Instream Habitat of the Wharekirauponga Stream and Tributaries

Prepared for Oceana Gold NZ Limited

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Executive summary

Oceana Gold Limited are proposing to open an underground mine beneath the Wharekirauponga Stream catchment, Coromandel Peninsula. Groundwater modelling suggests that when the proposed mine is dewatered, there may be some loss of surface water. The purpose of this report is to determine the effect of this loss on instream habitat in the Wharekirauponga Stream and its tributaries above the proposed mine, to inform the assessment of environmental effects of the proposed mine, which is a requirement of the resource consent application process.

- Surveys of the physical stream habitat were conducted for seven reaches in the tributaries and main stem of the Wharekirauponga Stream. The reaches studied were Adams Stream, Edmonds Stream, Teawaotemutu Stream, Thompson Stream, Tributary-R, Wharekirauponga Stream downstream reach (WKP1), and Wharekirauponga Stream upstream reach (WKP2).

- Longitudinal habitat mapping was used to quantify the proportions of pool, riffle, and run habitat types in each study reach, and to select representative cross-sections.

- Within the stream catchment, 105 study cross-sections were established with 15 in each study reach. Within each reach there were cross-sections through five pool, five riffle and five run habitat types. Measurements of depth, velocity and substrate occurred at each cross section, along with 2-3 follow up calibration measurements of water level and discharge.

- Instream habitat modelling, based on depth, velocity and riverbed substrate was used to determine the available instream physical habitat for a range of species/classes and how the available habitat for these species would respond to potential changes in flow in Wharekirauponga Stream and its tributaries.

- The instream habitat model predicts how physical habitat availability will vary in response to flow changes for a particular species/class by calculating the change in Area Weighted Suitability (AWS). AWS (m^2/m) is the average wetted area of a stream (per unit length) that is suitable for use by an aquatic species, or class of aquatic species. AWS takes into account the distribution of pool, riffle, and run habitat types within a study reach, as well as the distribution of depth, velocity and substrate within these habitat types, and the preferences (i.e., habitat suitability curves) of each species/class. Total suitable instream habitat (m^2) for a species/class is calculated by multiplying AWS (m^2/m) by reach length (m).

- The list of species that were considered to be appropriate to model for this catchment was obtained from Boffa Miskell (2023) and additional eDNA sampling by Boffa Miskell and Wilderlab.

- The results focussed on the effect of reductions to the 7-day Mean Annual Low Flow (7-day MALF) and changes to median flow according to detailed groundwater (FloSolutions 2023a, b) and surface water modelling (GHD 2024). The modelling results provided an 'average case' which is the most likely change in flow and a 'worst case' which is the unlikely 5th percentile of flow (i.e. 95th percentile of flow reduction). We focused results on the 'worst case' post-mining 7-day MALF as this would cause the largest reductions to instream habitat; however, our results also included the 'average case' post-mining 7-day MALF, and changes to median flow.

- The term post-mining is used throughout the report to cover modelled flow reductions after mining has commenced. However, the greatest effects on stream flows are predicted to occur

at the end of mining and immediately after mining completion. These effects are predicted to be relatively short lived and only impact streams for around two years after mining completion.

- Modelling results covered all seven of the study sites that we surveyed (Adams Stream, Edmonds Stream, Teawaotemutu Stream, Thompson Stream, Tributary-R, WKP1, and WKP2).

- For the average-case (most likely scenario) changes to suitable instream habitat between the pre-mining 7-day MALF and the predicted post-mining 7-day MALF varied between taxonomic groups (i.e. periphyton, invertebrates, and fish), species/classes within taxonomic groups, and study sites. Reductions in suitable instream habitat for taxonomic groups ranged from -0.72% for fish in Adams Stream to -4.20% for invertebrates in Thompson Stream[1]. The average reduction of suitable instream habitat for the seven study sites and three taxonomic groups was -2.08%.

- For the worst-case (unlikely scenario) changes to suitable instream habitat between the pre-mining 7-day MALF and the predicted post-mining 7-day MALF also varied between taxonomic groups (i.e. periphyton, invertebrates, and fish), species/classes within taxonomic groups, and study sites. Reductions in suitable instream habitat for taxonomic groups ranged from -1.20% for fish in Adams Stream to -5.66% for invertebrates in Thompson Stream[1]. The average reduction of suitable instream habitat for the seven study sites and three taxonomic groups was -3.20%.

- At median flow, which is representative of average annual flow conditions, the AWS curves were flatter than near the 7-day MALF, with changes in flow due to mining scenarios having much less impact on suitable instream habitat than those at the 7-day MALF.

[1] Taking into consideration the hydrogeological findings of Williamson Water & Land Advisory (WWLA), it is likely that for Thompson Stream in particular, the findings presented in this report are likely to be highly conservative.

1 Introduction - Study brief and background

Oceana Gold Limited are proposing to open an underground mine beneath the Wharekirauponga Stream catchment, Coromandel Peninsula. Groundwater modelling (FloSolutions 2023a, b) suggests that when the proposed mine is dewatered, there may be some loss of surface water. The purpose of this report is to determine the effect of this predicted loss on instream habitat in the Wharekirauponga Stream and its tributaries above the proposed underground mine. This information can be used to inform the Assessment of Environmental Effects of the proposed mine, which is a requirement of the resource consent application process.

Oceana Gold Limited have contracted NIWA to conduct surveys of physical habitat for seven reaches in the tributaries and main stem of the Wharekirauponga Stream, then model the response of physical habitat for a range of species/classes to changes in flow in the Wharekirauponga Stream and its tributaries above the proposed underground mine. The species/classes to be modelled were obtained from Boffa Miskell (2023) and additional eDNA sampling by Boffa Miskell and Wilderlab.

The specific aim of this study was:

- To assess the effects of the modelled reductions in flow on the amount of instream physical habitat available for a range of periphyton, macroinvertebrate and fish species present in the Wharekirauponga Stream and its tributaries. The full list of species/classes that were used in the habitat modelling is detailed in Section 3.4 and Table 3-2.

This project focused on physical habitat as defined by the combination of depths, velocities and substrates found in the Wharekirauponga Stream and its tributaries compared to those deemed suitable as specified by existing habitat suitability criteria. The instream habitat modelling that was undertaken is a time-intensive method for providing information (in this case for flow reduction) and the results produced are site-specific. Additional factors influencing habitat conditions such as geomorphological changes, sediment movement, floods, water quality, light availability and temperature were not investigated as part of this project. Since the project focused on species/classes that were observed to be present in the study reaches (and from eDNA sampling) it was assumed that these target species/classes were already adapted to the aforementioned factors.

2 Approach

2.1 General procedure

We followed procedures recommended by the *Instream Flow Guidelines* developed by the Ministry for the Environment (MfE 1998, 2008). As noted in Section 1 above, the instream values were selected for the periphyton, benthic macroinvertebrates and fish found to be in the streams, as identified in Boffa Miskell (2023) and from eDNA sampling. Ecological values are not the only values that are important because aesthetic values, landscape values, Māori cultural and traditional values can also be influenced by flow changes (MfE 1998). This report focuses on ecological instream values to assess any potential changes to the natural state of the streams due to possible flow reductions.

We used physical habitat modelling and related techniques to quantify the effects of flow reduction on the availability of suitable physical habitat for aquatic taxa. A brief review of the different methods for determining instream flow requirements is provided in Appendix A. The analysis contained in this report provides relationships between stream flow and availability of suitable physical habitat for aquatic taxa. This report outlines how the modelled reductions of flow influence physical habitat for each species/class and the relative changes in availability of suitable physical habitat for each species/class over a range of flows.

2.2 Physical habitat modelling

The approach adopted in many physical habitat studies is described by Johnson et al. (1995), Jowett (1997) and Clausen et al. (2004). This approach includes four main steps: identification of river sections and species of interest; identification of habitats that exist within the sections of interest; selection of cross-sections which represent replicates of each habitat type; and collection of model calibration data (water surface elevation, depth and velocity). These calibration data are used to determine the spatial distribution of depths and velocities across each cross-section (e.g., Figure 2-1) and the relationship between water levels at each cross-section and the quantity of water flowing in the river (e.g., Figure 2-2).

The calibration data are collected in order to simulate hydraulic conditions in the river for a range of flows which can then be combined with appropriate Habitat Suitability Criteria (HSC)[2]. This allows prediction of useable physical habitat for the species/class of interest. Useable physical habitat is termed Area Weighted Suitability (AWS) and is expressed as m^2 per m of river channel. AWS is an aggregate measure of physical habitat quality and quantity and will be specific to a particular discharge and species/class. It can be interpreted as the average wetted width of the stream suitable for that species/class, with the area suitable for the species/class found by multiplying AWS by reach length. Assessment of the changes in AWS which might occur as a result of any proposed changes in flow regime can then be made.

[2] HSC are available for different species/classes in the SEFA programme or have been developed by other researchers in New Zealand. The same HSC are typically used across the country so they are not specific to this catchment.

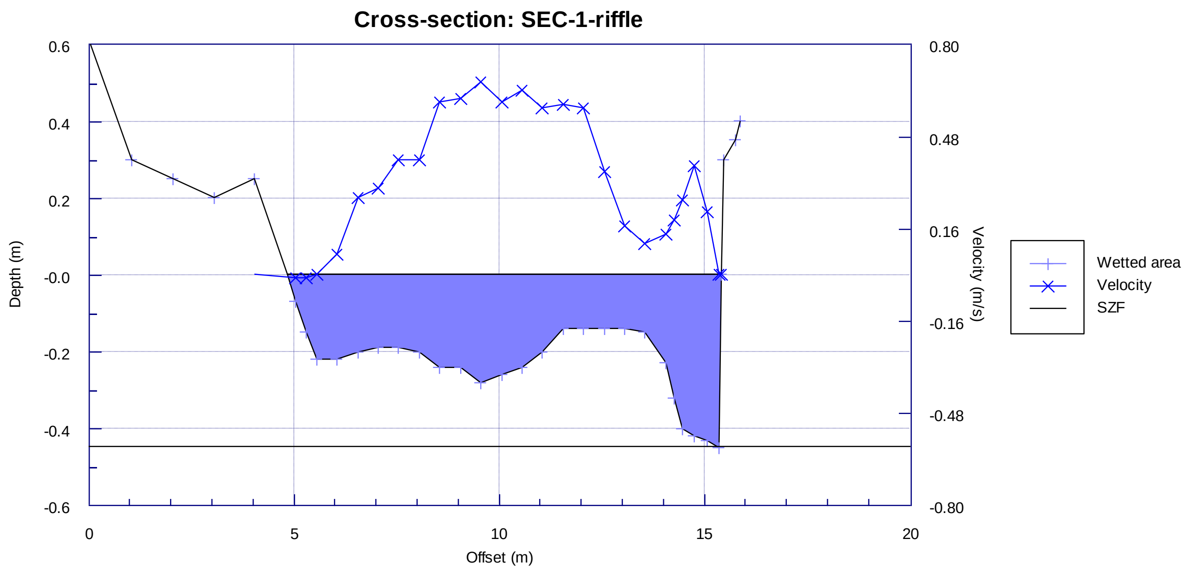

Figure 2-1: Example of velocities and depths measured for a cross-section. SZF = Stage at Zero Flow.

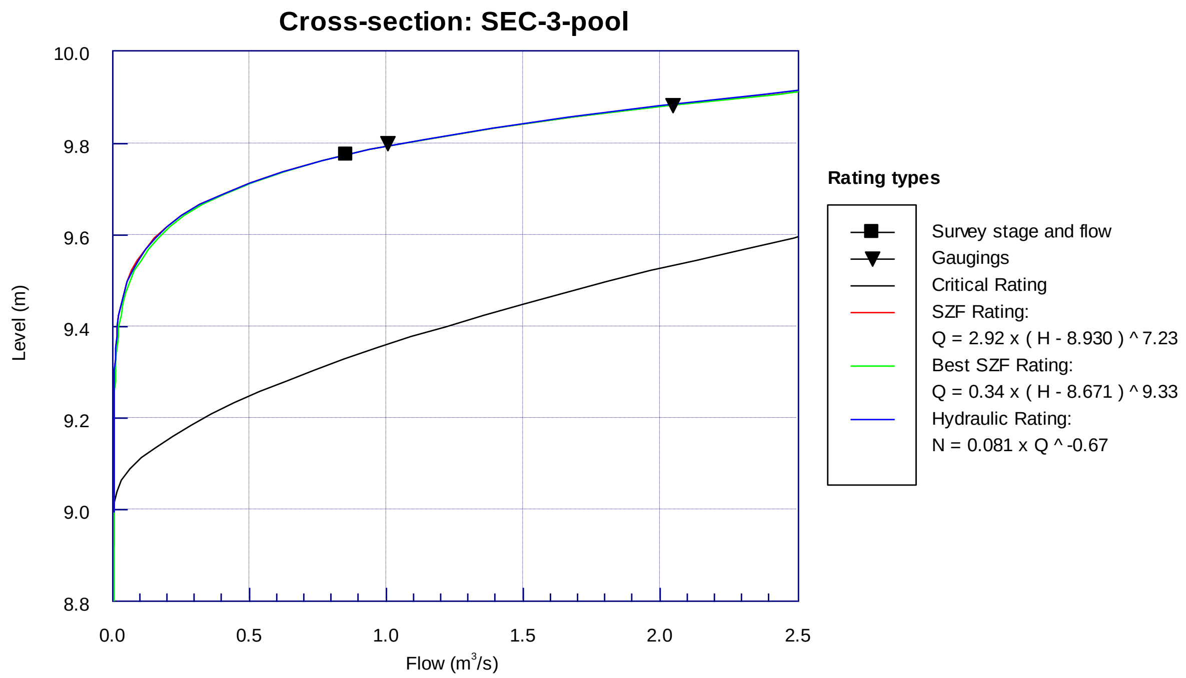

Figure 2-2: Example of a water level (stage) to discharge relationship at a cross-section.

In New Zealand habitat modelling has typically followed either one of two methods. The first method is known as the "habitat mapping" method. The number and distribution of habitat types (pools, riffles and runs) within the reach of interest are identified using habitat mapping techniques. Stage-discharge relationships are applied to simulate hydraulic conditions at isolated cross-sections placed throughout the reach of interest. Identification of the habitat type and several observations of water surface level and discharge are required at each cross-section. Modelled conditions at these cross-sections are then used in conjunction with results from the habitat mapping to weight each cross-section and therefore represent conditions in the full reach of interest. The advantage of the habitat mapping method is that it does not require the selection of a “representative reach” from within the length of river that is of interest.

The second method is known as the “representative reach” method. One-dimensional hydraulic modelling approaches are applied to a series of cross-sections located contiguously along the river to form a study site within the length of river that is of interest. The habitat types of each cross-section may be identified and can be used to assess the representativeness of the modelled reach. The advantage of the representative reach approach is that it allows more physically-based methods to be used in hydraulic simulation. This can be advantageous in rivers with particularly complex hydraulic characteristics caused by low width-to-depth ratios, the presence of in-channel vegetation or frequent groundwater-surface water interactions.

In this study the “habitat mapping” method was used in the software SEFA (System for Environmental Flow Analysis). SEFA is a comprehensive habitat simulation software (Jowett et al. 2024) which was developed as a collaboration between Ian Jowett (RHYHABSIM), Bob Milhous (PHABSIM), and Tom Payne (RHABSIM) who were the primary creators of previous habitat simulation software.

3 Data collection

3.1 Site locations

To evaluate instream habitat in the Wharekirauponga Stream catchment, seven study reaches were established (Figure 3-1). There were two study reaches in the main Wharekirauponga Stream, comprising a downstream reach (WKP1) near the start of the Wharekirauponga Track (DOC walking track), and an upstream reach (WKP2) that was approximately 3.5 km from the downstream reach. Study reaches were also established in the major tributaries of the Wharekirauponga Stream in Teawaotemutu Stream (T-Stream East), Edmonds Stream, and Thompson Stream. Additional study reaches were established in the smaller tributaries Adams Stream and Tributary-R. In each study reach, 15 cross-sections were established, with five in pools, five in riffles, and five in runs (see Section 3.3 and Appendix B). Instream habitat mapping surveys were conducted for each study reach (see Section 3.3 and Appendix B), to quantify the proportion of each habitat type that was present. The catchment boundaries and study reaches are shown in Figure 3-1, with the locations of the surveyed cross-sections and habitat mapping surveys in Figure 3-2. Detailed information on each of the study reaches is provided in Appendix G to Appendix M.

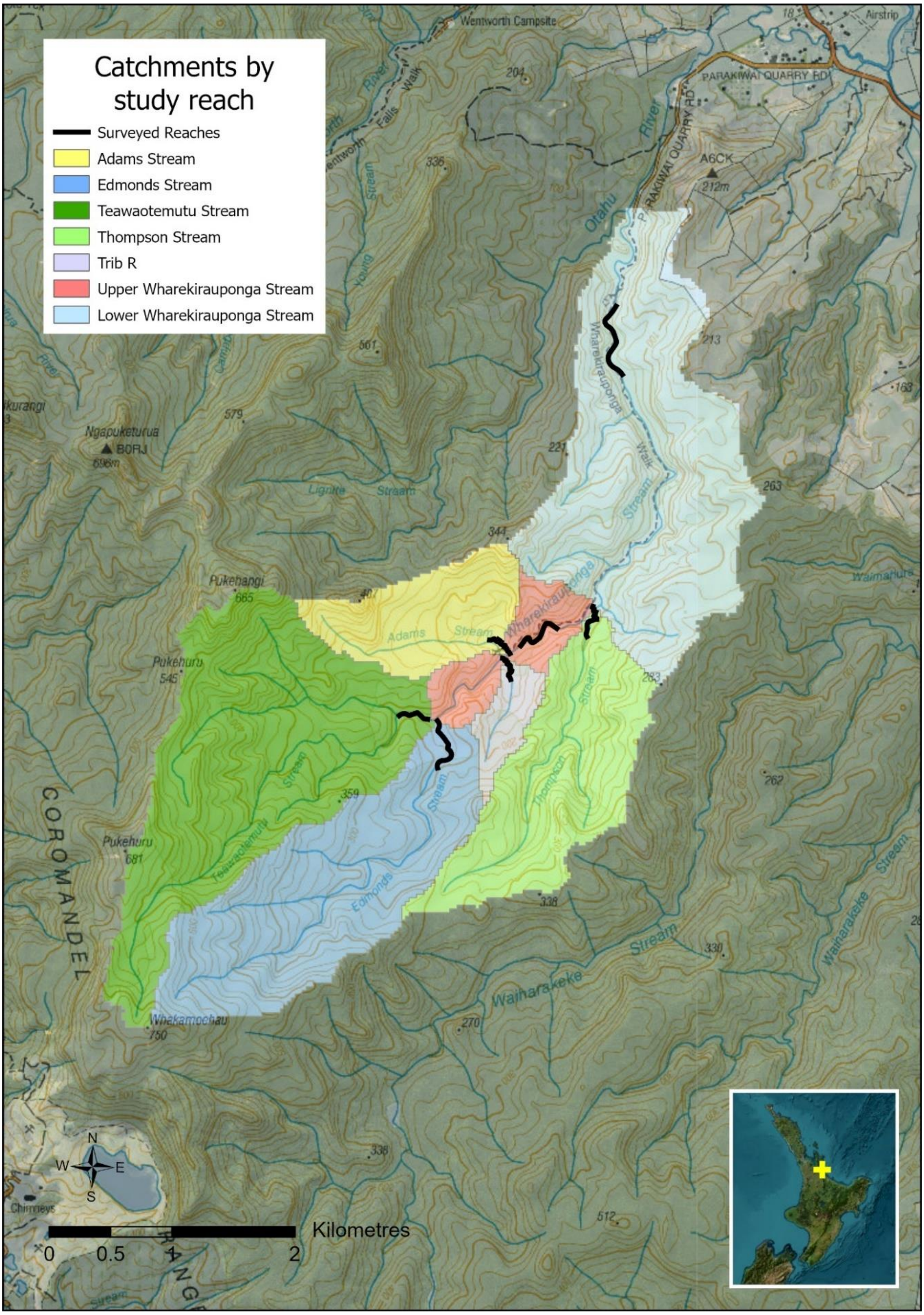

Figure 3-1: Map of the catchment boundaries and study reaches. Inset map (lower right) shows the location of the Wharekirauponga catchment in the Coromandel Forest Park.

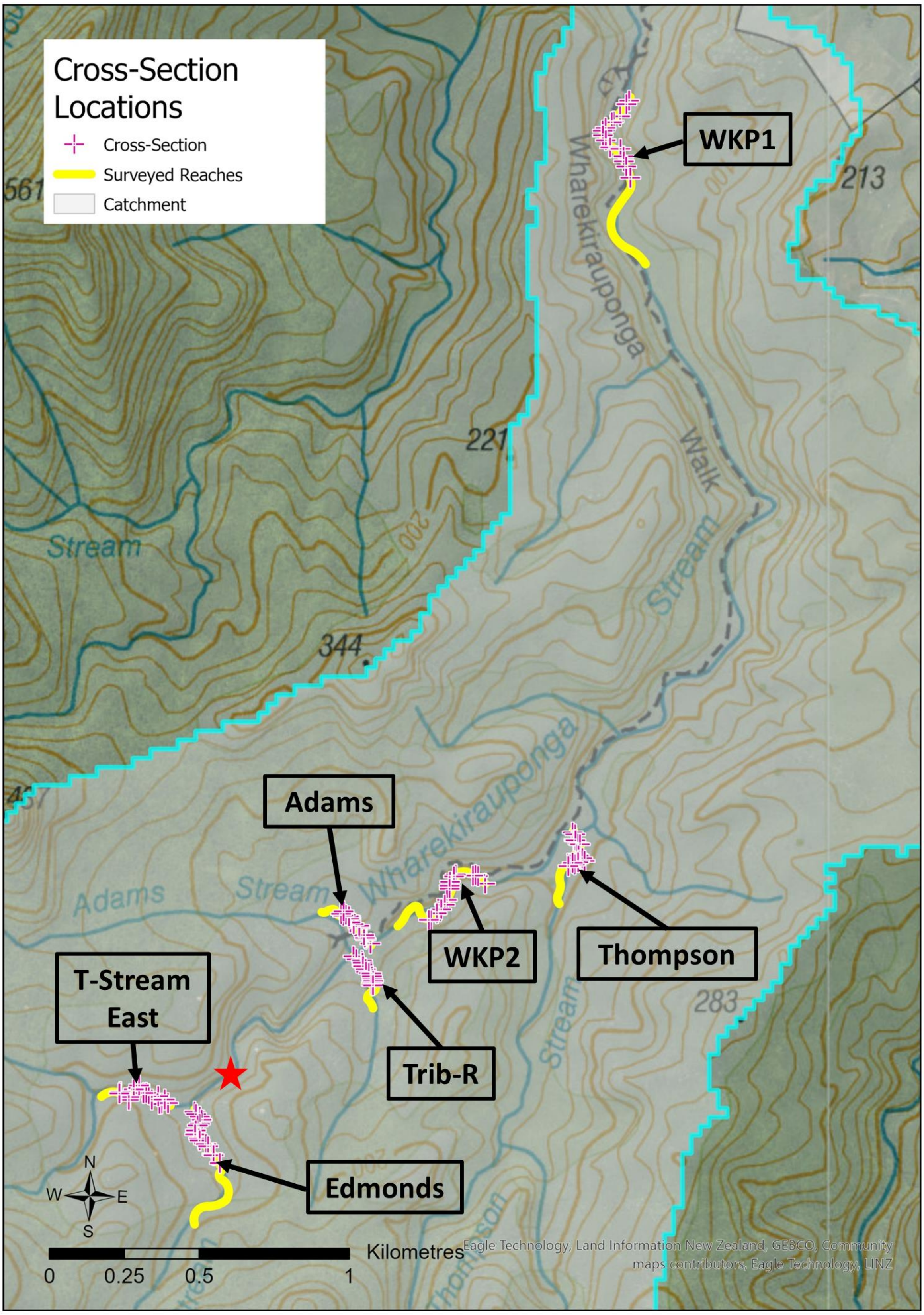

Figure 3-2: Map of the study reaches in the Wharekirauponga Stream catchment. Habitat mapping surveys are yellow, cross-section locations are pink, and a large waterfall (preventing upstream migration of non-climbing fish species) is shown with a red star.

3.2 Site hydrology

The hydrology for our study reaches has been modelled by GHD (2024). They developed a water balance model within GoldSim using the Australian Water Balance Model (AWBM). GoldSim is a dynamic probabilistic simulation software, and the AWBM is a rainfall-runoff model which can be used to simulate rainfall runoff in a catchment. Both GoldSim and the AWBM are widely used and well regarded.

The main driver for a water balance model is rainfall and the following data were used. Rain gauges were established in the Wharekirauponga catchment and data were available from 1 March 2019 to 1 March 2023. A rainfall record for Waihi for 1917 to 2022 was derived from a number of sources. Correlations were made between the Wharekirauponga and Waihi records to provide an estimated rainfall record for the Wharekirauponga catchment from 1917 to 2022 (GHD 2024).

The modelled flow data needs to be calibrated and verified against data measured in the catchment. Water level recorders were established and continuously monitored at five locations: Teawaotemutu Stream East, Teawaotemutu Stream West and at 3 locations in the Wharekirauponga Stream. Data were collected between 20/06/2019 and 01/12/2022. The flows at the five locations were calibrated for the period 01/03/2019 to 16/07/2021 using a daily timestep. Predictions for Thompson and Edmonds are based on a pro-rated assessment from two of the Wharekirauponga recorders and based on proportional catchment areas. The model was applied for 1917 to 2022 and flow statistics were derived for each catchment (GHD 2024).

The flow regime for the catchment is variable with high flows in winter and spring and generally low flows in summer, with the occasional summer flood. This type of regime is well simulated in Teawaotemutu Streams East and West giving FRE3 (Clausen & Biggs 1997) values of ~3 and ~4 for the recorded flow and calibration period simulations (FRE3 is the frequency/number of freshes exceeding three times the median flow over a 12-month period). For the Wharekirauponga sites, the simulations give FRE3 values between ~5.2 and ~9, but the recorded flows are less flashy.

To assess the effects of the proposed under-ground mine a groundwater model was developed by FloSolutions (FloSolutions 2023a, b) who provided (amongst other data) projected changes to river flows. FloSolutions provided 'Base Case' simulation results, which were the most probable flow reductions based on available data from drilling operations and hydrogeological surveying. They also provided 'Sensitivity Analysis' results where modelling parameters were adjusted to test different combinations of parameters that would have a larger impact on base flow reductions. Additional uncertainty analysis was performed by Intera (Intera 2024).

These data were applied to the calibrated GHD water balance model to provide post-mining flows (GHD 2024). The current state pre-mining simulation and flow reduction simulation (post-mining) were run over a long-term predictive period of 104 years. Both simulations were modelled stochastically over 100 model realisations (with rainfall and baseflow loss the stochastic modelled elements). The average (mean) results were provided as the most likely post-mining flow scenario (average case), while the 5th percentile post-mining flow (i.e. 95th percentile flow reduction) was provided as an unlikely post-mining flow scenario (worst case). These cases are deemed to conservatively reflect the likely range in flow statistics based on pre-mining and mining WBM predictions (including the predicted range of baseflow loss) and taking into account the long-term rainfall record (GHD 2024).

A selection of the resultant flow statistics are presented in Table 3-1, with the pre-mining case in Table 3-1A, the average post-mining case in Table 3-1B, and the unlikely post-mining worst case in Table 3-1C.

Table 3-1: Flow statistics from the hydrological model for: A Pre-mining; B Post-mining average case; C Post-mining worst case.

A. Pre-mining

Statistics (L/s)	Adams	Edmonds	T Stream East	Thompson	Trib R	WKP01	WKP02
Mean flow	34.34	106.66	151.81	77.14	4.85	522.87	326.63
Median flow	28.62	87.29	123.87	61.58	4.31	422.36	266.53
MALF	10.48	22.89	27.98	17.86	1.42	108.06	67.37
7-day MALF	11.06	24.97	31.21	19.20	1.53	118.42	73.95

B. Post-mining average case

Statistics (L/s)	Adams	Edmonds	T Stream East	Thompson[3]	Trib R	WKP01	WKP02
Mean flow	33.87	103.95	150.77	74.94	4.79	510.38	321.65
Median flow	28.15	84.58	122.84	59.38	4.25	409.88	261.55
MALF	10.01	20.18	26.94	15.65	1.33	95.57	62.40
7-day MALF	10.59	22.26	30.17	16.99	1.45	105.93	68.98

C. Post-mining worst case

Statistics (L/s)	Adams	Edmonds	T Stream East	Thompson[3]	Trib R	WKP01	WKP02
Mean flow	33.15	101.30	146.90	72.87	4.69	497.40	313.73
Median flow	27.45	82.00	119.00	57.61	4.15	397.35	253.72
MALF	9.76	19.32	25.64	15.08	1.29	91.40	59.69
7-day MALF	10.31	21.25	28.61	16.27	1.39	100.94	65.89

These flow reductions will be used to determine the extent of any changes to the instream habitat for the biota found in the streams.

3.3 Instream habitat survey methods and analysis

3.3.1 Cross-section establishment

For each survey reach, 15 cross-sections were established, with five in riffles, five in runs, and five in pools. For the seven reaches studied, this was a total of 105 cross-sections. Following establishment cross-sections were surveyed with a Trimble M3 mechanical total station. An example cross-section is shown in Figure 3-3, with detailed information on cross-section establishment and surveying in Appendix B.

[3] Taking into consideration the hydrogeological findings of Williamson Water & Land Advisory (WWLA), it is likely that for Thompson Stream in particular, the findings presented in this report are likely to be highly conservative.

Figure 3-3: Example cross-section in the Wharekirauponga Stream (cross-section WL06).

3.3.2 Habitat mapping surveys

Habitat mapping was conducted along the centreline of each reach, with a tape measure used to measure the length of each habitat segment. Habitat mapping was used to quantify the proportions of each habitat type in each study reach, with this information used as input weightings for cross-sections in SEFA. Detailed information on habitat mapping is provided in Appendix B, with maps showing the locations and lengths of the habitat surveys shown in Section 3.1. Summary tables of habitat segment length distributions are provided in Section 4 for each survey reach, with histograms of habitat segment length distributions provided in the Appendices for each survey reach.

3.3.3 Velocity measurements and discharge gauging

Velocity measurements were made with a SonTek FlowTracker2, with a wading rod used to vertically position the probe, and to make depth measurements. Velocity measurements obtained at cross-sections for input to SEFA were measured with 20 second duration, following the SEFA user manual (Jowett et al. 2023). Typically, 12–15 measurement points were made across each cross-section, with more points (i.e., 20+) made in some cases were velocities and depths were highly variable (e.g., wide riffles in WKP reaches), and fewer points in some cases where channels were narrow, and velocities, depths, and substrate were relatively similar (e.g., small tributaries where wetted widths were ~1 m). Velocity measurements made for discharge gauging were recorded with 40 second duration and more measuring points (verticals) per gauging to increase confidence in the accuracy of the gauging. Detailed information on velocity measurements and discharge gauging is provided in Appendix B.

3.3.4 Substrate measurements

Substrate was divided into the classes: Bedrock, Boulders (>264 mm), Cobbles (64–264 mm), Coarse Gravel (8–64 mm), Fine Gravel (2–8 mm), Sand (0.06–2 mm), Silt/Mud (<0.06 mm), and Vegetation. The percentage of substrate in each class was estimated for each vertical in each cross-section. A bathyscope was used for verticals with deep water, and where surface turbulence or glare obscured the view of the riverbed. Detailed information on substrate measurements is provided in Appendix B.

3.3.5 Water level measurements

For the duration of the instream habitat study, three pressure transducers were installed to measure water level at the downstream ends of Teawaotemutu Stream (T-Stream East), Edmonds Steam, and Wharekirauponga Stream (WKP1). Seametrics PT2X vented pressure transducers were used, with 5-minute logging. Additional water level reference pegs were also established at the downstream end of study reaches where pressure transducers were located (as a fixed reference) with their water levels read each time pressure transducer data were downloaded, or each time a water level calibration run was conducted. Calibration runs consisted of water level measurements at each of the cross-sections and a reference discharge gauging measurement. Detailed information on water level measurements and calibration runs is provided in Appendix B.

3.4 Habitat suitability criteria and species present

The Habitat Suitability Criteria (HSC) chosen for this study were for species that have been observed and reported in Boffa Miskell (2023) and from eDNA data sampling by Boffa Miskell and Wilderlab. Some species of fish were not found at all sites, and some were not expected to be found upstream of the Wharekirauponga Stream waterfall (Figure 3-1) because it could block fish passage for many species. The HSC used in this report are listed in Table 3-2 and shown in Appendices D, E, and F.

Periphyton HSC initially used in this study were from NIWA unpublished data from large oligotrophic streams/rivers from the South Island of New Zealand; however, these conditions do not suitably represent water physiochemistry in the Wharekirauponga Stream catchment. These criteria led to there being very little available habitat for thin films, diatoms and short filamentous algae whereas Boffa Miskell (2023) show that in four of the streams there was between 55% and 80% cover. The NIWA survey teams for this study also noted widespread thin periphyton cover throughout the study reaches (where sufficient light reached the streambed and substrate was stable), although no formal estimates of cover were made. Photographs of the stream beds for this study also show widespread periphyton cover. Velocity, depth, and substrate measurements made during this study were noted for locations where thin periphyton was obvious in photographs. This information was used to update the periphyton HSC to better match conditions in the Wharekirauponga Stream catchment, notably that areas with lower velocities were also suitable for periphyton thin films, diatoms and short filamentous algae.

Table 3-2: Aquatic species/classes and habitat suitability criteria that were used in the habitat modelling.

Taxonomic Group	HSC Name	HSC Source
Periphyton	Thin films	unpublished NIWA data
	Diatoms	unpublished NIWA data
	Short filamentous	unpublished NIWA data
	Long filamentous	unpublished NIWA data
	Cyanobacteria (*Phormidium/Microcoleus*[4])	Adapted from Heath et al. (2013)

[4] *Phormidium autumnale* has been re-classified as *Microcoleus autumnalis* (Strunecký et al. 2013)

Taxonomic Group	HSC Name	HSC Source
Macroinvertebrates	Stony-cased caddisfly (*Pycnocentrodes*)	Jowett et al. (1991)
	Free-living Caddisfly (Hydrobiosidae)	Jowett et al. (1991)
	Net-spinning Caddisfly (*Aoteapsyche*)	Jowett et al. (1991)
	Horny-cased Caddisfly (*O. feredayi*)	Jowett et al. (1991)
	Mayfly (*C. humeralis*)	Jowett et al. (1991)
	Mayfly (*Nesameletus*)	Jowett et al. (1991)
	Mayfly nymphs (*Deleatidium*)	Jowett et al. (1991)
	Flies (Maoridiamesa)	Jowett et al. (1991)
	Beetles (Elmidae)	NIWA Waitaki Dataset
	Midges (Orthocladiinae)	NIWA Waitaki Dataset
	Snails (*Potamopyrgus*)	NIWA Waitaki Dataset
	Stonefly (*Zelandoperla*)	Jowett et al. (1991)
	Food Producing Invertebrates	Waters (1976)
Fish	Shortfin eel >300 mm	Jowett & Richardson (2008)
	Shortfin eel <300 mm	Jowett & Richardson (2008)
	Longfin eel >300 mm	Jowett & Richardson (2008)
	Longfin eel <300 mm	Jowett & Richardson (2008)
	Torrentfish	Jowett & Richardson (2008)
	Redfin bully	Jowett & Richardson (2008)
	Banded kōkopu juvenile	Jowett & Richardson (2008)
	Banded kōkopu adult	Jowett & Richardson (2008)
	Shortjaw kōkopu	Jowett & Richardson (2008)
	Kōaro	Jowett & Richardson (2008)

Table 3-3 shows which aquatic species were used in each stream in the later analysis to show the effect of the modelled flow reductions. Not every study reach was eDNA sampled for aquatic species. eDNA data were available for Adams Stream, Edmonds Stream, Thompson Stream, Tributary-R, and Wharekirauponga Stream (upstream site WKP2). eDNA data were not available for Teawaotemutu Stream and Wharekirauponga Stream (downstream site WKP1). Species found in the sampled streams as detailed in Boffa Miskell (2023) and confirmed by eDNA are shown in Table 3-3 in black font. Those in red font were assumed from adjacent sampled sites. Sites downstream of the Wharekirauponga waterfall between sites Teawaotemutu Stream East and WKP2 were assumed to have the same species as sampled sites downstream of the waterfall and those streams upstream of the waterfall were assumed to have the same species as those streams sampled upstream of the waterfall (unless eDNA data showed otherwise).

Table 3-3: The species used for each stream in the analysis of the effect of modelled flow reductions on instream biota. Black font indicates species found in the stream and red font indicates species assumed to be found in unsampled streams (see text above about the assumptions).

Biota	Adams	Edmonds	T-Stream East	Thompson	Trib-R	WKP1	WKP2
Periphyton							
Thin films	y	y	y	y	y	y	y
Diatoms	y	y	y	y	y	y	y
Short filamentous algae	y			y	y	y	y
Long filamentous algae	y			y	y	y	y
Phormidium/Microcoleus	y	y	y	y	y	y	y
Macroinvertebrates							
Pycnocentrodes (stony-cased caddis)	y	y	y	y	y	y	y
Hydrobiosidae (caddisfly)	y	y		y	y	y	y
Aoteapsyche (caddisfly		y		y		y	y
O. feredayi (caddisfly)		y			y	y	y
C. humeralis (mayfly)	y	y		y	y	y	y
Nesameletus (mayfly)		y			y	y	y
Deleatidium (mayfly)	y	y	y	y	y	y	y
Maoridiamesa (flies)	y	y		y	y	y	y
Elmidae (beetles)	y	y	y	y	y	y	y
Orthocladiinae (midges)	y	y	y	y	y	y	y
Potamopyrgus (snails)	y	y	y	y		y	y
Zelandoperla (stonefly)	y	y	y	y	y	y	y
Food Producing Invertebrates	y	y	y	y	y	y	y
Fish							
Shortfin eel >300 mm	y	y	y	y	y	y	Y
Shortfin eel <300 mm	y	y	y	y	y	y	y
Longfin eel >300 mm	y	y	y	y	y	y	y
Longfin eel <300 mm	y	y	y	y	y	y	y
Torrentfish	y			y		y	y
Redfin bully	y			y	y	y	y
Banded kōkopu juvenile	y	y	y	y	y	y	y
Banded kōkopu adult	y	y	y	y	y	y	y
Shortjaw Kōkopu		y	y			y	y
Kōaro		y	y			y	y

3.5 Data analysis

Survey data were collected following the procedures in Appendix B, then processed following the procedures in Appendix C to generate cross-section files of depth, velocity, and substrate. Habitat centreline surveys were used to calculate cross-section weightings (Appendix C).

The prepared data were loaded into SEFA and were checked using the internal tools (tables and cross-section plots) of SEFA. The stage (water-level) to discharge ratings were inspected and the most appropriate rating curve chosen for each section.

Habitat suitability curves (HSC) were loaded into the library file used by SEFA, for all species noted by Boffa Miskell (2023) and in the eDNA samples for which HSC were available. HSC were not available for every macroinvertebrate species noted by Boffa Miskell, but there were HSC for all invertebrate types (beetles, snails, etc.) and these were used where there was no specific HSC for a species. For the analysis of each study reach, only the species/types noted by Boffa Miskell or shown to contain eDNA as being present were loaded from the library file for the analysis of the effects of flow reduction in that study reach.

Plots of Area Weighted Suitability (AWS) vs flow were created for each study reach, and for each group of biota (periphyton, macroinvertebrates and fish). Only water depth, velocity and substrate were used to determine AWS. The flow range used was from zero flow to approximately median flow. It was assumed that the most critical flow is the 7-day mean annual low flow (7-day MALF). Each plot was annotated with the pre-mining 7-day MALF and the post-mining 7-day MALF. Two different cases were provided for the post-mining 7-day MALF (GHD 2024): (1) The average case (most likely), (2) The worst case 5th percentile of flow (highly unlikely). This enables assessment of the effect of post-mining flow reduction scenarios on the species or classes of biota observed to be present in each study reach.

The AWS plots also show the pre-mining median flow (i.e., flow exceeded 50% of the time), and the post-mining median flow scenarios (average and worst cases). The median flow is more representative of the streams average annual conditions than the 7-day MALF and needs to be taken into account when considering the average impact of flow reductions from the proposed underground mine.

Data tables were also included showing the percentage of total instream habitat suitable for different species or classes of biota at pre-mining and post-mining flows. The difference between suitable instream habitat from pre-mining to post-mining was then used to assess percentage changes in suitable instream habitat that can be expected for the post-mining flow scenarios.

The impact on suitable instream habitat was typically largest around the 7-day MALF compared to the median flow. To assist with minimum flow setting and assessment of average impacts of flow reductions on periphyton, macroinvertebrates and fish, additional figures and tables were provided in 'Instream habitat at low flows' sections of the results for each of the study reaches. These provide percentage changes in suitable instream habitat as a function of flow, relative to the pre-mining 7-day MALF. Data tables were also provided, showing the post-mining 7-day MALF flows that would cause changes in suitable instream habitat between 0% and -20%, at increments of -2.5%. Although the post-mining worst case flows typically result in changes to suitable instream habitat in the range of 0% to -5%, this additional data provides an extended analysis of impacts if flow reductions were larger. Data are provided as average impacts on instream habitat for each group of instream biota (i.e., periphyton, macroinvertebrates and fish), with percentage change being calculated from total group AWS (i.e., sum of AWS for all the species/classes within a group) at a post-mining 7-day MALF, compared to the total AWS for that group at the pre-mining 7-day MALF.

Limitations and assumptions

For some species, the HSC used were generic for that class of biota and may not fully reflect the habitat requirements of the particular species found in the streams.

The AWS curves for each species indicate the maximum amount of physical habitat suitable for that species, but it may not be fully used because of the limitations imposed by the flow regime (e.g., floods), fish passage (blockage by waterfalls), or light (shading limiting periphyton growth).

The velocity criteria for HSC for thin films, diatoms, and short filamentous were modified from the original NIWA unpublished data which was obtained from large oligotrophic streams/rivers, based on observations of periphyton cover and velocity measurements made in the study reaches (see Section 3.4). The modifications allowed lower velocity areas to have a higher suitability for periphyton than the HSC in the SEFA library. This matches observations in the study reaches; however, a detailed measurement campaign to derive better HSC curves for periphyton in a wider range of stream/river types would make future IFIM studies more robust.

There were insufficient calibration gaugings at high flows to accurately determine the shape of the top of the stage to discharge rating curve in some of the study reaches. However, this was a known limitation given the focus of the survey on low flows. Calibration gaugings were lower than the median flow which was more important for defensibly defining the rating curve in the critical range of the 7-day MALF.

4 Results

4.1 Adams Stream

4.1.1 Habitat mapping surveys

Habitat mapping surveys were conducted in Adams Stream following the methods in Appendix B. The results of these surveys are summarised in Table 4-1, with histograms of pool, riffle, and run lengths in Appendix G. Habitat proportions in Adams Stream were then used in SEFA as input weightings for the cross-section surveys and thus output calculations of suitable area for instream taxa.

Table 4-1: Summary of habitat surveys in Adams Stream.

	Number of Habitat Sections	Average Habitat Length (m)	Cumulative Length of Habitat (m)	Percentage of Survey Reach (%)
Pools	19	3.6	69	24.91
Riffles	37	3.4	127	45.85
Runs	21	3.9	81	29.24
Total	77	3.6	277	100

4.1.2 Area weighted suitability for periphyton (for species present)

Figure 4-1 shows the Area Weighted Suitability (AWS) for periphyton for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore all periphyton response curves must be within this model boundary. The other curves indicate the suitable habitat for various periphyton classes. The blue vertical lines show pre-mining and post-mining flows, including the most likely post-mining flow [Average] and the worst-case scenario [Worst] (GHD 2024; Section 3.2).

Adams Stream was most suitable for long filamentous algae and *Phormidium/Microcoleus* (Figure 4-1), with 82.89% and 61.70% of available habitat being suitable at the 7-day MALF (Table 4-2). Long filamentous algae AWS increases rapidly with flow up to 3 L/s, then increases more gradually, and reaches a peak near the 7-day MALF, before gradually declining until at median flow AWS is 76.73% of total AWS. *Phormidium/Microcoleus* AWS also increases rapidly as flow increased to 3 L/s, then AWS increases almost linearly up to the median flow where AWS is 63.87% of total AWS (Table 4-2). Adams Stream was less suitable for thin films and diatoms, with only 41.41% and 21.98% of available instream habitat being suitable at the 7-day MALF (Table 4-2). There was limited suitable habitat for short filamentous algae in Adams Stream with AWS of only 5.32% at the 7-day MALF.

The reductions in AWS between the pre-mining 7-day MALF and the most likely post-mining 7-day MALF (average case) are -0.11% for long filamentous algae, -0.46% for *Phormidium/Microcoleus*, -1.47% for thin films, and -2.28% for diatoms (Table 4-3). For the worst-case post-mining 7-day MALF the reductions in AWS are -0.21% for long filamentous algae, -0.76% for *Phormidium/Microcoleus*, -2.39% for thin films, and -3.69% for diatoms (Table 4-3). The largest impact on instream habitat was for short filamentous algae (Table 4-3); however, the stream was not very suitable for short filamentous algae to begin with (Table 4-2).

The AWS curves in the vicinity of the median flow are flatter than at the 7-day MALF, so flow reductions near the median flow have less effect on suitable instream habitat for periphyton. The worst case post-mining median flow results in changes to suitable instream habitat between +0.24% for long filamentous algae and -2.02% for diatoms (Table 4-3).

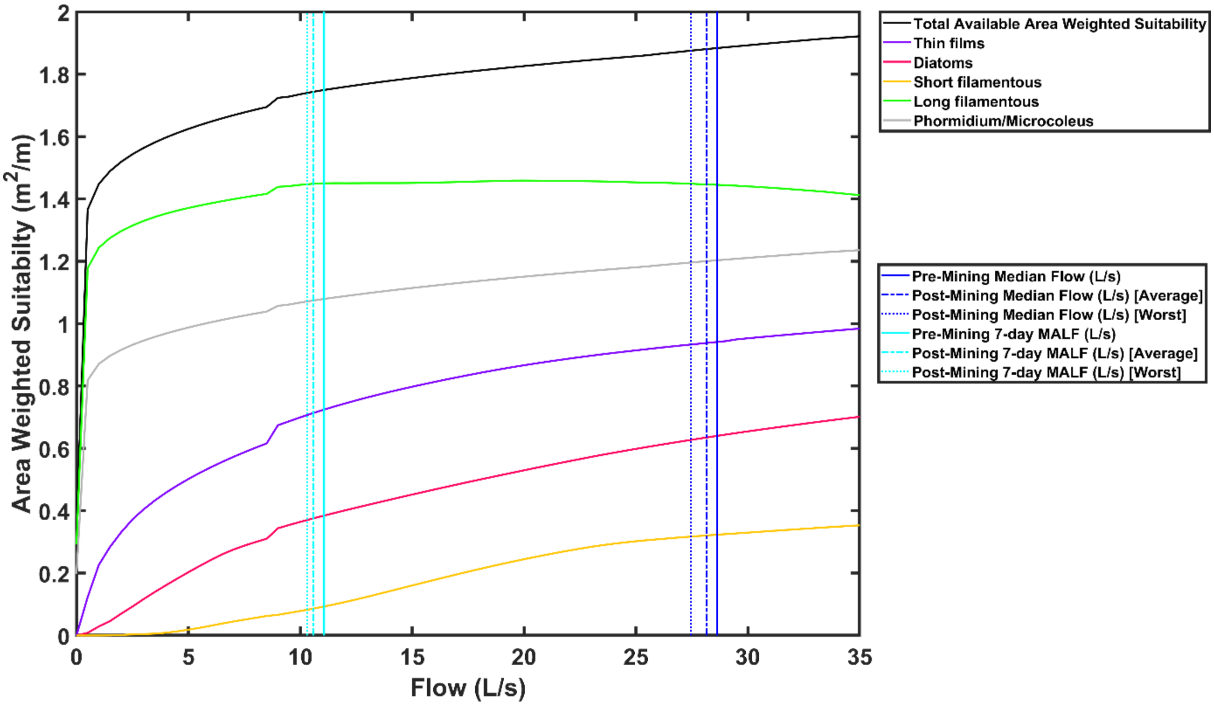

Figure 4-1: Area Weighted Suitability for periphyton in Adams Stream.

Table 4-2: Percentage of total available AWS suitable for periphyton in Adams Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	49.97	49.88	49.75	41.41	40.93	40.63
Diatoms	33.98	33.77	33.44	21.98	21.55	21.29
Short filamentous	17.16	17.06	16.91	5.32	4.95	4.75
Long filamentous	76.73	76.93	77.24	82.89	83.07	83.17
Phormidium/Microcoleus	63.87	63.84	63.78	61.70	61.61	61.56

Table 4-3: Percentage change of AWS for periphyton in Adams Stream.

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	-0.35	-0.88	-1.47	-2.39
Diatoms	-0.80	-2.02	-2.28	-3.69
Short filamentous	-0.76	-1.91	-7.16	-11.24
Long filamentous	0.09	0.24	-0.11	-0.21

Phormidium/Microcoleus	-0.23	-0.58	-0.46	-0.76

4.1.3 Area weighted suitability for invertebrates (for species present)

Figure 4-2 and Figure 4-3 shows the AWS for macroinvertebrates for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore all invertebrate response curves must be within this model boundary. The other curves indicate the suitable habitat for various macroinvertebrates.

In Adams Stream there were less caddisfly and mayfly taxa present than in the Wharekirauponga Stream and some of the other tributaries (Section 3.4). This is also reflected by the limited suitable habitat for the caddisfly and mayfly taxa that were present (Figure 4-2). Adams Stream was most suitable for *Deleatidium*, with the AWS curve rising very rapidly from zero flow, then rising gradually through the 7-day MALF to beyond the median flow. At the 7-day MALF, *Deleatidium* AWS is 22.51% of the total available AWS at that flow (Table 4-4). The AWS curves for the caddisflies *Pycnocentrodes* and Hydrobiosidae gradually increase from zero flow, then rise almost linearly from the 7-day MALF to the median flow (Figure 4-2). At the 7-day MALF their AWS are 7.26% and 7.41%, respectively, of the total available AWS at that flow.

The reductions in AWS between the pre-mining 7-day MALF and worst-case post-mining 7-day MALF are -1.42% for *Deleatidium*, -5.74% for *Pycnocentrodes* and -3.82% for Hydrobiosidae (Table 4-5). There is less impact on suitable instream habitat for the most likely reduction in 7-day MALF (average case), with changes of -0.88% for *Deleatidium*, -3.56% for *Pycnocentrodes* and -2.35% for Hydrobiosidae (Table 4-5).

