040m. (Distances and diversion schedule from the Revised Feasibility Study,2024). This staged approach should reduce the impact of habitat loss on the aquatic ecosystem by spreading that impact over several years.

Positives that accrue from this approach are that fish salvage and relocation puts less pressure on available habitat as additional fish will be released into already occupied habitat. If for example fish salvaged from say 100m can be released over 500m of existing habitat the crowding pressure will be much less than if the release site was only 100m of stream.
In addition there will be shorter sections of stream in the rehabilitation phase which will not be as productive as stable established stream. It will take time for the new channels to stabilize and rise to production levels of the original stream.

The shorter distances of stream to be salvaged will also reduce stresses on the fish as release sites will be closer at hand and therefore less transport required. Elevated water temperature and diminishing oxygen levels during transport would be stressful for fish but this can largely be avoided when short distances are involved.

The attention to the detail of stream habitat reconstruction still apply but the staged approach gives additional time for new channels (post mining) to stabilize and production capability to rise to natural channel levels. In this scenario fish would be released into habitat that has food available rather than an environment devoid of food, a very important consideration for the salvage to be successful.

Shorter diversions in the staged approach also gives a chance to monitor the effectiveness of the salvage and release operation.

Habitat Reconstruction Post Mining

An additional point of discussion was habitat reconstruction, replanting, boulder and cobble habitat components.

Planting

To provide habitat in a timely manner, and maximise channel stability, I recommend hybrid willows. These have numerous advantages,

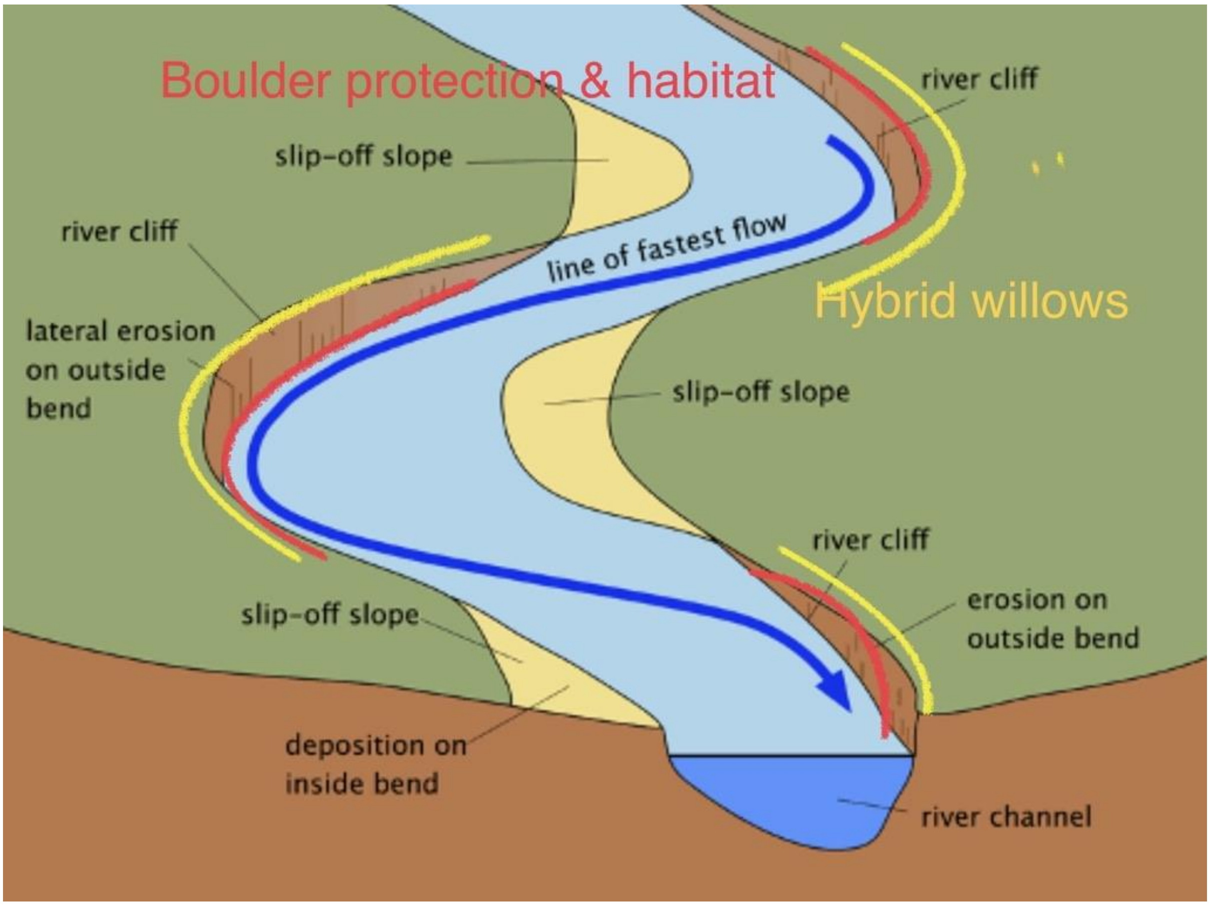
1. Ease of procurement
2. Ease of establishment
3. Rapid growth, 3 years to provide habitat
4. Maximum erosion resistance

Habitat Components

Boulders and cobbles salvaged during mining can have a major role in habitat reconstruction by providing

1. armouring at erosion pressure points
2. habitat for fish, large and small. Eels are abundant in existing boulder dominated habitats of the Waikaka Stream.
3. invertebrate habitat (food for fish). (cobbles are highly beneficial habitat as they provide shelter and food production surfaces).

The stylized diagram below outlines habitat components that the planting and boulders can be used to recreate. Location of hybrid willows shown in yellow and the boulders for erosion protection and habitat in red. The willows have a dual role of providing exceptional erosion resistance as well as critical shading. Cobbles can also be placed across the channel perpendicular to flow to form riffle areas, as are present in the existing channel. They provide habitat diversity, bed armouring and food production zones where algae and invertebrates flourish, thus supporting fish populations.



Willow and boulder stream distribution schematic.

Salvage Schedule

The process of dewatering a channel, salvaging fish from a channel, and introducing fish successfully to a new channel can all be assisted by developing a schedule. Ideally flow would be reduced in a staged manner from the channel to be dewatered. This allows a proportion of the fish population to depart of their own accord therefore reducing the numbers to be salvaged.

A newly constructed channel should also be flooded in stages, this allows algae to begin to establish thus providing food for the invertebrates which are in turn food for the fish. A freshly flooded channel will obviously lack this beginning to the food chain but one where some flow has been previously introduced can be in food production mode prior to the arrival of fish salvaged from other locations.

The diversion channels will provide some limited habitat but their value can be improved by allowing some flow prior to complete diversion for algal and invertebrate communities to establish. Food would then be available when fish are released after salvage from a diverted section. These channels are likely to be in place for 1-2 years and will be occupied by various fish species but at much lower densities than the existing channels that have more extensive habitat components.

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