The AWS curves are flatter in the vicinity of the median flow, so the post-mining median flow scenarios have a smaller impact on suitable instream habitat. The worst-case post-mining median flow results in reductions of suitable instream habitat of -1.07% for *Deleatidium*, -2.75% for *Pycnocentrodes* and -1.64% Hydrobiosidae (Table 4-5).

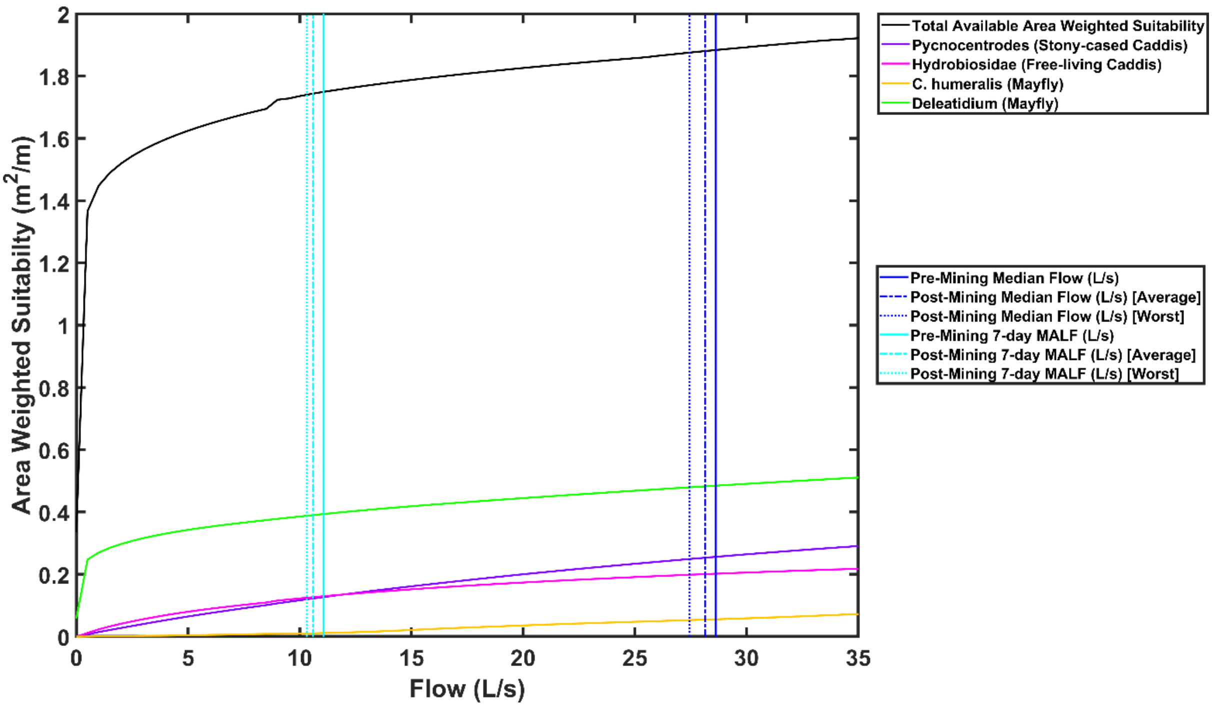

Figure 4-2: Area weighted suitability for caddisflies and mayflies in Adams Stream.

The AWS curves for Elmidae and *Potamopyrgus* (Figure 4-3) increase rapidly from 0 to 3 L/s then are relatively flat to beyond median flow. Elmidae have the highest AWS at the 7-day MALF, with 55.44% of the total available instream habitat being suitable (Table 4-4). AWS for Orthocladiinae rises slowly from zero flow to beyond the median flow and at the 7-day MALF AWS is 13.50% of the total available (Table 4-4). The AWS curves for Elmidae and *Potamopyrgus* in the vicinity of the 7-day MALF and the median flow are very flat, so any flow losses dues to mining would have limited impact on these invertebrates. Figure 4-3 shows that Adams Stream is not very suitable for *Zelandoperla,* Maoridiamesa, and food producing invertebrates.

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -0.35% for Elmidae, -1.18% for *Potamopyrgus*, and -4.57% for Orthocladiinae (Table 4-5). For the most likely post-mining 7-day MALF (average case) the reductions in AWS are -0.20% for Elmidae, -0.72% for *Potamopyrgus*, and -2.82% for Orthocladiinae (Table 4-5).

Flow reductions near the median flow cause negligible changes to instream habitat for Elmidae and *Potamopyrgus* due to the flat slope of their AWS curves in the vicinity of the median flow. The largest impact is on Orthocladiinae with the worst-case post-mining median flow causing a decrease in suitable instream habitat of -2.08% (Table 4-5).

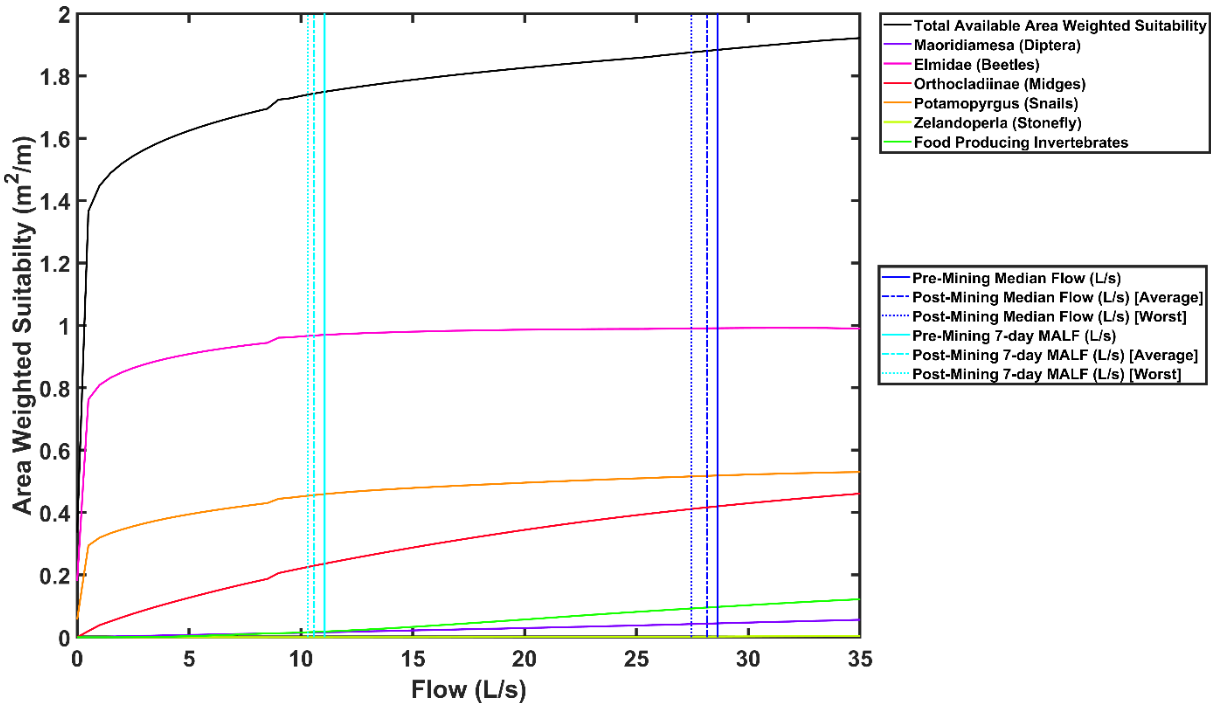

Figure 4-3: Area weighted suitability for other invertebrates in Adams Stream.

Table 4-4: Percentage of total available AWS suitable for invertebrates in Adams Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	13.60	13.48	13.29	7.26	7.03	6.88
Hydrobiosidae (Free-living Caddis)	10.72	10.67	10.59	7.41	7.26	7.17
***C. humeralis* (Mayfly)**	2.95	2.90	2.83	0.66	0.62	0.60
***Deleatidium* (Mayfly)**	25.73	25.67	25.57	22.51	22.38	22.31
Maoridiamesa (Diptera)	2.37	2.32	2.26	0.91	0.87	0.85
Elmidae (Beetles)	52.62	52.70	52.81	55.44	55.50	55.54
Orthocladiinae (Midges)	22.29	22.15	21.93	13.50	13.16	12.95
***Potamopyrgus* (Snails)**	27.53	27.52	27.50	26.25	26.15	26.08
***Zelandoperla* (Stonefly)**	0.12	0.12	0.11	0.01	0.01	0.01
Food Producing Invertebrates	5.16	5.07	4.92	1.05	0.98	0.93

Table 4-5: Percentage change of AWS for invertebrates in Adams Stream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]

***Pycnocentrodes* (Stony-cased Caddis)**	-1.10	-2.75	-3.56	-5.74
Hydrobiosidae (Free-living Caddis)	-0.65	-1.64	-2.35	-3.82
***Deleatidium* (Mayfly)**	-0.43	-1.07	-0.88	-1.42
Elmidae (Beetles)	-0.02	-0.07	-0.20	-0.35
Orthocladiinae (Midges)	-0.82	-2.08	-2.82	-4.57
***Potamopyrgus* (Snails)**	-0.22	-0.56	-0.72	-1.18

4.1.4 Area weighted suitability for fish (for species present)

Figure 4-4 and Figure 4-5 show the AWS for fish for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all response curves must be within this model boundary.

Suitable habitat for small shortfin and longfin eels (<300 mm long) initially rises sharply to around the 7-day MALF and then increases more slowly until beyond the median flow (Figure 4-4). At the 7-day MALF their AWS are 42.92% and 21.20% of total AWS (Table 4-6). AWS for large shortfin and longfin eels (>300 mm long) initially rises moderately steeply to about 5 L/s and then continues to rise more slowly to beyond the median flow. At the 7-day MALF their AWS are 16.46% and 9.87% of total AWS so smaller eels of both species have more suitable instream habitat than larger eels (Table 4-6).

The reductions in AWS between the pre-mining 7-day MALF and the unlikely post-mining 7-day MALF worst case are -2.57% for small shortfin eels (<300 mm), -2.81% for small longfin eels, -2.03% for large shortfin eels (>300 mm), and -2.61% for large longfin eels (Table 4-7). The most likely post-mining 7-day MALF average case causes reductions of suitable instream habitat between -1.25% and -1.74% (Table 4-7). All species/classes have relatively flat AWS curves in the vicinity of the median flow (more representative of average annual flows) so reductions in flow would have less impact on suitable instream habitat around the median flow. Changes to suitable instream habitat are between -0.59% and -1.32% for the unlikely worst case post-mining median flow, and between -0.23% and -0.52% for the most likely average case post-mining median flow (Table 4-7).

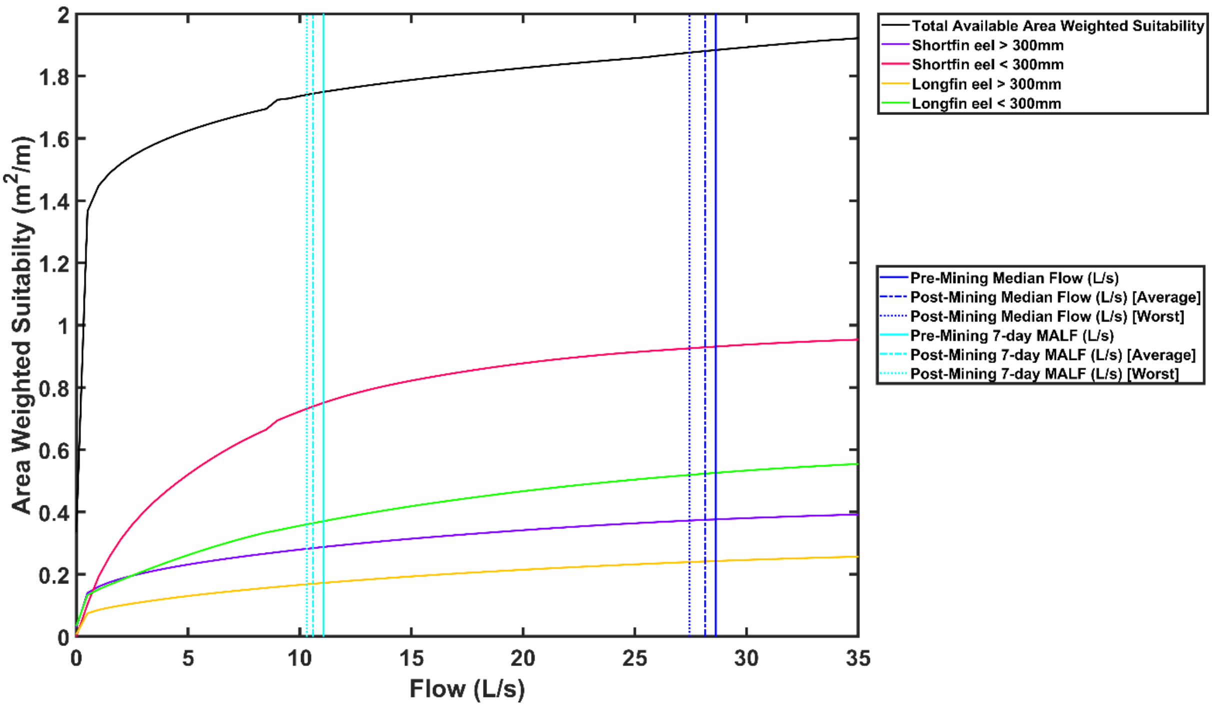

Figure 4-4: Area weighted suitability for eels in Adams Stream.

AWS for banded kōkopu juveniles and adults rises very steeply between 0 and 4 L/s, then flattens off and peaks near the 7-day MALF (Figure 4-5), which provides 46.48% and 39.16% of total AWS respectively at that flow (Table 4-6). From there AWS declines slowly to beyond the median flow. Suitable habitat for redfin bully initially rises sharply, then rises more gradually to the 7-day MALF where it provides 41.94% of the total available AWS (Table 4-6). From the 7-day MALF, AWS for redfin bully increases more slowly until beyond the median flow and peaks at 45.5 L/s. There is very little suitable instream habitat for torrentfish at any flow (Figure 4-5, Table 4-6).

The AWS curves for banded kokopu and redfin bully are relatively flat near the 7-day MALF (Figure 4-5). The post-mining 7-day MALF scenarios are in this relatively flat portion of the curves indicating that there is a relatively low reduction in suitable instream habitat even in the worst case. For the unlikely worst case post-mining 7-day MALF, suitable instream habitat increases for kōkopu juveniles and adults, with changes to AWS of +0.47%, and +0.76% (Table 4-7). Suitable instream habitat for redfin bully decreases by -1.90% for the worst-case post-mining 7-day MALF (Table 4-7). The most likely (average case) post-mining 7-day MALF causes less impact on suitable instream habitat for redfin bully, with a decrease of -1.16% (Table 4-7). AWS curves in the vicinity of the median flow are very flat (Figure 4-23) so small reductions in flow would not have a substantial impact on instream habitat around average annual flows. For example, changes in suitable instream habitat for the worst case post-mining median flow are -0.63%, +0.35%, and +1.01%, for redfin bully, banded kōkopu juveniles and adults (Table 4-7).

In summary, a small reduction in post-mining flows could provide slightly more suitable instream habitat for banded kōkopu but would reduce suitable habitat for eels and redfin bully. The stream is not suitable for torrentfish. The AWS curves for all species are relatively flat around the median flow and for most species AWS curves are also relatively flat around the 7-day MALF, so the post-mining flow would have to be substantially reduced before the overall suitable habitat for eels and other fish species was substantially affected. The largest impact from post-mining flow scenarios is on small longfin eels (<300 mm), with changes to suitable instream habitat of -2.81% for the unlikely worst case post-mining 7-day MALF, and -1.74% for the most likely (average case) post-mining 7-day MALF (Table 4-7).

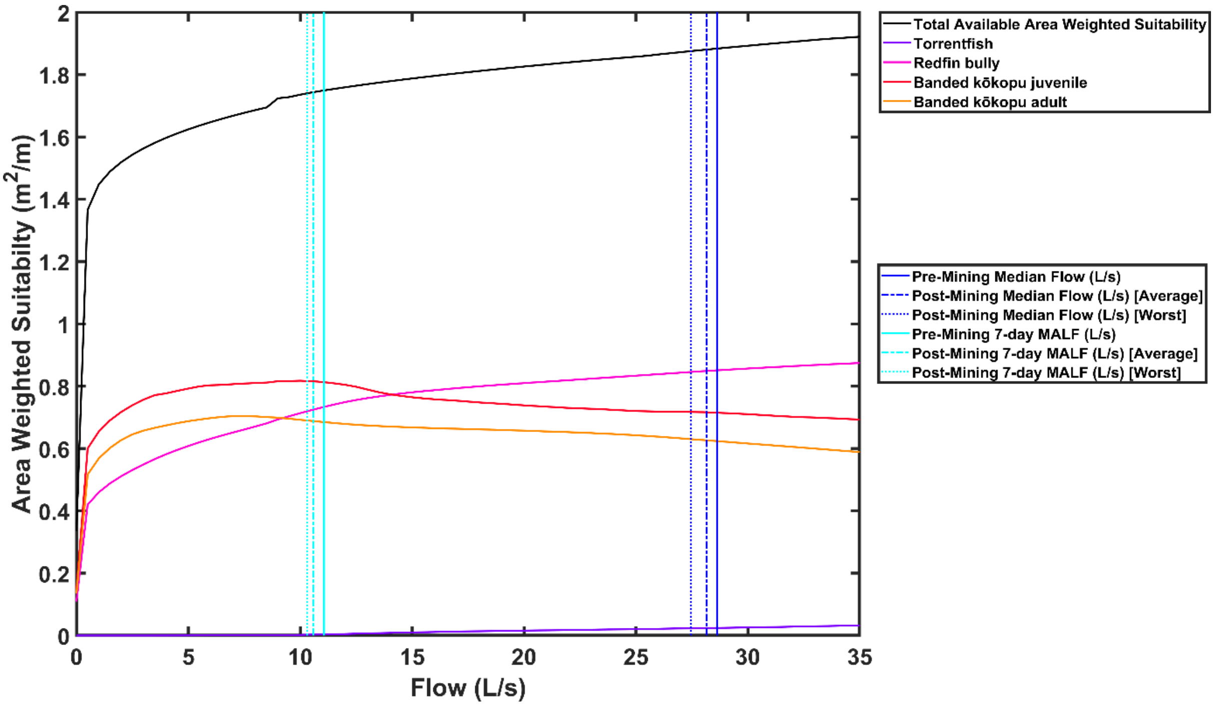

Figure 4-5: Area weighted suitability for native fish in Adams Stream.

Table 4-6: Percentage of total available AWS suitable for fish in Adams Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	19.99	19.94	19.88	16.46	16.30	16.21
Shortfin eel <300 mm	49.44	49.41	49.37	42.92	42.39	42.05
Longfin eel >300 mm	12.89	12.84	12.77	9.87	9.74	9.66
Longfin eel <300 mm	27.93	27.84	27.70	21.20	20.90	20.72
Torrentfish	1.30	1.27	1.24	0.20	0.17	0.15
Redfin bully	45.18	45.16	45.10	41.94	41.59	41.37
Banded kōkopu juvenile	37.96	38.10	38.26	46.48	46.79	46.95
Banded kōkopu adult	33.13	33.32	33.61	39.16	39.46	39.67

Table 4-7: Percentage change of AWS for fish in Adams Stream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	-0.39	-0.99	-1.25	-2.03
Shortfin eel <300 mm	-0.23	-0.59	-1.56	-2.57
Longfin eel >300 mm	-0.52	-1.32	-1.60	-2.61
Longfin eel <300 mm	-0.50	-1.27	-1.74	-2.81
Redfin bully	-0.24	-0.63	-1.16	-1.90
Banded kōkopu juvenile	0.19	0.35	0.35	0.47
Banded kōkopu adult	0.41	1.01	0.46	0.76

4.1.5 Instream habitat at low flows

Flow changes have the largest impact on suitable instream habitat at low flows. Previous sections have shown the impacts on instream habitat for species and classes of biota present in Adams Stream for the most likely post-mining 7-day MALF (average case) and the unlikely post-mining 7-day MALF (worst case). Setting minimum post-mining flows requires a subjective assessment of the allowable reduction of instream habitat for different groups of instream biota (Section 3.5). To assist with this assessment Figure 4-6 provides percentage reductions of suitable instream habitat for periphyton, invertebrates and fish in Adams Stream for flows less than the pre-mining 7-day MALF. Table 4-8 provides post-mining 7-day MALF flows that correspond to percentage reductions of suitable instream habitat between 0% and -20%.

The largest impact on suitable instream habitat in Adams Stream is for invertebrates (Figure 4-6). To keep impacts on suitable instream habitat within -5% for all groups of biota a post-mining 7-day MALF of 8.98 L/s would need to be maintained (Table 4-8). To keep impacts on suitable instream habitat within -10% for all groups of biota a post-mining 7-day MALF of 7.65 L/s would need to be maintained (Table 4-8). The most likely post-mining 7-day MALF (average case) of 10.59 L/s results in small changes to suitable instream habitat and keeps impacts within -1.09% for all groups of biota (Figure 4-6). The unlikely post-mining 7-day MALF (worst case) of 10.31 L/s also results in small changes to suitable instream habitat and keeps impacts within -1.77% for all groups of biota (Figure 4-6).

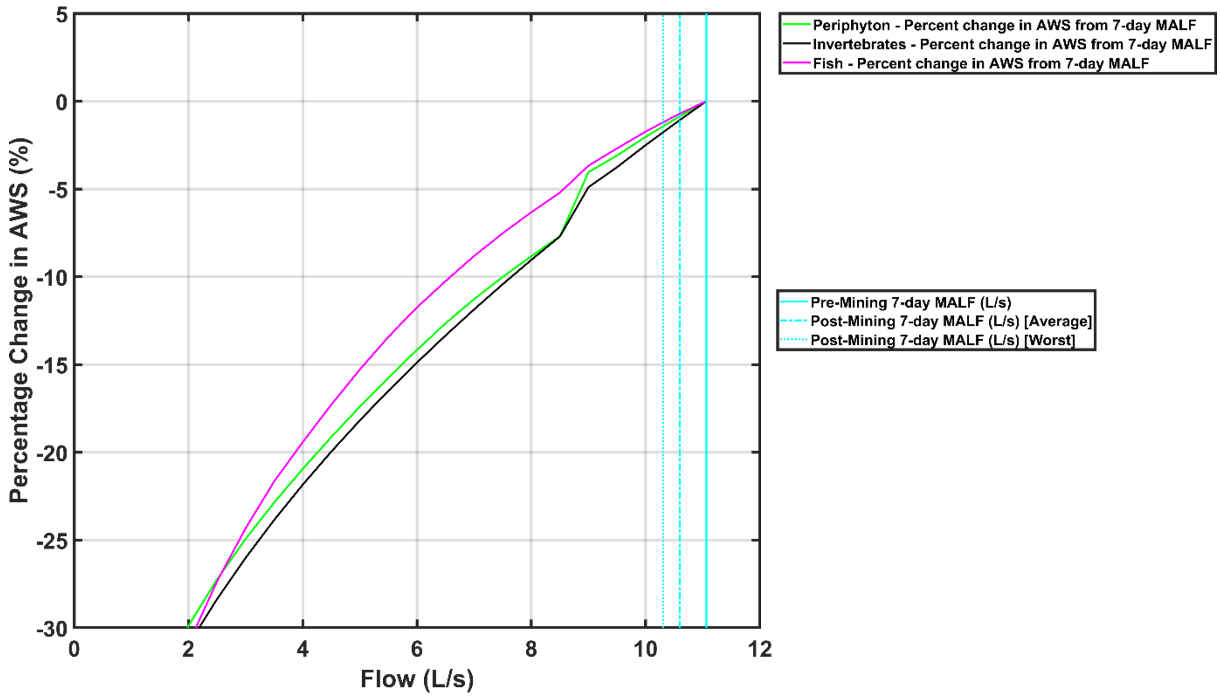

Figure 4-6: Percentage changes in Area Weighted Suitability for flows less than the pre-mining 7-day MALF for periphyton, invertebrates, and fish in Adams Stream.

Table 4-8: Percentage changes in AWS between 0% and -20% relative to pre-mining 7-day MALF and their corresponding flows for periphyton, invertebrates, and fish in Adams Stream.

Percentage Change in AWS From Pre-Mining 7-day MALF	Periphyton Flow (L/s)	Invertebrate Flow (L/s)	Fish Flow (L/s)
0%	11.06	11.06	11.06
-2.5%	9.78	10.00	9.60
-5%	8.87	8.98	8.57
-7.5%	8.53	8.54	7.51
-10%	7.51	7.65	6.59
-12.5%	6.56	6.78	5.77
-15%	5.74	5.96	5.08
-17.5%	4.97	5.20	4.45
-20%	4.26	4.49	3.87

4.2 Edmonds Stream

4.2.1 Habitat mapping surveys

Habitat mapping surveys were conducted in Edmonds Stream following the methods in Appendix B. The results of these surveys are summarised in Table 4-9, with histograms of pool, riffle, and run lengths in Appendix H. Habitat proportions in Edmonds Stream were then used in SEFA as input weightings for the cross-section surveys and thus output calculations of suitable area for instream taxa.

Table 4-9: Summary of habitat surveys in Edmonds Stream.

	Number of Habitat Sections	Average Habitat Length (m)	Cumulative Length of Habitat (m)	Percentage of Survey Reach (%)
Pools	16	7.9	127	24.24
Riffles	38	5.5	208.5	39.79
Runs	29	6.5	188.5	35.97
Total	83	6.31	524	100

4.2.2 Area weighted suitability for periphyton (for species present)

Figure 4-7 shows the AWS for periphyton for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore all periphyton response curves must be within this model boundary. The other curves indicate the suitable habitat for various periphyton classes. The top black curve is the total available habitat for the reach studied for a given flow, therefore all periphyton response curves must be within this model boundary. The other curves indicate the suitable habitat for various periphyton classes. The blue vertical lines show pre-mining and post-mining flows, including the most likely post-mining flow [Average] and the worst case scenario [Worst] (GHD 2024; Section 3.2).

AWS rises sharply between 0 and 10 L/s for all classes (Figure 4-7), then increases more gradually between the 7-day MALF and the median flow. Long filamentous and short filamentous taxa were not found to be present in this stream (Section 3.4). At the 7-day MALF, the percentages of AWS that are suitable for each class are 39.29% for thin films, 20.19% for diatoms, and 67.68% for *Phormidium/Microcoleus* (Table 4-10).

The reductions in AWS between the pre-mining 7-day MALF and the most likely post-mining 7-day MALF (average case) are -3.85% for thin films, -7.84% for diatoms and -1.57% for *Phormidium/Microcoleus* (Table 4-11). For the worst-case post-mining 7-day MALF the reductions in AWS are -5.43% for thin films, -10.89% for diatoms and -2.19% for *Phormidium/Microcoleus* (Table 4-11).

The AWS curves in the vicinity of the median flow are flatter than at the 7-day MALF and flow reductions have less effect on periphyton instream habitat. The worst-case post-mining median flow results in decreases of AWS of -1.86% for thin films, -2.14% for diatoms and -1.38% for *Phormidium/Microcoleus* compared to the pre-mining median flow (Table 4-11).

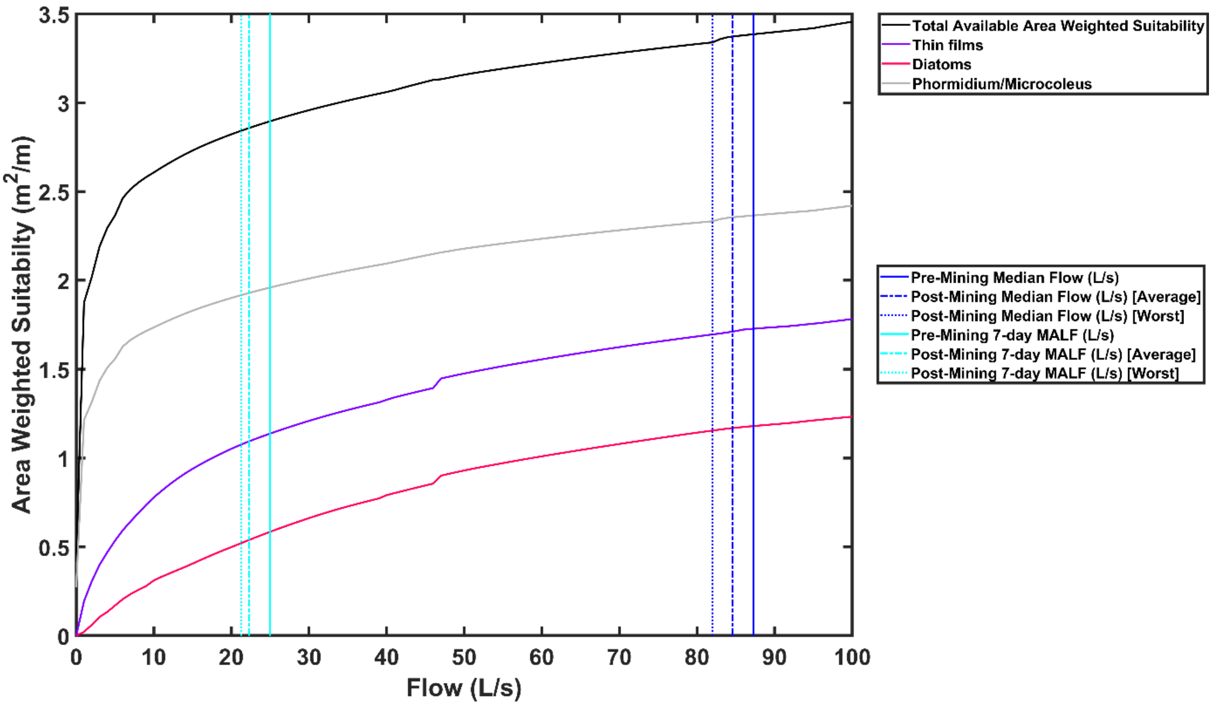

Figure 4-7: Area weighted suitability for periphyton in Edmonds Stream.

Table 4-10: Percentage of total available AWS suitable for periphyton in Edmonds Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	51.04	50.76	50.77	39.29	38.28	37.85
Diatoms	34.86	34.65	34.58	20.19	18.85	18.33
Phormidium/Microcoleus	69.87	69.83	69.85	67.68	67.51	67.44

Table 4-11: Percentage change of AWS for periphyton in Edmonds Stream.

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	-0.94	-1.86	-3.85	-5.43
Diatoms	-0.97	-2.14	-7.84	-10.89
Phormidium/Microcoleus	-0.45	-1.38	-1.57	-2.19

4.2.3 Area weighted suitability for invertebrates (for species present)

Figure 4-8 and Figure 4-9 shows the AWS for macroinvertebrates for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore all invertebrate response curves must be within this model boundary. The other curves indicate the suitable habitat for various macroinvertebrate species and classes.

Figure 4-8 shows the AWS curves for caddisflies and mayflies. At the 7-day MALF there is virtually no suitable instream habitat for *C. humeralis* and *Aoteapsyche.* AWS for *O. feredayi* and *Deleatidium* initially rises very sharply from zero flow, then increases more gradually near the 7-day MALF and flattens off towards median flow. At the 7-day MALF, *O. feredayi* has the highest AWS at 45.35% of the maximum possible AWS. The AWS curves for *Pycnocentrodes,* Hydrobiosidae and *Nesameletus* gradually increase with flow to beyond the median flow. At the 7-day MALF, the species with the highest AWS of this group is *Nesameletus* which has an AWS of 20.51%.

The reductions in AWS between the pre-mining 7-day MALF and worst-case post-mining 7-day MALF are -2.76% for *O. feredayi*, -3.55% for *Deleatidium* and -7.12% for *Nesameletus* (Table 4-13). There is less impact on suitable instream habitat for the most likely reduction in 7-day MALF (average case), with changes of -1.97% for *O. feredayi*, -2.54% for *Deleatidium* and -5.02% for *Nesameletus* (Table 4-13).

All species have relatively flat AWS curves in the vicinity of the median flow, so the post-mining median flow scenarios have a smaller impact on suitable instream habitat. For example, the worst-case post-mining median flow results in reductions of AWS of -0.84% for *O. feredayi*, -1.52% for *Deleatidium* and -1.54% for *Nesameletus* (Table 4-13). Flows around the median are more representative of average annual conditions than the 7-day MALF, so there is small overall impact on suitable instream habitat for caddisflies and mayflies in Edmonds stream.

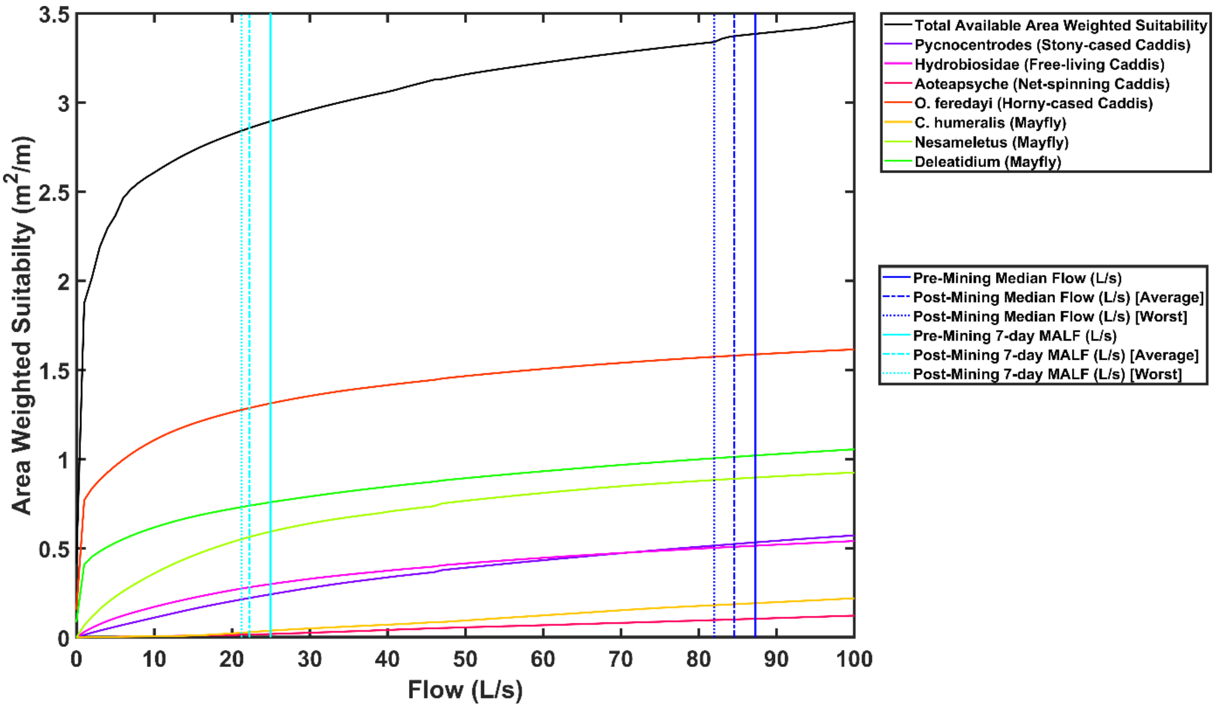

Figure 4-8: Area weighted suitability for caddisflies and mayflies in Edmonds Stream.

Figure 4-9 shows the AWS curves for the other invertebrates in the stream. The AWS curves for Elmidae and *Potamopyrgus* increase rapidly from 0 to 5 L/s, then are relatively flat from 10 L/s to beyond the median flow (Figure 4-9). At the 7-day MALF, Elmidae AWS is 57.78% of the total available. The AWS curve for Orthocladiinae rises gradually from 0 L/s to beyond the median flow. AWS for Orthocladiinae is 13.77% of the total available at the 7-day MALF. Figure 4-9 shows there is very little suitable habitat for *Zelandoperla,* Maoridiamesa, and food producing invertebrates.

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -1.18% for Elmidae, -2.14% for *Potamopyrgus* and -9.33% for Orthocladiinae (Table 4-13). Reductions in AWS for the most likely post-mining 7-day MALF (average case) are smaller (Table 4-13).

All species have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would not have a substantial impact on instream habitat around the median flow. For example, the worst-case post-mining median flow results in reductions of AWS of -0.74% for Elmidae, -0.93% for *Potamopyrgus* and -2.53% for Orthocladiinae (Table 4-13).

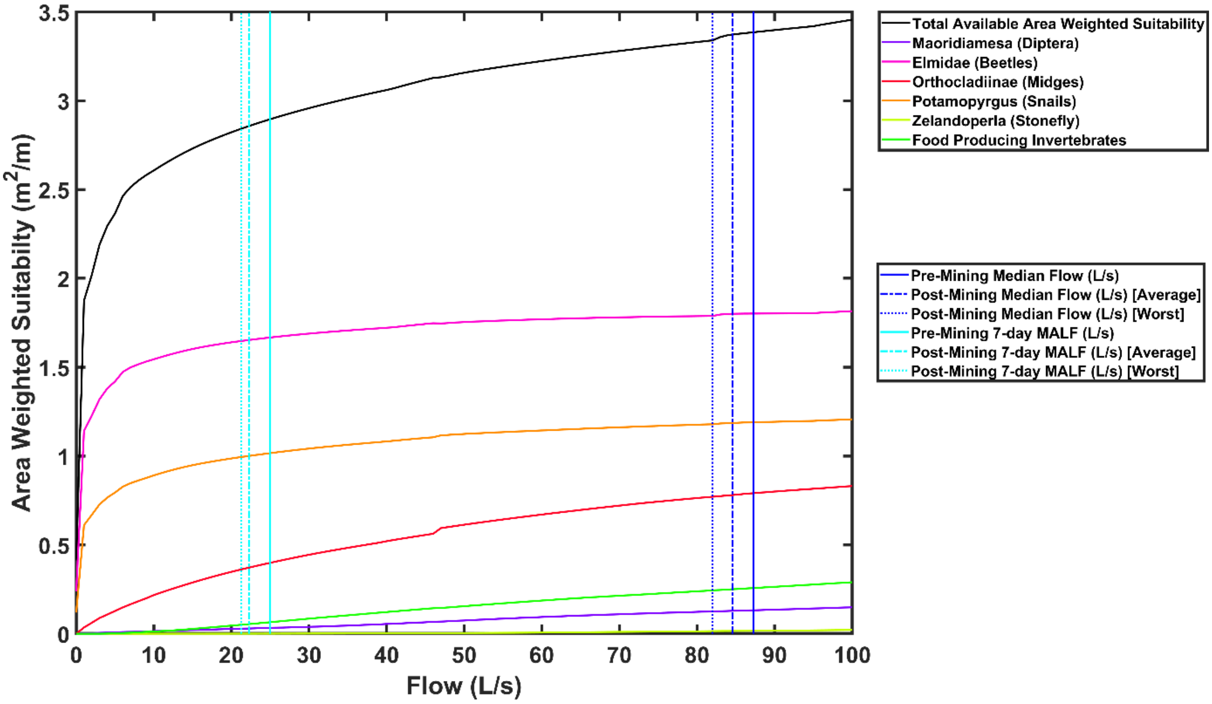

Figure 4-9: Area weighted suitability for other invertebrates in Edmonds Stream.

Table 4-12: Percentage of total available AWS suitable for invertebrates in Edmonds Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Pycnocentrodes **(Stony-cased Caddis)**	15.75	15.54	15.43	8.36	7.75	7.51
Hydrobiosidae (Free-living Caddis)	15.20	15.08	15.05	10.34	9.86	9.65
Aoteapsyche **(Net-spinning Caddis)**	3.10	3.00	2.93	0.67	0.56	0.53
O. feredayi **(Horny-cased Caddis)**	46.89	46.87	47.14	45.35	45.05	44.92
C. humeralis **(Mayfly)**	5.68	5.53	5.42	1.32	1.04	0.93

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Nesameletus* (Mayfly)**	26.50	26.39	26.44	20.51	19.74	19.40
***Deleatidium* (Mayfly)**	30.15	30.03	30.10	26.19	25.87	25.74
Maoridiamesa (Diptera)	3.89	3.81	3.76	1.13	1.03	0.99
Elmidae (Beetles)	53.22	53.40	53.55	57.58	57.86	57.97
Orthocladiinae (Midges)	23.37	23.14	23.09	13.77	13.02	12.72
***Potamopyrgus* (Snails)**	35.15	35.18	35.30	35.10	35.02	34.99
***Zelandoperla* (Stonefly)**	0.49	0.46	0.44	0.02	0.01	0.01
Food Producing Invertebrates	7.59	7.42	7.30	2.23	1.89	1.77

Table 4-13: Percentage change of AWS for invertebrates in Edmonds Stream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	-1.70	-3.34	-8.50	-11.80
Hydrobiosidae (Free-living Caddis)	-1.18	-2.32	-5.93	-8.34
***O. feredayi* (Horny-cased Caddis)**	-0.43	-0.84	-1.97	-2.76
***Nesameletus* (Mayfly)**	-0.79	-1.54	-5.02	-7.12
***Deleatidium* (Mayfly)**	-0.78	-1.52	-2.54	-3.55
Elmidae (Beetles)	-0.06	-0.74	-0.84	-1.18
Orthocladiinae (Midges)	-1.33	-2.53	-6.70	-9.33
***Potamopyrgus* (Snails)**	-0.30	-0.93	-1.54	-2.14

4.2.4 Area weighted suitability for fish (for species present)

Figure 4-10 and Figure 4-11 show the AWS for fish for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all fish response curves must be within this model boundary. The other curves indicate the suitable habitat for various fish species, size classes or life stages.

Suitable habitat for small shortfin and longfin eels (<300 mm long) initially rises sharply and then less steeply to about the 7-day MALF and then increases more slowly until beyond the median flow (Figure 4-10). At the 7-day MALF their AWS are 37.74% and 21.17% of total AWS respectively (Table 4-14). AWS for large shortfin and longfin eels (>300 mm long) initially rises steeply to about 2 L/s, then less steeply to the 7-day MALF, and then rises gradually until beyond the median flow. At the 7-day MALF their AWS are 23.59% and 20.02% of total AWS respectively (Table 4-14).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are most significant for small shortfin and longfin eels (<300 mm) with -5.21% and -6.49% respectively (Table 4-15). Reductions in AWS for the most likely post-mining 7-day MALF (average case) are less significant and are between -3.32% and -4.62% for all eel classes (Table 4-15).

All eels classes have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would not have a substantial impact on instream habitat around average annual flows. Even for the post-mining worst case scenario (unlikely) the largest impact on suitable instream habitat is only -1.59%, which is for large longfin eels >300 mm (Table 4-15).

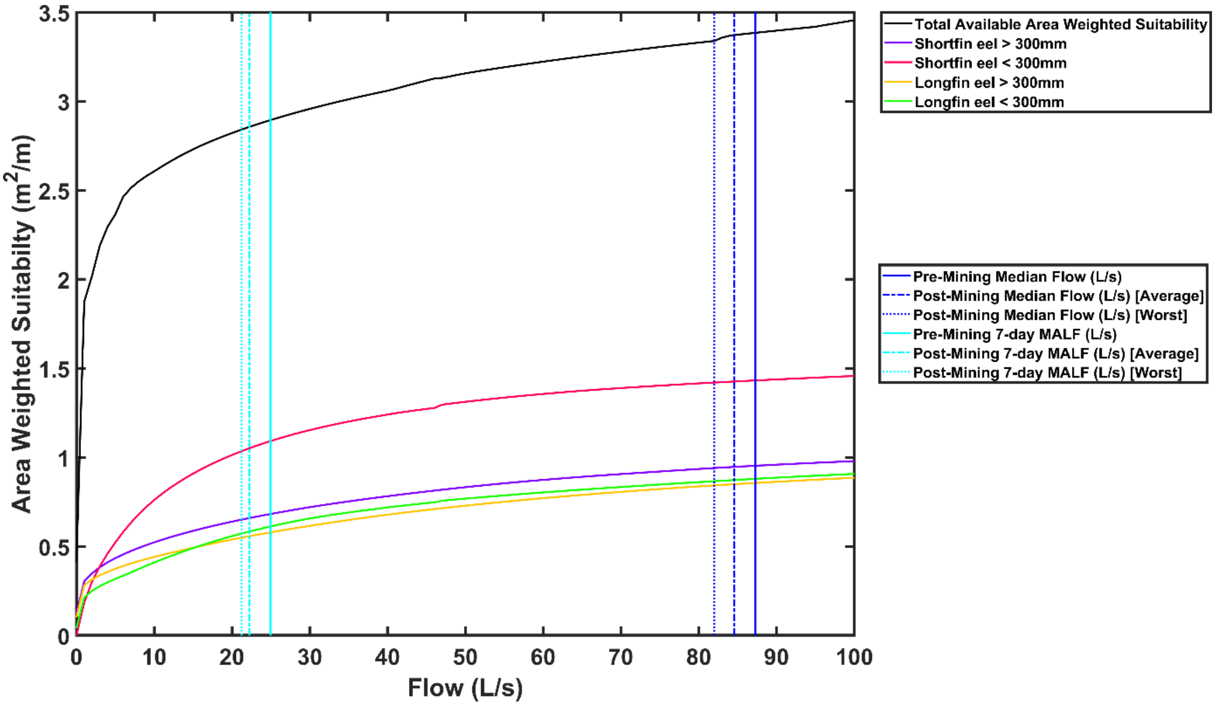

Figure 4-10: Area weighted suitability for eels in Edmonds Stream.

AWS for banded kōkopu juveniles and adults rises very steeply between 0 and 2 L/s, then rises more gradually before flattening and peaking near the 7-day MALF. At the 7-day MALF, AWS for banded kōkopu juveniles and adults is 47.79% and 47.81% of the total available (Table 4-14). From the peak AWS near the 7-day MALF there is a gradual decline to beyond the median flow. AWS for shortjaw kōkopu shows a similar trajectory, but with less suitable habitat. Edmonds Stream is not very suitable for kōaro, with AWS rising gradually and nearly linearly from zero flow to the median flow.

The AWS curves for banded kōkopu and shortjaw kōkopu are relatively flat near the 7-day MALF. The post-mining 7-day MALF flow scenarios are in this flat portion of the curves indicating only small reductions in suitable instream habitat even in the worst case. The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -0.72% for banded kōkopu juveniles, -0.97% for banded kōkopu adults, and -2.36% for shortjaw kōkopu (Table 4-15). Flow reductions near the median flow would slightly increase suitable instream habitat for these taxa (Table 4-15).

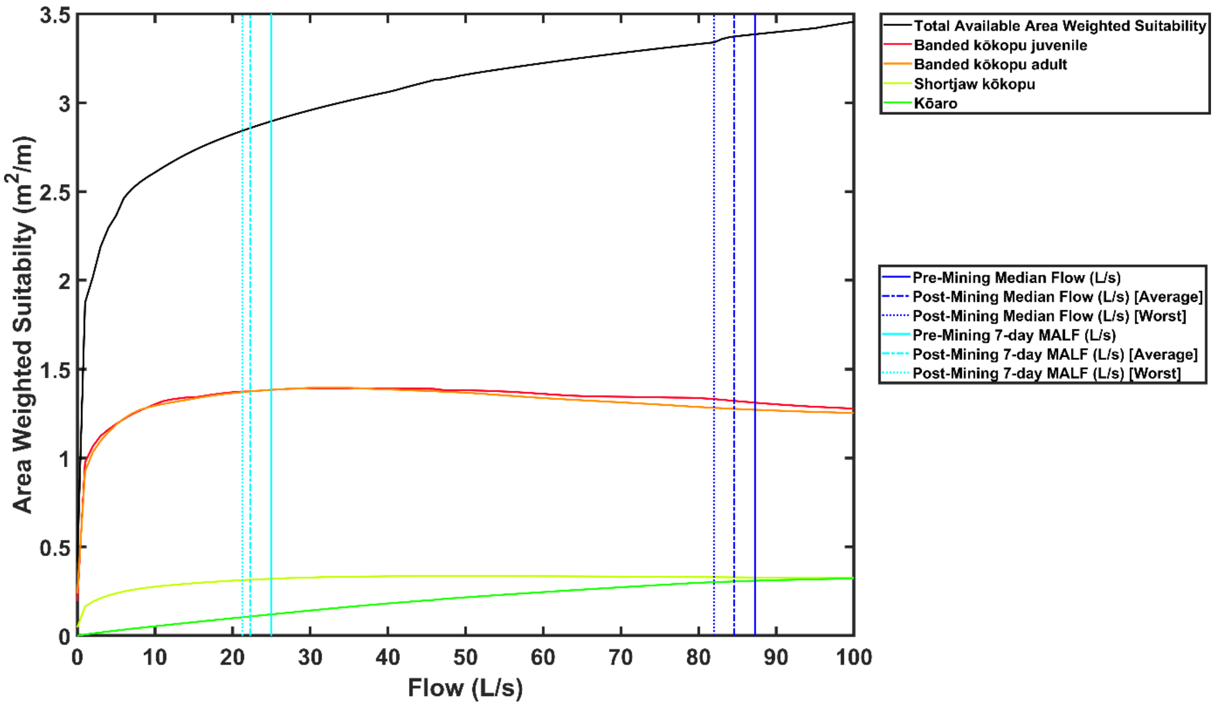

Figure 4-11: Area weighted suitability for native fish in Edmonds Stream.

Table 4-14: Percentage of total available AWS suitable for fish in Edmonds Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	28.17	28.09	28.17	23.59	23.11	22.92
Shortfin eel <300 mm	42.33	42.31	42.55	37.74	36.83	36.44
Longfin eel >300 mm	25.32	25.21	25.25	20.02	19.54	19.35
Longfin eel <300 mm	26.00	25.90	25.96	21.17	20.46	20.17
Banded kōkopu juvenile	38.74	39.19	39.88	47.79	48.15	48.34
Banded kōkopu adult	37.56	37.86	38.40	47.81	48.14	48.24
Shortjaw kōkopu	9.69	9.75	9.87	11.06	11.02	11.01
Kōaro	9.14	9.06	9.02	4.15	3.79	3.66

Table 4-15: Percentage change of AWS for fish in Edmonds Stream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	-0.67	-1.35	-3.32	-4.63
Shortfin eel <300 mm	-0.42	-0.83	-3.69	-5.21
Longfin eel >300 mm	-0.79	-1.59	-3.70	-5.15
Longfin eel <300 mm	-0.77	-1.51	-4.62	-6.49
Banded kōkopu juvenile	0.79	1.57	-0.58	-0.72
Banded kōkopu adult	0.41	0.85	-0.66	-0.97
Shortjaw kōkopu	0.20	0.40	-1.67	-2.36

4.2.5 Instream habitat at low flows

Flow changes have the largest impact on suitable instream habitat at low flows. Previous sections have shown the impacts on instream habitat for species and classes of biota present in Edmonds Stream for the most likely post-mining 7-day MALF (average case) and the unlikely post-mining 7-day MALF (worst case). Setting minimum post-mining flows requires a subjective assessment of the allowable reduction of instream habitat for different groups of instream biota (Section 3.5). To assist with this assessment Figure 4-12 provides percentage reductions of suitable instream habitat for periphyton, invertebrates and fish in Edmonds Stream for flows less than the pre-mining 7-day MALF. Table 4-16 provides post-mining 7-day MALF flows that correspond to percentage reductions of suitable instream habitat between 0% and -20%.

The largest impact on suitable instream habitat in Edmonds Stream was for periphyton (Figure 4-12). To keep impacts on suitable instream habitat within -5% for all groups of biota a post-mining 7-day MALF of 20.92 L/s would need to be maintained (Table 4-16). To keep impacts on suitable instream habitat within -10% for all groups of biota a post-mining 7-day MALF of 17.37 L/s would need to be maintained (Table 4-16). The most likely post-mining 7-day MALF (average case) of 22.26 L/s keeps impacts within -3.27% for all groups of biota (Figure 4-12). The unlikely post-mining 7-day MALF (worst case) of 21.25 L/s keeps impacts within -4.57% for all groups of biota (Figure 4-12).

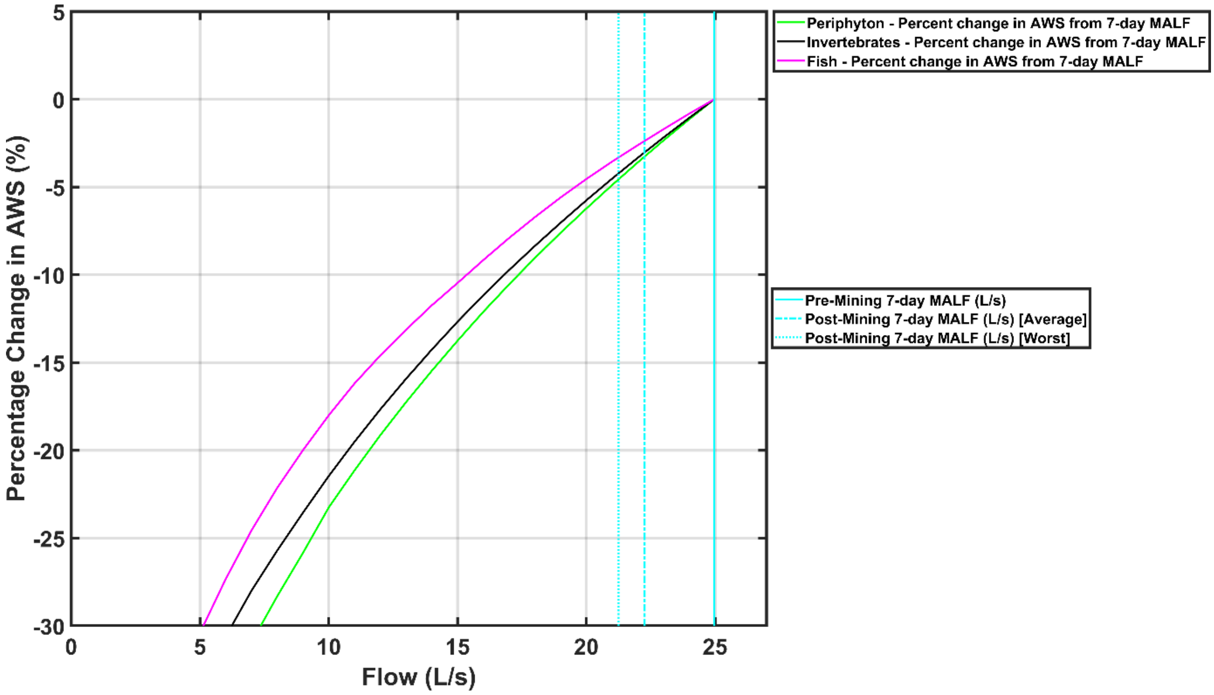

Figure 4-12: Percentage changes in Area Weighted Suitability for flows less than the pre-mining 7-day MALF for periphyton, invertebrates, and fish in Edmonds Stream.

Table 4-16: Percentage changes in AWS between 0% and -20% relative to pre-mining 7-day MALF and their corresponding flows for periphyton, invertebrates, and fish in Edmonds Stream.

Percentage Change in AWS From Pre-Mining 7-day MALF	Periphyton Flow (L/s)	Invertebrate Flow (L/s)	Fish Flow (L/s)
0%	24.97	24.97	24.97
-2.5%	22.88	22.72	22.13
-5%	20.92	20.62	19.57
-7.5%	19.08	18.65	17.34
-10%	17.37	16.81	15.36
-12.5%	15.77	15.12	13.46
-15%	14.28	13.56	11.75
-17.5%	12.87	12.10	10.28
-20%	11.57	10.75	9.00

4.3 Teawaotemutu Stream

4.3.1 Habitat mapping surveys

Habitat mapping surveys were conducted in Teawaotemutu Stream following the methods in Appendix B. The results of these surveys are summarised in Table 4-17, with histograms of pool, riffle, and run lengths in Appendix I. Habitat proportions in Teawaotemutu Stream were then used in SEFA as input weightings for the cross-section surveys and thus output calculations of suitable area for instream taxa.

Table 4-17: Summary of habitat surveys in Teawaotemutu Stream.

	Number of Habitat Sections	Average Habitat Length (m)	Cumulative Length of Habitat (m)	Percentage of Survey Reach (%)
Pools	10	8.8	88	31.48
Riffles	13	8.7	113	40.43
Runs	9	8.7	78.5	28.09
Total	32	8.73	279.5	100

4.3.2 Area weighted suitability for periphyton (for species present)

Figure 4-13 shows the AWS for periphyton for a flow up to approximately the median flow. The top curve is the total available habitat for the reach studied for a given flow, therefore, all periphyton response curves must be within this model boundary. The other curves indicate the suitable habitat for various periphyton classes. The blue vertical lines show pre-mining and post-mining flows, including the most likely post-mining flow [Average] and the worst-case scenario [Worst] (GHD 2024; Section 3.2).

The figure shows that for *Phormidium/Microcoleus,* AWS rises very sharply between 0 and 10 L/s and then increases more gradually but has still not peaked at median flow (Figure 4-13). Long filamentous and short filamentous taxa were not found in this stream (Section 3.4). AWS for thin films and diatoms rises steeply from zero flow, then rises more gradually between the 7-day MALF and median flow (Figure 4-13). At the 7-day MALF, the percentages of AWS that are suitable for each class are 53.56% for thin films, 26.93% for diatoms, and 73.56% for *Phormidium/Microcoleus* (Table 4-18). The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -4.10% for thin films, -7.42% for diatoms and -1.09% for *Phormidium/Microcoleus* (Table 4-19). For the most likely reduction in 7-day MALF (average case) changes in suitable instream habitat are between -0.41% and -3.36% (Table 4-19).

The AWS curves in the vicinity of the median flow are flatter than at the 7-day MALF, so any flow losses dues to mining would have less effect on periphyton habitat availability around the median flow. For the worst-case reduction in median flow changes in suitable instream habitat are between -0.54% and -1.62% (Table 4-19).

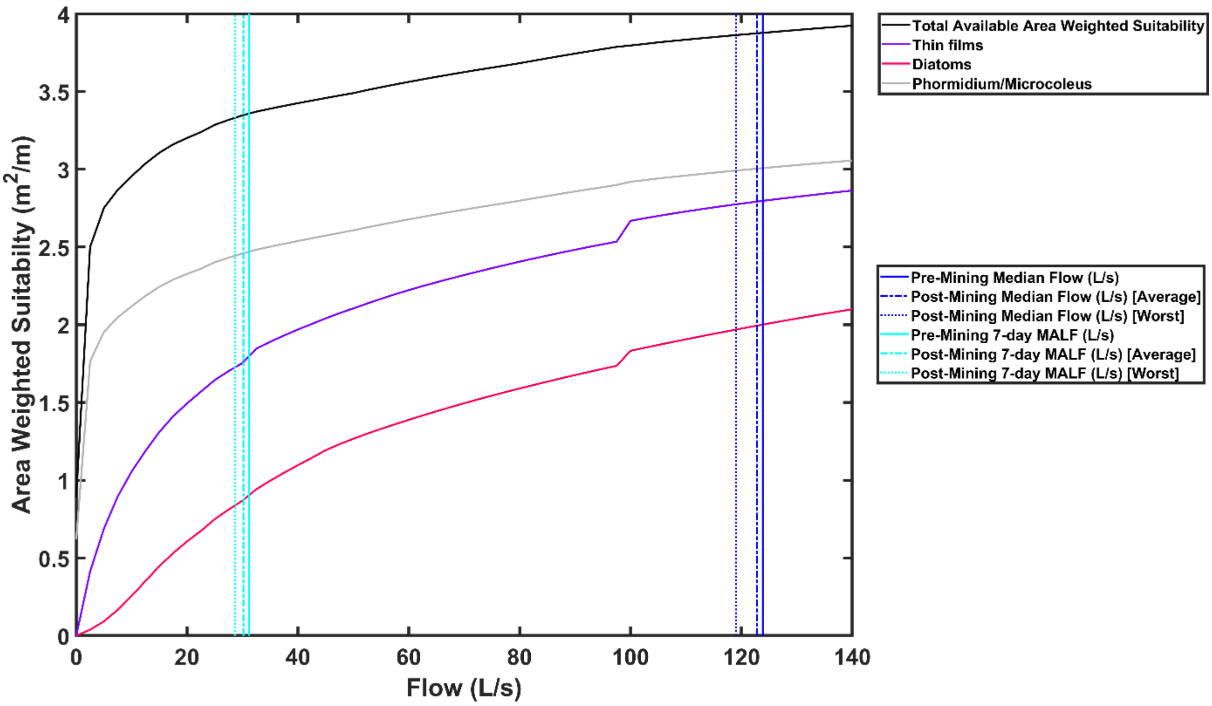

Figure 4-13: Area weighted suitability for periphyton in Teawaotemutu Stream.

Table 4-18: Percentage of total available AWS suitable for periphyton in Teawaotemutu Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	72.13	72.07	71.82	53.56	52.57	51.79
Diatoms	51.60	51.47	50.97	26.93	26.10	25.14
Phormidium/Microcoleus	77.56	77.54	77.44	73.56	73.47	73.36

Table 4-19: Percentage change of AWS for periphyton in Teawaotemutu Stream.

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	-0.16	-0.81	-2.14	-4.10
Diatoms	-0.33	-1.62	-3.36	-7.42
Phormidium/Microcoleus	-0.11	-0.54	-0.41	-1.09

4.3.3 Area weighted suitability for invertebrates (for species present)

Figure 4-14 and Figure 4-15 shows the AWS for macroinvertebrates for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all invertebrate response curves must be within this model boundary. The other curves indicate the suitable habitat for various macroinvertebrate species and classes.

Figure 4-14 shows the AWS curves for caddisflies and mayflies in Teawaotemutu Stream. The AWS curve for *Pycnocentrodes,* gradually increases with flow to beyond the median flow. AWS for *Deleatidium* rises very sharply from zero flow to about 3 L/s then rises gradually to beyond the median flow. At the 7-day MALF, the AWS for *Pycnocentrodes* is 9.45% of the total available and for *Deleatidium* the AWS is 27.29% of the total available (Table 4-20).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -7.14% for *Pycnocentrodes* and -2.00% for *Deleatidium* (Table 4-21). The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF average case (most likely scenario) are -2.91% for *Pycnocentrodes* and -0.78% for *Deleatidium* (Table 4-21).

These species have relatively flat AWS curves in the vicinity of the median flow so small reductions around the median flow would have limited impact on suitable instream habitat. For example, the worst case post-mining median flow (unlikely scenario) results in reductions of suitable instream habitat of -2.16% for *Pycnocentrodes* and -1.10% for *Deleatidium* (Table 4-21). For the most likely post-mining median flow (average case) the reductions of suitable instream habitat are -0.45% for *Pycnocentrodes* and -0.23% for *Deleatidium* (Table 4-21).

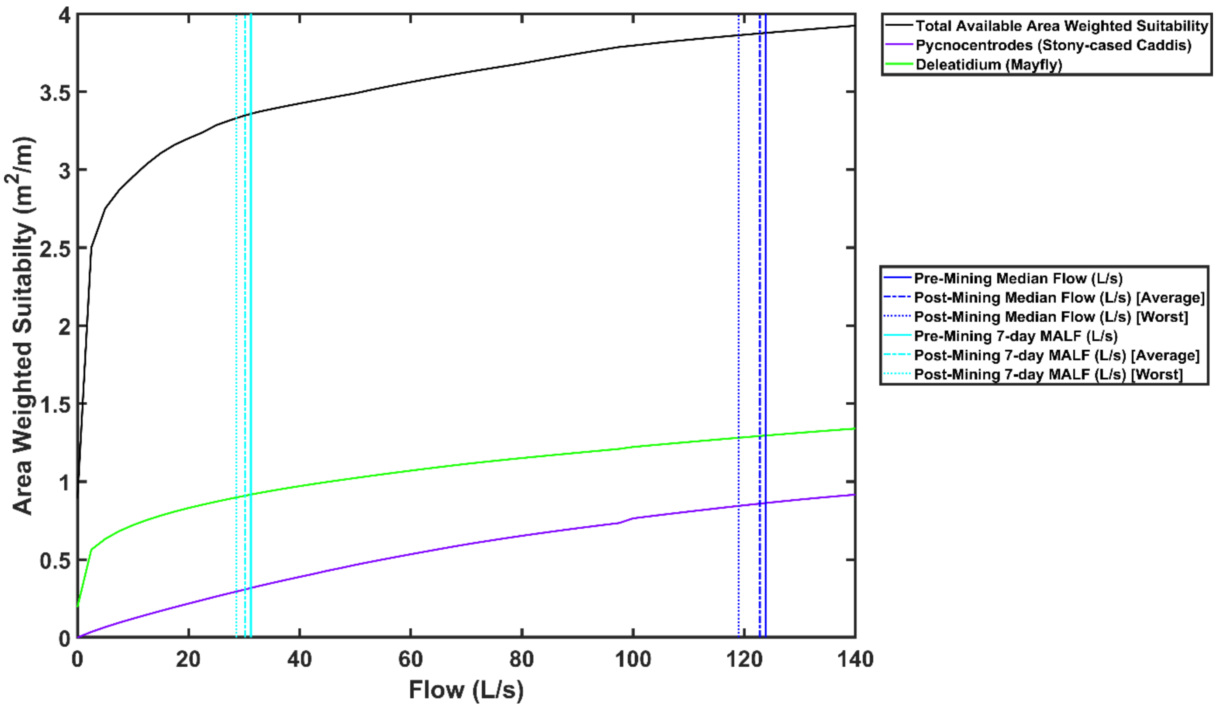

Figure 4-14: Area weighted suitability for caddisflies and mayflies in Teawaotemutu Stream.

Figure 4-15 shows the AWS curves for the other invertebrates in the stream. The AWS curves for Elmidae and *Potamopyrgus* increase rapidly from 0 to 5 L/s, then rise gradually to the 7-day MALF and are relatively flat from the 7-day MALF to beyond the median flow. At the 7-day MALF, Elmidae AWS is 56.00% and *Potamopyrgus* is 35.84% of the total available (Table 4-20). The AWS curve for Orthocladiinae rises gradually all the way to beyond median flow and is 14.29% of the total available at the 7-day MALF. There is virtually no habitat suitable for *Zelandoperla* and food producing invertebrates at the 7-day MALF (Figure 4-15, Table 4-20).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -0.59% for Elmidae, -1.58% for *Potamopyrgus* and -6.75% for Orthocladiinae (Table 4-21). For the post-mining 7-day MALF average case (most likely scenario) the largest impact is -3.04% for Orthocladiinae (Table 4-21). All species have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would not have a substantial impact on instream habitat around average annual flows (Table 4-21).

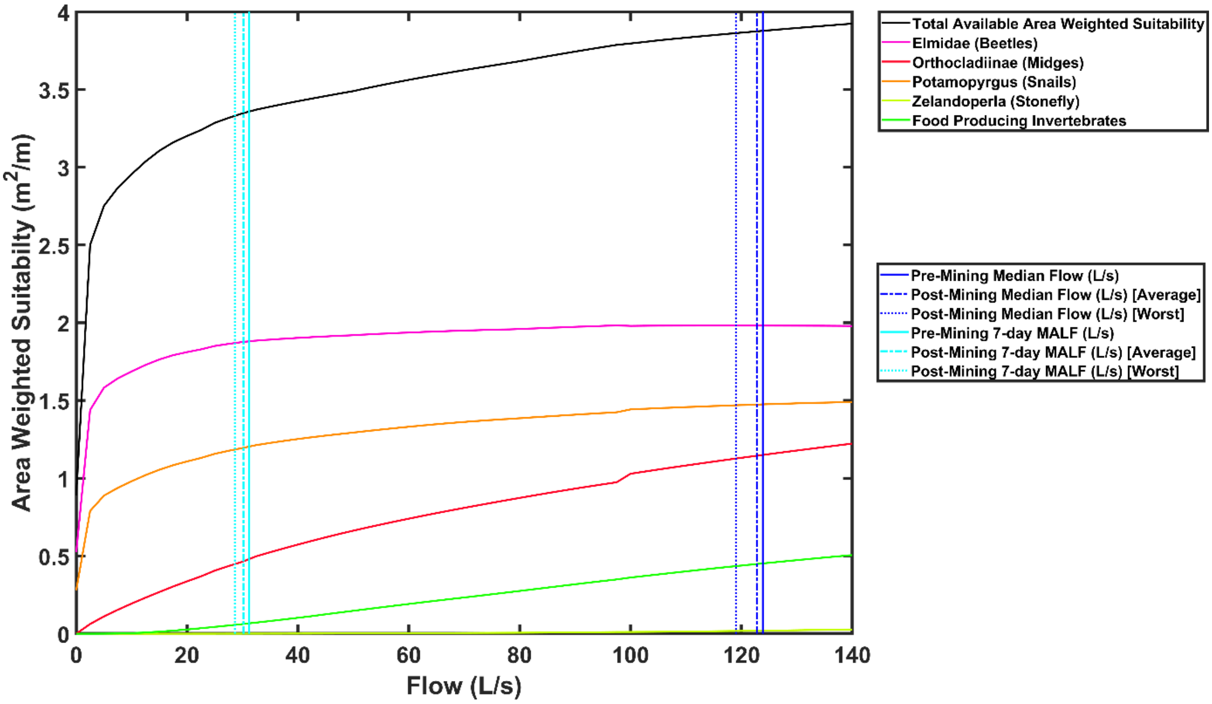

Figure 4-15: Area weighted suitability for other invertebrates in Teawaotemutu Stream.

Table 4-20: Percentage of total available AWS suitable for invertebrates in Teawaotemutu Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	22.25	22.16	21.85	9.45	9.20	8.85
***Deleatidium* (Mayfly)**	33.41	33.36	33.17	27.29	27.16	26.97
Elmidae (Beetles)	51.11	51.15	51.31	56.00	56.05	56.13
Orthocladiinae (Midges)	29.65	29.55	29.17	14.29	13.90	13.44
***Potamopyrgus* (Snails)**	38.04	38.04	38.04	35.84	35.71	35.57
Zelandoperla (Stonefly)	0.51	0.50	0.46	0.02	0.02	0.01
Food Producing Invertebrates	11.66	11.57	11.26	1.98	1.87	1.71

Table 4-21: Percentage change of AWS for invertebrates in Teawaotemutu Stream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	-0.45	-2.16	-2.91	-7.14
***Deleatidium* (Mayfly)**	-0.23	-1.10	-0.78	-2.00
Elmidae (Beetles)	0.01	0.02	-0.20	-0.59
Orthocladiinae (Midges)	-0.42	-2.02	-3.04	-6.75
***Potamopyrgus* (Snails)**	-0.08	-0.40	-0.64	-1.58

4.3.4 Area weighted suitability for fish (for species present)

Figure 4-16 and Figure 4-17 shows the AWS for fish for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all fish response curves must be within this model boundary. The other curves indicate the suitable habitat for various fish species, size classes or life stages.

Suitable habitat for small shortfin and longfin eels (<300 mm long) initially rises steeply to around 10 L/s, then less steeply to the 7-day MALF, then increases gradually until beyond the median flow (Figure 4-16). At the 7-day MALF their AWS are 46.70% and 25.47% of total AWS respectively (Table 4-22). AWS for large shortfin and longfin eels (>300 mm long) initially rises steeply to about 5 L/s and then less steeply than for small eels to about the 7-day MALF and then increases gradually until beyond the median flow. At the 7-day MALF their AWS are 19.37% and 12.98% of total AWS respectively (Table 4-22).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -3.29% for small shortfin eels (<300 mm) and -3.65% for small longfin eels (Table 4-23). All classes of eels have relatively flat AWS curves in the vicinity of the median flow (more representative of average annual conditions) so small reductions in flow would not have a substantial impact on instream habitat around this flow (Table 4-23).

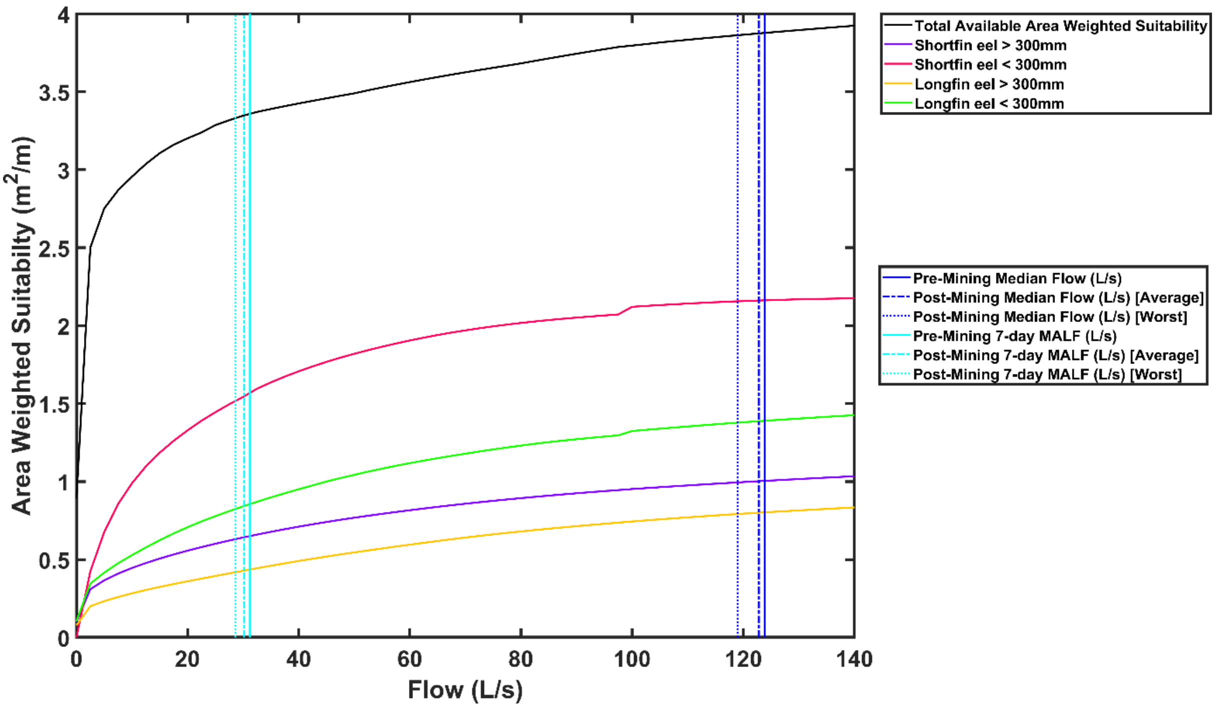

Figure 4-16: Area weighted suitability for eels in Teawaotemutu Stream.

AWS for banded kōkopu juveniles and adults rises very steeply between 0 and 10 L/s, then flattens off and peaks near the 7-day MALF. AWS at the 7-day MALF is 47.57% and 44.14% of total AWS respectively (Table 4-22). AWS for banded kōkopu juveniles and adults declines gradually between the 7-day MALF and the median flow (Figure 4-17). AWS for shortjaw kōkopu shows a similar trajectory, but at a lower level. AWS for shortjaw kōkopu is 12.74% of total AWS at the 7-day MALF (Table 4-22). AWS for kōaro rises gradually and almost linearly from zero to beyond the median flow; however, this stream has limited suitable habitat for kōaro with AWS of only 4.50% at 7-day MALF (Table 4-22).

The AWS curves for kōkopu (Figure 4-17) are all relatively flat near the 7-day MALF. The various post-mining 7-day MALFs are in this relatively flat portion of the curves indicating that there is a relatively low reduction in suitable instream habitat even in the worst-case scenario, with the most significant reduction of AWS being for shortjaw kōkopu of -1.12% (Table 4-23). For the most likely reduction in 7-day MALF (average case), changes in suitable habitat are negligible (Table 4-23).

AWS peaks before the median flow for all kōkopu classes so small reductions in flow relative to the median flow result in small increases in suitable instream habitat (Table 4-23).

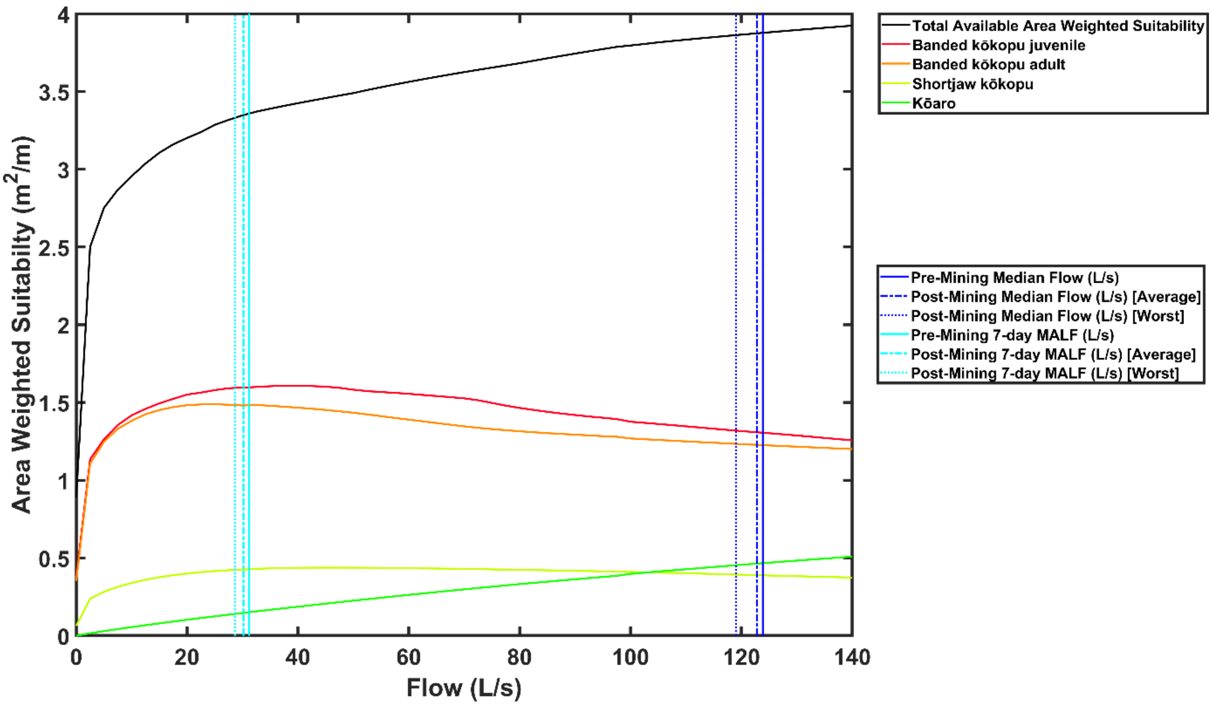

Figure 4-17: Area weighted suitability for native fish in Teawaotemutu Stream.

Table 4-22: Percentage of total available AWS suitable for fish in Teawaotemutu Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	25.91	25.88	25.75	19.37	19.20	18.94
Shortfin eel <300 mm	55.77	55.79	55.83	46.70	46.19	45.54
Longfin eel >300 mm	20.70	20.66	20.51	12.98	12.81	12.57
Longfin eel <300 mm	35.85	35.82	35.68	25.47	25.18	24.75
Banded kōkopu juvenile	33.67	33.76	34.16	47.57	47.66	47.84
Banded kōkopu adult	31.61	31.68	31.95	44.14	44.23	44.54
Shortjaw kōkopu	10.02	10.05	10.18	12.74	12.72	12.70
Kōaro	12.03	11.97	11.73	4.50	4.38	4.21

Table 4-23: Percentage change of AWS for fish in Teawaotemutu Stream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	-0.20	-0.98	-1.18	-3.05
Shortfin eel <300 mm	-0.06	-0.29	-1.39	-3.29
Longfin eel >300 mm	-0.27	-1.33	-1.56	-3.93
Longfin eel <300 mm	-0.18	-0.87	-1.43	-3.65
Banded kōkopu juvenile	0.20	1.06	-0.11	-0.26
Banded kōkopu adult	0.14	0.68	-0.09	0.07
Shortjaw kōkopu	0.25	1.18	-0.49	-1.12

4.3.5 Instream habitat at low flows

Flow changes have the largest impact on suitable instream habitat at low flows. Previous sections have shown the impacts on instream habitat for species and classes of biota present in Teawaotemutu Stream for the most likely post-mining 7-day MALF (average case) and the unlikely post-mining 7-day MALF (worst case). Setting minimum post-mining flows requires a subjective assessment of the allowable reduction of instream habitat for different groups of instream biota (Section 3.5). To assist with this assessment Figure 4-18 provides percentage reductions of suitable instream habitat for periphyton, invertebrates and fish in Teawaotemutu Stream for flows less than the pre-mining 7-day MALF. Table 4-24 provides post-mining 7-day MALF flows that correspond to percentage reductions of suitable instream habitat between 0% and -20%.

The largest impact on suitable instream habitat in Teawaotemutu Stream was for periphyton (Figure 4-18). To keep impacts on suitable instream habitat within -5% for all groups of biota a post-mining 7-day MALF of 26.98 L/s would need to be maintained (Table 4-24). To keep impacts on suitable instream habitat within -10% for all groups of biota a post-mining 7-day MALF of 23.17 L/s would need to be maintained (Table 4-24). The most likely post-mining 7-day MALF (average case) of 30.17 L/s results in small changes to suitable instream habitat and keeps impacts within -1.53% for all groups of biota (Figure 4-18).The unlikely post-mining 7-day MALF (worst case) of 28.61 L/s keeps impacts within -3.24% for all groups of biota (Figure 4-18).

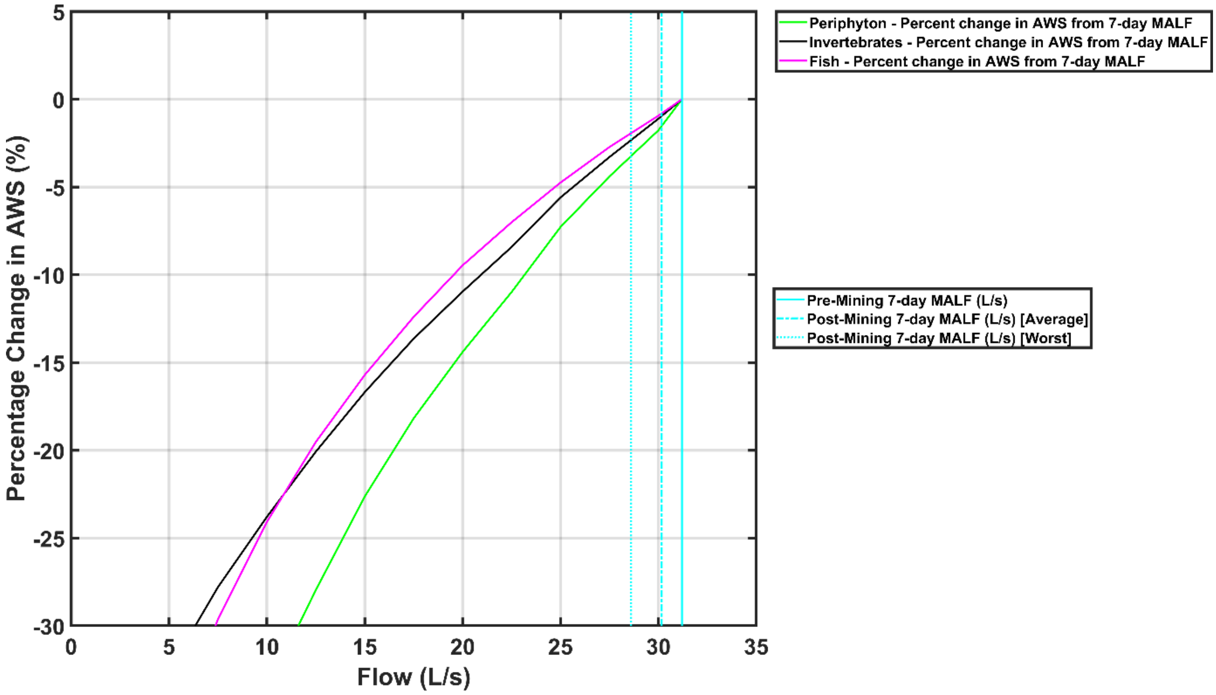

Figure 4-18: Percentage changes in Area Weighted Suitability for flows less than the pre-mining 7-day MALF for periphyton, invertebrates, and fish in Teawaotemutu Stream.

Table 4-24: Percentage changes in AWS between 0% and -20% relative to pre-mining 7-day MALF and their corresponding flows for periphyton, invertebrates, and fish in Teawaotemutu Stream.

Percentage Change in AWS From Pre-Mining 7-day MALF	Periphyton Flow (L/s)	Invertebrate Flow (L/s)	Fish Flow (L/s)
0%	31.21	31.21	31.21
-2.5%	29.31	28.41	27.82
-5%	26.98	25.65	24.73
-7.5%	24.85	23.32	22.00
-10%	23.17	20.95	19.55
-12.5%	21.39	18.56	17.42
-15%	19.60	16.39	15.54
-17.5%	17.95	14.40	13.83
-20%	16.48	12.56	12.24

4.4 Thompson Stream

4.4.1 Habitat mapping surveys

Habitat mapping surveys were conducted in Thompson Stream following the methods in Appendix B. The results of these surveys are summarised in Table 4-25, with histograms of pool, riffle, and run lengths in Appendix J. Habitat proportions in Thompson Stream were then used in SEFA as input weightings for the cross-section surveys and thus output calculations of suitable area for instream taxa.

Table 4-25: Summary of habitat surveys in Thompson Stream.

	Number of Habitat Sections	Average Habitat Length (m)	Cumulative Length of Habitat (m)	Percentage of Survey Reach (%)
Pools	16	5.9	94	27.40
Riffles	33	3.7	122	35.57
Runs	24	5.3	127	37.03
Total	73	4.7	343	100

4.4.2 Area weighted suitability for periphyton (for species present)

Figure 4-19 shows the AWS for periphyton for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all periphyton response curves must be within this model boundary. The other curves indicate the suitable habitat for various periphyton classes. The blue vertical lines show pre-mining and post-mining flows, including the most likely post-mining flow [Average] and the worst-case scenario [Worst] (GHD 2024; Section 3.2).

For long filamentous algae, AWS rises vey sharply between 0 and 5 L/s, then increases more gradually to a peak around 23 L/s and then slightly decreases towards median flow (Figure 4-19). *Phormidium/Microcoleus* AWS follows a similar but lower trajectory but has still not peaked at median flow (Figure 4-19). AWS for thin films and diatoms rises quickly from zero flow, but the rate of increase becomes more gradual as flows increase (Figure 4-19). The stream has very little suitable habitat for short filamentous algae, with AWS of only 8.14% at the 7-day MALF (Table 4-26). The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -2.87% for long filamentous algae, -3.58% for *Phormidium/Microcoleus,* -5.61% for thin films, and -10.55% for diatoms (Table 4-27). The AWS curves are flatter around the median flow, so changes in AWS due to flow reductions will have less impact on instream habitat around the median flow (Figure 4-19). For the worst-case post-mining median flow reductions of suitable instream habitat range between -0.09% and -4.92% (Table 4-27).

Taking into consideration the hydrogeological findings of Williamson Water & Land Advisory (WWLA), it is likely that the modelled flow reductions and changes to instream habitat for Thompson Stream are highly conservative.

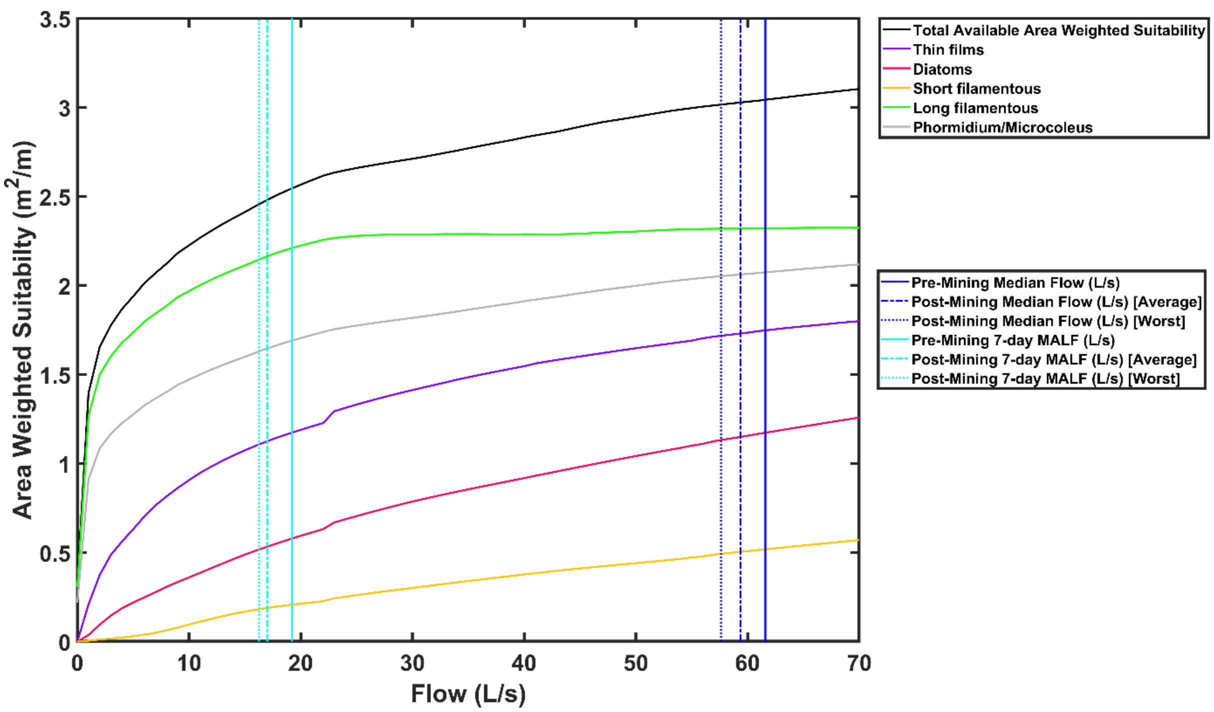

Figure 4-19: Area weighted suitability for periphyton in Thompson Stream.

Table 4-26: Percentage of total available AWS suitable for periphyton in Thompson Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	57.44	57.15	56.95	46.10	45.37	45.08
Diatoms	38.55	37.97	37.53	22.73	21.49	21.06
Short filamentous	17.04	16.65	16.34	8.14	7.62	7.41
Long filamentous	76.26	76.61	76.89	86.83	87.25	87.37
Phormidium/Microcoleus	68.15	68.10	68.05	66.41	66.36	66.34

Table 4-27: Percentage change of AWS for periphyton in Thompson Stream.

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	-0.99	-1.73	-4.09	-5.61
Diatoms	-2.00	-3.52	-7.87	-10.55
Short filamentous	-2.74	-4.92	-8.73	-12.07
Long filamentous	-0.05	-0.09	-2.07	-2.87
Phormidium/Microcoleus	-0.57	-1.04	-2.61	-3.58

4.4.3 Area weighted suitability for invertebrates (for species present)

Figure 4-20 and Figure 4-21 show the Area Weighted Suitability (AWS) for macroinvertebrates for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all invertebrate response curves must be within this model boundary. The other curves indicate the suitable habitat for various macroinvertebrate species and classes.

Figure 4-20 shows the AWS curves for caddisflies and mayflies. Habitat modelling indicates that Thompson Stream does not have particularly suitable habitat conditions for these classes of invertebrates as the AWS for all species/classes is low relative to the total available habitat. AWS for *Deleatidium* rises very sharply from zero flow to about 5 L/s then increases more gradually to beyond the median flow. The AWS curves for *Pycnocentrodes* and Hydrobiosidae, gradually increase with flow to beyond the median flow. At the 7-day MALF the AWS for *Deleatidium*, Hydrobiosidae, and *Pycnocentrodes* are 25.98%, 11.16%, and 8.39% respectively of the total available (Table 4-28). There is very little instream habitat suitable for *C. humeralis* and *Aoteapsyche* (Table 4-28).

The reduction in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case is -4.87% for *Deleatidium* (Table 4-29). There are larger reductions for Hydrobiosidae and *Pycnocentrodes* (Table 4-29); however, the stream is not very suitable for them regardless of any flow change (Figure 4-20). All of these species have relatively flat AWS curves in the vicinity of the median flow so reductions in flow would have less impact on instream habitat around this flow, with changes in AWS for the worst-case post-mining median flow between -1.99% and -4.07% (Table 4-29).

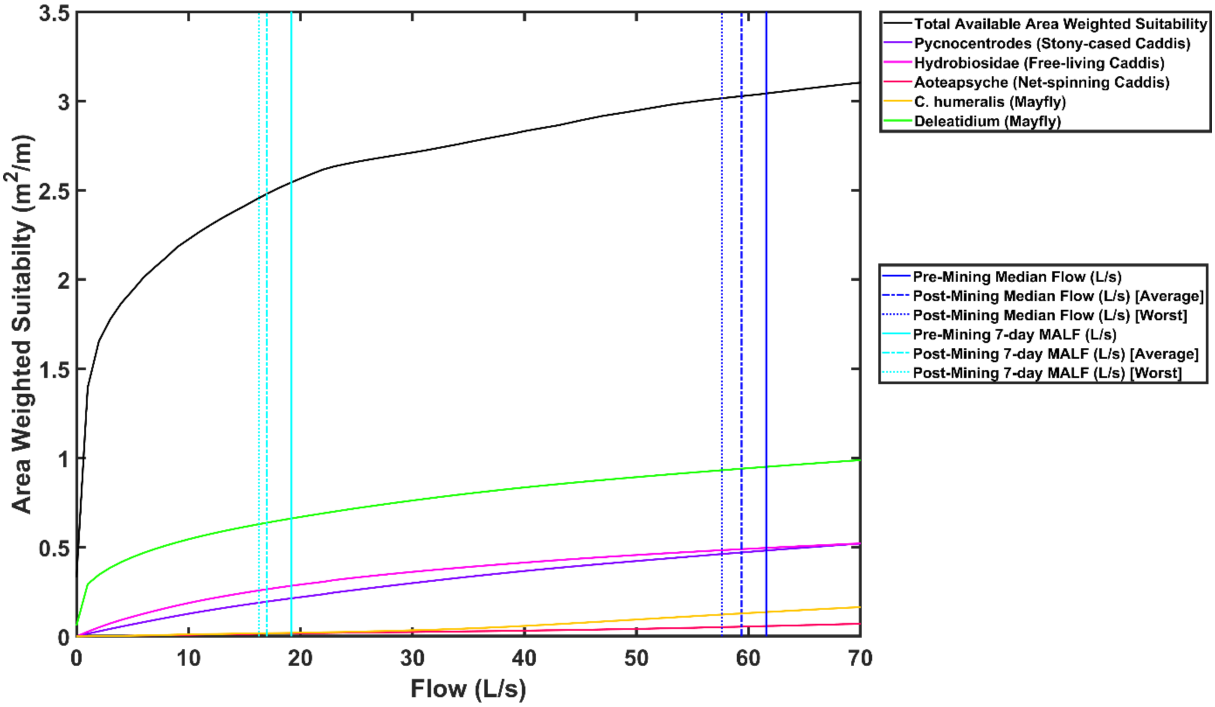

Figure 4-20: Area weighted suitability for caddisflies and mayflies in Thompson Stream.

Figure 4-21 shows the AWS curves for the other invertebrates in the stream. The AWS curves for Elmidae and *Potamopyrgus*, (Figure 4-21) increase rapidly from 0 to 5 L/s, continue to rise gradually to around 20 L/s and then are relatively flat to beyond the median flow. At the 7-day MALF, Elmidae AWS is 58.66% of the total available (Table 4-28). The AWS curve for Orthocladiinae rises gently all the way to beyond median flow and is 16.00% of the total available at the 7-day MALF. Figure 4-21 shows there is virtually no habitat available for food producing invertebrates, *Zelandoperla* and Maoridiamesa at the 7-day MALF.

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worstcase are -3.21% for Elmidae, -4.22% for *Potamopyrgus*, and -9.60% for Orthocladiinae (Table 4-29). For the most likely post-mining 7-day MALF (average case) the reductions in AWS are -2.34% for Elmidae, -3.12% for *Potamopyrgus*, and -7.12% for Orthocladiinae (Table 4-29). These species have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would have less impact on instream habitat around the median flow (Table 4-29).

Taking into consideration the hydrogeological findings of Williamson Water & Land Advisory (WWLA), it is likely that the modelled flow reductions and changes to instream habitat for Thompson Stream are highly conservative.

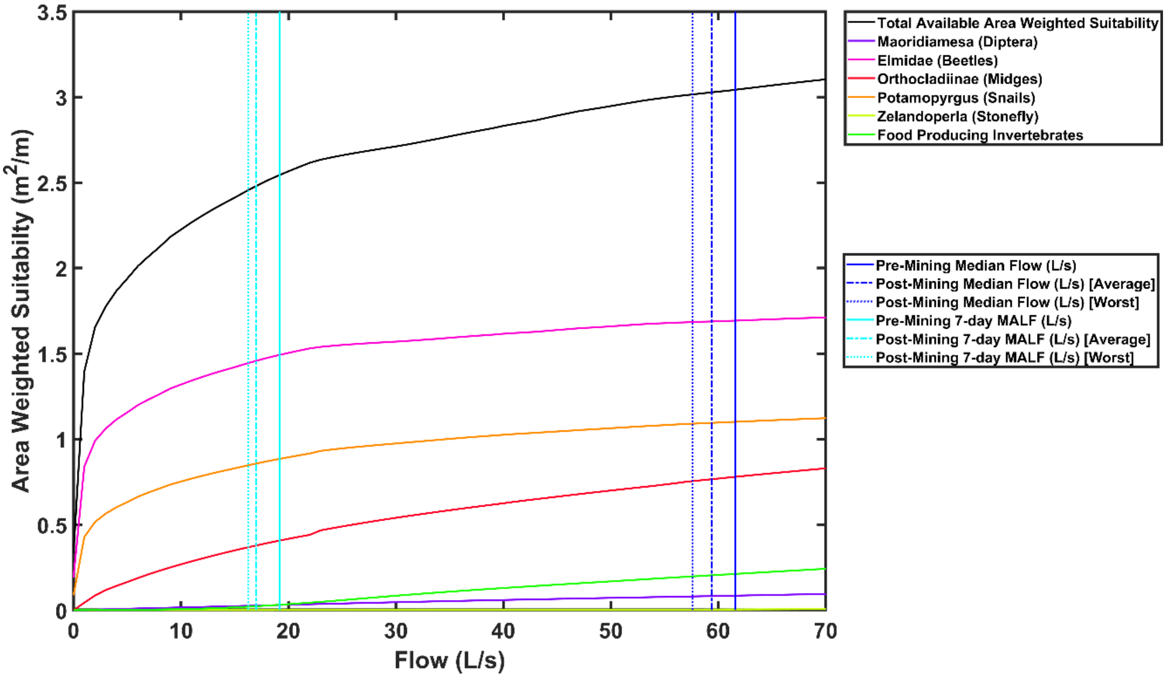

Figure 4-21: Area weighted suitability for other invertebrates in Thompson Stream.

Table 4-28: Percentage of total available AWS suitable for invertebrates in Thompson Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	15.82	15.54	15.31	8.39	7.86	7.68
Hydrobiosidae (Free-living Caddis)	16.30	16.15	16.02	11.16	10.66	10.48
***Aoteapsyche* (Net-spinning Caddis)**	1.90	1.80	1.72	0.68	0.63	0.61
***C. humeralis* (Mayfly)**	4.49	4.25	4.06	0.79	0.72	0.70
***Deleatidium* (Mayfly)**	31.23	31.05	30.89	25.98	25.69	25.61
Maoridiamesa (Diptera)	2.79	2.72	2.66	1.19	1.08	1.04

Elmidae (Beetles)	55.63	55.76	55.86	58.66	58.78	58.83
Orthocladiinae (Midges)	25.62	25.29	25.02	16.00	15.25	14.99
***Potamopyrgus* (Snails)**	36.19	36.17	36.16	34.77	34.56	34.50
Zelandoperla (Stonefly)	0.14	0.13	0.12	0.01	0.00	0.00
Food Producing Invertebrates	6.96	6.73	6.55	1.24	0.93	0.84

Table 4-29: Percentage change of AWS for invertebrates in Thompson Stream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		**Percentage change from Pre-Mining 7-day MALF**	
	Post-Mining Median Flow [Average Case]	**Post-Mining Median Flow [Worst Case]**	**Post-Mining 7-day MALF [Average Case]**	**Post-Mining 7-day MALF [Worst Case]**
***Pycnocentrodes* (Stony-cased Caddis)**	-2.25	-4.07	-8.71	-11.66
Hydrobiosidae (Free-living Caddis)	-1.42	-2.59	-6.89	-9.32
***Deleatidium* (Mayfly)**	-1.10	-1.99	-3.63	-4.87
Elmidae (Beetles)	-0.28	-0.49	-2.34	-3.21
Orthocladiinae (Midges)	-1.80	-3.21	-7.12	-9.60
***Potamopyrgus* (Snails)**	-0.55	-0.98	-3.12	-4.22

4.4.4 Area weighted suitability for fish (for species present)

Figure 4-22 and Figure 4-23 shows the AWS for fish for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all fish response curves must be within this model boundary. The other curves indicate the suitable habitat for various fish species, size classes or life stages.

Suitable habitat for small shortfin and longfin eels (<300 mm long) initially rises sharply, then less steeply to near the 7-day MALF and then increases more gradually until beyond the median flow (Figure 4-22). At the 7-day MALF their AWS are 44.05% and 24.66% of total AWS respectively (Table 4-30). AWS curves for large shortfin and longfin eels (>300 mm long) have a similar shape to those for small eels, but at lower levels and changes are more gradual. At the 7-day MALF their AWS are 13.37% and 7.87% of total AWS respectively (Table 4-30).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -6.85% for small shortfin eels (<300 mm), -8.08% for small longfin eels, -7.40% for large shortfin eels (>300 mm), and -9.03% for large longfin eels (Table 4-31). All species have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would not have less impact on instream habitat around this flow (Table 4-31).

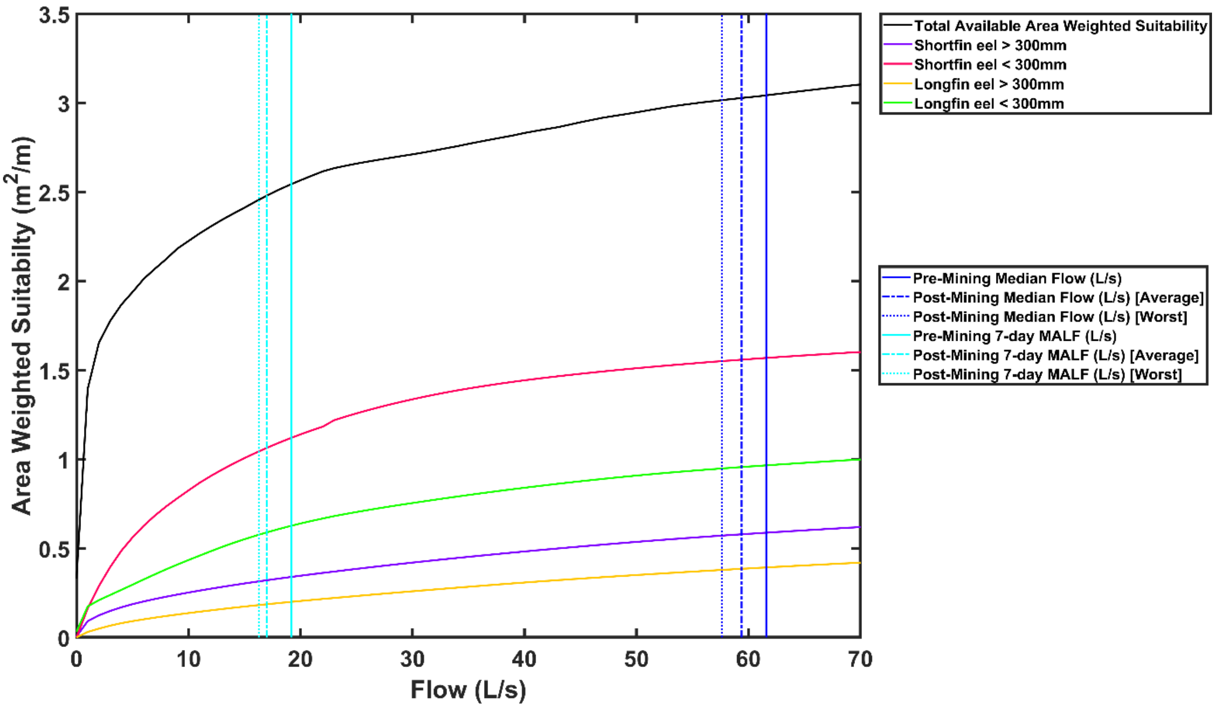

Figure 4-22: Area weighted suitability for eels in Thompson Stream.

AWS for redfin bully, banded kōkopu juveniles and adults rises very steeply between 0 and 5 L/s, then rises more gradually towards the 7-day MALF. AWS for banded kōkopu juveniles and adults peaks between the 7-day MALF and the median flow. The stream is quite suitable for redfin bully, banded kōkopu juveniles and adults with AWS of 42.00%, 43.18% and 37.82% of total AWS respectively at 7-day MALF (Table 4-30). Torrentfish have very little suitable habitat at any flow (Figure 4-23).

The AWS curves for all these species are relatively flat near the 7-day MALF. The post-mining 7-day MALF scenarios are in this relatively flat portion of the curves indicating that there is a relatively low reduction in potential habitat even in the worst case. The most significant change is for redfin bully of -4.98% (Table 4-31). AWS curves in the vicinity of the median flow are very flat (Figure 4-23) so small reductions in flow would not have a substantial impact on instream habitat around average annual flows. For example, changes in suitable instream habitat for the worst case post-mining median flow are -0.75%, +0.32%, and -0.31%, for redfin bully, banded kōkopu juveniles and adults (Table 4-31).

Taking into consideration the hydrogeological findings of Williamson Water & Land Advisory (WWLA), it is likely that the modelled flow reductions and changes to instream habitat for Thompson Stream are highly conservative.

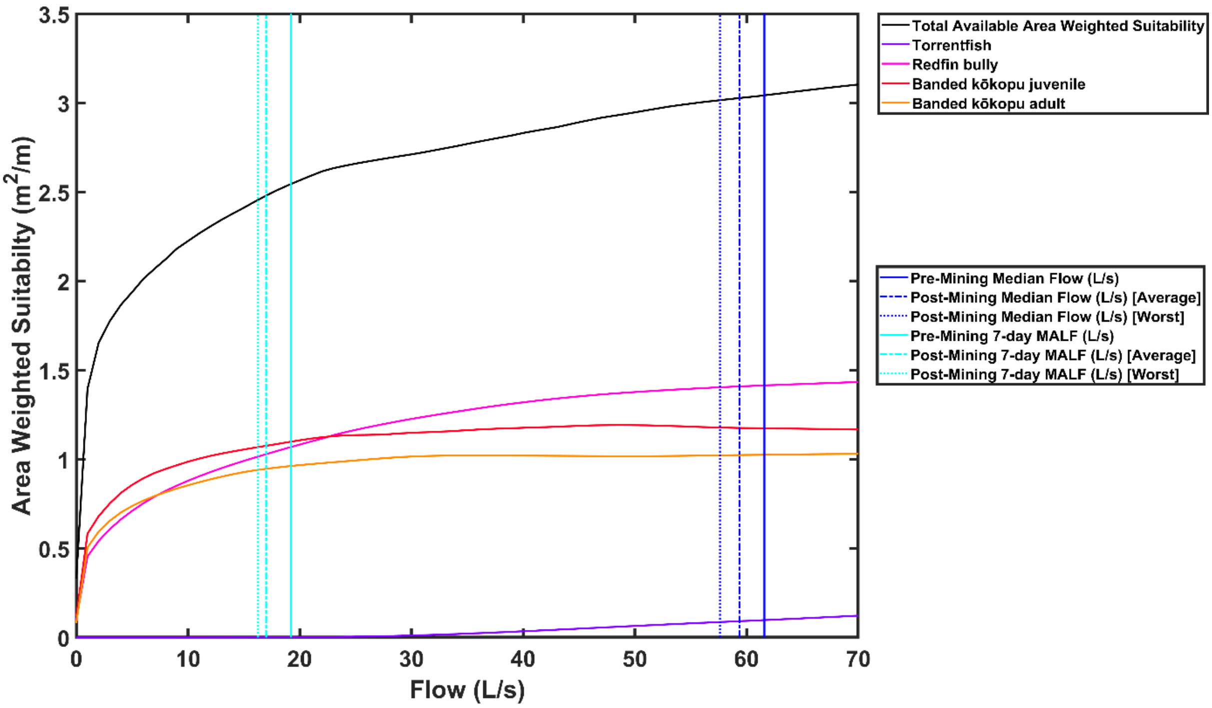

Figure 4-23: Area weighted suitability for fish in Thompson Stream.

Table 4-30: Percentage of total available AWS suitable for fish in Thompson Stream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	19.33	19.13	18.96	13.37	12.96	12.83
Shortfin eel <300 mm	51.57	51.50	51.43	44.05	42.92	42.51
Longfin eel >300 mm	12.92	12.74	12.58	7.87	7.53	7.42
Longfin eel <300 mm	31.75	31.60	31.45	24.66	23.79	23.48
Torrentfish	3.21	3.03	2.88	0.07	0.04	0.04
Redfin bully	46.50	46.54	46.57	42.00	41.49	41.35
Banded kōkopu juvenile	38.59	38.84	39.07	43.18	43.39	43.51
Banded kōkopu adult	33.70	33.81	33.90	37.82	38.18	38.31

Table 4-31: Percentage change of AWS for fish in Thompson Stream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	-1.52	-2.78	-5.53	-7.40
Shortfin eel <300 mm	-0.63	-1.15	-5.06	-6.85
Longfin eel >300 mm	-1.95	-3.55	-6.75	-9.03
Longfin eel <300 mm	-0.99	-1.83	-5.95	-8.08
Redfin bully	-0.40	-0.75	-3.73	-4.98
Banded kōkopu juvenile	0.14	0.32	-2.08	-2.75
Banded kōkopu adult	-0.17	-0.31	-1.61	-2.24

4.4.5 Instream habitat at low flows

Flow changes have the largest impact on suitable instream habitat at low flows. Previous sections have shown the impacts on instream habitat for species and classes of biota present in Thompson Stream for the most likely post-mining 7-day MALF (average case) and the unlikely post-mining 7-day MALF (worst-case). Setting minimum post-mining flows requires a subjective assessment of the allowable reduction of instream habitat for different groups of instream biota (Section 3.5). To assist with this assessment Figure 4-24 provides percentage reductions of suitable instream habitat for periphyton, invertebrates and fish in Thompson Stream for flows less than the pre-mining 7-day MALF. Table 4-32 provides post-mining 7-day MALF flows that correspond to percentage reductions of suitable instream habitat between 0% and -20%.

The largest impact on suitable instream habitat in Thompson Stream was for invertebrates (Figure 4-24). To keep impacts on suitable instream habitat within -5% for all groups of biota a post-mining 7-day MALF of 16.60 L/s would need to be maintained (Table 4-32). To keep impacts on suitable instream habitat within -10% for all groups of biota a post-mining 7-day MALF of 14.21 L/s would need to be maintained (Table 4-32).

Thompson Stream showed the largest impact on suitable instream habitat of the seven study sites, with the most likely post-mining 7-day MALF (average case) of 16.99 L/s resulting in a reduction of instream suitable habitat of -4.20% for invertebrates (Figure 4-24) and the unlikely post-mining 7-day MALF (worst case) of 16.27 L/s resulting in a reduction of instream habitat of -5.66% for invertebrates (Figure 4-24). To keep impacts on suitable instream habitat within -7.5% for all groups of biota a post-mining 7-day MALF of 15.39 L/s would need to be maintained (Table 4-32).

Taking into consideration the hydrogeological findings of Williamson Water & Land Advisory (WWLA), it is likely that the modelled flow reductions and changes to instream habitat for Thompson Stream are highly conservative.

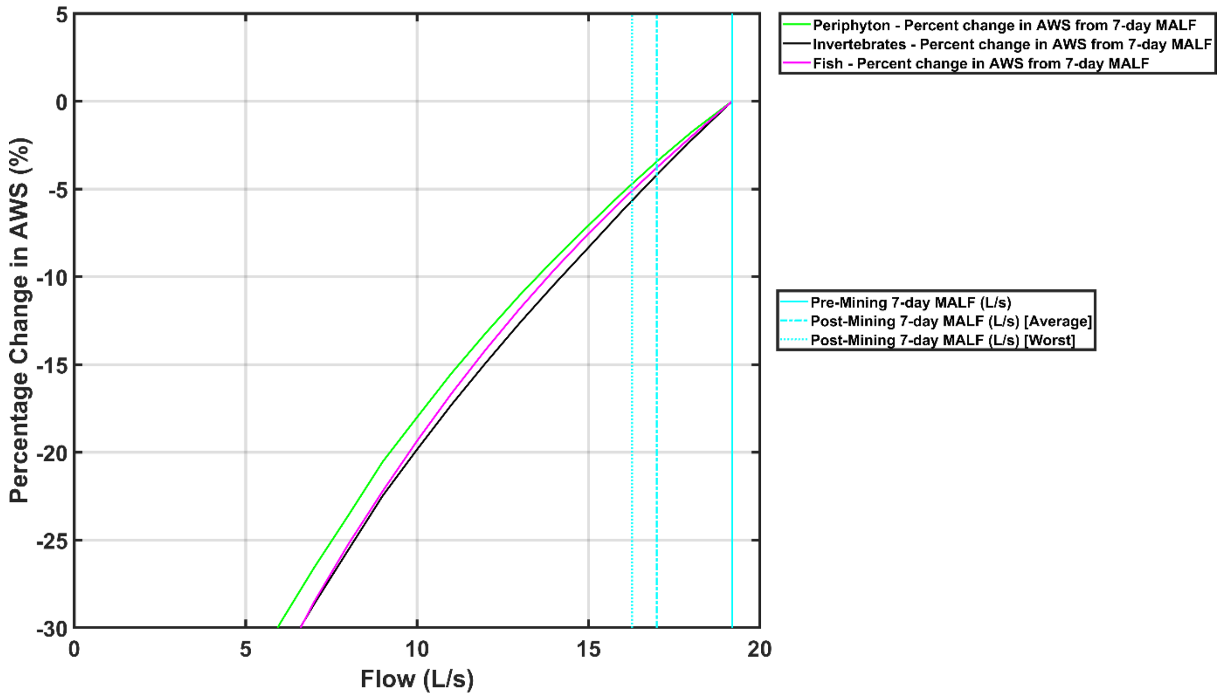

Figure 4-24: Percentage changes in Area Weighted Suitability for flows less than the pre-mining 7-day MALF for periphyton, invertebrates, and fish in Thompson Stream.

Table 4-32: Percentage changes in AWS between 0% and -20% relative to pre-mining 7-day MALF and their corresponding flows for periphyton, invertebrates, and fish in Thompson Stream.

Percentage Change in AWS From Pre-Mining 7-day MALF	Periphyton Flow (L/s)	Invertebrate Flow (L/s)	Fish Flow (L/s)
0%	19.20	19.20	19.20
-2.5%	17.56	17.86	17.72
-5%	16.11	16.60	16.33
-7.5%	14.78	15.39	15.02
-10%	13.51	14.21	13.82
-12.5%	12.33	13.06	12.71
-15%	11.22	11.97	11.67
-17.5%	10.20	10.92	10.69
-20%	9.21	9.94	9.77

4.5 Tributary-R

4.5.1 Habitat mapping surveys

Habitat mapping surveys were conducted in Tributary-R following the methods in Appendix B. The results of these surveys are summarised in Table 4-33, with histograms of pool, riffle, and run lengths in Appendix K. Habitat proportions in Tributary-R were then used in SEFA as input weightings for the cross-section surveys and thus output calculations of suitable area for instream taxa.

Table 4-33: Summary of habitat surveys in Tributary-R.

	Number of Habitat Sections	Average Habitat Length (m)	Cumulative Length of Habitat (m)	Percentage of Survey Reach (%)
Pools	22	3.1	67.5	29.03
Riffles	38	2.2	82	35.27
Runs	22	3.8	83	35.7
Total	82	2.84	232.5	100

4.5.2 Area weighted suitability for periphyton (for species present)

Figure 4-25 shows the AWS for periphyton for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all periphyton response curves must be within this model boundary. The other curves indicate the suitable habitat for various periphyton classes. The blue vertical lines show pre-mining and post-mining flows, including the most likely post-mining flow [Average] and the worst-case scenario [Worst] (GHD 2024; Section 3.2).

AWS for long filamentous algae rises very sharply at low flows (Figure 4-25), then more gradually to beyond median flow. *Phormidium/Microcoleus* AWS follows a similar but lower trajectory (Figure 4-25). AWS for thin films rises quickly from zero flow, then increases more gradually between 7-day MALF and median flow (Figure 4-25). The AWS response curve for diatoms is almost linear. The stream has very little suitable habitat for short filamentous algae. AWS values at the pre-mining 7-day MALF are 85.42% for long filamentous algae, 58.85% for *Phormidium/Microcoleus,* 23.72% for thin films, and 6.25% for diatoms (Table 4-34).

The reductions in AWS between the pre-mining 7-day MALF and the most likely post-mining 7-day MALF (average case) are -0.38% for long filamentous algae, -0.45% for *Phormidium/Microcoleus*, and -2.98% for thin films (Table 4-35). For the worst-case post-mining 7-day MALF the reductions in AWS are -0.65% for long filamentous algae, -0.76% for *Phormidium/Microcoleus*, and -5.07% for thin films (Table 4-35).

The AWS curves in the vicinity of the median flow are flatter than at the 7-day MALF and flow reductions have less effect on suitable instream habitat for periphyton. The worst-case post-mining median flow results in decreases of AWS of -0.33% for long filamentous algae, -0.46% for *Phormidium/Microcoleus*, and -1.49% for thin films compared to the pre-mining median flow (Table 4-35).

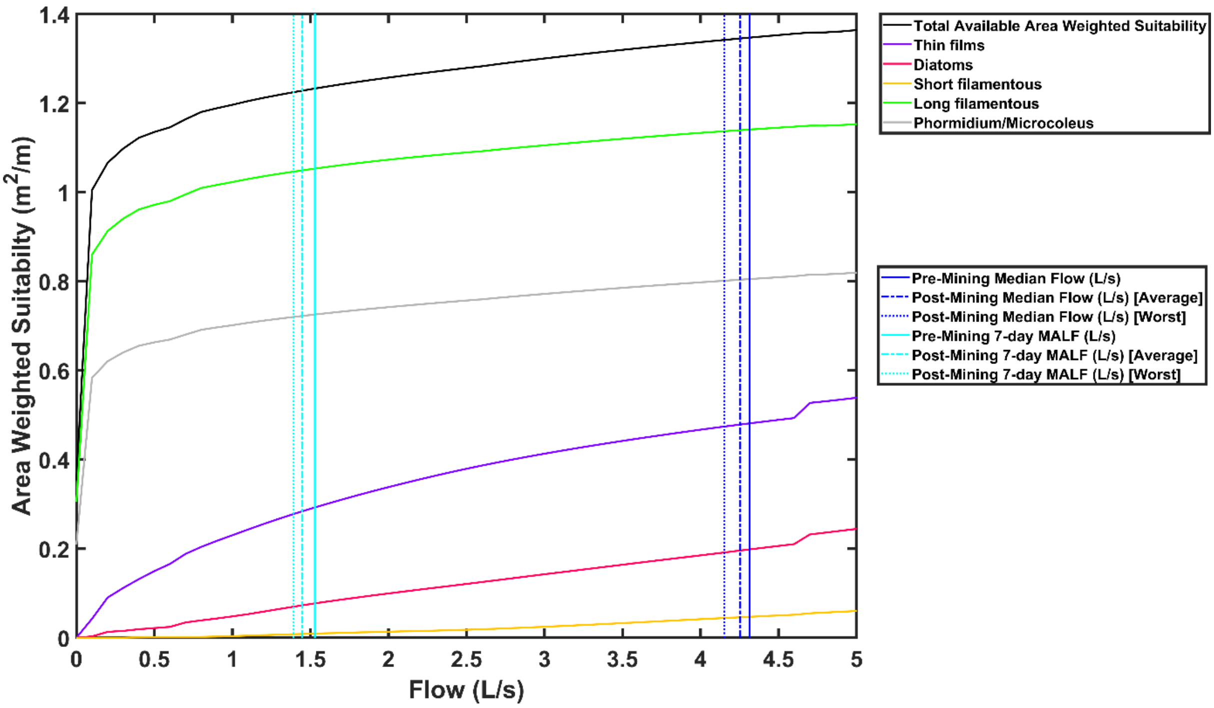

Figure 4-25: Area weighted suitability for periphyton in Tributary-R.

Table 4-34: Percentage of total available AWS suitable for periphyton in Tributary-R.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	35.72	35.58	35.32	23.72	23.10	22.67
Diatoms	14.72	14.55	14.26	6.25	5.92	5.68
Short filamentous	3.49	3.42	3.30	0.75	0.69	0.64
Long filamentous	84.69	84.70	84.73	85.42	85.44	85.44
Phormidium/Microcoleus	59.76	59.75	59.72	58.85	58.82	58.80

Table 4-35: Percentage change of AWS for periphyton in Tributary-R.

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	-0.54	-1.49	-2.98	-5.07
Diatoms	-1.28	-3.49	-5.70	-9.72
Long filamentous	-0.12	-0.33	-0.38	-0.65
Phormidium/Microcoleus	-0.17	-0.46	-0.45	-0.76

4.5.3 Area weighted suitability for invertebrates (for species present)

Figure 4-26 and Figure 4-27 shows the AWS for macroinvertebrates for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all invertebrate response curves must be within this model boundary. The other curves indicate the suitable habitat for various macroinvertebrate species and classes.

Figure 4-26 shows the AWS curves for caddisflies and mayflies. Like Thompson Stream, Tributary-R does not seem to be very suitable for these classes of invertebrates as AWS for most of the species/classes is low relative to the total available habitat. AWS for *O. feredayi* and *Deleatidium* rises sharply from zero flow to 0.1 L/s, then increases gradually to beyond the median flow. At the 7-day MALF the AWS for *O. feredayi* and *Deleatidium* are 35.49% and 20.30% of the total available respectively (Table 4-36). The AWS curves for *Nesameletus*, *Pycnocentrodes* and Hydrobiosidae, gradually increase with flow to beyond the median flow. There is very little suitable instream habitat for *C. humeralis.*

The reductions in AWS between the pre-mining 7-day MALF and worst-case post-mining 7-day MALF are -1.57% for *O. feredayi* and -1.63% for *Deleatidium* (Table 4-37). There is less impact on suitable instream habitat for the most likely reduction in 7-day MALF (average case), with changes of -0.92% for *O. feredayi* and -0.96% for *Deleatidium* (Table 4-37).

The AWS curves are relatively flat in the vicinity of the median flow and the post-mining median flow scenarios have a small impact on suitable instream habitat. For example, the worst-case post-mining median flow results in reductions of AWS of -0.57% for *O. feredayi* and -0.71% for *Deleatidium* (Table 4-37).

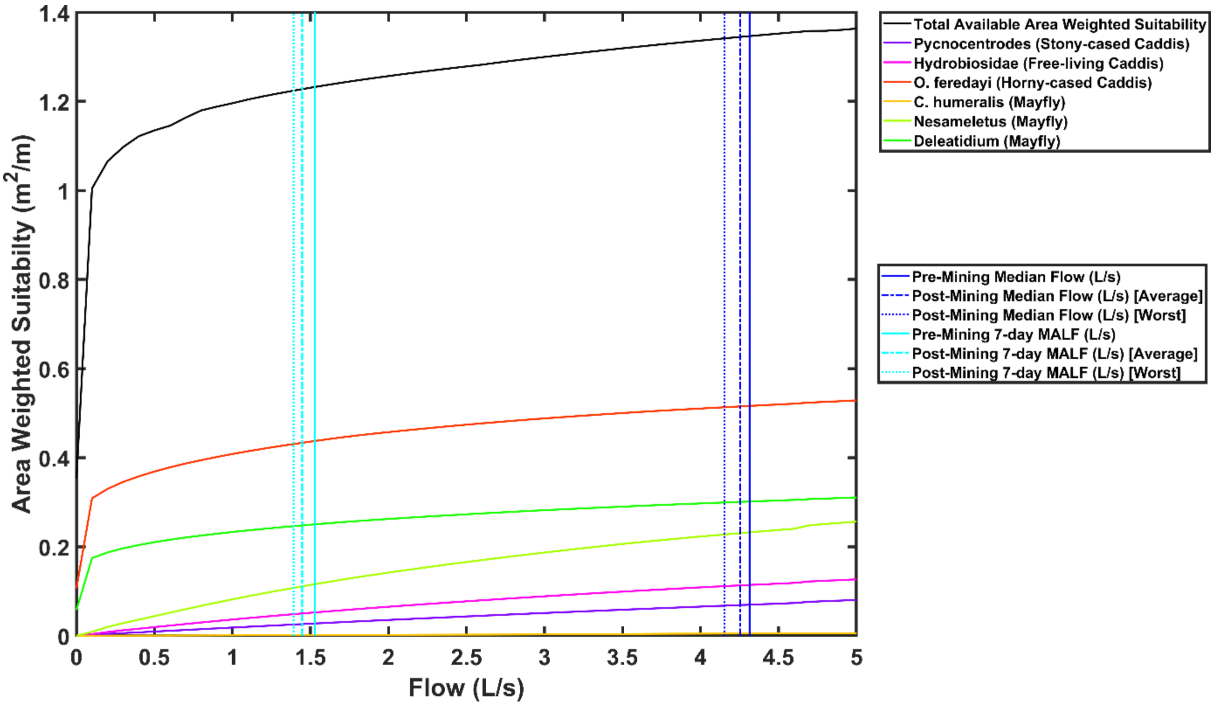

Figure 4-26: Area weighted suitability for caddisflies and mayflies in Tributary-R.

Figure 4-27 shows the AWS curves for the other invertebrates in the stream. The AWS curve for Elmidae (Figure 4-27) increases rapidly to 0.1 L/s, then increases gradually to beyond median flow. At the 7-day MALF, Elmidae AWS is 63.85% of the total available (Table 4-36). The AWS curve for Orthocladiinae is much lower and rises gradually from zero flow to beyond median flow. AWS for

Orthocladiinae is only 6.01% of the total available at the 7-day MALF (Table 4-36). Figure 4-27 shows there is virtually no suitable habitat for food producing invertebrates, *Zelandoperla* and Maoridiamesa.

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -0.63% for Elmidae and -6.61% for Orthocladiinae (Table 4-37). Reductions in AWS for the most likely post-mining 7-day MALF (average case) are -0.37% for Elmidae and -3.90% for Orthocladiinae (Table 4-37).

All species have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow have less impact on suitable instream habitat around the median flow. For example, the worst-case post-mining median flow results in reductions of AWS of -0.32% for Elmidae, and -2.59% for Orthocladiinae (Table 4-37).

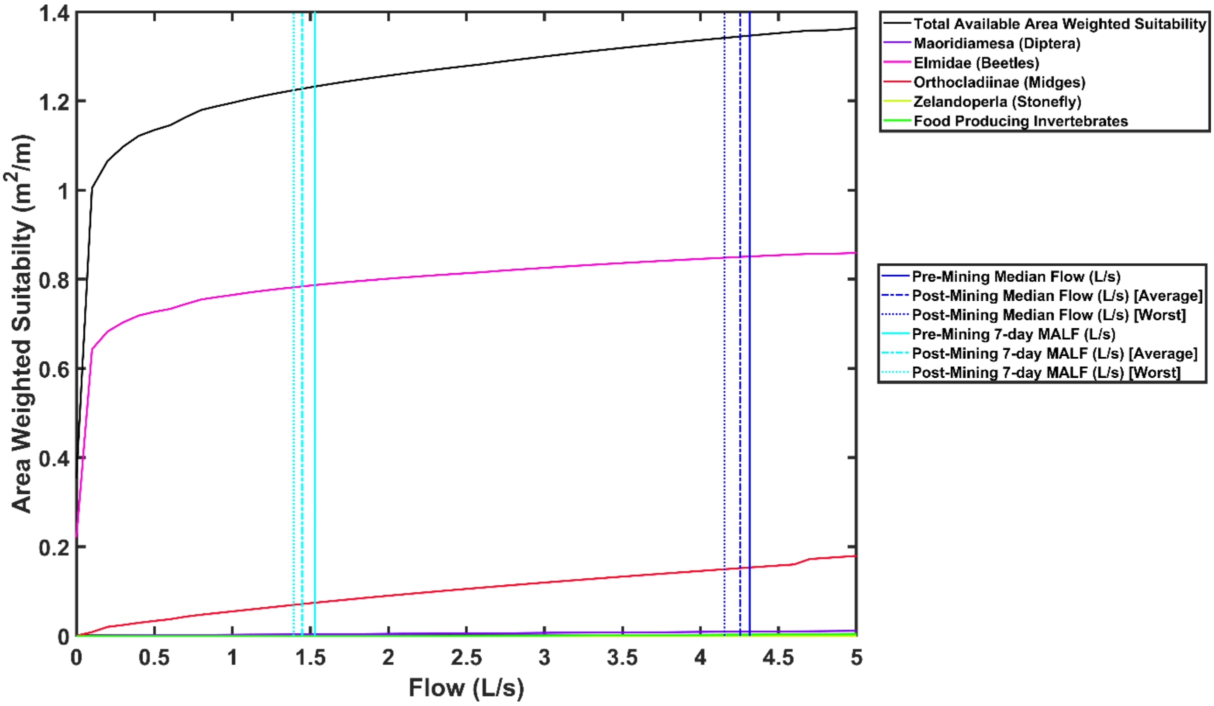

Figure 4-27: Area weighted suitability for other invertebrates in Tributary-R.

Table 4-36: Percentage of total available AWS suitable for invertebrates in Tributary-R.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	5.18	5.12	5.03	2.24	2.14	2.06
Hydrobiosidae (Free-living Caddis)	8.47	8.41	8.30	4.25	4.08	3.96
***O. feredayi* (Horny-cased Caddis)**	38.33	38.30	38.25	35.49	35.30	35.17
***C. humeralis* (Mayfly)**	0.39	0.38	0.37	0.12	0.12	0.11
***Nesameletus* (Mayfly)**	17.25	17.14	16.96	9.39	9.03	8.78
***Deleatidium* (Mayfly)**	22.38	22.36	22.31	20.30	20.19	20.11

Maoridiamesa (Diptera)	0.68	0.67	0.66	0.27	0.26	0.25
Elmidae (Beetles)	63.20	63.22	63.24	63.85	63.87	63.88
Orthocladiinae (Midges)	11.37	11.28	11.12	6.01	5.80	5.65
Zelandoperla (Stonefly)	0.00	0.00	0.00	0.00	0.00	0.00
Food Producing Invertebrates	0.20	0.19	0.18	0.00	0.00	0.00

Table 4-37: Percentage change of AWS for invertebrates in Tributary-R (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
O. feredayi **(Horny-cased Caddis)**	-0.21	-0.57	-0.92	-1.57
Nesameletus **(Mayfly)**	-0.74	-2.04	-4.24	-7.17
Deleatidium **(Mayfly)**	-0.26	-0.71	-0.96	-1.63
Elmidae (Beetles)	-0.12	-0.32	-0.37	-0.63
Orthocladiinae (Midges)	-0.95	-2.59	-3.90	-6.61

4.5.4 Area weighted suitability for fish (for species present)

Figure 4-28 and Figure 4-29 shows the Area Weighted Suitability (AWS) for fish for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all fish response curves must be within this model boundary. The other curves indicate the suitable habitat for various fish species, size classes or life stages.

The AWS for eels in Tributary-R is relatively low (Figure 4-28). Suitable habitat for small longfin eels (<300 mm long) initially rises sharply and then rises more gradually to beyond median flow. AWS for small shortfin eels (<300 mm long) rises gradually from zero flow and is still climbing at median flow to be greater than that of small longfin eels (Figure 4-28). At the 7-day MALF, small shortfin and small longfin eel AWS are 22.17% and 12.49% of total AWS respectively (Table 4-38). AWS curves for large shortfin and longfin eels are low and relatively flat (Figure 4-28). At the 7-day MALF their AWS are 6.59% and 2.59% of total AWS respectively (Table 4-38).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are most significant for small shortfin (<300 mm) with -6.21% (Table 4-39). Reductions in AWS for the most likely post-mining 7-day MALF (average case) are less significant and are between -1.00% and -3.64% for all eel classes (Table 4-39).

All eel classes have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would not have a substantial impact on instream habitat around average annual flows. Even for the post-mining worst case scenario (unlikely) the largest impact on suitable instream habitat is only -1.83%, which is for longfin eels >300 mm (Table 4-39).

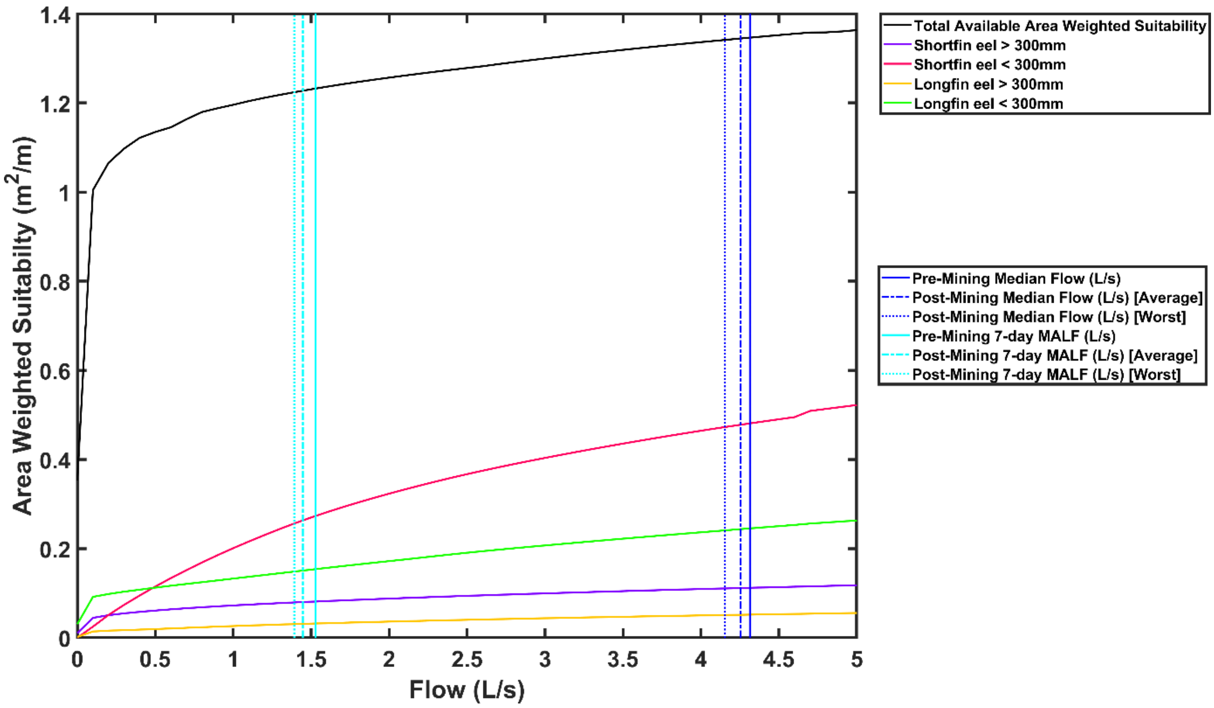

Figure 4-28: Area weighted suitability for eels in Tributary-R.

AWS for redfin bully and banded kōkopu juveniles and adults rises very steeply between 0 and 0.5 L/s. AWS for redfin bully then increases gradually between the 7-day MALF and the median flow. At the 7-day MALF AWS for redfin bully is 33.97% of the total available (Table 4-38). The stream is quite suitable for banded kōkopu juveniles and adults, with 50.17% and 37.39% of available instream habitat being suitable at the 7-day MALF.

The AWS curves for redfin bully and banded kōkopu are relatively flat near the 7-day MALF. The post-mining 7-day MALF flow scenarios are in this relatively flat portion of the curves indicating only small reductions in suitable instream habitat even in the worst case. The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -1.35% for redfin bully, -1.23% for banded kōkopu juveniles, and -2.56% for banded kōkopu adults (Table 4-39). Flow reductions near the median flow have less impact on suitable instream habitat for these taxa (Table 4-39).

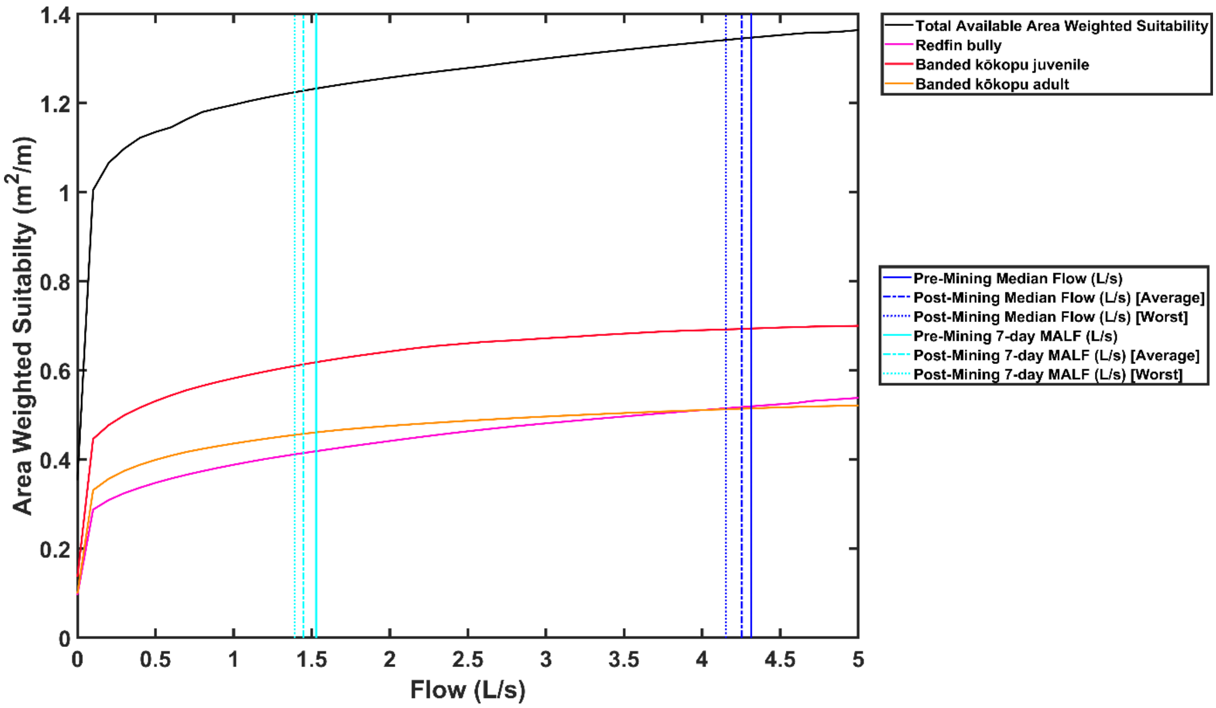

Figure 4-29: Area weighted suitability for native fish in Tributary-R.

Table 4-38: Percentage of total available AWS suitable for fish in Tributary-R.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	8.31	8.29	8.24	6.59	6.51	6.46
Shortfin eel <300 mm	35.72	35.54	35.23	22.17	21.45	20.93
Longfin eel >300 mm	3.84	3.82	3.79	2.59	2.53	2.49
Longfin eel <300 mm	18.22	18.12	17.95	12.49	12.27	12.13
Redfin bully	38.56	38.49	38.38	33.97	33.76	33.61
Banded kōkopu juvenile	51.52	51.54	51.57	50.17	49.97	49.83
Banded kōkopu adult	38.22	38.22	38.22	37.39	37.27	37.18

Table 4-39: Percentage change of AWS for fish in Tributary-R.

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	-0.46	-1.26	-1.51	-2.56
Shortfin eel <300 mm	-0.63	-1.73	-3.64	-6.21
Longfin eel >300 mm	-0.67	-1.83	-2.11	-3.56
Longfin eel <300 mm	-0.30	-0.83	-1.00	-1.70
Redfin bully	-0.11	-0.30	-0.79	-1.35
Banded kōkopu juvenile	-0.14	-0.38	-0.71	-1.23
Banded kōkopu adult	-0.46	-1.26	-1.51	-2.56

4.5.5 Instream habitat at low flows

Flow changes have the largest impact on suitable instream habitat at low flows. Previous sections have shown the impacts on instream habitat for species and classes of biota present in Tributary-R for the most likely post-mining 7-day MALF (average case) and the unlikely post-mining 7-day MALF (worst case). Setting minimum post-mining flows requires a subjective assessment of the allowable reduction of instream habitat for different groups of instream biota (Section 3.5). To assist with this assessment Figure 4-30 provides percentage reductions of suitable instream habitat for periphyton, invertebrates and fish in Tributary-R for flows less than the pre-mining 7-day MALF. Table 4-40 provides post-mining 7-day MALF flows that correspond to percentage reductions of suitable instream habitat between 0% and -20%.

The largest impact on suitable instream habitat in Tributary-R was for fish (Figure 4-30). To keep impacts on suitable instream habitat within -5% for all groups of biota a post-mining 7-day MALF of 1.24 L/s would need to be maintained (Table 4-40). To keep impacts on suitable instream habitat within -10% for all groups of biota a post-mining 7-day MALF of 0.99 L/s would need to be maintained (Table 4-40). The most likely post-mining 7-day MALF (average case) of 1.45 L/s results in small changes to suitable instream habitat and keeps impacts within -1.35% for all groups of biota (Figure 4-30). The unlikely post-mining 7-day MALF (worst case) of 1.39 L/s results in small changes to suitable instream habitat and keeps impacts within -2.31% for all groups of biota (Figure 4-30).

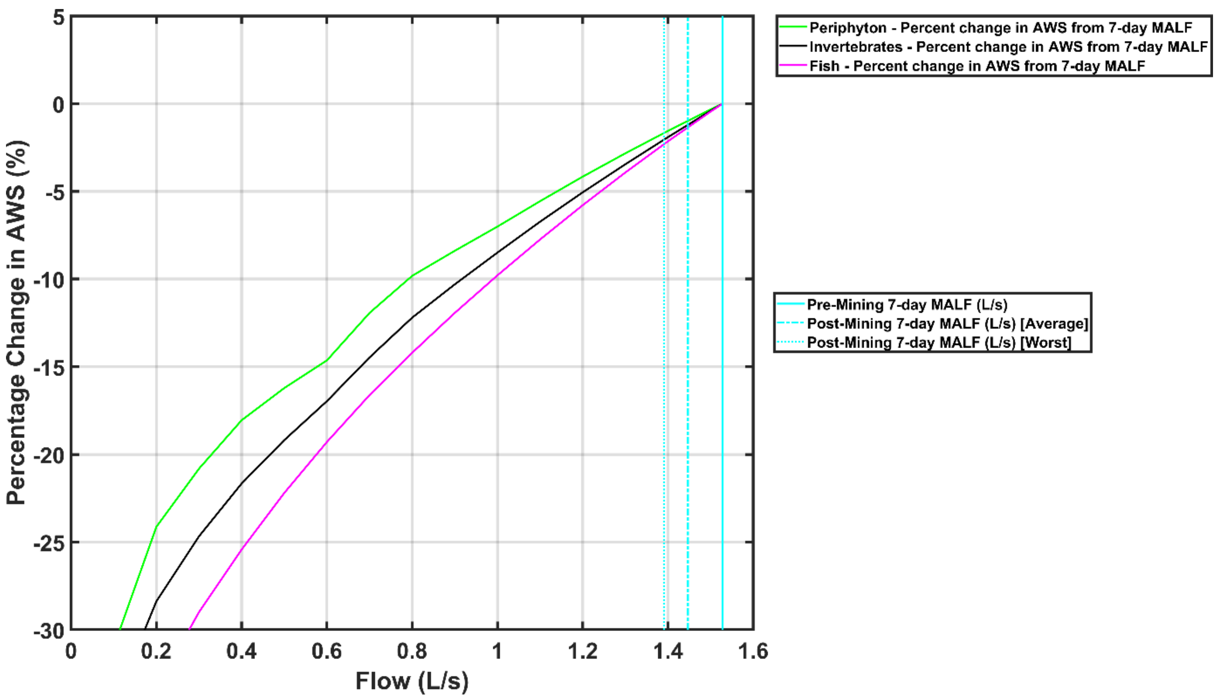

Figure 4-30: Percentage changes in Area Weighted Suitability for flows less than the pre-mining 7-day MALF for periphyton, invertebrates, and fish in Tributary-R.

Table 4-40: Percentage changes in AWS between 0% and -20% relative to pre-mining 7-day MALF and their corresponding flows for periphyton, invertebrates, and fish in Tributary-R.

Percentage Change in AWS From Pre-Mining 7-day MALF	Periphyton Flow (L/s)	Invertebrate Flow (L/s)	Fish Flow (L/s)
0%	1.53	1.53	1.53
-2.5%	1.33	1.36	1.38
-5%	1.14	1.20	1.24
-7.5%	0.96	1.06	1.11
-10%	0.79	0.92	0.99
-12.5%	0.68	0.79	0.87
-15%	0.58	0.68	0.77
-17.5%	0.43	0.58	0.67
-20%	0.33	0.47	0.58

4.6 Wharekirauponga Stream - WKP1 - Downstream Site

4.6.1 Habitat mapping surveys

Habitat mapping surveys were conducted in WKP1 following the methods in Appendix B. The results of these surveys are summarised in Table 4-41, with histograms of pool, riffle, and run lengths in Appendix L. Habitat proportions in WKP1 were then used in SEFA as input weightings for the cross-section surveys and thus output calculations of suitable area for instream taxa.

Table 4-41: Summary of habitat surveys in Wharekirauponga Stream - Downstream - WKP1.

	Number of Habitat Sections	Average Habitat Length (m)	Cumulative Length of Habitat (m)	Percentage of Survey Reach (%)
Pools	8	29	234.5	34.23
Riffles	15	15	229.5	33.51
Runs	16	14	221	32.26
Total	39	17.56	685	100

4.6.2 Area weighted suitability for periphyton (for species present)

Figure 4-31 shows the AWS for periphyton for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all periphyton response curves must be within this model boundary. The other curves indicate the suitable habitat for various periphyton classes. The blue vertical lines show pre-mining and post-mining flows, including the most likely post-mining flow [Average] and the worst-case scenario [Worst] (GHD 2024; Section 3.2).

For long filamentous algae AWS rises very sharply between 0 and 10 L/s, then increases more gradually and peaks at 70 L/s (56.14% of total AWS) and then decreases towards median flow (Figure 4-31). AWS for *Phormidium/Microcoleus* follows a similar initial trajectory but has still not peaked at median flow (Figure 4-31). AWS for thin films and diatoms rises quickly from zero flow, then the rate of rise decreases as flow increases (Figure 4-31). The stream has less suitable habitat for short filamentous algae.

The changes in AWS between the pre-mining 7-day MALF and the post-mining 7-day MALF worst case are +0.63% for long filamentous algae, -1.89% for *Phormidium/Microcoleus,* -5.68% for thin films, -8.57% for diatoms and -18.12% for short filamentous algae (Table 4-43). However, the stream is not very suitable for short filamentous algae for flows in the vicinity of the 7-day MALF, with only 11.01% of available instream habitat being suitable (Table 4-42).

AWS curves in the vicinity of the median flow, which is more representative of average annual conditions, are flatter than at the 7-day MALF so any flow losses due to mining would have less effect on periphyton near the median flow. For the worst-case post-mining median flow, changes in AWS are small, with +1.70% for long filamentous algae, -0.71% for *Phormidium/Microcoleus,* -1.49% for thin films, -2.61% for diatoms and -1.57% for short filamentous algae (Table 4-43).

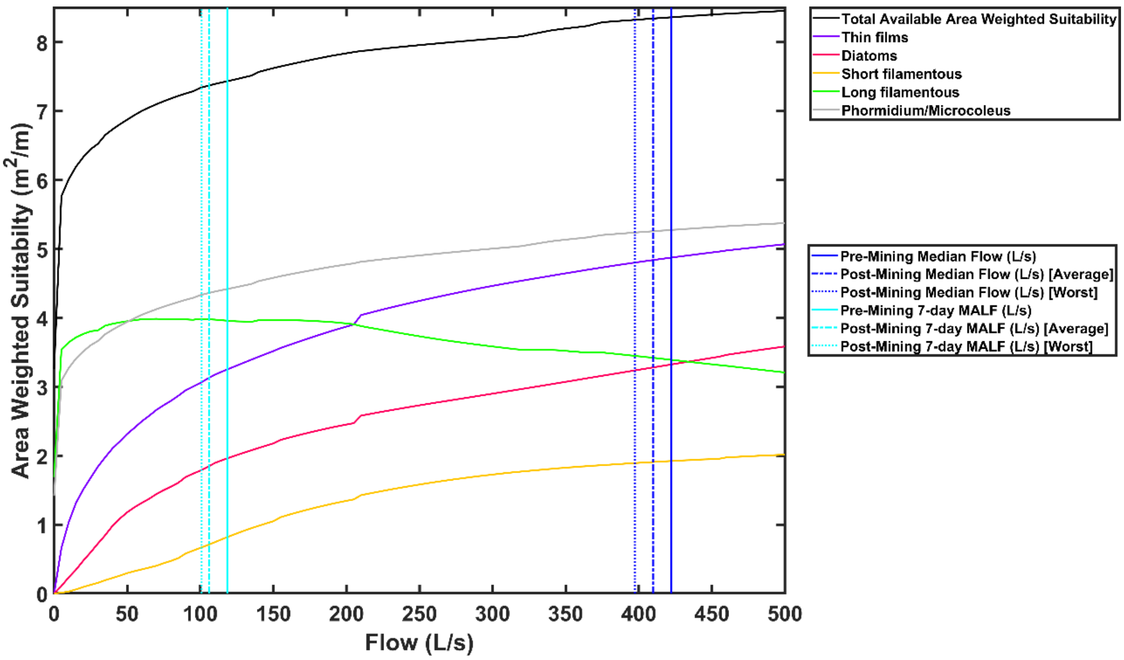

Figure 4-31: Area weighted suitability for periphyton in Wharekirauponga Stream - WKP1 - Downstream.

Table 4-42: Percentage of total available AWS suitable for periphyton in Wharekirauponga Stream - WKP1 - Downstream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	58.30	58.00	57.69	43.74	42.45	41.77
Diatoms	39.76	39.33	38.89	26.38	25.06	24.42
Short filamentous	23.00	22.87	22.74	11.01	9.64	9.12
Long filamentous	40.55	41.00	41.43	53.26	53.97	54.26
Phormidium/Microcoleus	63.10	63.01	62.92	59.44	59.16	59.04

Table 4-43: Percentage change of AWS for periphyton in Wharekirauponga Stream - WKP1 - Downstream.

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	-0.73	-1.49	-3.76	-5.68
Diatoms	-1.30	-2.61	-5.82	-8.57
Short filamentous	-0.76	-1.57	-13.13	-18.12
Long filamentous	0.87	1.70	0.49	0.63
Phormidium/Microcoleus	-0.35	-0.71	-1.30	-1.89

4.6.3 Area weighted suitability for invertebrates (for species present)

Figure 4-32 and Figure 4-33 shows the AWS for macroinvertebrates for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all invertebrate response curves must be within this model boundary. The other curves indicate the suitable habitat for various macroinvertebrate species and classes.

Figure 4-32 shows the AWS curves for caddisflies and mayflies. The downstream site of Wharekirauponga Stream does not seem to be very suitable for some of these invertebrates as their AWS is low relative to the total available (Figure 4-32). AWS for *O. feredayi* and *Deleatidium* rises very sharply from zero flow to 10 L/s then increases more gradually to beyond the median flow. At the 7-day MALF, AWS for *O. feredayi* and *Deleatidium* is 42.24% and 24.97% of the total available respectively. The AWS curves for *Nesameletus*, *Pycnocentrodes* and Hydrobiosidae, gradually increase with flow to beyond the median flow. Their AWS at the 7-day MALF are 24.67%, 10.75% and 12.42% of the total available AWS respectively (Table 4-44). There is very little suitable habitat for *C. humeralis* and *Aoteapsyche*.

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -2.81% for *O. feredayi*, -3.56% for *Deleatidium*, and -6.87% for *Nesameletus* (Table 4-45). There are larger reductions for Hydrobiosidae and *Pycnocentrodes* (Table 4-45); however, the stream is not very suitable for them regardless of any flow change (Figure 4-32).

These species all have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would have less impact on instream habitat availability around the median flow. The changes in AWS are between -0.64% and -2.48% for the worst-case post-mining median flow (Table 4-45).

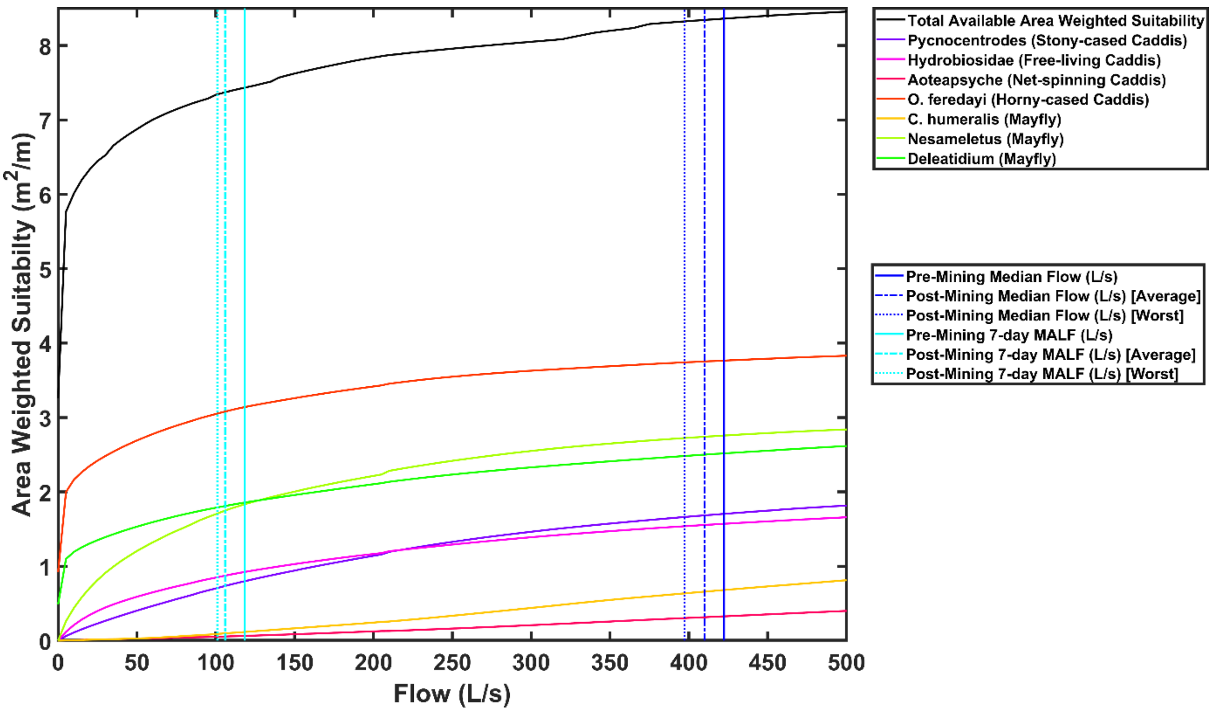

Figure 4-32: Area weighted suitability for caddisflies and mayflies in Wharekirauponga Stream - WKP1 - Downstream.

Figure 4-33 shows the AWS curves for the other invertebrates in the stream. The AWS curves for Elmidae and *Potamopyrgus*, (Figure 4-33) increase rapidly from 0 to 10 L/s, then rise gradually and peak near the median flow. At the 7-day MALF, Elmidae AWS is 55.50% and *Potamopyrgus* AWS is

33.93% of the total available (Table 4-44). The AWS curve for Orthocladiinae rises gradually to beyond median flow and is 17.37% of the total available at the 7-day MALF (Table 4-44). Figure 4-33 shows that there is virtually no suitable habitat for food producing invertebrates and Maoridiamesa at the 7-day MALF.

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -0.80% for Elmidae, -2.44% for *Potamopyrgus*, and -9.63% for Orthocladiinae (Table 4-45). For the most likely reduction in 7-day MALF (average case) changes are between -0.53% and -6.61% (Table 4-45).

These species all have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would have less impact on instream habitat availability around this flow. The reductions in AWS between the pre-mining median flow and worst-case post-mining median flow are +0.08% for Elmidae, -0.43% for *Potamopyrgus*, and -2.28% for Orthocladiinae (Table 4-45).

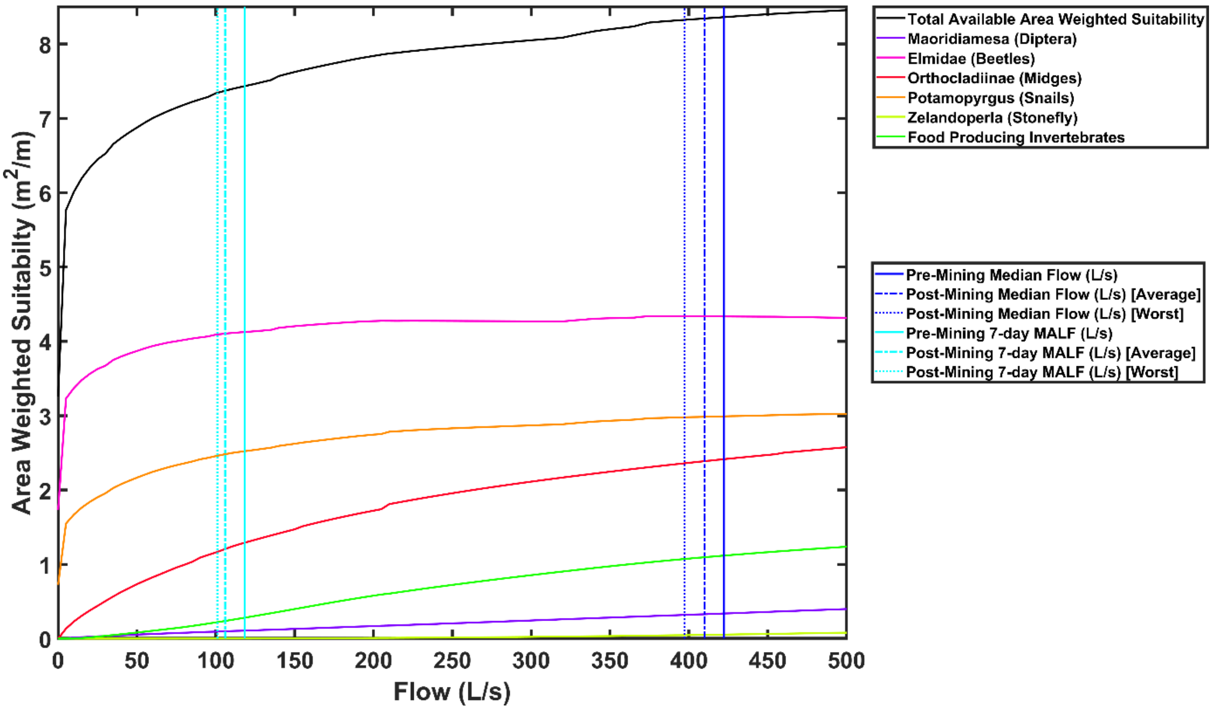

Figure 4-33: Area weighted suitability for other invertebrates in Wharekirauponga Stream - WKP1 - Downstream.

Table 4-44: Percentage of total available AWS suitable for invertebrates in Wharekirauponga Stream - WKP1 - Downstream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	20.38	20.18	19.96	10.75	9.97	9.63
Hydrobiosidae (Free-living Caddis)	18.78	18.64	18.48	12.42	11.86	11.59
***Aoteapsyche* (Net-spinning Caddis)**	3.91	3.77	3.64	0.86	0.76	0.72
***O. feredayi* (Horny-cased Caddis)**	45.03	44.98	44.93	42.24	41.77	41.56
***C. humeralis* (Mayfly)**	8.14	7.89	7.63	1.57	1.33	1.22
***Nesameletus* (Mayfly)**	32.98	32.85	32.72	24.67	23.72	23.26
***Deleatidium* (Mayfly)**	30.10	29.96	29.82	24.97	24.56	24.38
Maoridiamesa (Diptera)	4.05	3.94	3.84	1.46	1.35	1.30
Elmidae (Beetles)	51.84	51.98	52.11	55.50	55.67	55.73
Orthocladiinae (Midges)	28.88	28.62	28.35	17.37	16.36	15.90
***Potamopyrgus* (Snails)**	35.77	35.77	35.77	33.93	33.66	33.51
Zelandoperla (Stonefly)	0.66	0.61	0.57	0.04	0.03	0.03
Food Producing Invertebrates	13.37	13.13	12.88	3.80	3.24	3.03

Table 4-45: Percentage change of AWS for invertebrates in Wharekirauponga Stream - WKP1 - Downstream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	-1.22	-2.48	-8.07	-11.52
Hydrobiosidae (Free-living Caddis)	-1.00	-2.04	-5.35	-7.80
***O. feredayi* (Horny-cased Caddis)**	-0.32	-0.64	-1.93	-2.81
***Nesameletus* (Mayfly)**	-0.59	-1.22	-4.65	-6.87
***Deleatidium* (Mayfly)**	-0.68	-1.39	-2.48	-3.56
Elmidae (Beetles)	0.04	0.08	-0.53	-0.80
Orthocladiinae (Midges)	-1.12	-2.28	-6.61	-9.63
***Potamopyrgus* (Snails)**	-0.21	-0.43	-1.62	-2.44

4.6.4 Area weighted suitability for fish (for species present)

Figure 4-34 and Figure 4-35 show the AWS for fish for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all fish response curves must be within this model boundary. The other curves indicate the suitable habitat for various fish species, size classes or life stages.

AWS for large shortfin and longfin eels (>300 mm long) initially rises steeply to about 20 L/s and then increases more gradually until flattening near the median flow. At the 7-day MALF their AWS are 40.59% and 37.76% of total AWS respectively (Table 4-46). Suitable habitat for small shortfin and longfin eels (<300 mm long) rises more gradually than for longfin eels; however, the AWS curves also flatten near the median flow (Figure 4-34). At the 7-day MALF there is a lot more suitable habitat for small shortfin eels than for small longfin eels, with 38.47% and 23.37% of total AWS respectively (Table 4-46).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst-case are most significant for small shortfin and small longfin eels, with -5.27% and -6.35% respectively (Table 4-47). All size classes of eels have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would have less impact on suitable instream habitat around the median flow than around the 7-day MALF. Flow reductions relative to the median flow have the largest impact on large longfin eels (>300 mm) with the worst case post-mining median flow causing a reduction of suitable instream habitat of -1.08% (Table 4-47); however, this flow reduction would result in more suitable instream habitat for small shortfin eels (<300 mm) with a small increase of +0.37% (Table 4-47).

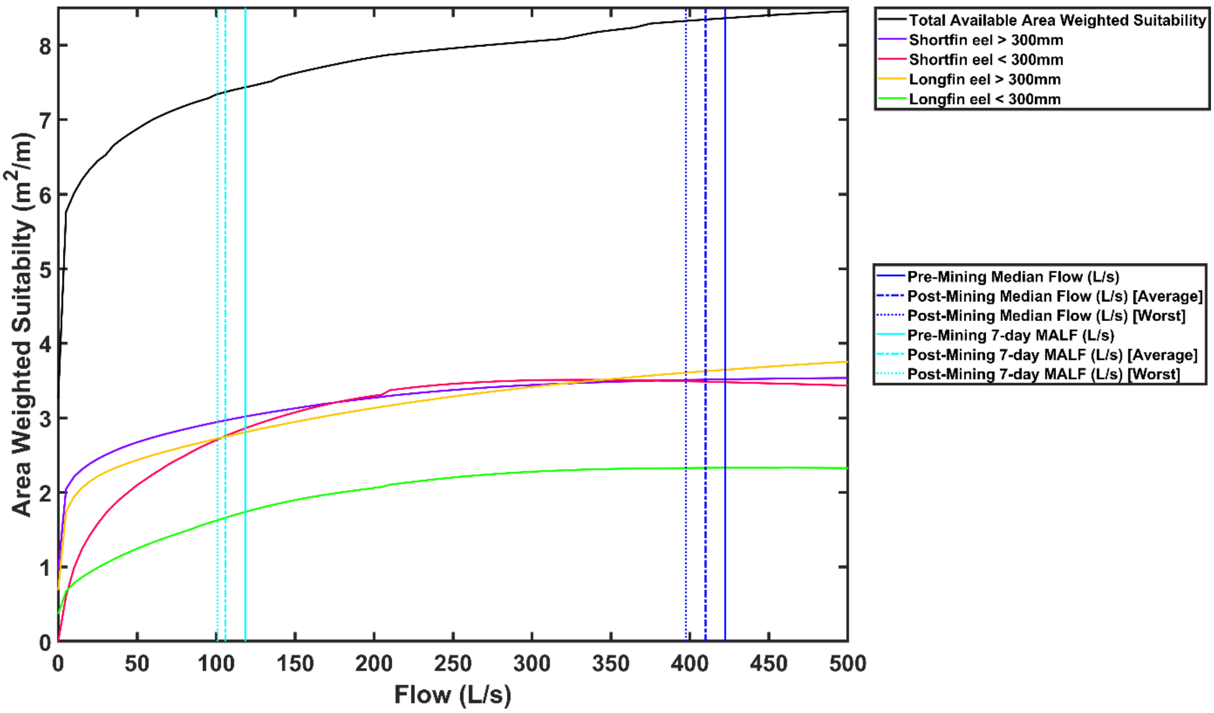

Figure 4-34: Area weighted suitability for eels in Wharekirauponga Stream - WKP1 - Downstream.

AWS for redfin bully, banded kōkopu juveniles and adults rises very steeply between 0 and 20 L/s, then continues to rise more gradually until AWS peaks at 255 L/s, 70 L/s, and 50 L/s respectively (Figure 4-35). Beyond the peaks, AWS declines gradually towards median flow (Figure 4-35).

Shortjaw kōkopu AWS also rises steeply from zero flow but soon peaks at a low level (12.74% of total available AWS) at 70 L/s and then declines gradually. Kōaro and torrentfish AWS increases very slowly from zero flow. There is very little suitable instream habitat for torrentfish at the 7-day MALF, with only 1.00% of the total available AWS (Table 4-46).

The AWS curves for all fish species are relatively flat near the 7-day MALF. The changes in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are +1.21% for banded kōkopu juveniles, +0.52% for banded kōkopu adults, -2.98% for redfin bully, and +0.96% for shortjaw kōkopu (Table 4-47). The most significant change is for kōaro with -11.73%; however, this site is not very suitable for kōaro with AWS of only 4.93% of the total available at the 7-day MALF (Table 4-46). For the most likely reduction in 7-day MALF (average case) there are smaller changes in AWS with +0.88% for banded kōkopu juveniles, +0.37% for banded kōkopu adults, -2.02% for redfin bully, +0.70% for shortjaw kokopu, and -8.30% for kōaro (Table 4-47).

All native fish in Figure 4-35 have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would have less impact on instream habitat availability around this flow. For the worst case post-mining median flow there are small increases in suitable instream habitat between +0.53% and +0.96% for banded kōkopu juveniles, banded kōkopu adults, redfin bully, and shortjaw kōkopu (Table 4-47). Kōaro and torrent fish have reduced suitable instream habitat due to flow reduction near the median flow; however, the stream isn't very suitable for them to begin with.

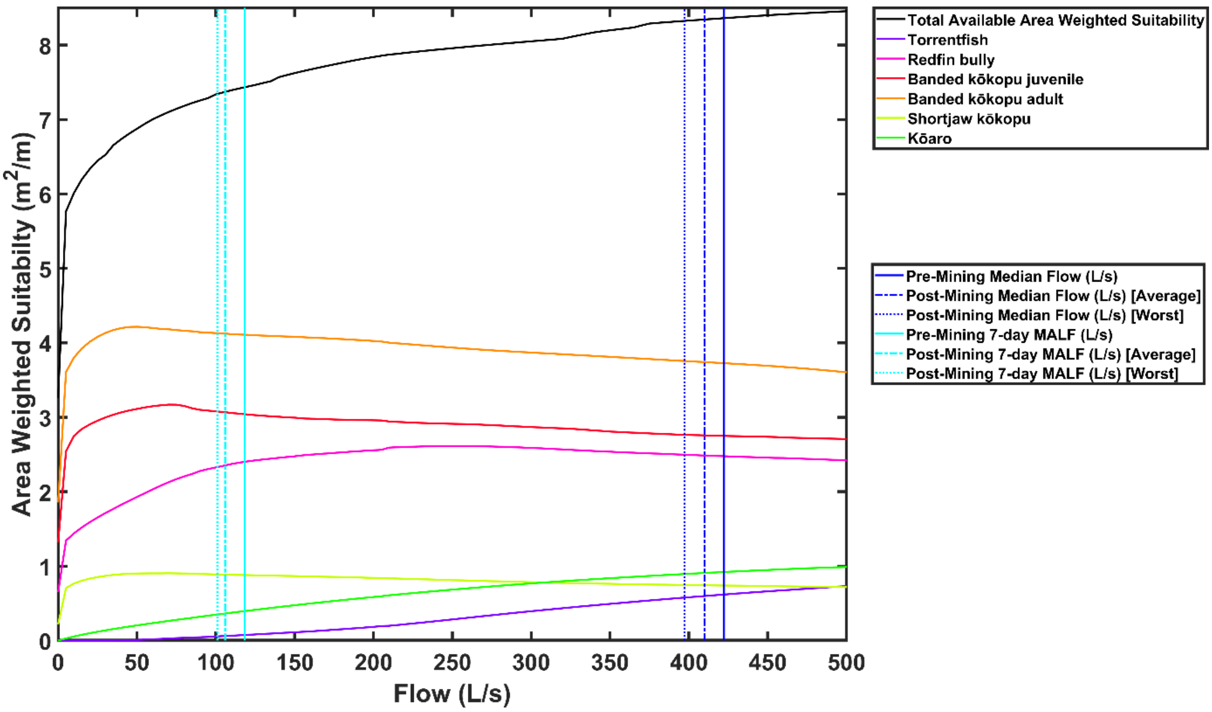

Figure 4-35: Area weighted suitability for fish in Wharekirauponga Stream - WKP1 - Downstream.

Table 4-46: Percentage of total available AWS suitable for fish in Wharekirauponga Stream - WKP1 - Downstream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	42.05	42.10	42.13	40.59	40.24	40.11
Shortfin eel <300 mm	41.60	41.78	41.94	38.47	37.41	36.90
Longfin eel >300 mm	43.60	43.46	43.31	37.76	37.27	37.08
Longfin eel <300 mm	27.86	27.91	27.95	23.37	22.52	22.16
Torrentfish	7.40	7.17	6.93	1.00	0.83	0.76
Redfin bully	29.62	29.80	29.99	32.30	31.92	31.73
Banded kōkopu juvenile	32.89	33.04	33.21	40.90	41.61	41.91
Banded kōkopu adult	44.56	44.84	45.11	55.26	55.94	56.24
Shortjaw kōkopu	8.84	8.90	8.97	11.84	12.02	12.10
Kōaro	11.02	10.88	10.74	5.33	4.93	4.76

Table 4-47: Percentage change of AWS for fish in Wharekirauponga Stream - WKP1 - Downstream (showing taxa where at least 4% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]

Shortfin eel >300 mm	-0.12	-0.25	-1.69	-2.39
Shortfin eel <300 mm	0.19	0.37	-3.58	-5.27
Longfin eel >300 mm	-0.53	-1.08	-2.13	-3.01
Longfin eel <300 mm	-0.04	-0.11	-4.46	-6.35
Redfin bully	0.38	0.80	-2.02	-2.98
Banded kōkopu juvenile	0.24	0.53	0.88	1.21
Banded kōkopu adult	0.40	0.78	0.37	0.52
Shortjaw kōkopu	0.47	0.96	0.70	0.96
Kōaro	-1.42	-2.90	-8.30	-11.73

4.6.5 Instream habitat at low flows

Flow changes have the largest impact on suitable instream habitat at low flows. Previous sections have shown the impacts on instream habitat for species and classes of biota present in Wharekirauponga Stream (WKP1 – Downstream) for the most likely post-mining 7-day MALF (average case) and the unlikely post-mining 7-day MALF (worst case). Setting minimum post-mining flows requires a subjective assessment of the allowable reduction of instream habitat for different groups of instream biota (Section 3.5). To assist with this assessment Figure 4-36 provides percentage reductions of suitable instream habitat for periphyton, invertebrates and fish in Wharekirauponga Stream (WKP1 – Downstream) for flows less than the pre-mining 7-day MALF. Table 4-48 provides post-mining 7-day MALF flows that correspond to percentage reductions of suitable instream habitat between 0% and -20%.

The largest impact on suitable instream habitat in Wharekirauponga Stream (WKP1 – Downstream) is for invertebrates (Figure 4-36). To keep impacts on suitable instream habitat within -5% for all groups of biota a post-mining 7-day MALF of 99.36 L/s would need to be maintained (Table 4-48). To keep impacts on suitable instream habitat within -10% for all groups of biota a post-mining 7-day MALF of 83.11 L/s would need to be maintained (Table 4-48). The most likely post-mining 7-day MALF (average case) of 105.93 L/s keeps impacts within -3.13% for all groups of biota (Figure 4-36). The unlikely post-mining 7-day MALF (worst case) of 100.94 L/s keeps impacts within -4.54% for all groups of biota (Figure 4-36).

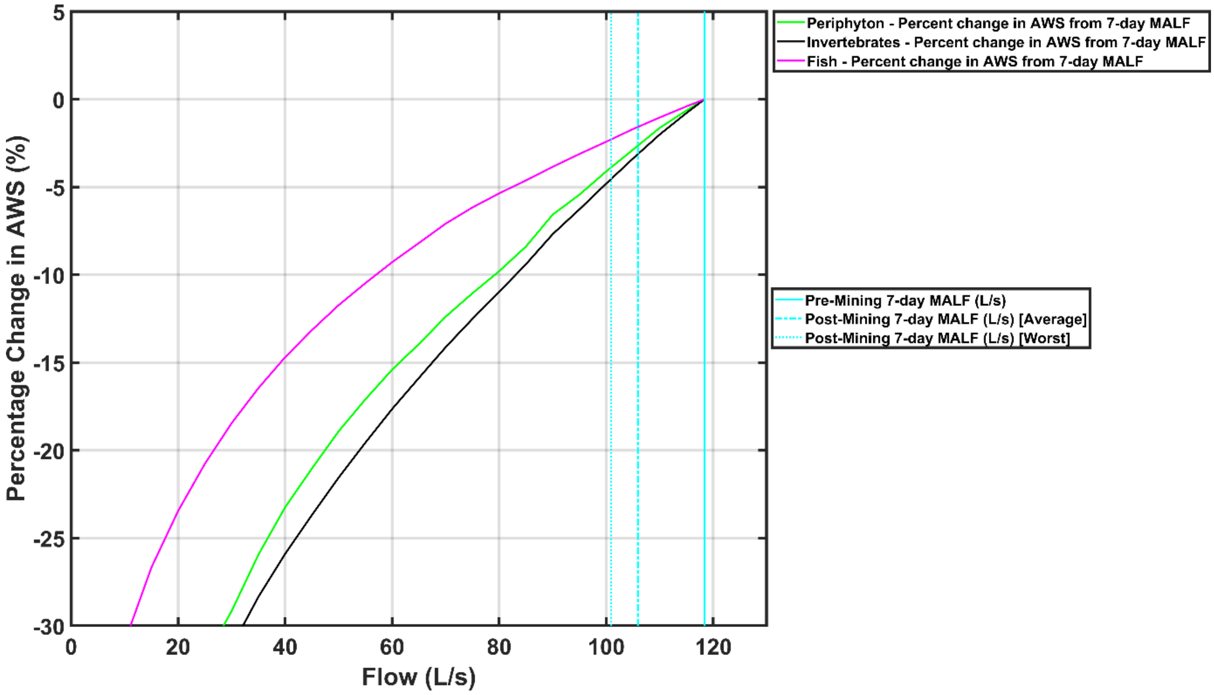

Figure 4-36: Percentage changes in Area Weighted Suitability for flows less than the pre-mining 7-day MALF for periphyton, invertebrates, and fish in Wharekirauponga Stream - WKP1 - Downstream.

Table 4-48: Percentage changes in AWS between 0% and -20% relative to pre-mining 7-day MALF and their corresponding flows for periphyton, invertebrates, and fish in Wharekirauponga Stream - WKP1 - Downstream.

Percentage Change in AWS From Pre-Mining 7-day MALF	Periphyton Flow (L/s)	Invertebrate Flow (L/s)	Fish Flow (L/s)
0%	118.42	118.42	118.42
-2.5%	106.53	108.23	99.47
-5%	96.66	99.36	82.48
-7.5%	87.46	90.67	68.14
-10%	79.20	83.11	57.00
-12.5%	69.65	75.05	47.30
-15%	61.39	67.51	39.14
-17.5%	53.89	60.42	32.38
-20%	47.45	53.91	26.65

4.7 Wharekirauponga Stream - WKP2 - Upstream Site

4.7.1 Habitat mapping surveys

Habitat mapping surveys were conducted in WKP2 following the methods in Appendix B. The results of these surveys are summarised in Table 4-49, with histograms of pool, riffle, and run lengths in Appendix M. Habitat proportions in WKP2 were then used in SEFA as input weightings for the cross-section surveys and thus output calculations of suitable area for instream taxa.

Table 4-49: Summary of habitat surveys in Wharekirauponga Stream - Upstream - WKP2.

	Number of Habitat Sections	Average Habitat Length (m)	Cumulative Length of Habitat (m)	Percentage of Survey Reach (%)
Pools	7	15	102	21.77
Riffles	20	12	244.5	52.19
Runs	13	9.4	122	26.04
Total	40	11.71	468.5	100

4.7.2 Area weighted suitability for periphyton (for species present)

Figure 4-37 shows the AWS for periphyton for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all periphyton response curves must be within this model boundary. The other curves indicate the suitable habitat for various periphyton classes. The blue vertical lines show pre-mining and post-mining flows, including the most likely post-mining flow [Average] and the worst-case scenario [Worst] (GHD 2024; Section 3.2).

For long filamentous algae and *Phormidium/Microcoleus*, AWS rises very sharply between 0 and 25 L/s, then rises more gradually to the 7-day MALF (Figure 4-37). For long filamentous algae, AWS peaks between the 7-day MALF and median flow. AWS for *Phormidium/Microcoleus* follows a similar initial trajectory but has still not peaked at median flow (Figure 4-31). AWS for thin films and diatoms rises more gradually than for long filamentous algae and *Phormidium/Microcoleus* (Figure 4-31). The stream has less suitable habitat for short filamentous algae, with AWS of only 8.72% of the total available at 7-day MALF, compared to 75.27% for long filamentous algae (Table 4-50).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -0.93% for long filamentous algae, -2.16% for *Phormidium/Microcoleus,* -5.41% for thin films, and -10.28% for diatoms (Table 4-51). For the most likely post-mining 7-day MALF (average case), changes in suitable habitat are smaller, with the largest impact being on diatoms with a -6.37% reduction in suitable instream habitat (Table 4-51).

The AWS curves in the vicinity of the median flow are flatter than at the 7-day MALF so any flow losses dues to mining would have less effect on periphyton habitat availability. For the worst-case post-mining median flow, changes to suitable instream habitat are between -0.68% and -4.54%, with the largest impact being on short filamentous algae (Table 4-51).

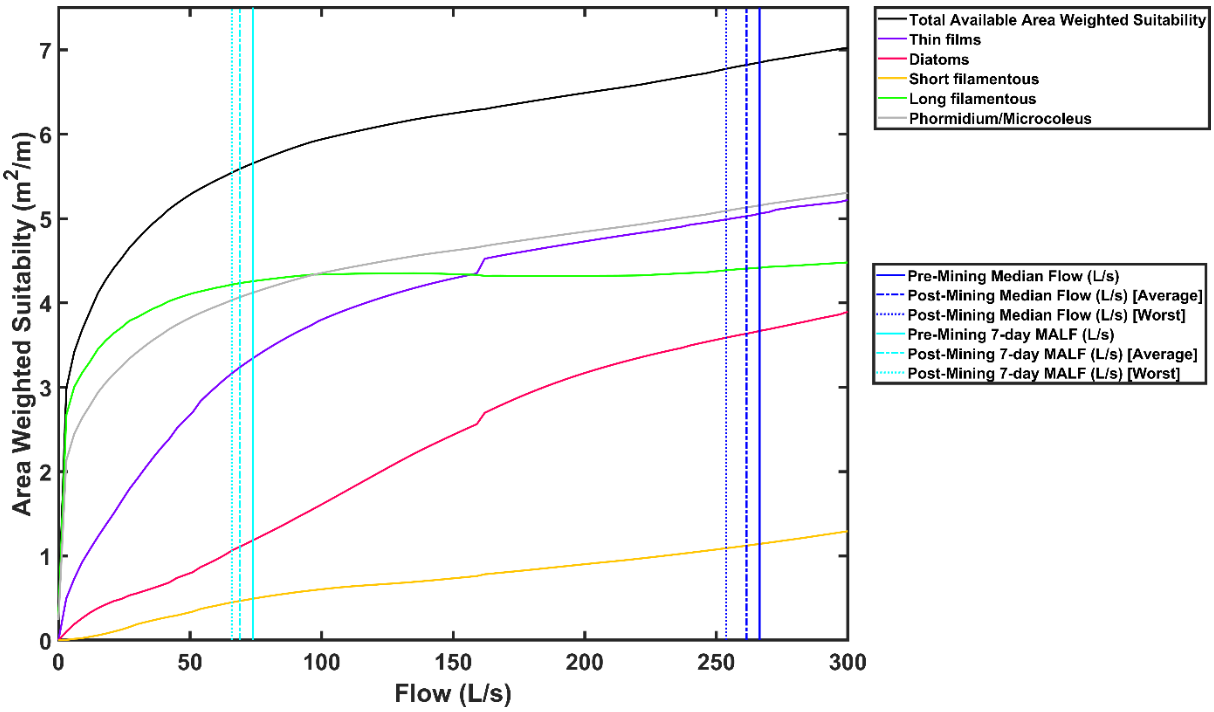

Figure 4-37: Area weighted suitability for periphyton in Wharekirauponga Stream - WKP2 - Upstream.

Table 4-50: Percentage of total available AWS suitable for periphyton in Wharekirauponga Stream - WKP2 - Upstream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	73.84	73.71	73.65	59.14	57.92	57.06
Diatoms	53.54	53.30	52.96	20.97	19.86	19.19
Short filamentous	16.69	16.46	16.11	8.72	8.36	8.11
Long filamentous	64.47	64.59	64.76	75.27	75.76	76.06
Phormidium/Microcoleus	75.26	75.22	75.15	72.89	72.79	72.73

Table 4-51: Percentage change of AWS for periphyton in Wharekirauponga Stream - WKP2 - Upstream.

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Thin films	-0.59	-1.37	-3.21	-5.41
Diatoms	-0.87	-2.19	-6.37	-10.28
Short filamentous	-1.77	-4.54	-5.31	-8.82
Long filamentous	-0.24	-0.68	-0.52	-0.93
Phormidium/Microcoleus	-0.47	-1.25	-1.28	-2.16

4.7.3 Area weighted suitability for invertebrates (for species present)

Figure 4-38 and Figure 4-39 shows the AWS for macroinvertebrates for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all invertebrate response curves must be within this model boundary. The other curves indicate the suitable habitat for various macroinvertebrate species and classes.

Figure 4-38 shows the AWS curves for caddisflies and mayflies. The upstream Wharekirauponga Stream reach is not very suitable for some classes of caddisflies and mayflies, with low AWS relative to the total available. AWS for *O. feredayi* and *Deleatidium* rises very sharply from zero flow to around 10 L/s then increases more gradually to beyond the median flow. At the pre-mining 7-day MALF, AWS for *O. feredayi* and *Deleatidium* is 47.74% and 28.22% of the total available respectively (Table 4-52). The AWS curves for *Nesameletus*, *Pycnocentrodes* and Hydrobiosidae, gradually increase with flow to beyond the median flow. Their AWS at the 7-day MALF are 26.77%, 9.58% and 11.17% of the total available respectively (Table 4-52). There is very little suitable instream habitat for *C. humeralis* and *Aoteapsyche*.

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -2.88% for *O. feredayi*, -3.40% for *Deleatidium*, -7.44% for *Nesameletus*, -8.94% for *Pycnocentrodes* and -7.77% for Hydrobiosidae (Table 4-53). For the most likely post-mining 7-day MALF (average case) impacts on instream habitat are smaller and range between -1.74% and -5.49% (Table 4-53).

The AWS curves for caddisflies and mayflies are all relatively flat in the vicinity of the median flow (Figure 4-38) so small reductions in flow due to mining would have less impact on instream habitat availability around the median flow, which is more representative of average annual conditions than the 7-day MALF. For the worst-case post-mining median flow changes to suitable instream habitat range from -1.03% to -2.85% (Table 4-53).

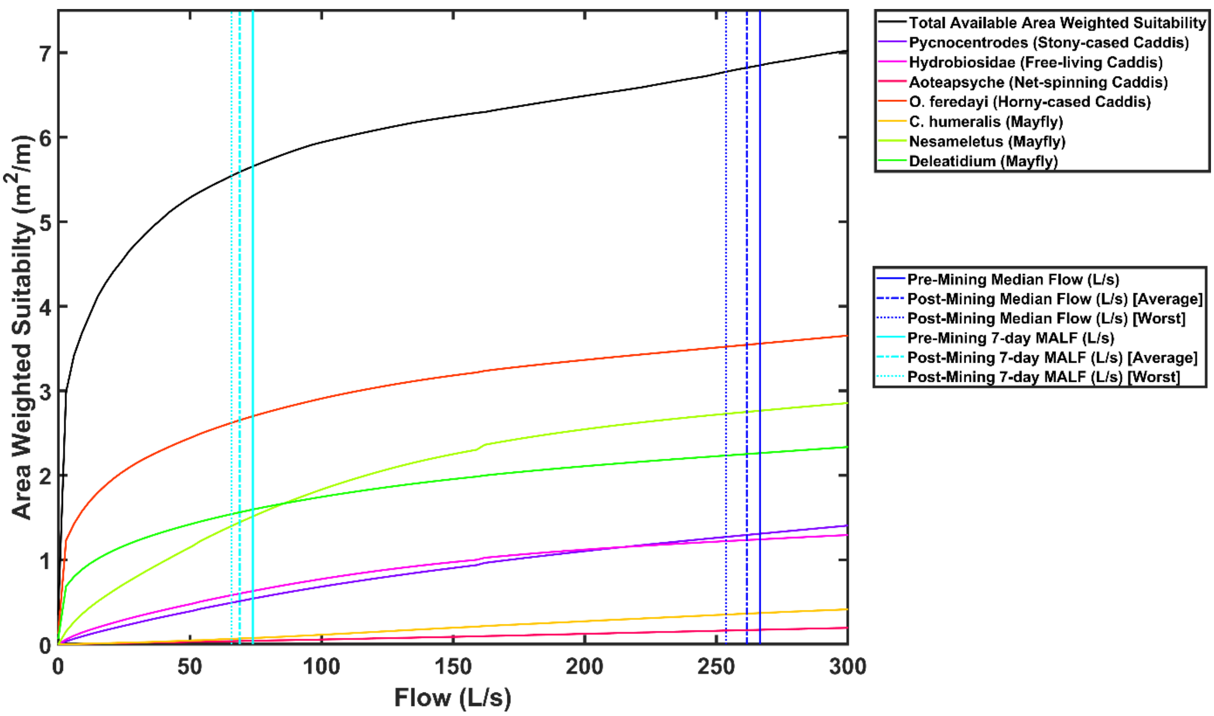

Figure 4-38: Area weighted suitability for caddisflies and mayflies in Wharekirauponga Stream - WKP2 - Upstream.

Figure 4-39 shows the AWS curves for the other invertebrates in the stream. The AWS curves for Elmidae and *Potamopyrgus* increase rapidly from 0 to 10 L/s, continue to rise gradually to the 7-day MALF, then flatten between the 7-day MALF and median flow (Figure 4-39). At the 7-day MALF Elmidae AWS is 54.60% and the *Potamopyrgus* AWS is 30.93% of the total available (Table 4-52). The AWS curve for Orthocladiinae rises gradually from zero flow to beyond median flow and is 16.23% of the total available at the 7-day MALF (Table 4-52). Figure 4-39 shows that at the 7-day MALF there is virtually no suitable habitat for food producing invertebrates, Zelandoperla and Maoridiamesa.

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -1.99% for Elmidae, -3.22% for *Potamopyrgus*, and -7.18% for Orthocladiinae (Table 4-53). For the most likely post-mining 7-day MALF (average case) reductions in AWS are -1.18% for Elmidae, -1.92% for *Potamopyrgus*, and -4.33% for Orthocladiinae (Table 4-53).

These species all have relatively flat AWS curves in the vicinity of the median flow (representative of average annual conditions) so small reductions in flow would have less impact on instream habitat availability around this flow. For the worst-case post-mining median flow reductions in suitable instream habitat range from -0.95% for Elmidae to -2.78% for Orthocladiinae (Table 4-53).

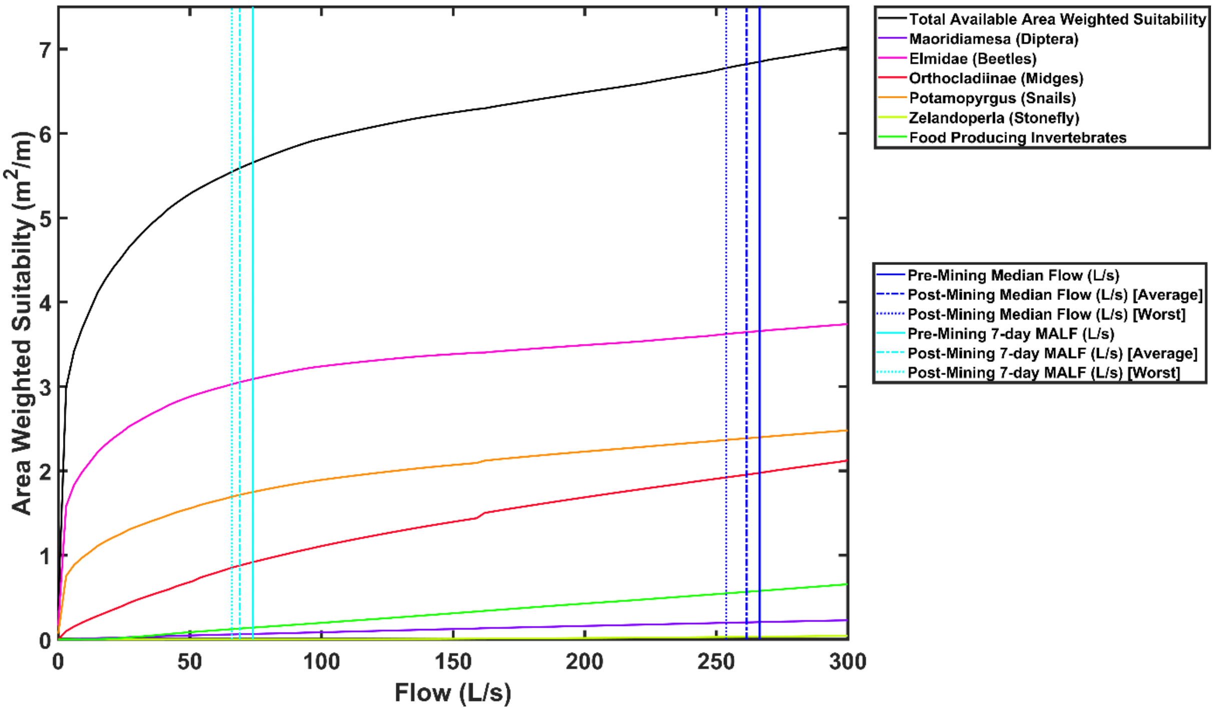

Figure 4-39: Area weighted suitability for other invertebrates in Wharekirauponga Stream - WKP2 - Upstream.

Table 4-52: Percentage of total available AWS suitable for invertebrates in Wharekirauponga Stream - WKP2 - Upstream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Pycnocentrodes **(Stony-cased Caddis)**	19.11	18.98	18.78	9.58	9.16	8.90

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Hydrobiosidae (Free-living Caddis)	18.14	18.10	18.04	11.17	10.77	10.51
***Aoteapsyche* (Net-spinning Caddis)**	2.52	2.48	2.42	0.76	0.72	0.69
***O. feredayi* (Horny-cased Caddis)**	51.95	51.95	51.99	47.74	47.46	47.29
***C. humeralis* (Mayfly)**	5.42	5.34	5.21	1.34	1.24	1.18
***Nesameletus* (Mayfly)**	40.36	40.32	40.27	26.77	25.86	25.28
***Deleatidium* (Mayfly)**	33.03	33.01	32.99	28.22	27.97	27.81
Maoridiamesa (Diptera)	3.02	2.99	2.93	1.18	1.13	1.10
Elmidae (Beetles)	53.38	53.42	53.47	54.60	54.59	54.58
Orthocladiinae (Midges)	28.86	28.65	28.37	16.23	15.71	15.36
***Potamopyrgus* (Snails)**	35.01	34.97	34.93	30.93	30.70	30.54
Zelandoperla (Stonefly)	0.50	0.48	0.45	0.03	0.02	0.02
Food Producing Invertebrates	8.43	8.29	8.08	2.50	2.33	2.23

Table 4-53: Percentage change of AWS for invertebrates in Wharekirauponga Stream - WKP2 - Upstream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
***Pycnocentrodes* (Stony-cased Caddis)**	-1.11	-2.85	-5.49	-8.94
Hydrobiosidae (Free-living Caddis)	-0.65	-1.67	-4.74	-7.77
***O. feredayi* (Horny-cased Caddis)**	-0.40	-1.03	-1.74	-2.88
***Nesameletus* (Mayfly)**	-0.51	-1.32	-4.54	-7.44
***Deleatidium* (Mayfly)**	-0.48	-1.25	-2.07	-3.40
Elmidae (Beetles)	-0.34	-0.95	-1.18	-1.99
Orthocladiinae (Midges)	-1.12	-2.78	-4.33	-7.18
***Potamopyrgus* (Snails)**	-0.51	-1.33	-1.92	-3.22

4.7.4 Area weighted suitability for fish (for species present)

Figure 4-40 and Figure 4-41 shows the AWS for fish for a flow up to approximately the median flow. The top black curve is the total available habitat for the reach studied for a given flow, therefore, all fish response curves must be within this model boundary. The other curves indicate the suitable habitat for various fish species, size classes or life stages.

Suitable habitat for all eels initially rises sharply, then increases more gradually through the 7-day MALF up to the median flow, where the AWS curves are flatter (Figure 4-40). At the 7-day MALF there is a lot more suitable for habitat for small shortfin eels than for small longfin eels, with 48.44% and 23.67% of total AWS respectively (Table 4-54). At the 7-day MALF the AWS for large shortfin and longfin eels are 32.12% and 28.10% of total AWS respectively (Table 4-54).

The reductions in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are most significant for small shortfin and small longfin eels, with -3.66% and -4.74% respectively (Table 4-55). For the most likely reduction in 7-day MALF (average case) there is less impact on suitable instream habitat for eels, with changes ranging from -1.99% and -2.89% (Table 4-55).

All classes of eels have relatively flat AWS curves in the vicinity of the median flow so small reductions in flow would have less impact on suitable instream habitat around this flow. For the unlikely worst case post-mining median flow changes in suitable instream habitat for eels range from -0.40% to -1.93% (Table 4-55).

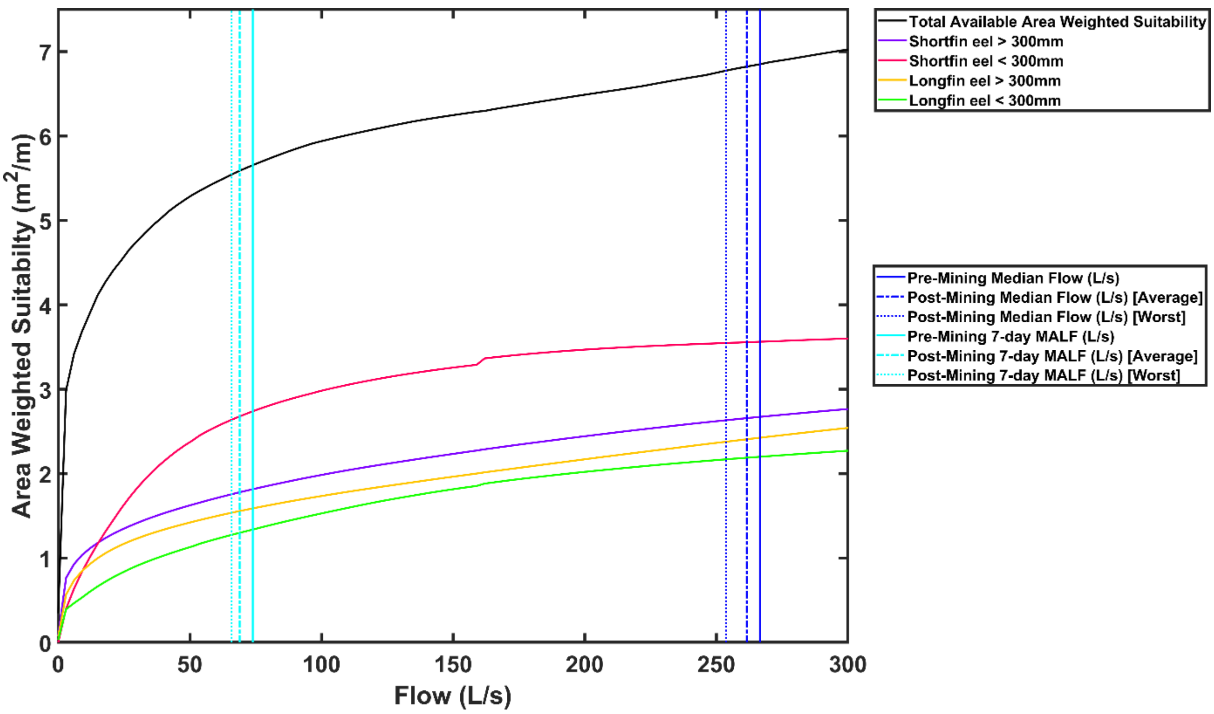

Figure 4-40: Area weighted suitability for eels in Wharekirauponga Stream - WKP2 - Upstream.

AWS for banded kōkopu juveniles and adults rises very steeply between 0 and 10 L/s, then continues to rise more gradually until AWS peaks at 177 and 141 L/s respectively. Beyond the peaks, AWS falls slowly towards median flow (Figure 4-41). AWS for banded kōkopu juveniles and adults at the 7-day MALF is 43.70% and 49.72% respectively (Table 4-54). Redfin bully AWS also initially rises sharply and then increases more gradually to beyond median flow (Figure 4-41). Shortjaw kōkopu AWS also rises steeply from zero flow, then flattens off and peaks at only 21.04% of total available AWS at 147 L/s, then gradually declines to beyond median flow (Figure 4-41). Kōaro and torrentfish AWS increases very gradually from zero flow. There is very little suitable instream habitat for torrentfish.

The AWS curves for all fish species are gradually sloping near the 7-day MALF. The changes in AWS between the pre-mining 7-day MALF and post-mining 7-day MALF worst case are -1.99% for banded kōkopu juveniles, -2.14% for banded kōkopu adults, -3.29% for redfin bully, and -1.70% for shortjaw kōkopu (Table 4-55). For the most likely reduction in 7-day MALF (average case) changes to suitable instream habitat for native fish range from -1.03% to -1.98% (Table 4-55).

All native fish have relatively flat AWS curves in the vicinity of the median flow (Figure 4-41), so small reductions in flow would have less impact on suitable instream habitat around this flow. For kōkopu there would be slight increases in suitable instream habitat for small flow reductions near the median flow. For the worst-case post-mining median flow changes to suitable instream habitat range from -1.02% for redfin bully to +2.21% for banded kōkopu adults (Table 4-55).

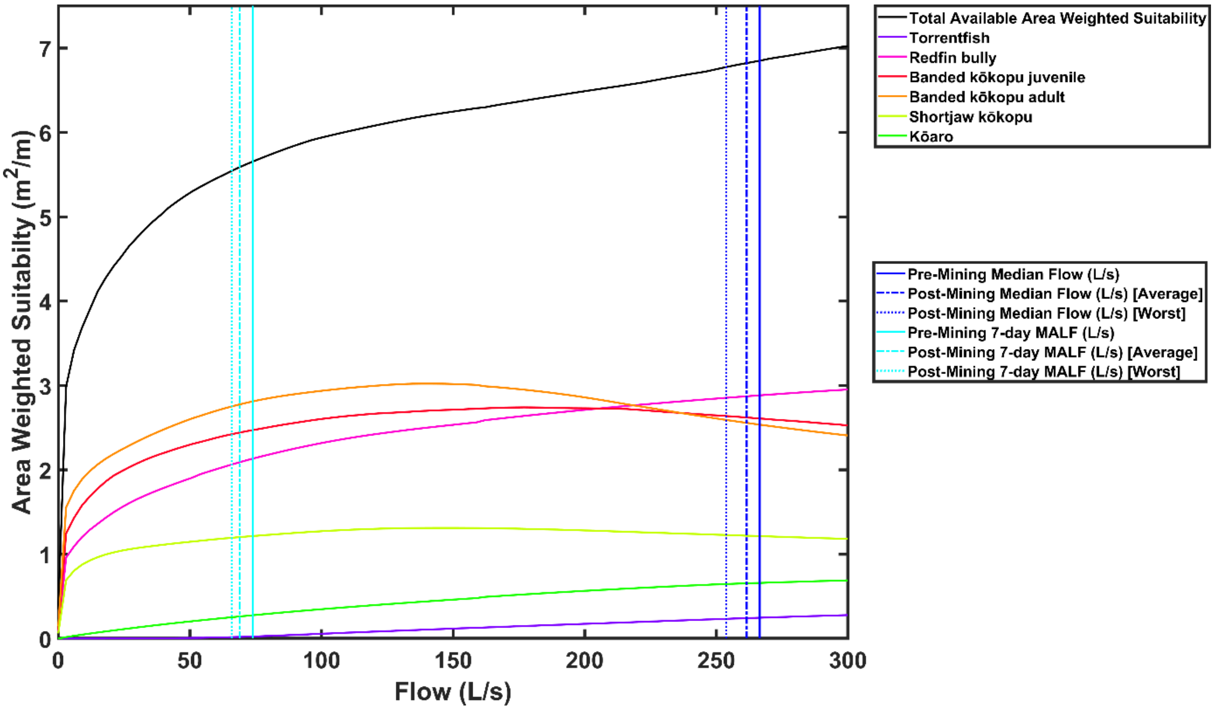

Figure 4-41: Area weighted suitability for fish in Wharekirauponga Stream - WKP2 - Upstream.

Table 4-54: Percentage of total available AWS suitable for fish in Wharekirauponga Stream - WKP2 - Upstream.

	Pre-Mining Median Flow	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Pre-Mining 7-day MALF	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	39.02	38.96	38.88	32.12	31.85	31.69
Shortfin eel <300 mm	52.01	52.14	52.38	48.44	47.94	47.60
Longfin eel >300 mm	35.41	35.29	35.12	28.10	27.87	27.73
Longfin eel <300 mm	32.12	32.09	32.04	23.67	23.26	23.00
Torrentfish	3.60	3.54	3.45	0.43	0.35	0.31
Redfin bully	42.09	42.10	42.13	37.72	37.41	37.21
Banded kōkopu juvenile	38.09	38.42	38.94	43.70	43.71	43.69
Banded kōkopu adult	37.02	37.48	38.26	49.72	49.67	49.63
Shortjaw kōkopu	17.73	17.87	18.12	21.49	21.52	21.55
Kōaro	9.63	9.60	9.54	4.89	4.69	4.56

Table 4-55: Percentage change of AWS for fish in Wharekirauponga Stream - WKP2 - Upstream (showing taxa where at least 5% of available AWS is suitable at 7-day MALF).

	Percentage change from Pre-Mining Median Flow		Percentage change from Pre-Mining 7-day MALF	
	Post-Mining Median Flow [Average Case]	Post-Mining Median Flow [Worst Case]	Post-Mining 7-day MALF [Average Case]	Post-Mining 7-day MALF [Worst Case]
Shortfin eel >300 mm	-0.56	-1.47	-1.99	-3.29
Shortfin eel <300 mm	-0.16	-0.40	-2.18	-3.66
Longfin eel >300 mm	-0.75	-1.93	-1.97	-3.26
Longfin eel <300 mm	-0.52	-1.36	-2.89	-4.74
Redfin bully	-0.39	-1.02	-1.98	-3.29
Banded kōkopu juvenile	0.46	1.12	-1.15	-1.99
Banded kōkopu adult	0.84	2.21	-1.27	-2.14
Shortjaw kōkopu	0.42	1.09	-1.03	-1.70

4.7.5 Instream habitat at low flows

Flow changes have the largest impact on suitable instream habitat at low flows. Previous sections have shown the impacts on instream habitat for species and classes of biota present in Wharekirauponga Stream (WKP2 – Upstream) for the most likely post-mining 7-day MALF (average case) and the unlikely post-mining 7-day MALF (worst-case). Setting minimum post-mining flows requires a subjective assessment of the allowable reduction of instream habitat for different groups of instream biota (Section 3.5). To assist with this assessment Figure 4-42 provides percentage reductions of suitable instream habitat for periphyton, invertebrates and fish in Wharekirauponga Stream (WKP2 – Upstream) for flows less than the pre-mining 7-day MALF. Table 4-56 provides post-mining 7-day MALF flows that correspond to percentage reductions of suitable instream habitat between 0% and -20%.

The largest impact on suitable instream habitat in Wharekirauponga Stream (WKP2 – Upstream) was for invertebrates (Figure 4-42). To keep impacts on suitable instream habitat within -5% for all groups of biota a post-mining 7-day MALF of 64.75 L/s would need to be maintained (Table 4-56). To keep impacts on suitable instream habitat within -10% for all groups of biota a post-mining 7-day MALF of 56.30 L/s would need to be maintained (Table 4-56). The most likely post-mining 7-day MALF (average case) of 68.98 L/s keeps impacts within -2.62% for all groups of biota (Figure 4-42). The unlikely post-mining 7-day MALF (worst case) of 65.89 L/s keeps impacts within -4.33% for all groups of biota (Figure 4-42).

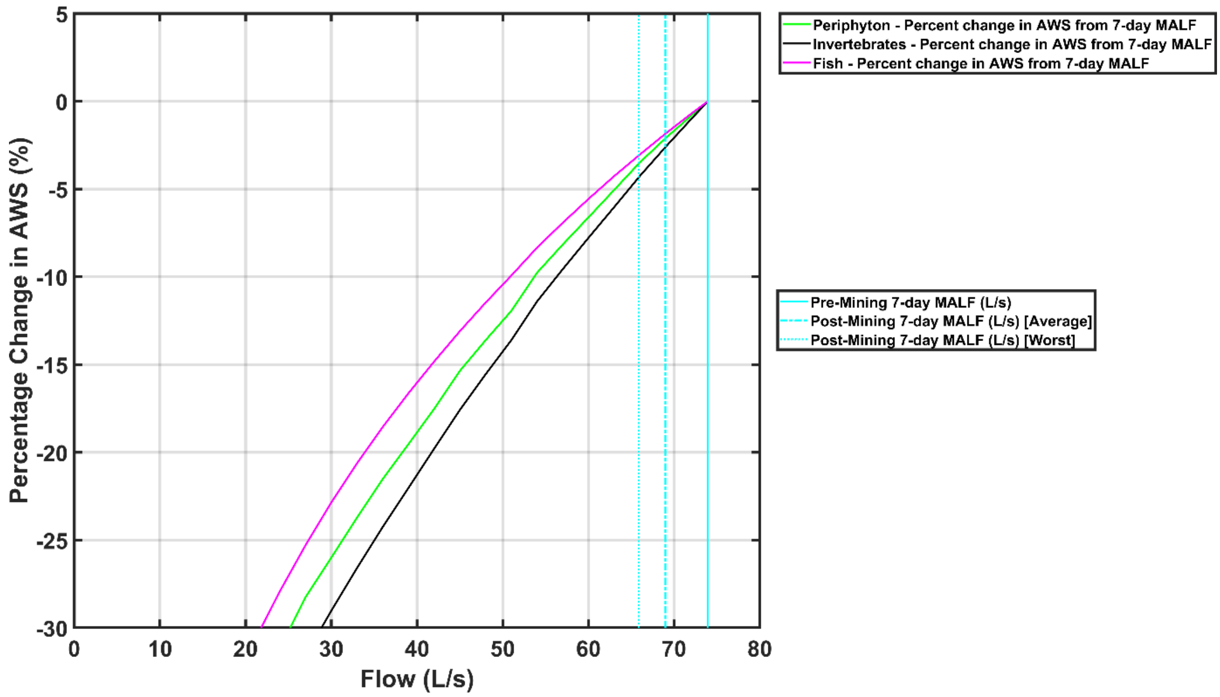

Figure 4-42: Percentage changes in Area Weighted Suitability for flows less than the pre-mining 7-day MALF for periphyton, invertebrates, and fish in Wharekirauponga Stream - WKP2 - Upstream.

Table 4-56: Percentage changes in AWS between 0% and -20% relative to pre-mining 7-day MALF and their corresponding flows for periphyton, invertebrates, and fish in Wharekirauponga Stream - WKP2 - Upstream.

Percentage Change in AWS From Pre-Mining 7-day MALF	Periphyton Flow (L/s)	Invertebrate Flow (L/s)	Fish Flow (L/s)
0%	73.95	73.95	73.95
-2.5%	68.15	69.20	67.36
-5%	63.11	64.75	61.31
-7.5%	58.29	60.49	55.79
-10%	53.69	56.30	50.87
-12.5%	50.00	52.52	46.11
-15%	45.62	48.86	41.72
-17.5%	42.04	45.13	37.65
-20%	38.30	41.72	33.91

5 Discussion - Flow reduction scenarios and impacts on instream habitat

5.1 Flow reduction scenarios examined

The flow reduction scenarios we focused on were 7-day mean annual low flows (7-day MALF) as these flows are when the most significant changes to instream habitat from flow reductions will occur, due to the slope of the AWS response curves at low flows (Section 4). However, it should be noted that these very low flow conditions are not common and comprise a very small proportion of the flow duration curve. When compared to median flows in the study reaches (which are representative of average annual flow conditions), potential flow reductions have a much smaller impact on suitable instream habitat. Even for the improbable worst-case scenario of the groundwater and surface water modelling there are very small changes to suitable instream habitat for flow reductions relative to the median flow. This is illustrated for the Area Weighted Suitability curves for eels in WKP1 shown below (Figure 5-1).

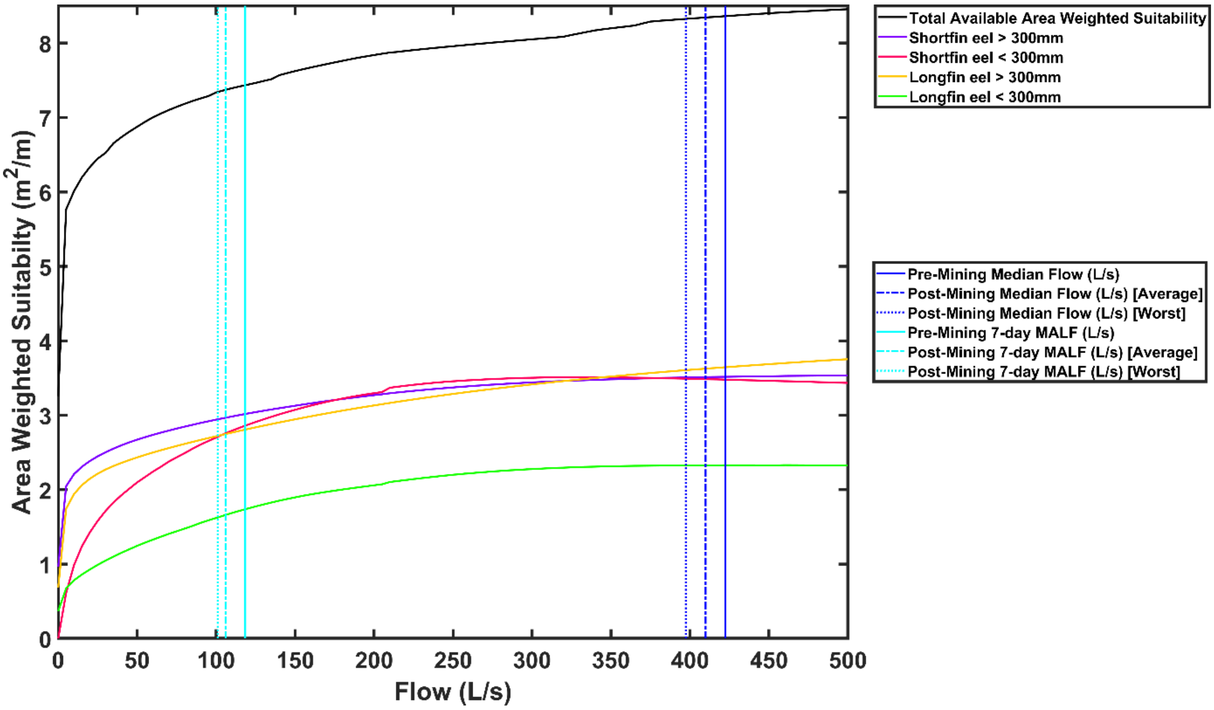

Figure 5-1: Area weighted suitability for eels in Wharekirauponga Stream - WKP1 - Downstream. Showing changes to median flow from flow reduction scenarios.

5.2 Changes to suitable instream habitat

The flow reductions at low flows (7-day MALF) result in small reductions to suitable instream habitat for most species; however, some species prefer shallower flows and/or lower velocities. For these species suitable instream habitat may actually increase at lower flows, which is somewhat counterintuitive. For example, banded kōkopu, shortjaw kōkopu, and long filamentous algae.

For most of the species/classes there is a steep increase in AWS as flows increase from zero to approximately half the pre-mining 7-day MALF, then the slope of the AWS curves typically become much less steep around the pre-mining 7-day MALF, and most curves are reasonably flat (or gradually increasing/decreasing) around the pre-mining median flow. We attribute the flattening of curves towards the median flow to: (1) wetted width plateauing since many of the streams are confined by steep banks; (2) increases in velocity as flows increase because the streams are steep. Many of the fish species are quite small and apart from torrentfish and kōaro are not adapted to high velocity water.

For the average-case (most likely scenario) changes in suitable instream habitat between the pre-mining 7-day MALF and the predicted post-mining 7-day MALF varied between taxonomic groups (i.e. periphyton, invertebrates, and fish), species/classes within taxonomic groups, and study sites. Reductions in suitable instream habitat for taxonomic groups ranged from -0.72% for fish in Adams Stream to -4.20% for invertebrates in Thompson Stream. The average reduction of suitable instream habitat[5] for the seven study sites and three taxonomic groups was -2.08%.

For the worst-case (unlikely scenario) changes in suitable instream habitat between the pre-mining 7-day MALF and the predicted post-mining 7-day MALF also varied between taxonomic groups (i.e. periphyton, invertebrates, and fish), species/classes within taxonomic groups, and study sites. Reductions in suitable instream habitat for taxonomic groups ranged from -1.20% for fish in Adams Stream to -5.66% for invertebrates in Thompson Stream. The average reduction of suitable instream habitat[5] for the seven study sites and three taxonomic groups was -3.20%.

Average changes to suitable instream habitat for taxonomic groups masks some of the variability within taxonomic group (see Section 4), for example there is typically more impact on eels and less on kōkopu. The largest average impacts on instream habitat for fish are in Thompson Stream, with a reduction of suitable instream habitat of -5.10% for the unlikely worst case post-mining 7-day MALF, and a reduction of instream habitat of -3.79% for the most likely average case post-mining 7-day MALF. However, within the fish taxonomic group the largest impacts are on large longfin eels (>300 mm) in Thompson Stream with a reduction of suitable instream habitat of -9.03% for the unlikely worst case post-mining 7-day MALF and a reduction of -6.75% for the most likely average case post-mining 7-day MALF (Section 4.4.4). Thompson Stream showed the largest impacts of all the study sites, with smaller impacts on the Wharekirauponga Stream sites and other tributaries.

Changes to suitable instream habitat for flows around the median (more representative of annual flow conditions) are typically much less significant than those around the 7-day MALF for all study reaches and all species/classes. Since the AWS curves are flatter in the vicinity of the median flow there is also less impact on instream habitat from larger flow reductions (i.e. worst case) than the average case near the median flow. For example, reductions in suitable instream habitat in Thompsons Stream for large longfin eels (>300 mm) are -1.95% for the most likely average case post-mining median flow and -3.55% for the unlikely worst case post-mining median flow (Section 4.4.4). At the other study sites reductions in suitable instream habitat for all eel classes were much less significant and are within -0.79% for the most likely average case post-mining median flow and within -1.93% for the unlikely worst case post-mining median flow (Section 4).

5.3 Other impacts on habitat utilisation – floods and flushing flows, fish passage and light availability

The figures showing area weighted suitability provide an estimate of the maximum amount of habitat suitable for each species over the flow range shown. The amount of habitat used is limited by many factors including the frequency and severity of floods which can flush fish and invertebrates out of the

[5] Calculated as the arithmetic mean of the reductions in suitable instream habitat for the 7x study reaches and 3x taxonomic groups, which assigns equal weighting to each of the study reaches and taxonomic groups.

catchment and detach filamentous algae. Algal films may also be abraded by moving sediment or if the sediment it is attached to moves. Once the flood is over, it takes time for biota to re-establish. For algae and macroinvertebrates this may only take from days to weeks, but for fish it may take months or years.

Impediments to fish passage may also limit utilisation of potential habitat, i.e., the four-metre-high Wharekirauponga Waterfall likely limits the use of habitat upstream of the waterfall for some fish species.

Many of the streams in this study are overhung by bankside vegetation and/or have extensive overhead forest canopy cover that may limit the amount of light reaching the stream bed. This may limit the primary productivity of the stream and hence the number of invertebrates and fish the stream can support.

All these factors may have the effect of reducing the actual carrying capacity of the streams to less than that indicated by the AWS curves. Thus, small reductions in physical habitat due to dewatering may have a lesser effect on stream biota if the available physical habitat is not already being utilised.

6 Summary

- Seven reaches in the Wharekirauponga Stream catchment were studied: Adams Stream, Edmonds Stream, Teawaotemutu Stream, Thompson Stream, Tributary-R, Wharekirauponga Stream (downstream site WKP1), and Wharekirauponga Stream (upstream site WKP2).
- Comprehensive surveys of each reach were conducted to map instream habitat and select pools, riffles, and runs to provide representative study cross-sections.
- 105 study cross-sections were established, with 15 in each study reach, comprising 5x pools, 5x riffles, and 5x runs.
- Measurements of depth, velocity, and substrate were conducted at each cross-section.
- Repeated measurements of discharge and water level were conducted for each study reach (2-3 measurements) for calibration and generation of stage-discharge relationships.
- Biota present in the streams was assessed based on data provided by Boffa Miskell (2023) and additional eDNA sampling by Boffa Miskell and Wilderlab.
- Habitat Suitability Curves (HSC) for the biota found in the streams was assembled from library data and from our observations and measurements for some periphyton classes.
- Velocity, depth and substrate data were combined with HSC data using SEFA software to provide assessment of the change in Area Weighted Suitability (AWS) instream habitat for each biota class or species with flow.
- Changes in AWS were evaluated from the pre-mining 7-day MALF to the post-mining 7-day MALF flow scenarios (most likely 'average case' and unlikely 'worst case') to investigate the effect of modelled mine dewatering on instream habitat. Changes in AWS were also evaluated relative to pre-mining median flows and post-mining median flow scenarios. The modelled mine dewatering scenarios and flows were provided by FloSolutions and GHD.
- For the average-case (most likely scenario) changes in suitable instream habitat between the pre-mining 7-day MALF and the predicted post-mining 7-day MALF varied between taxonomic groups (i.e. periphyton, invertebrates, and fish), species/classes within taxonomic groups, and study sites. Reductions in suitable instream habitat for taxonomic groups ranged from -0.72% for fish in Adams Stream to -4.20% for invertebrates in Thompson Stream. The average reduction of suitable instream habitat for the seven study sites and three taxonomic groups was -2.08%.
- For the worst-case (unlikely scenario) changes in suitable instream habitat between the pre-mining 7-day MALF and the predicted post-mining 7-day MALF also varied between taxonomic groups (i.e. periphyton, invertebrates, and fish), species/classes within taxonomic groups, and study sites. Reductions in suitable instream habitat for taxonomic groups ranged from -1.20% for fish in Adams Stream to -5.66% for invertebrates in Thompson Stream. The average reduction of suitable instream habitat for the seven study sites and three taxonomic groups was -3.20%.
- Variability in impacts on instream habitat varied between species/classes within taxonomic groups (see Section 4 and Section 5.2), for example there was typically more impact on eels and less on kōkopu.

- At median flow, which is more representative of average annual flow conditions, the AWS curves were flatter than near the 7-day MALF, with modelled changes in flow due to mining scenarios having less impact on instream habitat.

- In assessing the effects of mine dewatering on instream biota it needs to be kept in mind that the AWS modelling indicates the maximum suitable habitat for each species at each flow, based on the velocity, depth, and substrate. However, since most of the tributaries are shaded by dense forest and floods are common, it is unlikely that all of the available suitable habitat will be fully utilised, which may decrease pressure on available habitat should there be small reductions in flows. There are also many other factors (e.g., flood severity, distance from the sea, sediment deposition, etc.) that will also influence whether a species or life stage can occupy a modelled stream reach.

- This study has reported whether the physical habitat conditions required for a range of aquatic species/classes are available. Moreover, this work robustly and transparently shows how the availability of instream habitat suitable for different species/classes will be altered under different flow conditions.

7 Acknowledgements

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8 Limitations/dependencies

The study has a number of limitations/dependencies that may impact the accuracy of results, these are:

Reliance on modelling data of groundwater and surface water to determine the 7-day MALF and median flow cases to use for assessment of changes in instream habitat (FloSolutions 2023a, b; GHD 2024).

Reliance on ecological assessments of instream taxa (Boffa Miskell 2023) and eDNA results for determining the instream taxa present.

- These data sources may miss taxa that were not present at the study sites at the times of the instream surveys and eDNA measurements (but it is noted that missed/rare taxa may not have had a habitat suitability curve that could have been included in the modelling).
- These data sources did not cover all seven of our study reaches and we assumed the presence of taxa in some tributaries based on their proximity to sites where measurements occurred.

Reliance on habitat suitability curves derived from datasets from different rivers and catchments.

- Whilst it is standard practice to use generalised habitat suitability curves developed for New Zealand waterways, differences in factors such as water chemistry in the Wharekirauponga Stream catchment may cause changes to the habitat preferences of a species that underlies the habitat suitability curves.
- This was notably the case for periphyton, for which previously used habitat suitability curves were mainly derived from oligotrophic (low nutrient) streams/rivers in the South Island of New Zealand.

Curves for thin films, diatoms, and short filamentous taxonomic groups that were previously used in oligotrophic streams/rivers did not match observations in the Wharekirauponga Stream. These curves were adjusted based on measured depths, velocities, substrate, and observed periphyton cover during this fieldwork. For example, thin films and diatoms coated most coarse substrate throughout the Wharekirauponga Catchment (where light was available).

Slight bias to the distribution of depth and velocity measurements (lack of very shallow and very deep measurements).

- It was not possible to measure depths and velocities in very deep pools (i.e., greater than 1.5 m) when conducting wading-based measurements. Thus, some pool cross-sections had to be placed near the exit of pools where wading was possible. This only occurred for some very deep pools in Wharekirauponga Stream, and Teawaotemutu Stream.
- It was also not possible to measure velocities in very shallow parts of riffles and close to rocks with the Sontek FlowTracker2 (see Appendix B).

Uncertainties in measured depth averaged velocities must also be acknowledged since velocity measurements primarily followed the one-point method (i.e., one measurement at 0.6 of depth). This method assumes that velocity profiles follow a logarithmic (or power law) profile, which may not be a good approximation at some points. Where velocities at 0.6 of depth were clearly impacted by secondary currents (i.e., wakes behind boulders and some pools) measurements were conducted using the three-point method (i.e., 0.2, 0.6, and 0.8 of depth) to increase accuracy.

Visual assessment of habitat types during habitat mapping surveys is subjective and is also flow dependent. Since our surveys occurred at relatively low flows during summer, we assume that our measured habitat proportions are representative of those at even lower flows (i.e., 7-day MALF). As discussed in Appendix B, uncertainties also exist for classification of stream segments with combined habitat types and for measurement of habitat lengths around bends.

Visual estimation of substrate proportions is subjective and will introduce some uncertainties into results. Currently, quantitative analysis of substrate (from images) is not yet advanced and reliable enough for the widespread coverage (and the wide range of conditions) encountered at the study sites. Other more quantitative methods such as Wolman counts (or bulk sieving) are not feasible for the large spatial coverage needed, and the coarse particle sizes encountered (i.e., boulders). Thus, whilst the method used was the most appropriate for the work (and is standard practice for these types of surveys) we acknowledge there is a subjective component to the substrate size grading.

9 Glossary of abbreviations and terms

AWS	Area Weighted Suitability. AWS (m^2/m) is the average wetted area of a stream (per unit length) that is suitable for use by an aquatic species, or class of aquatic species. AWS takes into account the distribution of pool, riffle, and run habitat types within a study reach, as well as the distribution of depth, velocity and substrate within these habitat types, and the preferences (i.e., habitat suitability curves) of each species/class. Total suitable instream habitat (m^2) for a species/class is calculated by multiplying AWS (m^2/m) by reach length (m).
BBM	Building Block Methodology
eDNA	Environmental DNA is the collection and analysis of DNA that is shed from organisms into the environment, rather than directly collected from organisms themselves. This provides a powerful tool for assessing taxa present within a stream (by sampling stream water) rather than visually identifying all taxa present.
ELOHA	Ecological Limits Of Hydrologic Alteration
FRE3	The number of freshes exceeding three times the median flow.
FROUDE NUMBER	A dimensionless number relating inertial forces to gravitational effects in fluids, relating in this study to flow in open channels.
HSC	Habitat Suitability Criteria or Curves define a suitability index of between 0 and 1 for hydraulic habitat variables or other variables such as substrate. Graphical or numerical tables that define the relative utility of increments or classes of habitat variables to a life stage of a species.
IFIM	Instream Flow Incremental Methodology
MALF	Mean Annual Low Flow. The mean of the lowest flow recorded for each water year.
7-DAY MALF	7-day Mean Annual Low Flow. The mean of the lowest recorded 7 day running mean flow for each water year (regarded as being a more reliable estimate of low flow than the MALF).
MfE	Ministry for the Environment
MEDIAN FLOW	The flow that is exceeded 50% of the time. The median flow is more representative of average annual conditions than the mean flow, which can be skewed by high discharge during flood flows.
MEAN FLOW	The mean flow over the period of record.
PHABSIM	Instream Habitat Simulation Software (developed before SEFA)
Post-mining	The term post-mining is used to cover modelled flow reductions after mining has commenced. However, the greatest effects on stream flows are predicted to occur at the end of mining and immediately after mining completion. These effects are predicted to be relatively short lived and only impact streams for around two years after mining completion.
RHABSIM	Instream Habitat Simulation Software (developed before SEFA)
RHYHABSIM	Instream Habitat Simulation Software (developed before SEFA)
RVA	Range of Variability Approach
SEFA	System for Environmental Flow Analysis (latest version of IFIM software, produced by RHYHABSIM, PHABSIM, and RHABSIM developers).
SZF	Stage at Zero Flow
WUA	Weighted Useable Area

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Appendix A Methods for determining instream flow requirements

Many factors influence the health of river ecosystems including temperature, oxygen, light, geomorphology and flow (Hynes 1970; Giller & Malmqvist 1998; Norris & Thoms 1999). All elements of a flow regime will influence the composition of the aquatic community in a reach, including floods, average and low flows (Junk et al. 1989; Poff et al. 1997; Richter et al. 1997). A holistic approach must therefore be taken for the long-term management of river systems. Such an approach considers how human activities impact upon interactions between factors such as geology, sediment transport, channel structure, riparian vegetation, water quality and biological habitat. However, apart from through dilution effects, flow rate (m^3s^{-1}) is only a surrogate variable; it is the water depth and velocity in a river, created by the interaction between flow rate and channel morphology, that provides physical habitat for plants, invertebrates and fish (Booker & Acreman 2006). Jowett (1992) found the single most important factor determining trout abundance was habitat for food; Gore et al. (1998) found relationships between physical habitat (i.e., wetted area) and actual benthic community diversity; and Gallagher & Gard (1999) found a positive correlation between physical habitat and spawning density of salmon.

The direct relationship between physical habitat and flow provides a means for assessing the ecological impact of changing the flow regime of a river (Cavendish & Duncan 1986; Jowett 1990; Beecher et al. 1993). However, assessment of river flow management options often involves assessing scenarios that fall outside the range of observed conditions, and thus predictive models are required. The Physical Habitat Simulation (PHABSIM) system (Bovee 1982; Bovee et al. 1998) was the first systematic modelling framework to be developed and many models based on a similar concept have been produced including CASiMIR in Germany (Jorde 1996; Eisner et al. 2005), EVHA in France (Ginot 1995), RHYHABSIM in New Zealand (Jowett 1989) and RSS in Norway (Killingtviet & Harby 1994). Essentially these models quantify the relationship between physical habitat, defined in terms of the combination of depth, velocity and substrate/cover, and various flows (e.g., Johnson et al. 1993; Elliott et al. 1996). Criticisms of this approach (Hudson 2003) include incorrect application of methods, habitat suitability curves that are not representative of local conditions, lack of biological realism (Orth 1986) and problems with mechanisms (Mathur et al. 1985; Booker et al. 2004). Nevertheless, the models have been applied throughout the world (Dunbar & Acreman 2001), primarily to assess impacts of abstraction or river impoundment. These models have also been used to assess the effects of channel restoration and modification (Acreman & Elliott 1996; Booker & Dunbar 2004). PHABSIM in particular has become a legal requirement for many impact studies in the USA (Reiser et al. 1989) and a standard tool employed by the Environment Agency of England and Wales to define the sensitivity of rivers to abstraction (Booker & Acreman 2006). RHYHABSIM has been applied to many rivers in New Zealand (Lamouroux & Jowett 2005) for a variety of reasons. Jowett and Biggs (2006) reviewed the results from six rivers in which habitat-based methods had been applied to flow setting. They found that in five of these cases the biological response and the retention of desired instream values was achieved.

The Instream Flow Incremental Methodology (IFIM; Bovee 1982; Bovee et al. 1998) is an example of an interdisciplinary framework that can be used in a holistic way to determine an appropriate flow regime by considering the effects of flow changes on instream values, river morphology, physical habitat, water temperature, water quality, and sediment (Figure A-1). This report uses the IFIM approach to examine the effect of flow on instream physical habitat only. The approach used did not investigate potential changes in water temperature, water quality or sediment transport arising from changes in flow management.

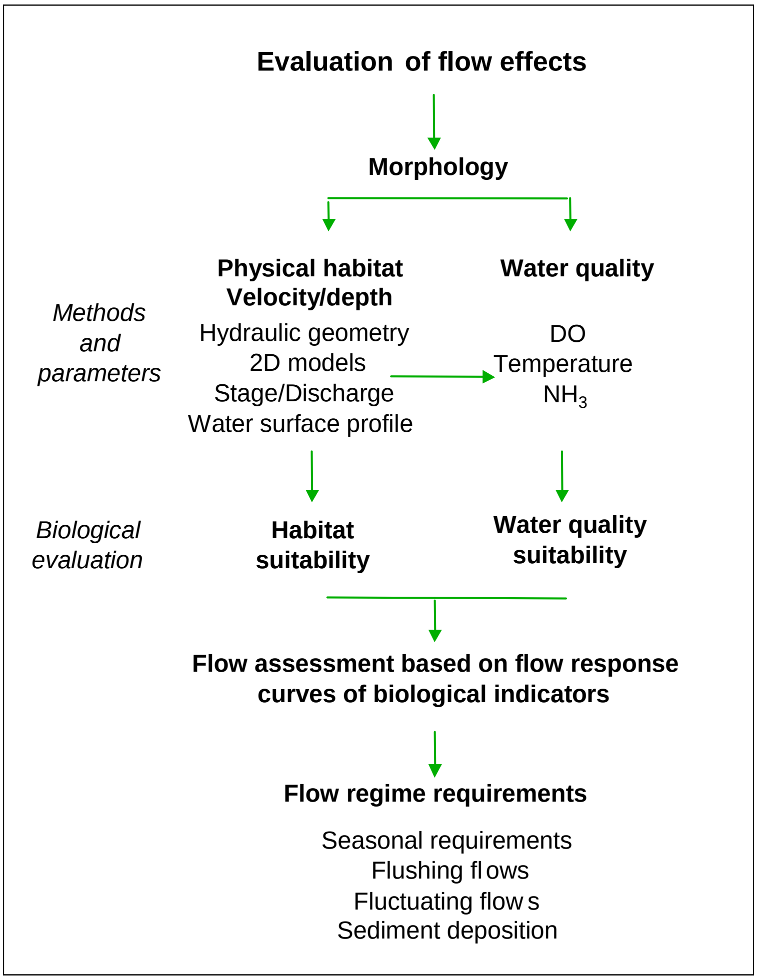

Figure A-1: A framework for the consideration of flow requirements (Jowett & Biggs 2006).

A variety of approaches and frameworks to instream flow methods exist (Jowett 1997). In contrast with IFIM, other flow assessment frameworks are more closely aligned with the "natural flow paradigm" (Poff et al. 1997). The Range of Variability Approach (RVA) and the associated Indicators of Hydrologic Alteration (IHA) allow an appropriate range of variation, usually one standard deviation, in a set of 32 hydrologic parameters derived from the 'natural' flow record (Richter et al. 1997). The implicit assumption in this method is that the natural flow regime has intrinsic values or important ecological functions that will be maintained by retaining the key elements of the natural flow regime. Arthington et al. (1992) described a holistic method that considers not only the magnitude of low flows, but also the timing, duration and frequency of high flows. This concept was extended to the Building Block Methodology (BBM), which "is essentially a prescriptive approach, designed to construct a flow regime for maintaining a river in a predetermined condition" (King et al. 2000). It is based on the concept that some flows within the complete hydrological regime are more important than others for the maintenance of the river ecosystem, and that these flows can be identified and described in terms of their magnitude, duration, timing, and frequency. Poff et al. (2010) proposed the Ecological Limits Of Hydrologic Alteration (ELOHA) framework in which stakeholders and decision-makers explicitly evaluate acceptable risk as a balance between the perceived value of the ecological goals, the economic costs involved and the scientific uncertainties in functional relationships between ecological responses and flow alteration. Whilst there are many methods available for setting flows, all of which have pros and cons, physical habitat modelling and IFIM is the technique most commonly used throughout New Zealand at present. Therefore, this technique has been used to assess the impact of low flows on physical habitat in the Wharekirauponga Stream and its tributaries.

RHYHABSIM (Jowett 2004) has been the most commonly used method in New Zealand for instream habitat assessment. Experience with the programme has resulted in updates and improvements over the years. The most recent update is called SEFA (System for Environmental Flow Analysis). SEFA has had input from Bob Milhous (PHABSIM), Ian Jowett (RHYHABSIM) and Tom Payne (RHABSIM) who were the primary creators of existing habitat simulation software. SEFA contains one dimensional habitat hydraulics analysis and a number of other features including water temperature modelling and sediment analysis (Jowett et al. 2023). Only the one-dimensional habitat hydraulics analysis of SEFA was used for this study.

Appendix B Instream habitat survey methods and analysis

Cross-section establishment and surveying

For each survey reach, 15 cross-sections were established, with five in riffles, five in runs, and five in pools. For the seven reaches studied, this was a total of 105 cross-sections. Each cross-section consisted of a left bank waratah, right bank waratah, and instream water level waratah. Where it was not possible to install waratahs, such as where the streams crossed bedrock, removable dynabolts were instead used (Figure B-1). This provided a robust method for establishing cross-sections, so that repeated measurements were consistent. It also provided security and redundancy in the event of any significant flood events and would have enabled us to detect whether there had been any change in the cross-sectional profile; however, there were no significant flood events during the study period.

D-shackles were installed in the side of each bank waratah/dynabolt to provide a consistent location for attaching taglines (i.e., fibreglass low stretch tape measures) for measuring cross stream distances. Where D-shackles were connected to waratahs/dynabolts, these provided a consistent location for total station surveying to establish the 3D spatial location of each end of the cross-section. Stream bank waratahs and dynabolts were labelled with robust tags with the cross-section ID for the repeat water-level surveys. Yellow plastic safety caps were installed on the top of all waratahs and secured to the waratah with a cable tie (or tie wire) (as seen in Figure B-2).

Figure B-1: Example cross-section where the channel bank was comprised of bedrock. In these cases, dynabolts were used for attaching the tagline to the channel bank (Wharekirauponga Stream, cross-section WL06).

Following cross-section establishment, surveys occurred with a Trimble M3 mechanical total station, accuracy 3 mm +/- 2 ppm (parts per million). Survey points consisted of:

- Water level waratah/dynabolt top.
- Left bank waratah/dynabolt top.
- Left bank waratah/dynabolt d-shackle.
- Right bank waratah/dynabolt top.
- Right bank waratah/dynabolt d-shackle.

- Stage at Zero Flow (SZF).
- Left bank and right bank water's edge points.
- Upstream and downstream water's edge points (for water surface slope at the cross-section).
- Topographic points across the cross-section and up the banks (surveying up the banks allows the software to model flows higher than those encountered during surveys).

The Stage at Zero Flow is the water level in the cross-section if the flow were zero (Jowett et al. 2023). For riffles and runs, this is typically the deepest point in the cross-section, whereas for pools it is commonly the level of the downstream exit of the pool, such as the head of the downstream riffle.

A total station was used for surveying, rather than a Real Time Kinematic Global Positioning System (RTK-GPS) due to the confined nature of the streams, and enclosed overhead tree canopy, which prevents accurate GPS signals. A total station provides an accurate survey of points in each cross-section; however, they are at an arbitrary vertical datum (compared to RTK-GPS), with elevation then converted to the local water level peg datum, or water surface datum for conversions to survey depths and elevations.

During measurements of depth, velocity, and substrate across the cross-section, a tagline was connected between the left and right bank d-shackles, with a tensioner used to keep it taught and minimise sag (Figure B-2).

Figure B-2: Tagline across the cross-section and tensioner (Thompson Stream, cross-section TH07).

To convert between the total station reference frame and the tagline reference frame (i.e., y co-ordinate across the cross-section), three values were measured. These were:

- The offset from the start of the tagline (i.e., zero value) to the left bank d-shackle.
- The length of the tagline to the right bank tensioner.
- The offset from the tensioner to the right bank d-shackle.

The total station measurements of the left and right bank d-shackles were used to calculate the span of the cross-section, elevation change across the cross-section, and tagline slope. Detailed information on total station survey data processing is provided in Appendix C.

Habitat mapping surveys

Habitat mapping was conducted along the centreline of each reach, with a tape measure used to measure the length of each habitat segment (Figure B-3). Measurements of habitat lengths were conducted in 0.5 m increments. Habitat mapping was conducted further upstream than cross-sections were distributed to ensure that the proportion of each habitat class was representative of the river/stream beyond where the cross-sections were located.

Following Jowett (1993), habitat classes were defined as:

Pool: A feature in a river where the water is deep, the water surface is flat, and the water velocity is slow. Pools typically have velocity/depth ratio <1.24, Froude number <0.18 and water surface slope <0.0039.

Riffle: A feature in a river where the water is very shallow, turbulent and fast and the water surface is broken. Riffles typically have velocity/depth ratio >3.2, Froude number >0.41 and slope >0.0099.

Run: A feature in a river where the water is shallow, the water surface is wavy, and the water velocity is swift. Runs have velocity/depth ratios, Froude numbers and slopes between those of pools and riffles.

Habitat mapping in the seven reaches included classification of hundreds of pools, riffles, and runs. The length of each habitat segment typically scales with river width, with more segments in smaller tributaries and fewer at the larger WKP sites (for the same length of channel surveyed). Summary tables and histograms of habitat segment length distributions are provided in Section 4 for each survey reach.

Maps showing the locations and lengths of the habitat surveys are shown in Section 3.1.

Figure B-3: Habitat mapping in T-Stream East (left) and WKP (right).

Habitat mapping uncertainties

Most habitat mapping was straightforward; however, some segments had a combination of habitat types within one segment, for example a small backwater area of pool habitat behind large boulders, but with most of the flow (and habitat area) comprising a run. These segments were generally rare, and the dominant (i.e., most abundant) habitat type was selected.

Small uncertainties also exist around the measurement of habitat lengths in meander bends. We attempted to follow the stream centreline with the tape measure path to record cumulative length of these habitat segments; however, in some cases the flow dragged the tape measure downstream away from the centreline and towards the inside of the bend. This acts to slightly shortcut the length of these segments. Again, these segments were generally rare, and this uncertainty is not significant, however it must be acknowledged.

Velocity and depth measurements

Velocity measurements were made with a SonTek FlowTracker2, with a wading rod used to vertically position the probe, and to make depth measurements (Figure B-4). Following standard practice, velocities were measured at 0.6 of depth to estimate the mean (depth averaged) velocity (i.e., if a velocity measurement was being taken in a location that was 100 cm deep, the measurement (0.6 of depth) would be taken 40 cm above the streambed). This assumes that velocity profiles are approximately logarithmic in shape. This is a typical assumption but can deviate from reality when flow is highly three dimensional, such as in pools with strong secondary currents, or in the wake of large upstream obstructions (i.e., boulders). In these cases, velocity was measured at 0.2, 0.6, and 0.8 of depth (following standard practices) then averaged.

Figure B-4: SonTek FlowTracker2 Acoustic Doppler Velocimeter (ADV) and wading rod, showing the handheld unit (left) and the ADV probe (right). Images from www.ysi.com.

Velocity measurements obtained at cross-sections for input to SEFA were measured with 20 second duration, following the SEFA user manual (Jowett et al. 2023). Typically, 12–15 measurement points were made across each cross-section, with more points (i.e., 20+) made in some cases were velocities and depths were highly variable (e.g., wide riffles in WKP reaches), and fewer points in some cases where channels were narrow, and velocities, depths, and substrate were relatively similar (e.g., small tributaries where wetted widths were ~1 m). Velocity measurements made for discharge gauging were recorded with 40 second duration and more measuring points (verticals) per gauging to increase confidence in the accuracy of the gauging (see section on 'Discharge gauging' below).

Measurement bias – Shallow velocities

The SonTek FlowTracker2 is generally very well suited for making velocity measurements in small streams and rivers; however, it is limited by the minimum depth that the probe head can be correctly positioned for. For depths lower than 8 cm the probe head cannot be lowered to 0.6 of depth (i.e., 0.4 of elevation), in these cases the probe head will be higher in the water column than the height of the theoretical mean velocity, resulting in a bias to higher velocities. However, these very shallow points are rare, and are typically located at the channel banks (or at the edges of instream boulders), where velocities are already relatively low, minimising the relative importance of any slight bias. Where possible measurement at these shallow (and positively biased) points was avoided, with measurement at a point >8 cm depth, then an additional measurement point at zero velocity and zero depth at the channel water's edge (or the edge of an instream boulder). Velocity is then automatically interpolated in SEFA (or the FlowTracker2 handheld unit) between the accurate velocity measurement location and the zero-velocity location. This is a better approach than recording biased measurements at the shallow points. However, there were still some points (typically riffles in small tributaries) where shallow measurements were unavoidable, and bias would occur. This was one of the reasons why each river reach included an accurate discharge gauging cross-section, with this discharge measurement applied to every cross-section in the reach in SEFA. Shallow water bias was not an issue for discharge gaugings, as the cross-sections selected for discharge gauging were typically straight runs with depths much larger than 8 cm. Besides surface velocimetry methods, which introduce their own uncertainties in measurement accuracy and conversions from surface velocity to depth averaged velocity, there are not any other suitable methods to measure velocities at these shallow points.

Measurement bias – Probe head locations
There were some cases (i.e., shallow riffles in small tributaries) where positioning of the ADV probe head was problematic, due to boulders and flow between boulders. In some cases, the probe head was turned 180° to make a measurement closer to an obstruction, with a velocity correction factor of -1 applied to the measurement point (following standard practices). In other cases, the probe head had to be positioned slightly upstream or downstream of the target measurement location, with positioning at a location and depth that was representative of the target measurement location. Although these points were rare, their existence must be acknowledged as a potential source of uncertainty, since positioning of the probe head at a representative location was subjective.

Discharge gauging

Discharge gauging in the study reaches was also conducted using the SonTek FlowTracker2. The accuracy of these discharge measurements was important for establishing accurate stage-discharge relationships for each of the cross-sections. In each reach, an optimal location for discharge gauging was selected, with this location then used for subsequent measurements during calibration surveys for consistency.

Discharge gauging measurements all exceeded ISO standards (ISO748 2007), and most were conducted to NEMS measurement standards (NEMS 2013) (i.e., 40 second verticals, ≥20 verticals, and <10% of the total discharge in each vertical). In a few of the smaller gauging cross-sections, depths and velocities were relatively consistent across the centre of the channel (away from the banks) in these cases slightly fewer than 20 verticals were used and maximum cross-section percentage discharges were in the range of 10–15%. This approach does not impact the accuracy of discharge gauging, because adding an extra measurement vertical with the same depth and velocity between two adjacent ones (i.e., each with percentage discharges of 10–15%) will only distribute discharge into an extra bin but will not change total discharge.

To obtain accurate discharge measurements with the SonTek FlowTracker2 (using the one-point method) it is important that velocity profiles are well approximated by a logarithmic (or power law) profile with depth averaged velocity at 0.6 of depth (measured down from the water surface), or 0.4 of water column elevation (measured up from the bed). Cross-sections with these characteristics are typically runs, with all of the flow in one main channel, a straight section of channel, a trapezoidal (or rectangular) cross-section, water surface slope parallel with bed slope and consistent channel width (i.e., flow not accelerating or decelerating) and avoiding locations with upstream boulders or obstructions generating wakes. These characteristics are typically found in straight runs. For velocity profiles without these characteristics (such as in pools with strong secondary currents) then more measurement verticals are needed (i.e., three-point method, six-point method) or using an ADCP. In most of the study reaches one of the surveyed runs was suitable for discharge gauging; however, in Adams Stream and Edmonds Stream a specific discharge gauging cross-section was established that had better characteristics than any of the study runs.

Substrate measurements

Substrate was divided into the classes: Bedrock, Boulders (>264 mm), Cobbles (64–264 mm), Coarse Gravel (8–64 mm), Fine Gravel (2–8 mm), Sand (0.06–2 mm), Silt/Mud (<0.06 mm), and Vegetation (Riparian Vegetation, Macrophytes, Woody Debris, Leaf Litter, etc.).

The percentage of substrate in each class was estimated for each vertical in each cross-section. The area of estimation was centred on the location of the vertical and spanned halfway to each of the adjacent verticals (cross stream), then approximately 1 m upstream and 1 m downstream. For wider cross-sections (i.e., WKP reaches) with larger spacing between verticals, larger distances upstream and downstream were used (i.e., 2–3 m upstream and downstream). A bathyscope (Figure B-5) was used at verticals with deep water, and where surface turbulence or glare obscured the view of the riverbed.

Outside of the wetted channel additional topographic points surveyed with the total station that fell between measured vertical had substate estimated by linear interpolation from measured substrate at adjacent verticals.

Substrate measurements were primarily used in SEFA for the calculation of Area Weighted Suitability for different taxa based on their habitat suitability curves. Cross-section averaged substrate, habitat type averaged substate (i.e., pools, riffles and runs), and reach averaged substrate are also shown in the results section of this report. Cross-section averaged substate was calculated as an area weighted average of instream (wet) points. Only instream wet points were used for this average since we are primarily interested in habitat at low flows, such as during the summer low flow conditions when the cross-section surveys were conducted, or at even lower flows (i.e., 7-day MALF).

Table B-1 shows the SEFA Indices and Codes of the Substrate Categories. This table is provided for interpretation of the Habitat Suitability Criteria (HSC).

Figure B-5: Bathyscope for underwater estimates of substrate size distributions.

Table B-1: SEFA Indices and Codes of the Substrate Categories.

SEFA Substrate Index	1	2	3	4	5	6	7	8
SEFA Code	"V"	"SI"	"S"	"F"	"G"	"C"	"B"	"BE"
Substrate Category	Vegetation	Silt/Mud (< 0.06 mm)	Sand (0.06-2 mm)	Fine Gravel (2-8 mm)	Coarse Gravel (8-64 mm)	Cobbles (64-264 mm)	Boulders (> 264 mm)	Bedrock

Water level measurements and calibration flows

For the duration of the instream habitat study, three pressure transducers were installed to measure water level at the downstream ends of Teawaotemutu Stream (T-Stream East), Edmonds Steam, and Wharekirauponga Stream (WKP1). Seametrics PT2X vented pressure transducers were used, with 5-minute logging. The pressure transducers were cable tied to instream waratahs (Figure B-6) and were located in pools (or backwater areas) to avoid any velocity head. During instream cross-section surveys in other downstream tributaries of the Wharekirauponga Stream an additional PT2X was deployed for the duration of the cross-section surveys to check that river levels were stable. This was a precautionary measure since some of the reach cross-section surveys (i.e., 15× cross-sections) took two days to complete. The cross-section surveys were all conducted during summer low flow conditions (December 2023 and January 2024), with no significant rainfall before any of the cross-section surveys and stable river levels. Additional water level reference pegs (or dynabolts) were also established at the downstream end of study reaches where pressure transducers were located (as a fixed reference) with their water levels read each time pressure transducer data were downloaded, or each time a calibration run was conducted.

Figure B-6: Deployment of a PT2X vented pressure transducer in Teawaotemutu Stream (East).

Calibration runs consisted of water level measurements at each of the cross-section water level waratahs (or dynabolts) and a reference discharge gauging measurement. For calibration runs conducted at stable flows (i.e., a long time after rain fall), water levels were not monitored over the short duration of the calibration run. For calibration runs conducted with rainfall on preceding days (i.e., falling limb of small rain events) either a pressure transducer was installed at the downstream end of the reach to provide a continuous record, or the water level at the downstream reference water level waratah (or dynabolt) was checked at the beginning and end of the calibration measurement. No measurements followed any significant rainfall events and no significant changes in water levels were observed in any of the study reaches within the relatively short measurement time (up to 2 hours) of a calibration run. At most, changes of ~3 mm were observed, which were within measurement error, and corrections of water level calibration measurements at each of the reach cross-sections were needed.

Appendix C Preparation of survey data for SEFA

Cross-section span and tagline slope

The total station measurements of the left and right bank d-shackles (Appendix B) were used to calculate the span of the cross-section $\Delta y = \sqrt{(E_{RB} - E_{LB})^2 + (N_{RB} - N_{LB})^2}$, and the elevation change across the cross-section $\Delta z = U_{RB} - U_{LB}$, where total station points are in a standard ENU (East North Up) coordinate system. The tagline slope was then calculated as $\theta = \mathrm{atan}\left(\frac{\Delta z}{\Delta y}\right)$. This tagline slope was used to correct the elevation of vertical measurements that were referenced to the tagline (i.e., dry points on channel banks where substrate proportions were estimated). This approach was followed as it was not possible to install waratahs (or dynabolts) at exactly the same elevation on either side of the cross-sections, and small tagline slopes existed. All instream measurement points had depth measured directly, which is more accurate than being referenced to the tagline and these points did not need corrections.

Vector projection of total station topographic points onto the tagline unit vector

Total station measurement points across the cross-sections (i.e., additional dry points, and points further up the banks) were collected between the left bank and right bank d-shackles. There were slight misalignments in the locations of these points, compared to the straight line that the tagline forms between the left and right bank d-shackles. These slight misalignments were corrected by vector projection of the total station points onto the cross-section unit vector (Figure C-1). The equations for performing this correction are:

$$\hat{y} = \begin{bmatrix} (E_{RB} - E_{LB})/\Delta y \\ (N_{RB} - N_{LB})/\Delta y \end{bmatrix}$$

where $\hat{y}$ is the tagline unit vector.

Total station EN (East North) point vectors P_i relative to the tagline origin at the left bank d-shackle are then calculated as:

$$P_i = p_i - \begin{bmatrix} E_{LB} \\ N_{LB} \end{bmatrix}$$

where p_i are the original EN total station points and i is the point index. The corrected points vectors $P_i{}'$ are then calculated using vector projection as:

$$P_i' = (P_i \bullet \hat{y})\hat{y}$$

Where • denotes the vector dot product. These corrected points can then be converted back into the global reference frame (if needed) as:

$$p_i' = P_i' + \begin{bmatrix} E_{LB} \\ N_{LB} \end{bmatrix}$$

Corrected points are converted into cross stream distances (i.e., tagline reference frame) as:

$$y_i = \mathrm{sign}(P_i{}' \bullet \hat{y})|P_i'|$$

Where $|P_i'|$ is the magnitude (i.e., length) of the P_i' vector, and $\mathrm{sign}(P_i{}' \bullet \hat{y})$ is a term to determine the sign of y_i. If P_i' and $\hat{y}$ point in the same direction, then $\mathrm{sign}(P_i{}' \bullet \hat{y}) = 1$. If P_i' and $\hat{y}$ point in opposite directions, then $\mathrm{sign}(P_i{}' \bullet \hat{y}) = -1$. This term is important to include to account for any topo points that are further up the left bank behind the left bank d-shackle (which have negative y values relative to the origin of the cross-stream coordinate system).

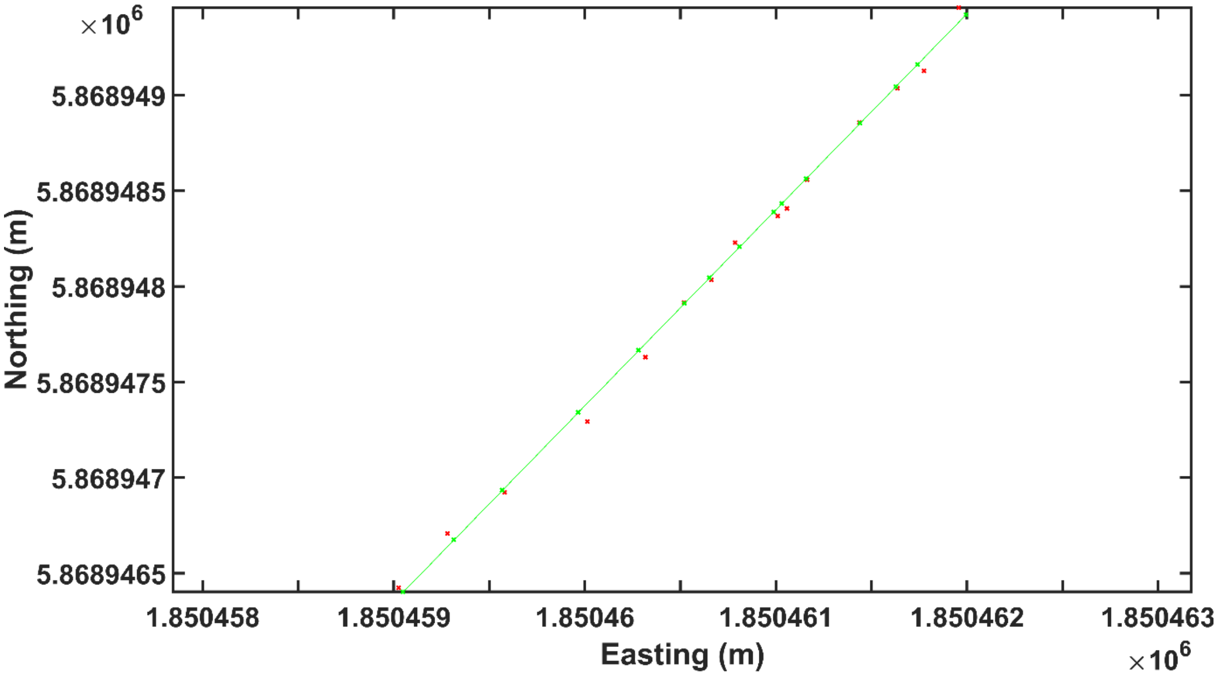

Figure C-1: Vector projection of total station topo points onto tagline to correct small misalignment in total station sampling locations, example shown is Adams Stream Cross-section 2 (AD02). Red points are total station topo points before correction, green are after correction.

Total station datum and gauge datum

Total station measurements at each cross-section are measured to an arbitrary datum. These are then converted to a fixed gauge datum, which is static and constant for subsequent measurements.

$$z_i = U_i - U_{gauge}$$

Where z_i is corrected elevation of point i, U_i is the elevation of the point in the total station ENU coordinate system and U_{gauge} is the elevation of the top of the gauge (i.e., water level waratah or bolt) in the total station ENU coordinate system. Water levels are then measured from the top of the static water level gauge to the water surface during all subsequent measurements to provide water surface elevation z_{ws}.

Inputs to SEFA are provided as depths (wet parts of channel) and negative depths (dry parts of the channel) for the survey flow and are calculated as $D_i = z_{ws} - z_i$.

Cross-section weightings from habitat mapping surveys

Habitat mapping surveys yielded the proportion of each habitat type in the survey reach. These proportions were then used as input weightings for each of the 15 cross-sections used in SEFA (i.e., five pools, five riffles, five runs). For example, Adams Stream was comprised of 24.91% pools, 45.85% riffles, and 29.24% runs. So, the input weighting for each pool cross-section is 24.91%/5 = 4.98%, each riffle cross-section is 45.85%/5 = 9.18%, and each run cross-section is 29.24%/5 = 5.84%.

Appendix D Fish Habitat Suitability Criteria

Habitat suitability curves for fish taxonomic groups found at study sites in the Wharekirauponga Stream catchment.

See Section 3.4 for further information on site specific presence/absence.

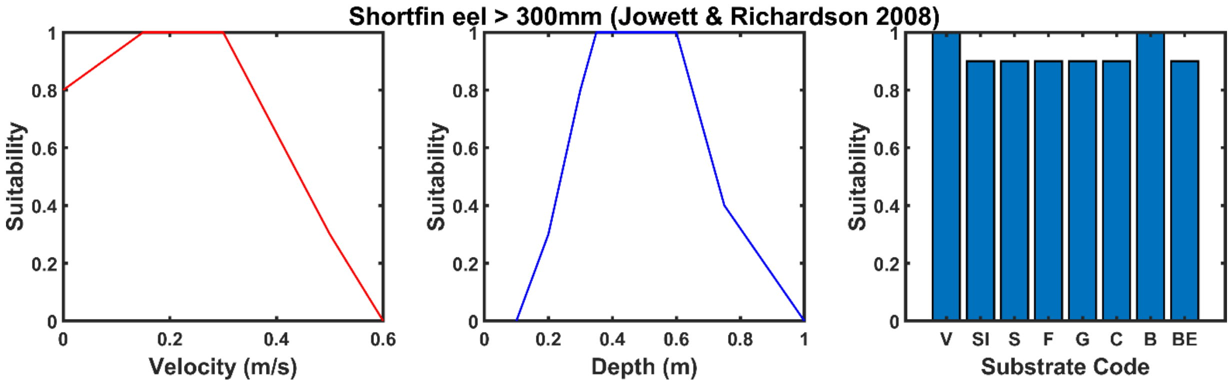

Figure D-1: Shortfin eel >300 mm habitat suitability curves.

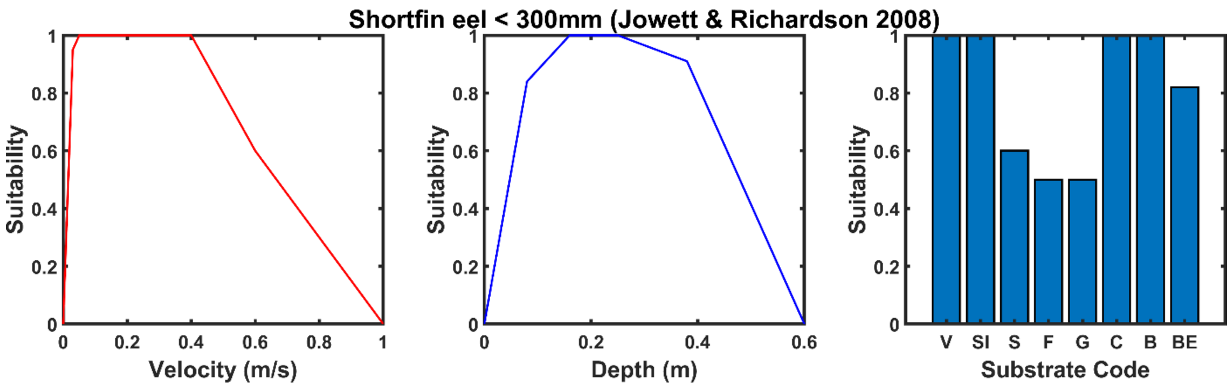

Figure D-2: Shortfin eel <300 mm habitat suitability curves.

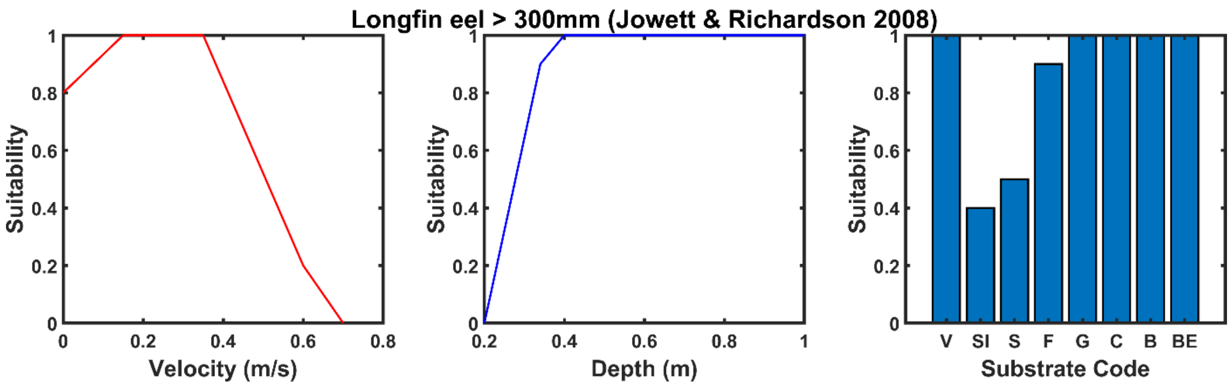

Figure D-3: Longfin eel >300 mm habitat suitability curves.

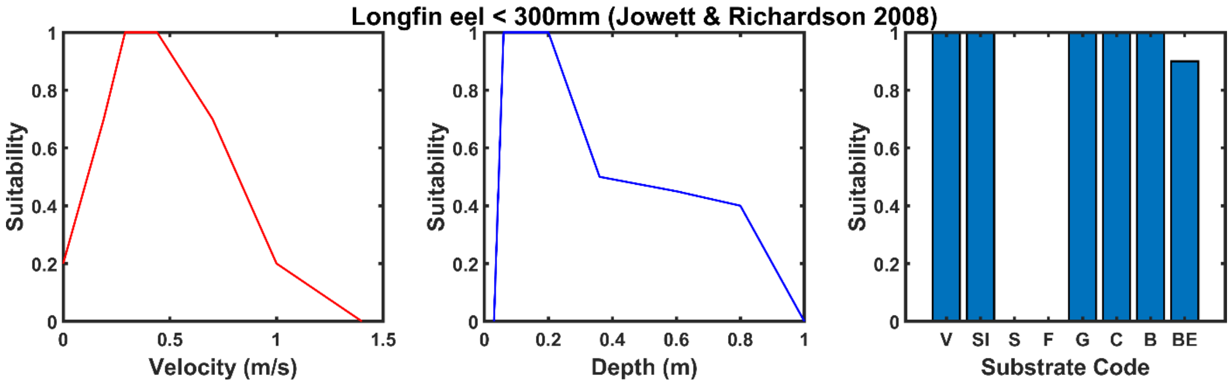

Figure D-4: **Longfin eel <300 mm habitat suitability curves.**

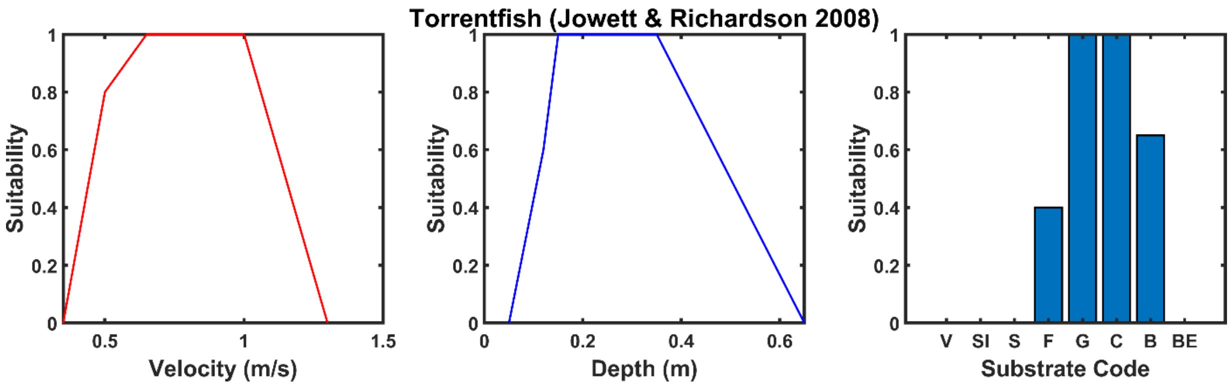

Figure D-5: **Torrentfish habitat suitability curves.**

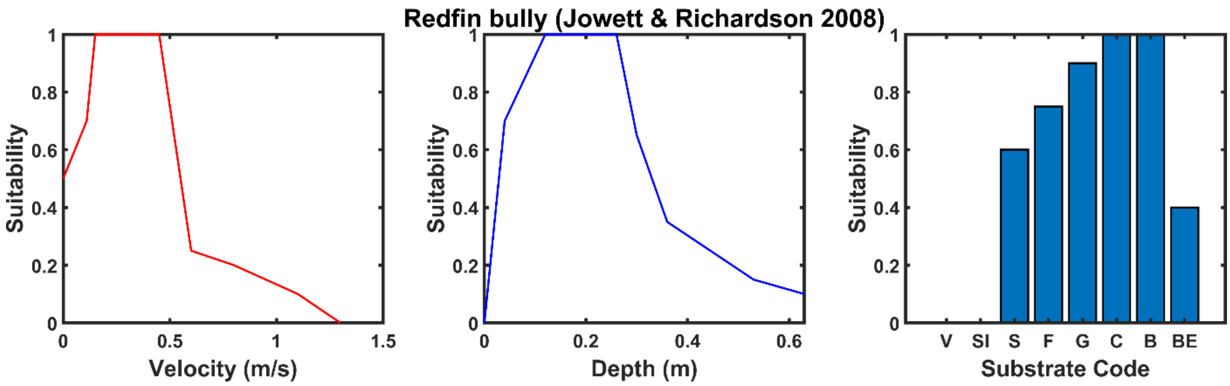

Figure D-6: **Redfin bully habitat suitability curves.**

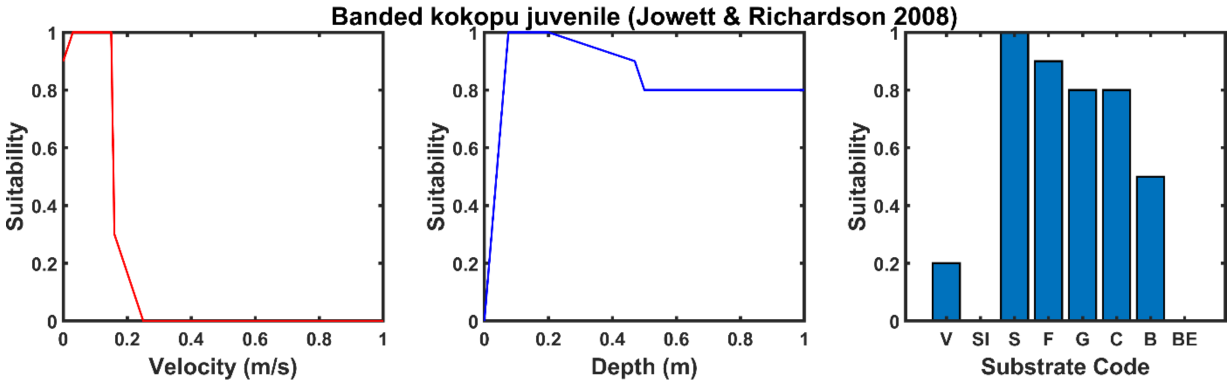

Figure D-7: Banded Kōkopu juvenile habitat suitability curves.

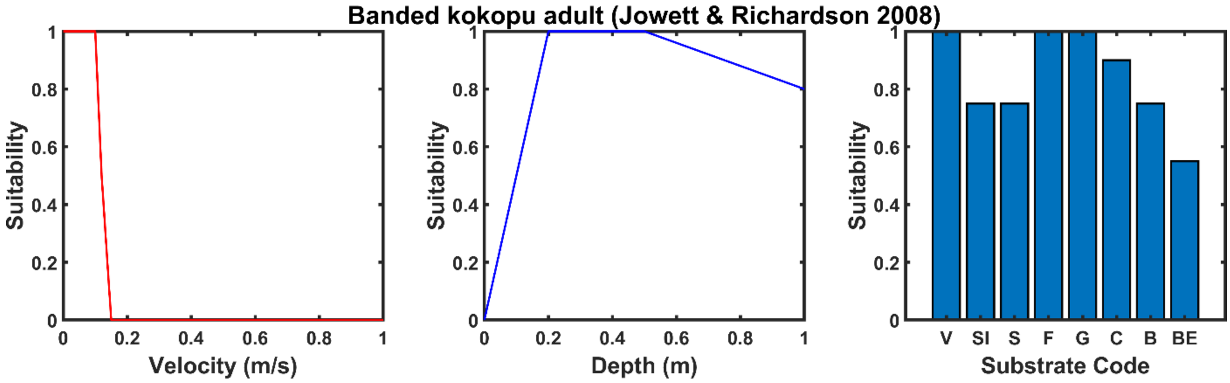

Figure D-8: Banded Kōkopu adult habitat suitability curves.

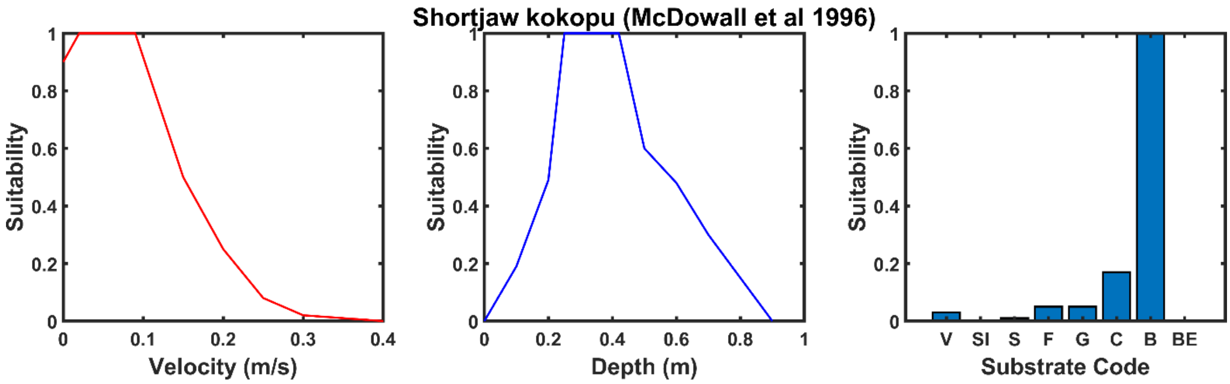

Figure D-9: Shortjaw kōkopu habitat suitability curves.

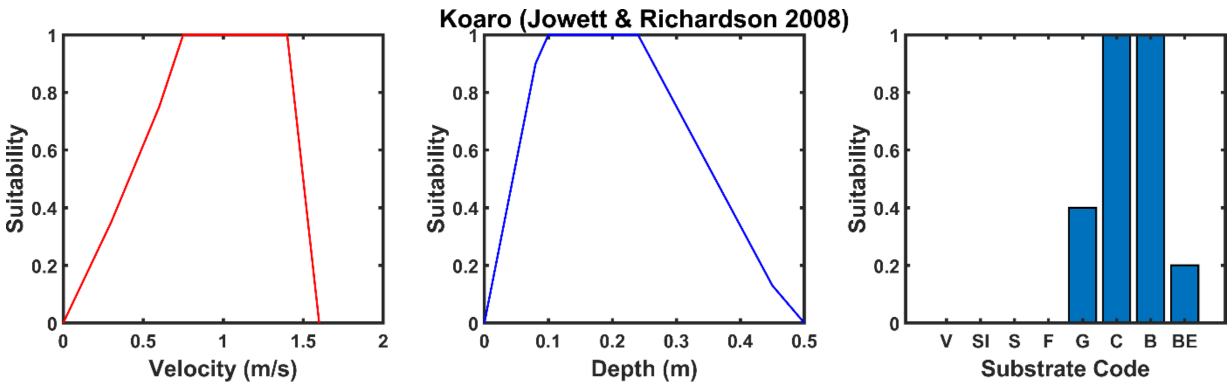

Figure D-10: Kōaro habitat suitability curves.

Appendix E Invertebrate Habitat Suitability Criteria

Habitat suitability curves for invertebrate taxonomic groups found at study sites in the Wharekirauponga Stream catchment.

See Section 3.4 for further information on site specific presence/absence.

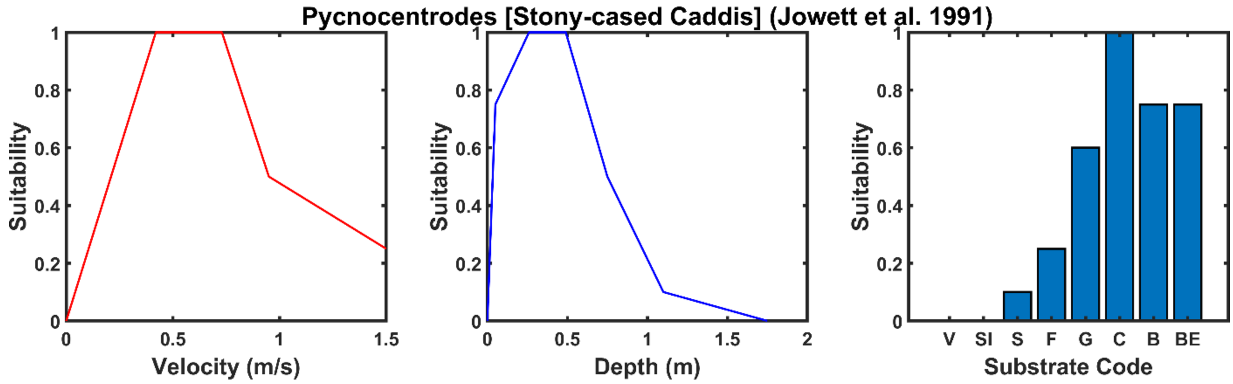

Figure E-1: ***Pycnocentrodes*** **(Stony-cased Caddis) habitat suitability curves.**

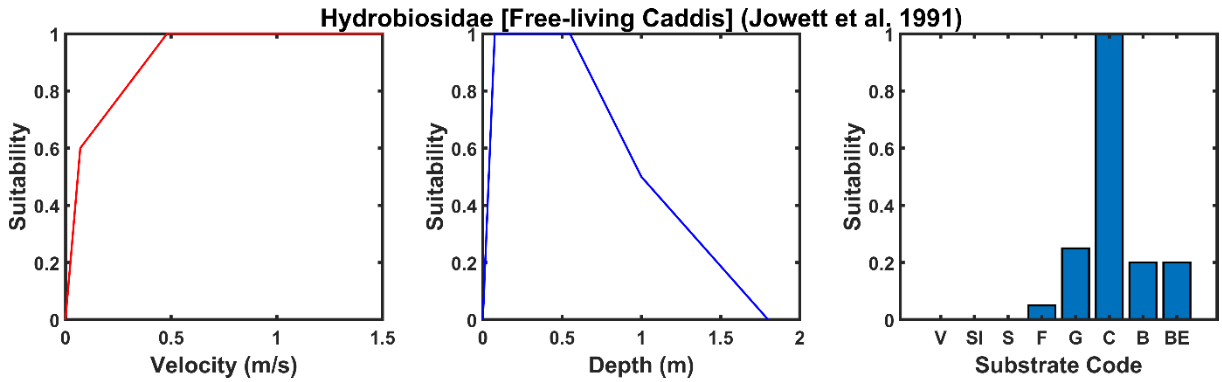

Figure E-2: Hydrobiosidae (Free-living Caddis) habitat suitability curves.

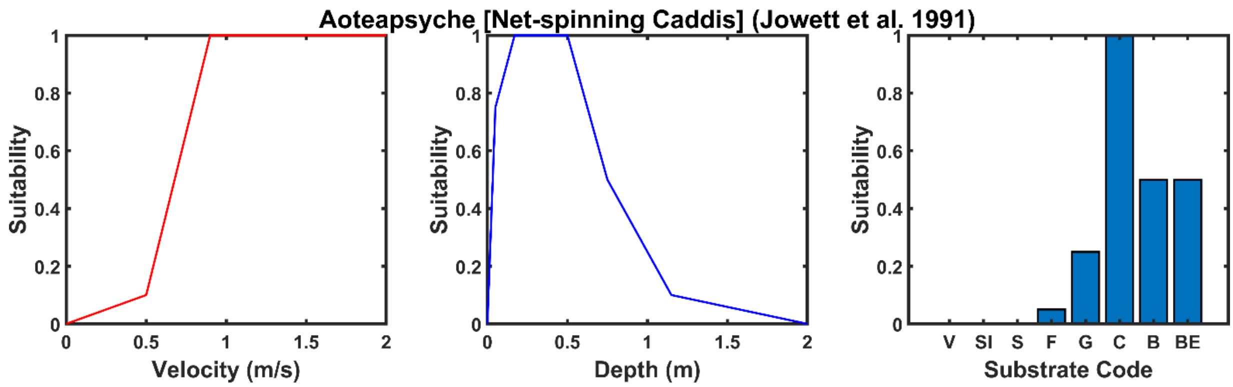

Figure E-3: ***Aoteapsyche*** **(Net-spinning Caddis) habitat suitability curves.**

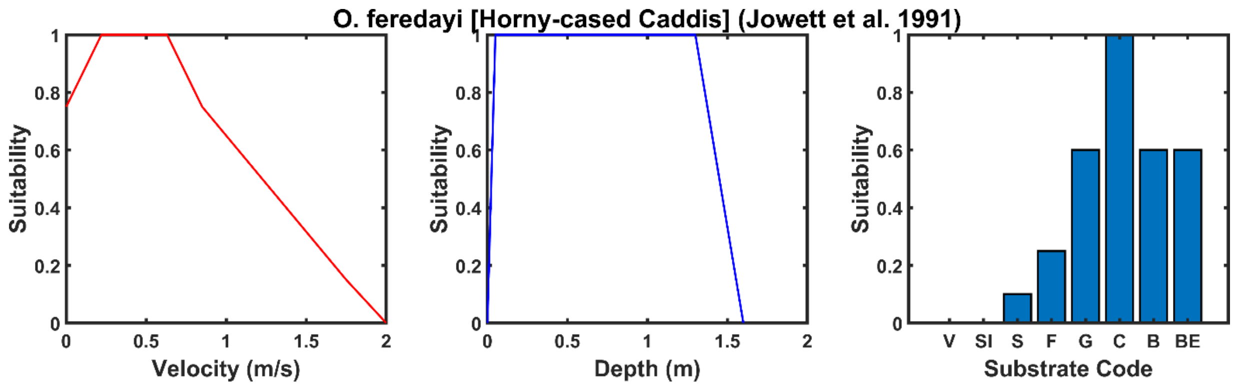

Figure E-4: *O. feredayi* (Horny-cased Caddis) habitat suitability curves.

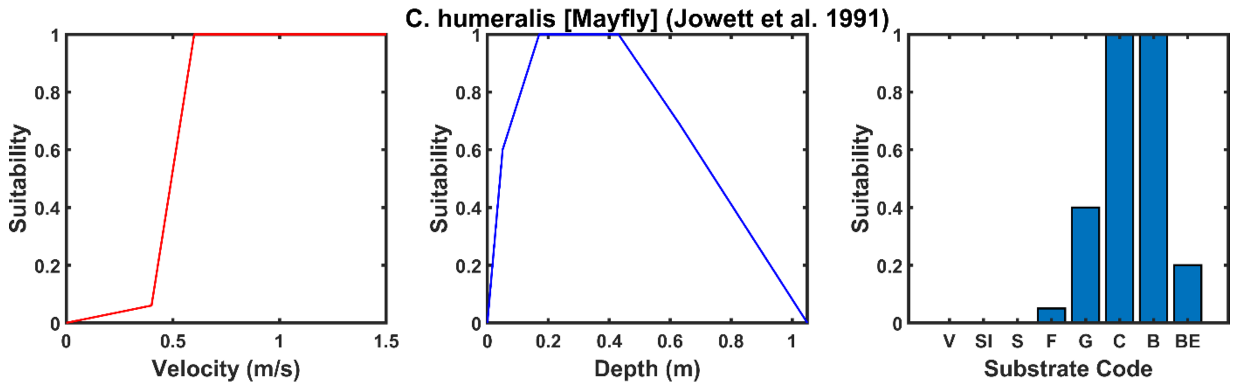

Figure E-5: *C. humeralis* (Mayfly) habitat suitability curves.

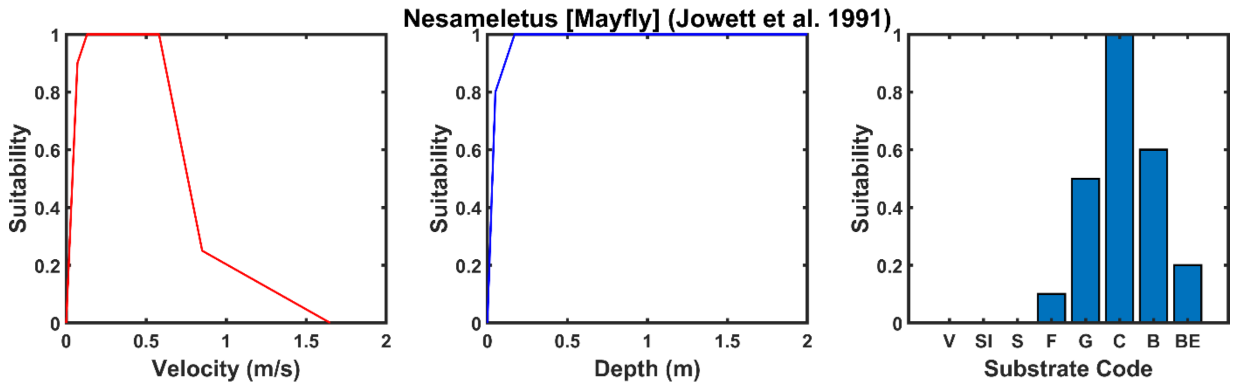

Figure E-6: *Nesameletus* (Mayfly) habitat suitability curves.

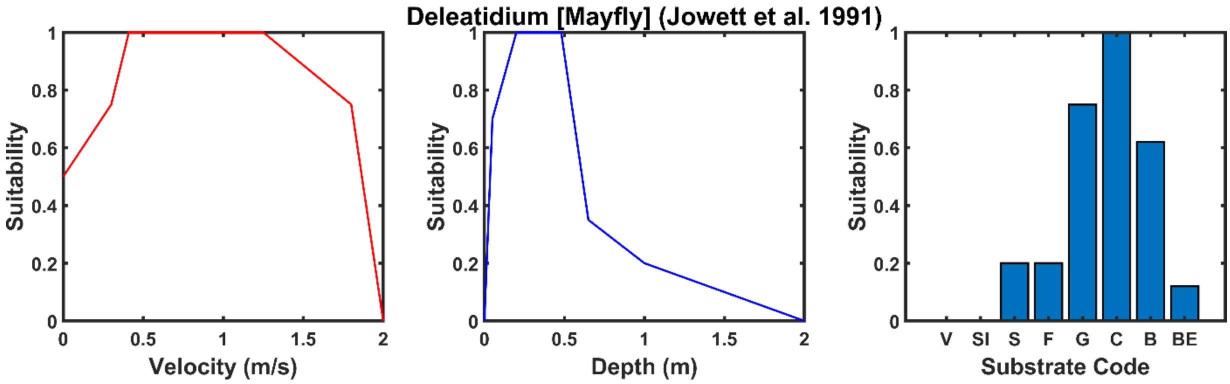

Figure E-7: ***Deleatidium*** **(Mayfly) habitat suitability curves.**

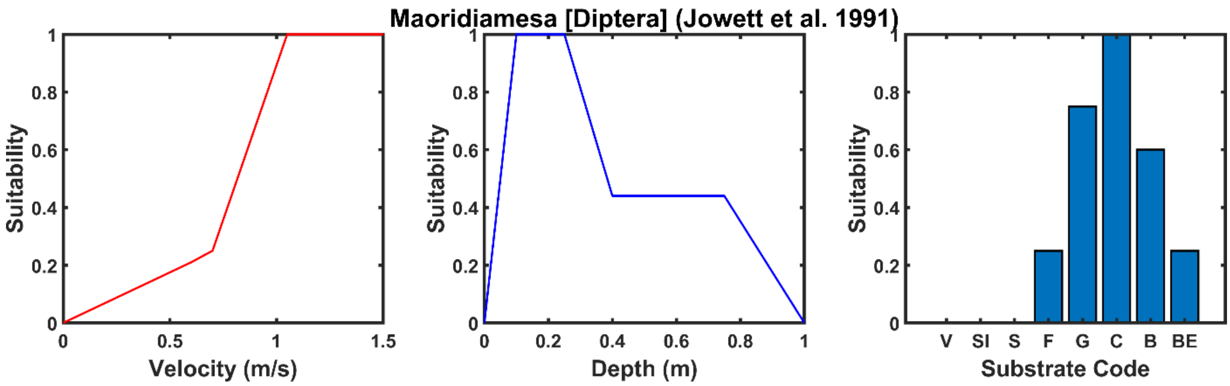

Figure E-8: Maoridiamesa (Diptera) habitat suitability curves.

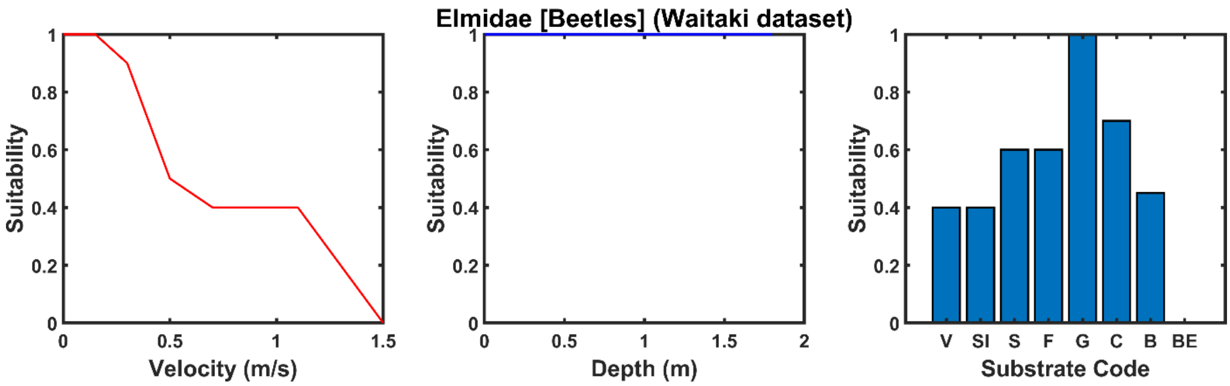

Figure E-9: Elmidae (Beetles) habitat suitability curves.

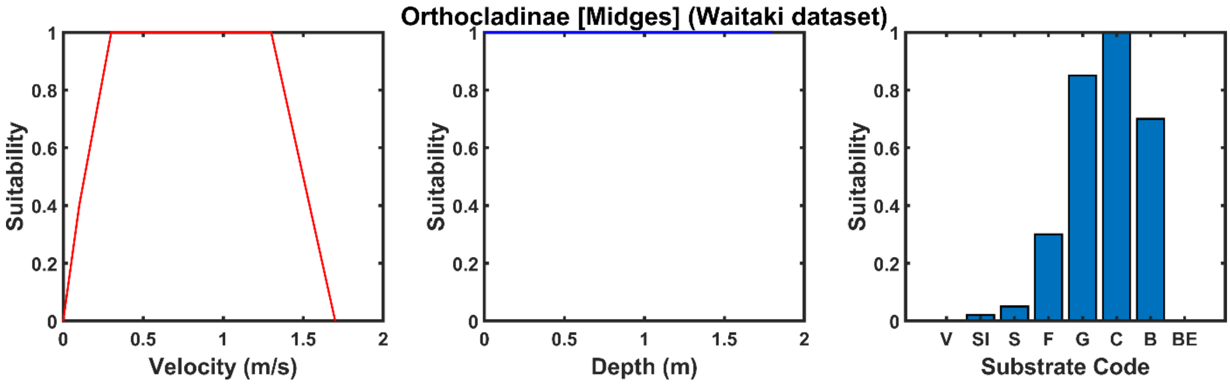

Figure E-10: **Orthocladiinae (Midges) habitat suitability curves.**

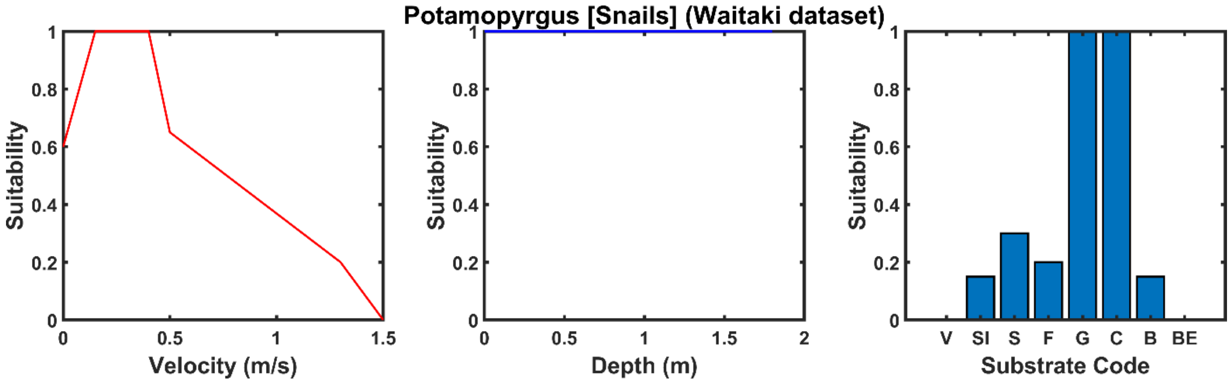

Figure E-11: ***Potamopyrgus* (Snails) habitat suitability curves.**

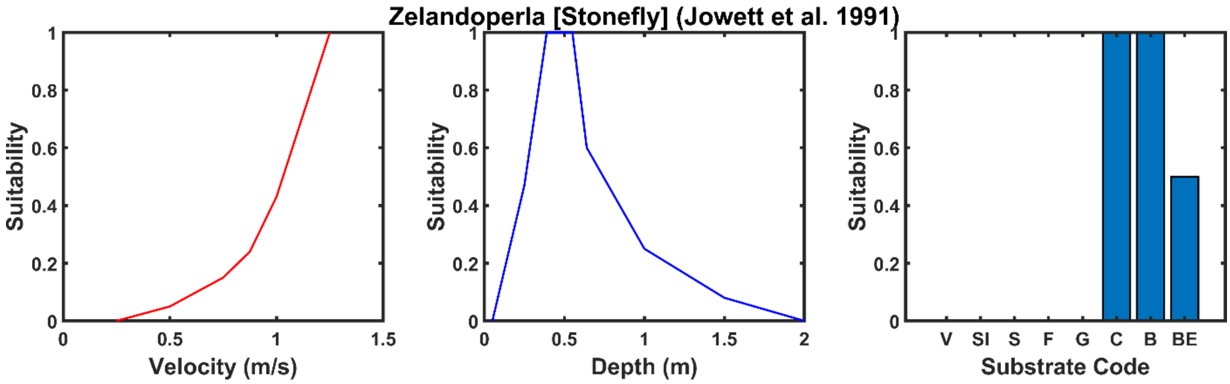

Figure E-12: **Zelandoperla (Stonefly) habitat suitability curves.**

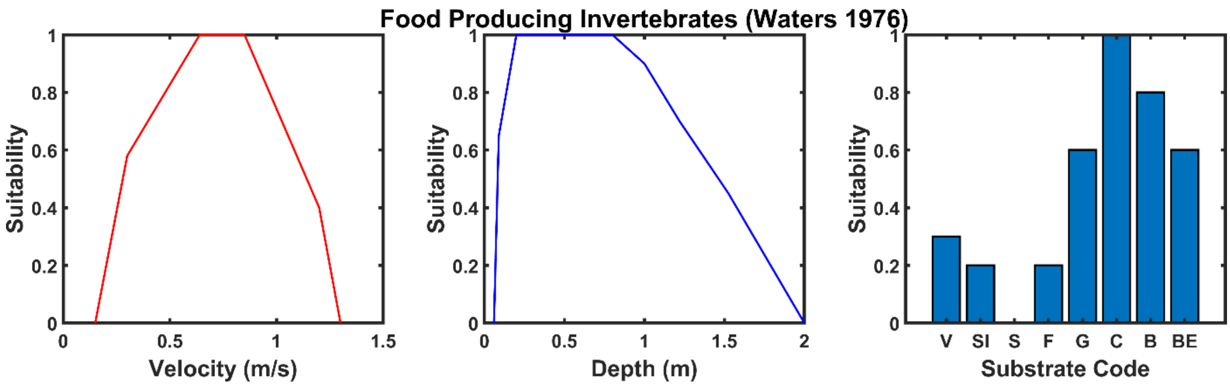

Figure E-13: Food Producing Invertebrates habitat suitability curves.

Appendix F Periphyton Habitat Suitability Criteria

Habitat suitability curves for periphyton taxonomic groups found at study sites in the Wharekirauponga Stream catchment.

See Section 3.4 for further information on site specific presence/absence.

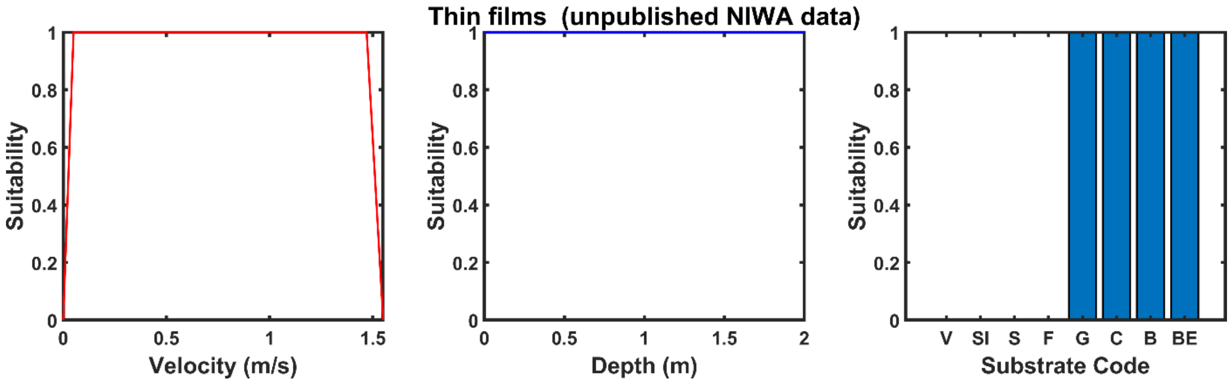

Figure F-1: Thin films habitat suitability curves.

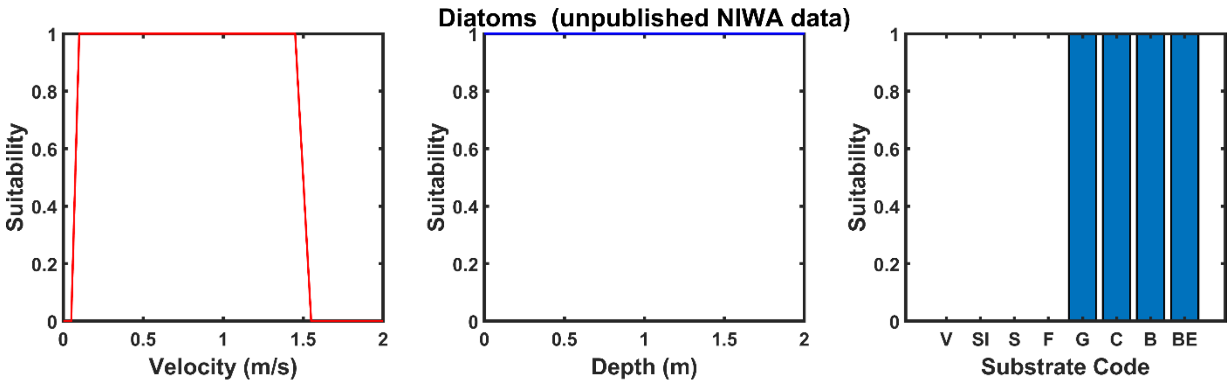

Figure F-2: Diatoms habitat suitability curves.

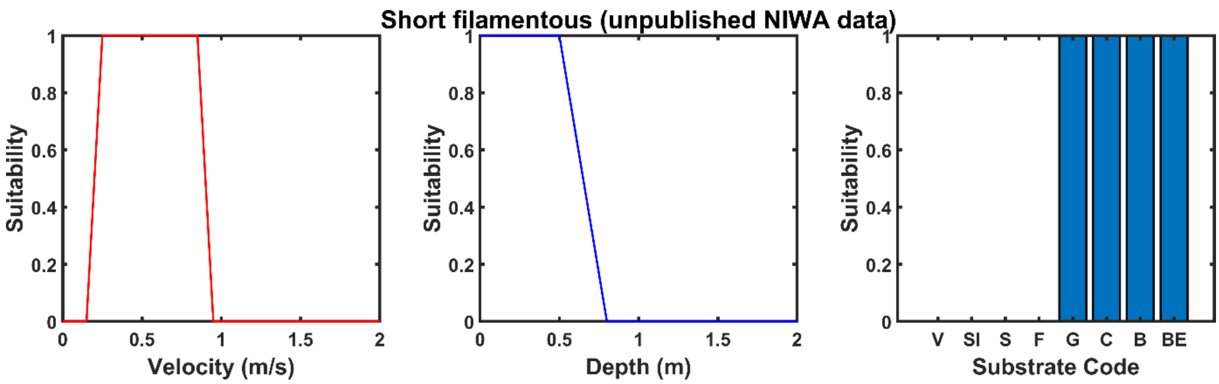

Figure F-3: Short filamentous habitat suitability curves.

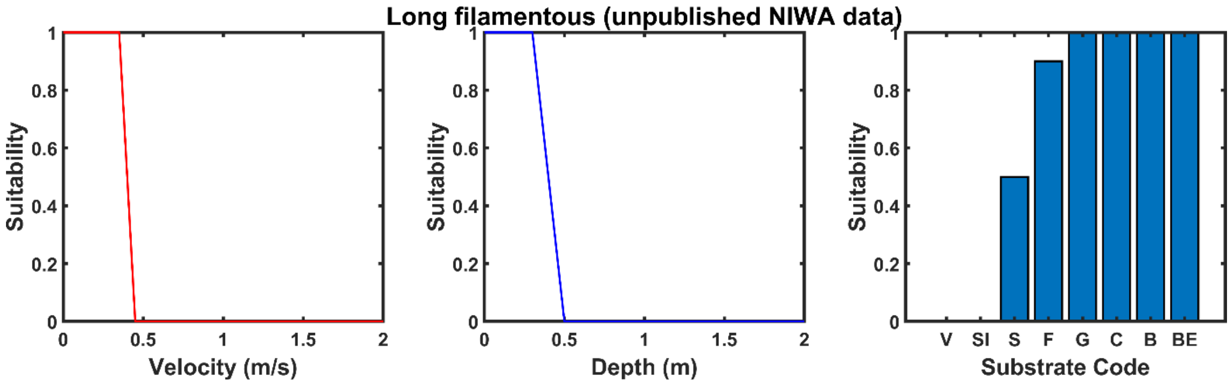

Figure F-4: Long filamentous habitat suitability curves.

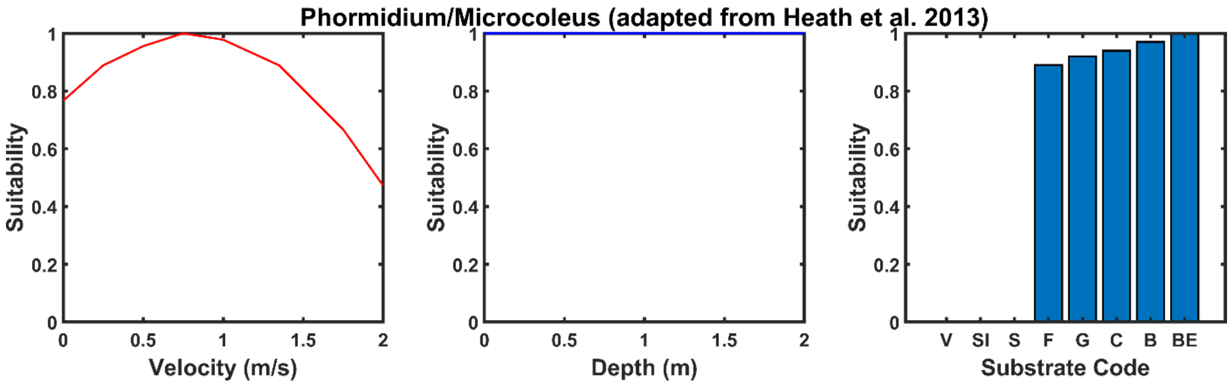

Figure F-5: ***Phormidium/Microcoleus*** **habitat suitability curves.**

Appendix G Adams Stream – Habitat surveys, cross-section measurements, and site photos

Additional information on the distributions of habitat lengths, cross-section characteristics, and site photos are provided in this appendix for Adams Stream.

Habitat mapping surveys

Histograms of the measured habitat lengths are provided below, with summary statistics found in Section 4.1.1.

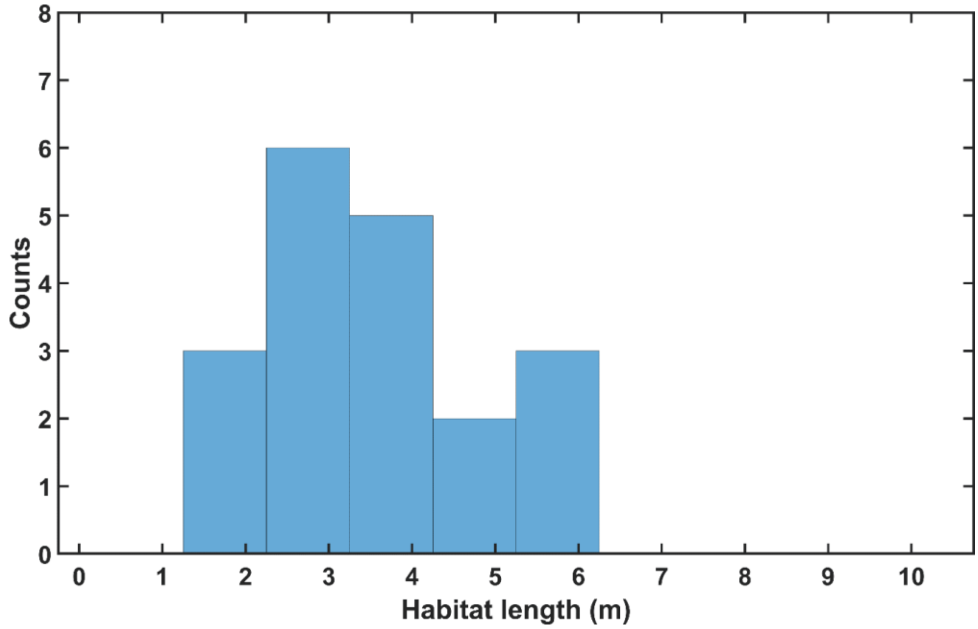

Figure G-1: Histogram of pool lengths in Adams Stream.

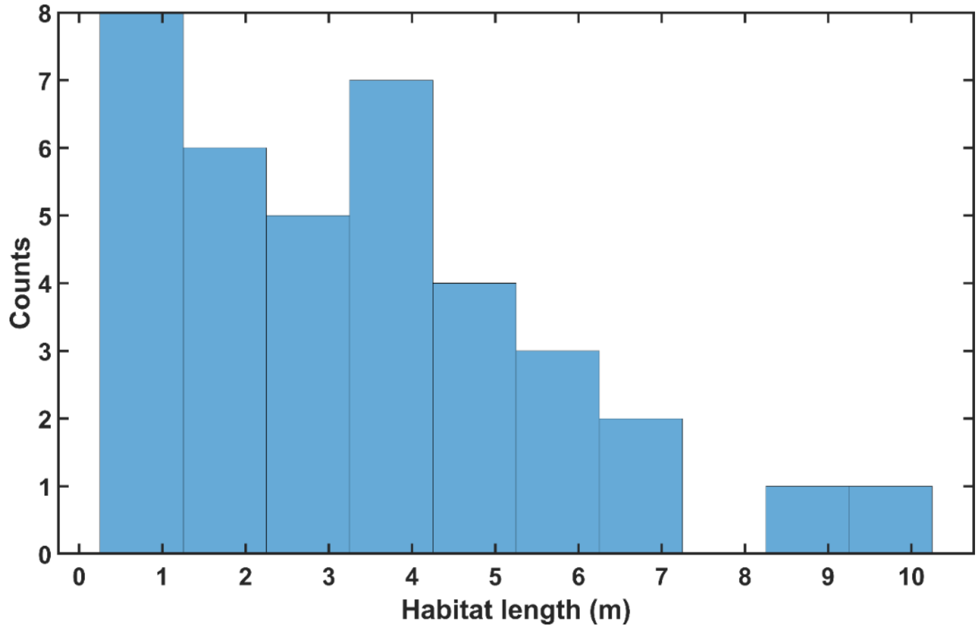

Figure G-2: Histogram of riffle lengths in Adams Stream.

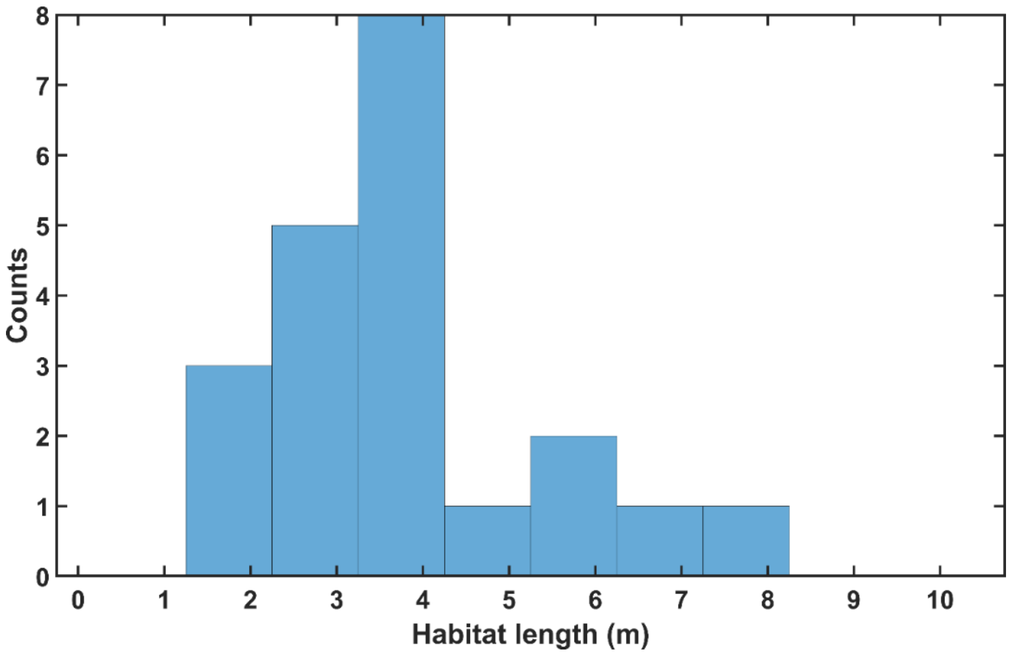

Figure G-3: Histogram of run lengths in Adams Stream.

Cross-section surveys of depth, velocity, and substrate

Physical habitat in Adams Stream is summarised in Table G-1 for the survey reach. Pool, riffle, and run weightings from the habitat mapping surveys (Section 4.1.1) are used to generate the 'Reach Average' physical habitat parameters. Substrate in Adams Stream is summarised in
Table G-2. Only wetted instream areas are used for the summary since we focused on instream habitat at low flows (i.e., 7-day MALF) and out of channel substate that was dry at the time of survey will not form instream habitat at these flows.

Table G-1: Adams Stream physical habitat summary from cross-section surveys.

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
AD01	Pool	2.050	0.458	0.223	0.026
AD02	Run	1.700	0.135	0.079	0.089
AD03	Riffle	1.400	0.086	0.061	0.140
AD04	Pool	2.050	0.325	0.159	0.037
AD05	Run	1.100	0.063	0.057	0.190
AD06	Riffle	0.600	0.129	0.216	0.093
AD07	Pool	3.500	0.593	0.169	0.020
AD08	Run	1.280	0.151	0.118	0.079
AD09	Pool	2.920	0.696	0.238	0.017
AD10	Riffle	1.250	0.074	0.059	0.163
AD11	Run	2.060	0.136	0.066	0.088
AD12	Run	1.730	0.299	0.173	0.040
AD13	Riffle	1.360	0.064	0.047	0.187
AD14	Riffle	1.060	0.052	0.049	0.232
AD15	Pool	2.310	0.209	0.090	0.057
Pool Average	All Pools	2.566	0.456	0.176	0.032

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
Riffle Average	All Riffles	1.134	0.081	0.086	0.163
Run Average	All Runs	1.574	0.157	0.099	0.097
Reach Average	Weighted	1.619	0.197	0.112	0.111

Table G-2: Adams Stream substrate summary (percentages) from cross-section surveys.

	Cross-section Type	Bedrock	Boulders	Cobbles	Coarse Gravel	Fine Gravel	Sand	Silt/Mud	Vegetation
AD01	Pool	0.0	48.9	7.6	7.6	9.5	18.0	4.0	4.4
AD02	Run	0.0	49.1	10.0	6.3	7.8	19.4	7.4	0.0
AD03	Riffle	0.0	50.9	8.9	6.2	9.8	17.5	6.7	0.0
AD04	Pool	0.0	44.9	8.3	5.0	16.0	20.7	3.7	1.5
AD05	Run	0.0	61.8	6.1	2.0	13.6	14.1	2.3	0.0
AD06	Riffle	37.1	15.8	9.6	5.0	13.8	18.3	0.4	0.0
AD07	Pool	0.0	37.4	11.4	11.2	18.0	20.2	1.8	0.0
AD08	Run	0.0	36.8	21.6	18.7	14.6	7.9	0.0	0.4
AD09	Pool	0.0	51.5	9.3	6.0	7.6	3.1	0.0	22.5
AD10	Riffle	32.0	49.2	3.4	5.3	8.1	2.0	0.0	0.0
AD11	Run	0.0	22.3	29.0	22.5	13.4	10.5	0.4	2.0
AD12	Run	0.0	65.3	7.1	9.1	11.9	6.6	0.0	0.0
AD13	Riffle	0.0	61.5	15.7	10.2	8.3	3.1	0.3	0.9
AD14	Riffle	0.0	32.4	31.1	15.4	12.6	8.4	0.0	0.0
AD15	Pool	0.0	18.2	36.0	20.0	11.4	11.9	0.0	2.4
Pool Average	All Pools	0.0	40.2	14.5	10.0	12.5	14.8	1.9	6.2
Riffle Average	All Riffles	13.8	42.0	13.7	8.4	10.5	9.9	1.5	0.2
Run Average	All Runs	0.0	47.1	14.8	11.7	12.3	11.7	2.0	0.5
Reach Average	Weighted	6.3	43.0	14.2	9.8	11.5	11.6	1.7	1.8

Average reach hydraulics

Relationships between discharge, average depth, average velocity, and average wetted width are shown in Figure G-4 for Adams Stream.

Average wetted width (m) is the same as 'Total Available Area Weighted Suitability (AWS)' (m^2/m) in Section 4, with total available instream habitat area (m^2) calculated by multiplying average wetted width and reach length.

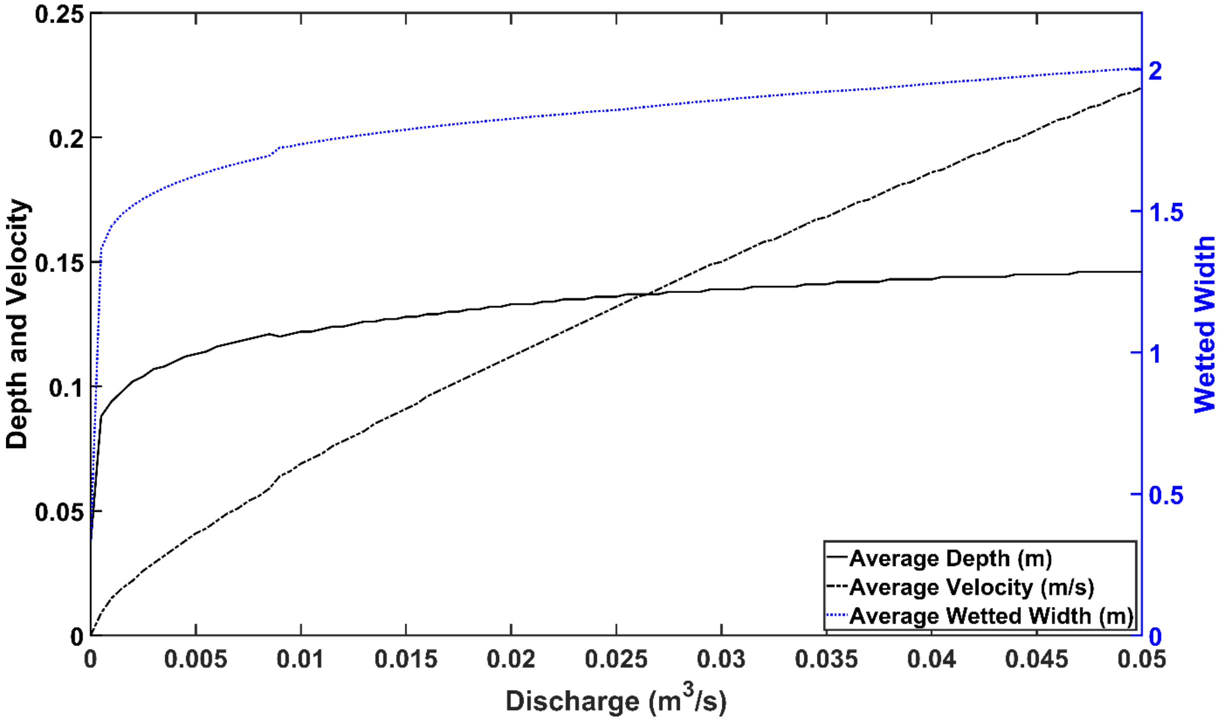

Figure G-4: Average reach hydraulics, showing average depth, average velocity, and average wetted width as a function of discharge for Adams Stream.

Site photos and cross-sections

To provide context for interpretation of study results, example cross-sections from each habitat type are presented below for Adams Stream.

Figure G-5: Adams Stream – AD05 (Run), cross-section photo.

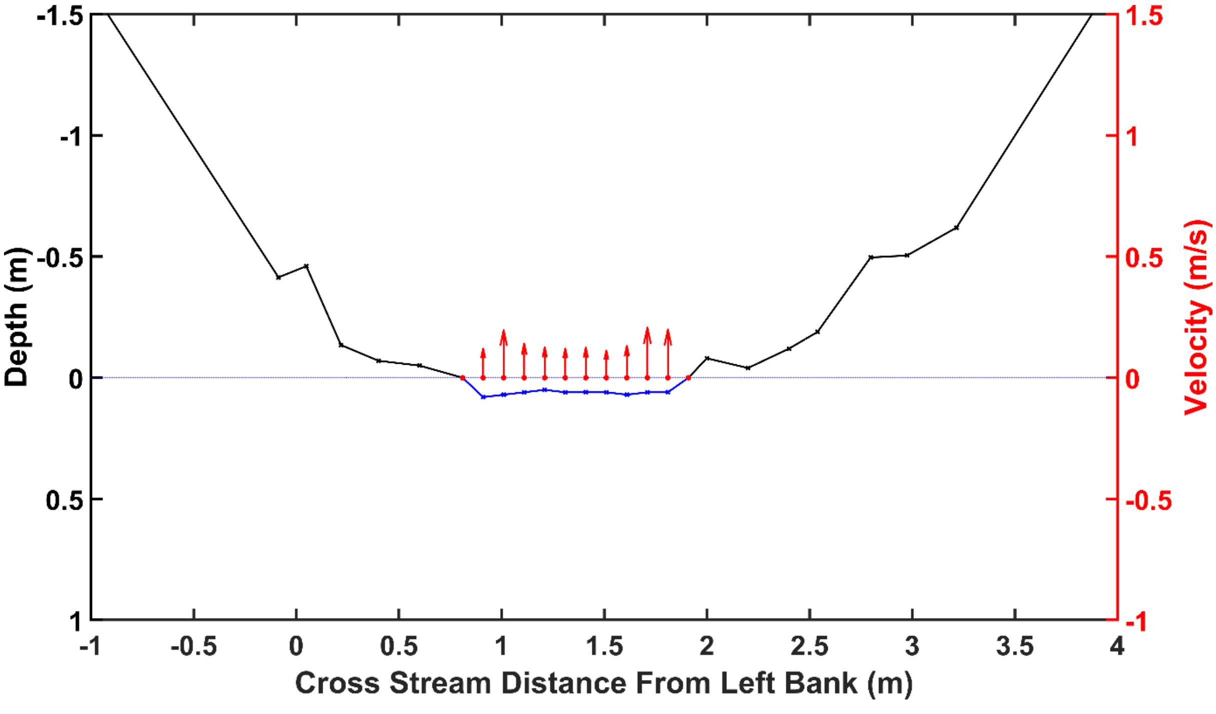

Figure G-6: Adams Stream – AD05 (Run), cross-section of depth and velocity.

Figure G-7: Adams Stream – AD03 (Riffle), cross-section photo.

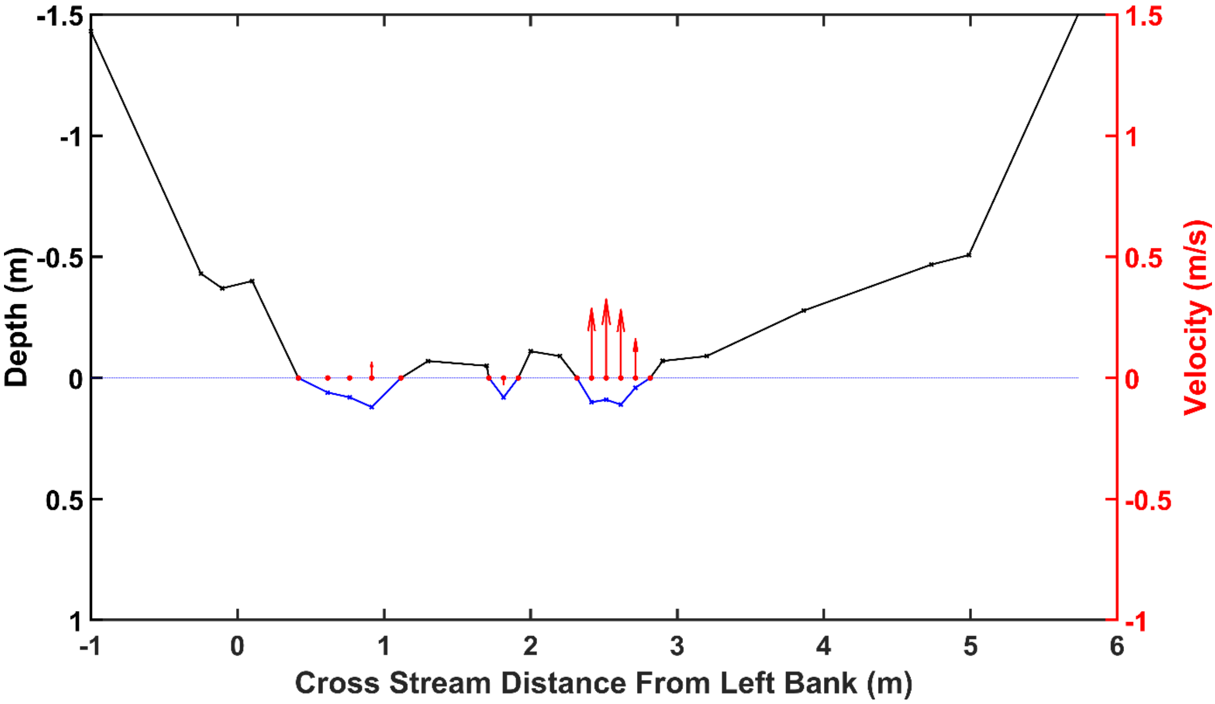

Figure G-8: Adams Stream – AD03 (Riffle), cross-section of depth and velocity.

Figure G-9: Adams Stream – AD07 (Pool), cross-section photo.

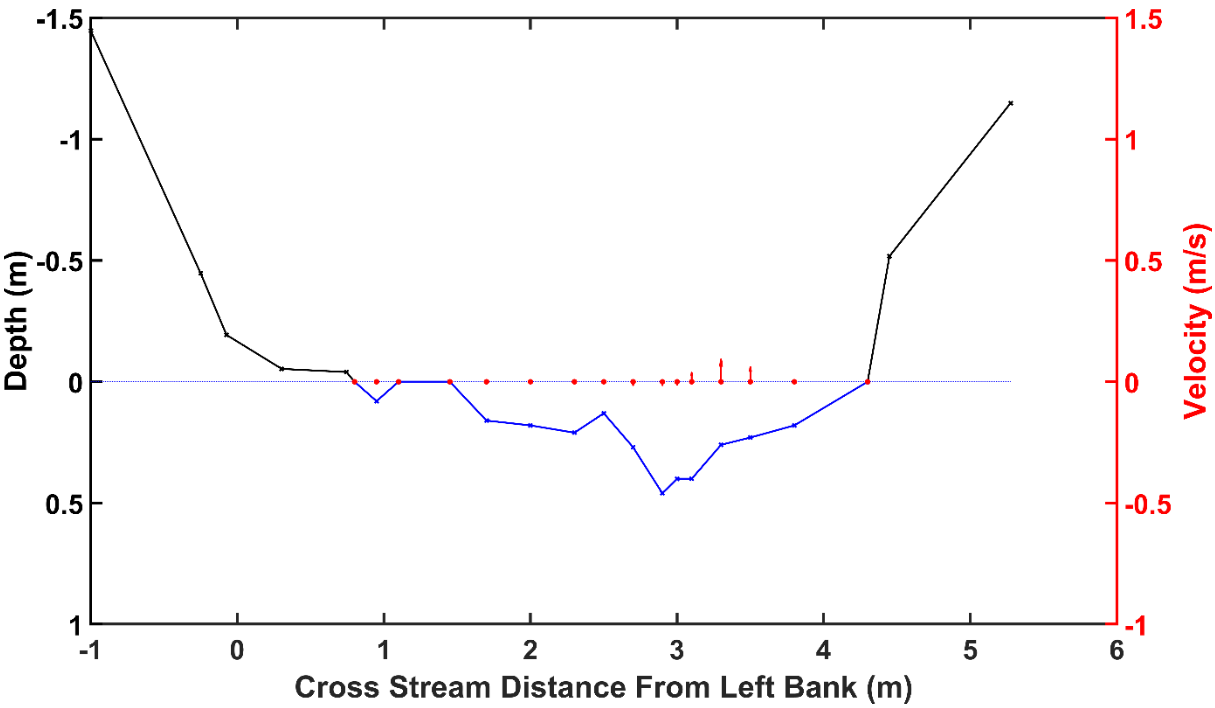

Figure G-10: Adams Stream – AD07 (Pool), cross-section of depth and velocity.

Appendix H Edmonds Stream – Habitat surveys, cross-section measurements, and site photos

Additional information on the distributions of habitat lengths, cross-section characteristics, and site photos are provided in this appendix for Edmonds Stream.

Habitat mapping surveys

Histograms of the measured habitat lengths are provided below, with summary statistics found in Section 4.2.1.

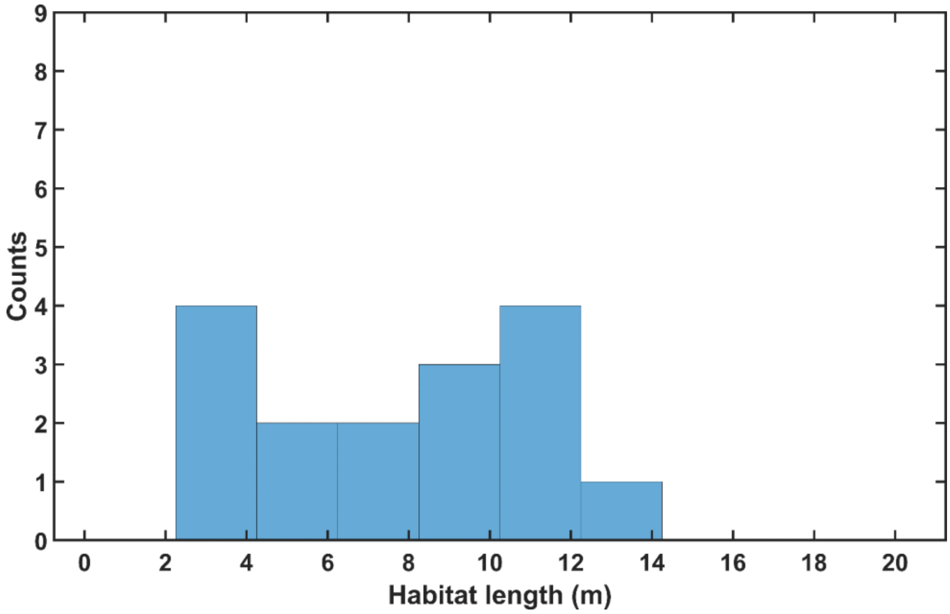

Figure H-1: Histogram of pool lengths in Edmonds Stream.

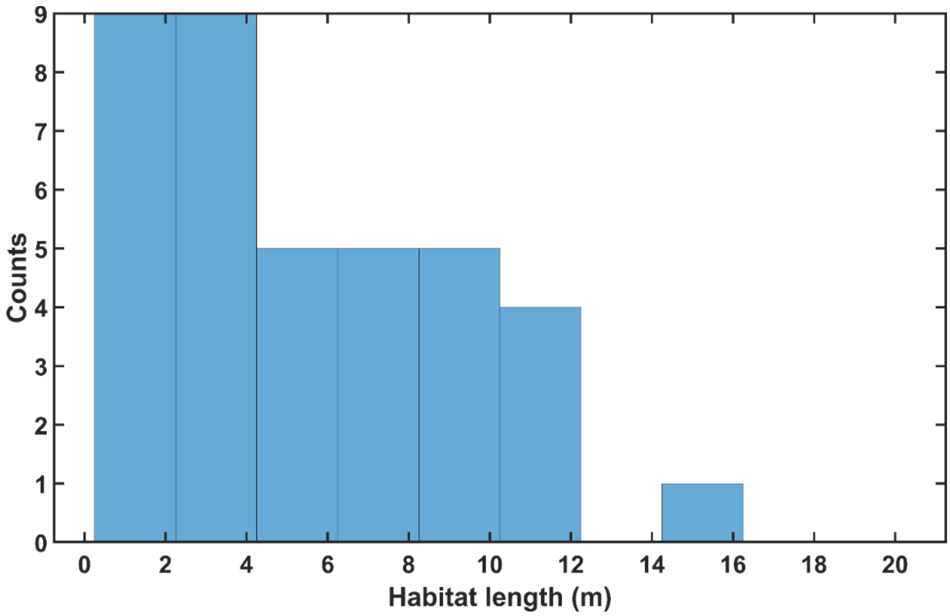

Figure H-2: Histogram of riffle lengths in Edmonds Stream.

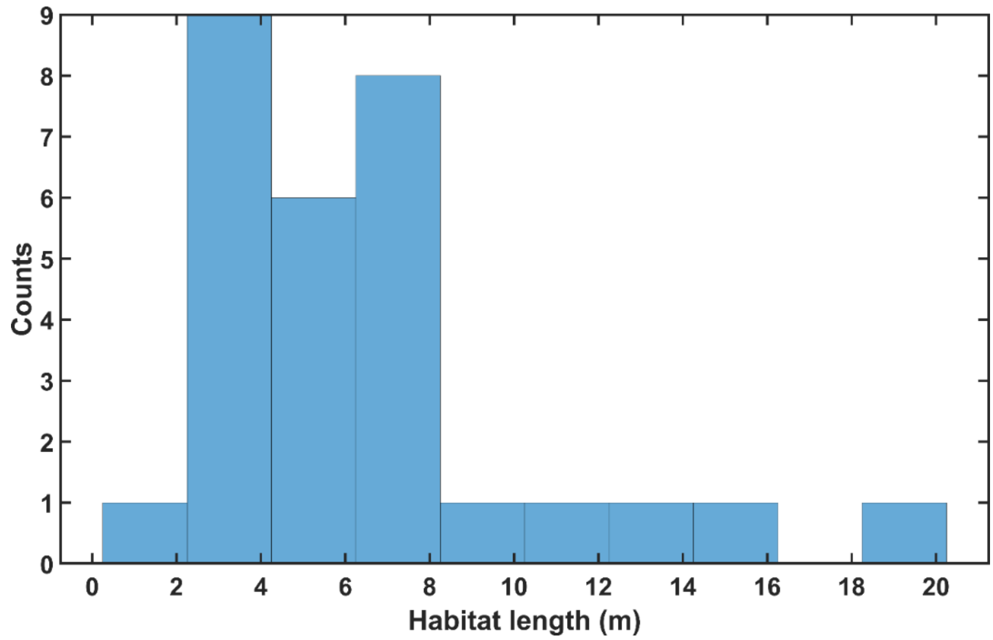

Figure H-3: Histogram of run lengths in Edmonds Stream.

Cross-section surveys of depth, velocity, and substrate

Physical habitat in Edmonds Stream is summarised in Table H-1 for the survey reach. Pool, riffle, and run weightings from the habitat mapping surveys (Section 4.2.1) are used to generate the 'Reach Average' physical habitat parameters. Substrate in Edmonds Stream is summarised in Table H-2. Only wetted instream areas are used for the summary since we focused on instream habitat at low flows (i.e., 7-day MALF) and out of channel substate that was dry at the time of survey will not form instream habitat at these flows.

Table H-1: Edmonds Stream physical habitat summary from cross-section surveys.

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
ED01	Run	3.500	0.643	0.184	0.081
ED02	Run	3.250	0.825	0.254	0.063
ED03	Riffle	2.350	0.303	0.129	0.172
ED04	Pool	3.500	0.878	0.251	0.059
ED05	Pool	6.600	3.865	0.586	0.013
ED06	Riffle	2.400	0.143	0.060	0.363
ED07	Run	2.800	0.385	0.137	0.135
ED08	Pool	3.000	0.735	0.245	0.071
ED09	Run	2.020	0.297	0.147	0.175
ED10	Riffle	2.500	0.192	0.077	0.270
ED11	Riffle	2.600	0.255	0.098	0.204
ED12	Pool	3.080	0.592	0.192	0.088
ED13	Riffle	2.200	0.258	0.117	0.201
ED14	Run	2.580	0.243	0.094	0.214
ED15	Pool	4.640	1.273	0.274	0.041

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
Pool Average	All Pools	4.164	1.469	0.310	0.054
Riffle Average	All Riffles	2.410	0.230	0.096	0.242
Run Average	All Runs	2.830	0.479	0.163	0.134
Reach Average	Weighted	2.986	0.619	0.172	0.158

Table H-2: Edmonds Stream substrate summary (percentages) from cross-section surveys.

	Cross-section Type	Bedrock	Boulders	Cobbles	Coarse Gravel	Fine Gravel	Sand	Silt/Mud	Vegetation
ED01	Run	0.0	32.0	40.9	11.4	13.7	2.0	0.0	0.0
ED02	Run	0.0	25.2	31.5	26.2	14.2	2.9	0.0	0.0
ED03	Riffle	45.4	13.3	26.0	10.6	3.6	0.6	0.0	0.4
ED04	Pool	30.0	31.7	10.3	5.4	6.3	6.3	0.0	10.0
ED05	Pool	22.4	3.0	13.9	35.2	15.2	5.5	0.0	4.8
ED06	Riffle	18.8	54.8	23.5	0.0	2.9	0.0	0.0	0.0
ED07	Run	25.0	34.7	20.6	11.4	5.3	2.9	0.0	0.0
ED08	Pool	3.3	33.5	19.0	11.1	16.2	16.8	0.0	0.0
ED09	Run	0.0	48.7	13.8	10.4	10.0	17.1	0.0	0.0
ED10	Riffle	0.0	55.1	17.8	13.8	7.2	6.1	0.0	0.0
ED11	Riffle	0.0	47.9	24.6	15.0	8.0	4.5	0.0	0.0
ED12	Pool	3.1	19.6	21.3	19.7	24.0	12.2	0.0	0.1
ED13	Riffle	0.0	54.0	15.0	10.8	7.2	13.0	0.0	0.0
ED14	Run	0.0	49.8	28.3	9.9	4.5	4.5	0.0	3.1
ED15	Pool	0.0	19.4	30.6	17.7	10.7	19.8	0.0	1.8
Pool Average	All Pools	11.8	21.4	19.0	17.8	14.5	12.1	0.0	3.4
Riffle Average	All Riffles	12.8	45.0	21.4	10.0	5.8	4.9	0.0	0.1
Run Average	All Runs	5.0	38.1	27.0	13.8	9.5	5.9	0.0	0.6
Reach Average	Weighted	9.8	36.8	22.8	13.3	9.2	7.0	0.0	1.1

Average reach hydraulics

Relationships between discharge, average depth, average velocity, and average wetted width are shown in Figure H-4 for Edmonds Stream.

Average wetted width (m) is the same as 'Total Available Area Weighted Suitability (AWS)' (m^2/m) in Section 4, with total available instream habitat area (m^2) calculated by multiplying average wetted width and reach length.

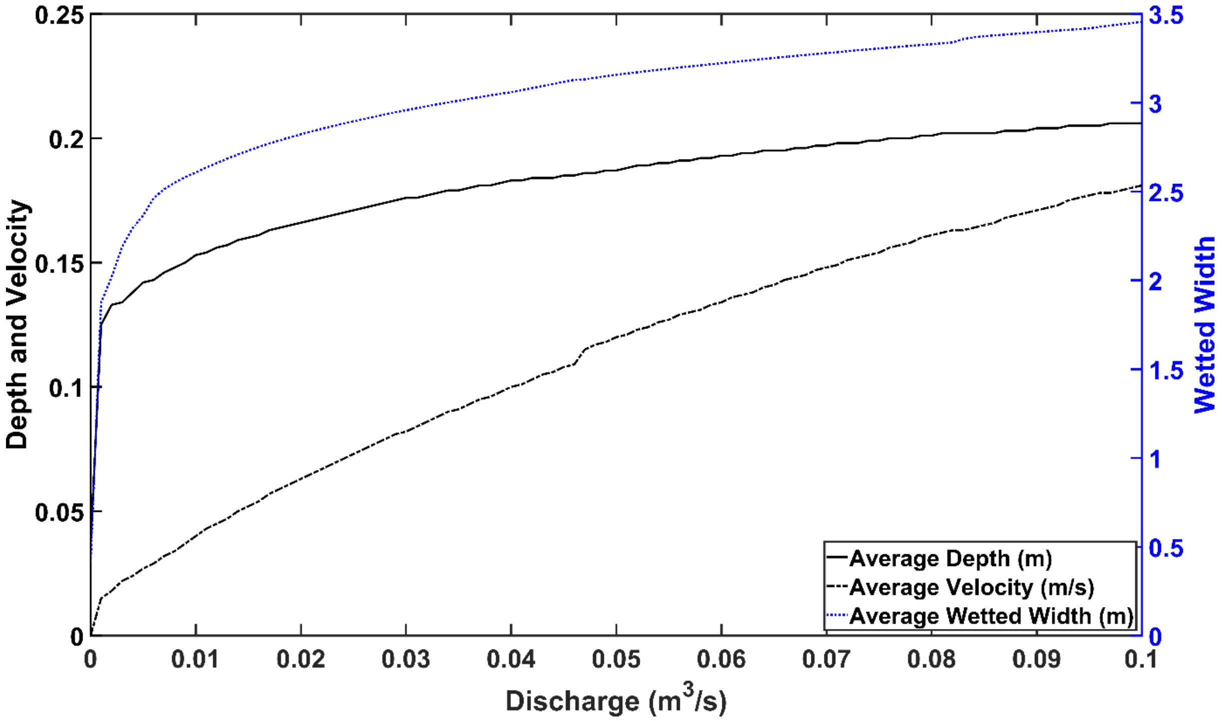

Figure H-4: Average reach hydraulics, showing average depth, average velocity, and average wetted width as a function of discharge for Edmonds Stream.

Site photos and cross-sections

To provide context for interpretation of study results, example cross-sections from each habitat type are presented below for Edmonds Stream.

Figure H-5: Edmonds Stream – ED04 (Pool), cross-section photo.

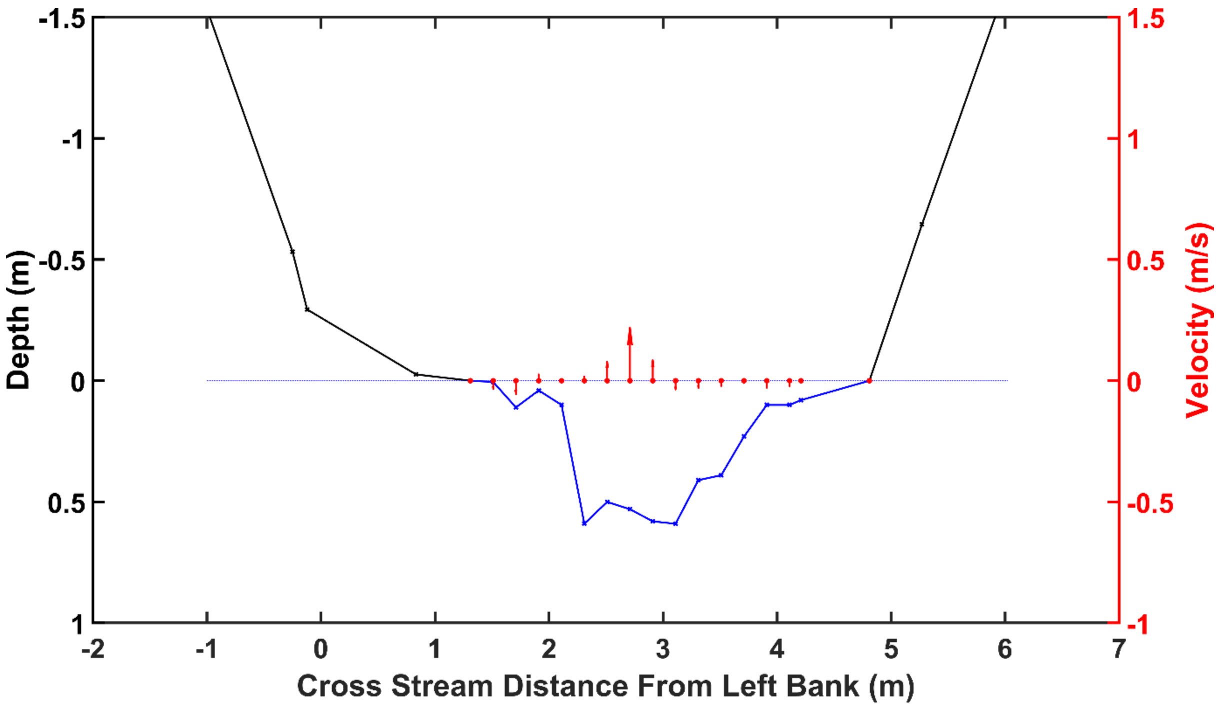

Figure H-6: Edmonds Stream – ED04 (Pool), cross-section of depth and velocity.

Figure H-7: Edmonds Stream – ED09 (Run), cross-section photo.

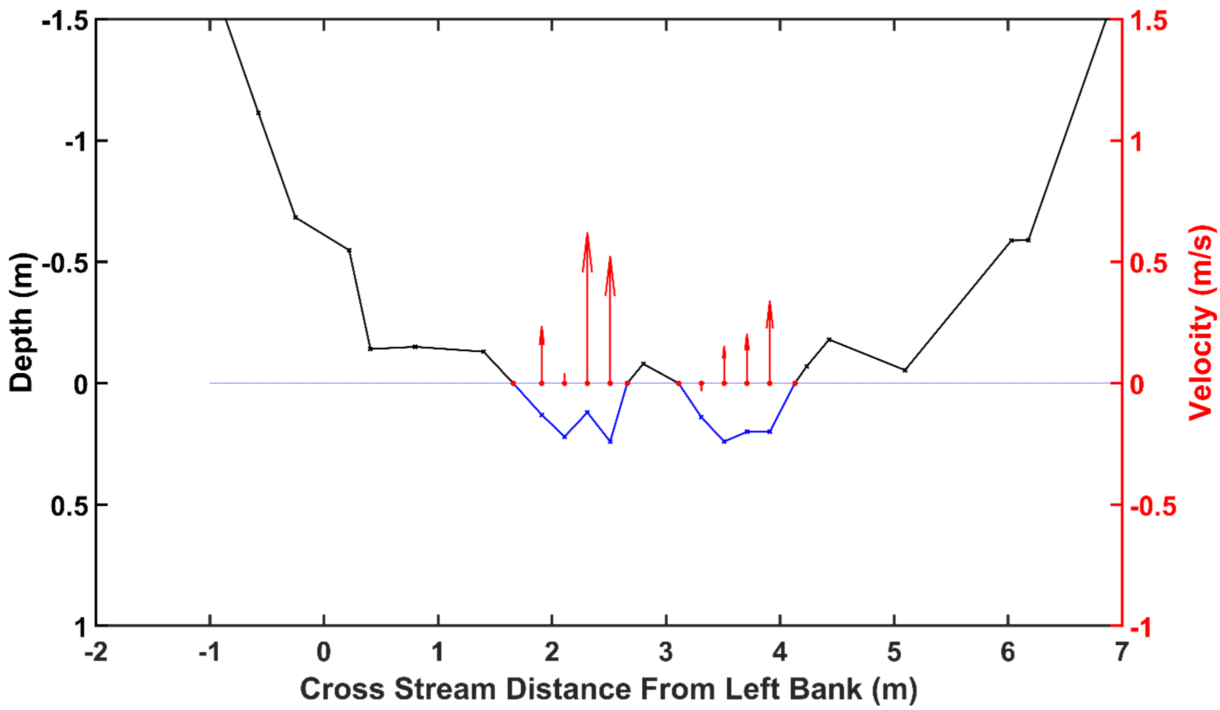

Figure H-8: Edmonds Stream – ED09 (Run), cross-section of depth and velocity.

Figure H-9: Edmonds Stream – ED10 (Riffle), cross-section photo.

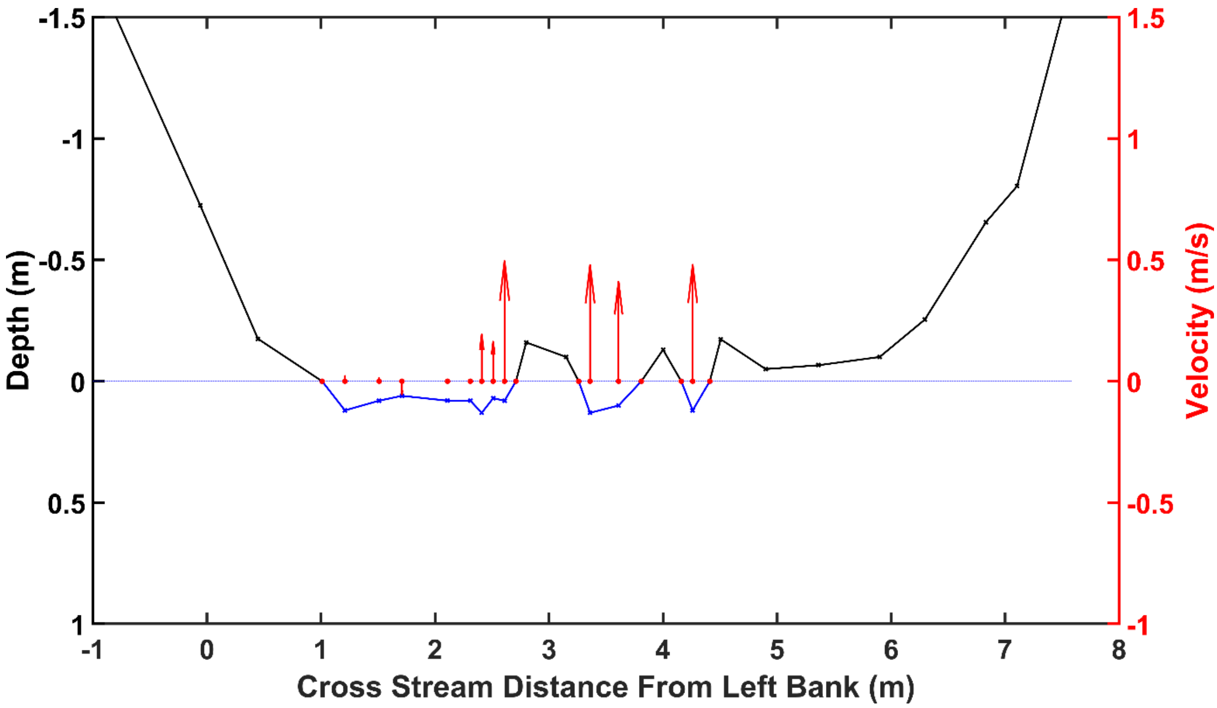

Figure H-10: Edmonds Stream – ED10 (Riffle), cross-section of depth and velocity.

Appendix I Teawaotemutu Stream – Habitat surveys, cross-section measurements, and site photos

Additional information on the distributions of habitat lengths, cross-section characteristics, and site photos are provided in this appendix for Teawaotemutu Stream.

Habitat mapping surveys

Histograms of the measured habitat lengths are provided below, with summary statistics found in Section 4.3.1.

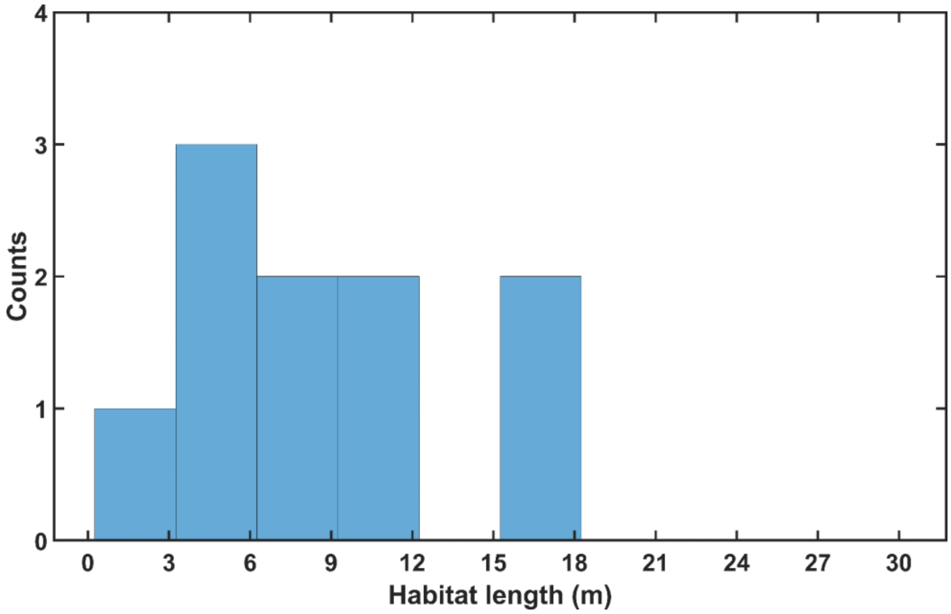

Figure I-1: Histogram of pool lengths in Teawaotemutu Stream.

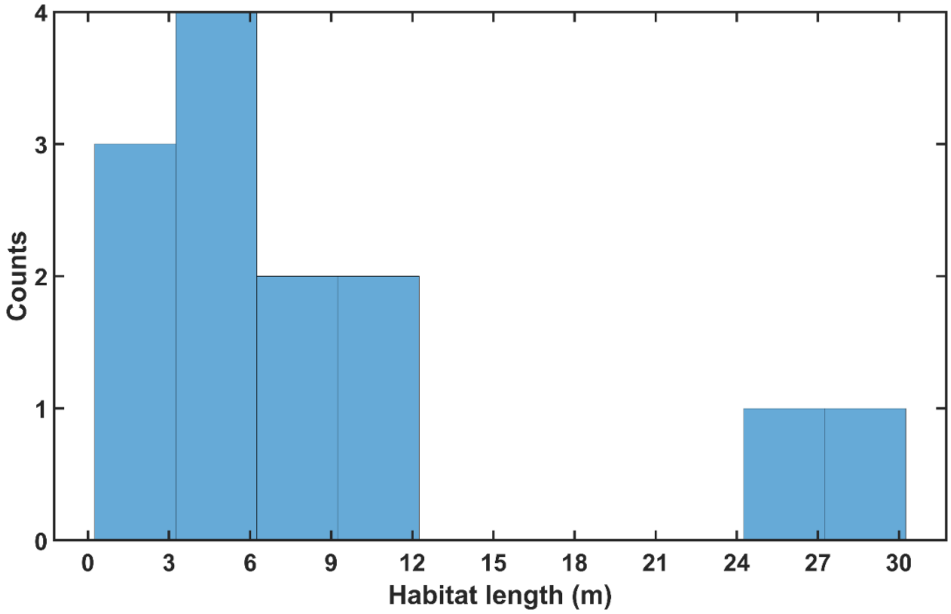

Figure I-2: Histogram of riffle lengths in Teawaotemutu Stream.

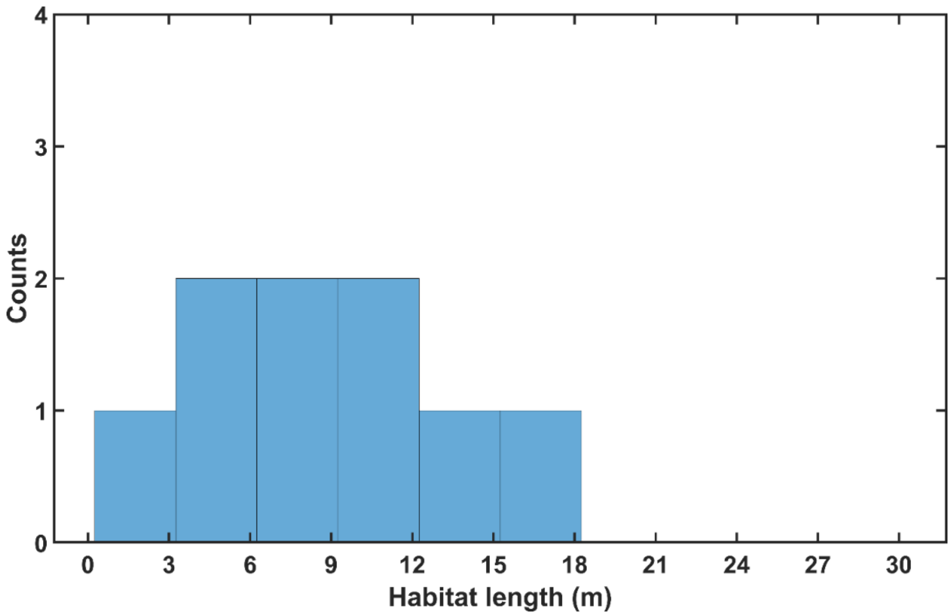

Figure I-3: Histogram of run lengths in Teawaotemutu Stream.

Cross-section surveys of depth, velocity, and substrate

Physical habitat in Teawaotemutu Stream is summarised in Table I-1 for the survey reach. Pool, riffle, and run weightings from the habitat mapping surveys (Section 4.3.1) are used to generate the 'Reach Average' physical habitat parameters. Substrate in Teawaotemutu Stream is summarised in Table I-2. Only wetted instream areas are used for the summary since we focused on instream habitat at low flows (i.e., 7-day MALF) and out of channel substate that was dry at the time of survey will not form instream habitat at these flows.

Table I-1: Teawaotemutu Stream physical habitat summary from cross-section surveys.

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
TE01	Pool	8.700	2.251	0.259	0.052
TE02	Riffle	3.550	0.356	0.100	0.329
TE03	Run	2.200	0.403	0.183	0.291
TE04	Pool	5.050	1.403	0.278	0.083
TE05	Riffle	1.350	0.265	0.196	0.442
TE06	Run	3.700	0.685	0.185	0.171
TE07	Riffle	3.250	0.314	0.097	0.373
TE08	Run	3.420	0.378	0.111	0.310
TE09	Pool	3.800	1.419	0.374	0.082
TE10	Riffle	2.000	0.317	0.159	0.369
TE11	Run	3.640	0.388	0.107	0.302
TE12	Riffle	2.280	0.212	0.093	0.553
TE13	Pool	7.850	1.254	0.160	0.093
TE14	Run	2.930	0.574	0.196	0.204
TE15	Pool	4.900	2.195	0.448	0.053
Pool Average	All Pools	6.060	1.704	0.304	0.073

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
Riffle Average	All Riffles	2.486	0.293	0.129	0.413
Run Average	All Runs	3.178	0.486	0.156	0.255
Reach Average	Weighted	3.806	0.792	0.192	0.262

Table I-2: Teawaotemutu Stream substrate summary (percentages) from cross-section surveys.

	Cross-section Type	Bedrock	Boulders	Cobbles	Coarse Gravel	Fine Gravel	Sand	Silt/Mud	Vegetation
TE01	Pool	10.3	40.2	16.0	17.0	10.2	0.0	0.0	6.3
TE02	Riffle	0.0	41.3	26.5	20.0	12.1	0.0	0.0	0.0
TE03	Run	54.2	18.4	13.4	12.4	1.6	0.0	0.0	0.0
TE04	Pool	0.0	27.4	38.5	21.7	12.3	0.0	0.0	0.0
TE05	Riffle	0.0	64.1	18.9	10.0	7.0	0.0	0.0	0.0
TE06	Run	0.0	45.3	24.9	18.6	9.3	0.0	0.0	1.9
TE07	Riffle	0.0	54.0	26.0	14.0	6.0	0.0	0.0	0.0
TE08	Run	0.0	10.8	48.7	28.8	5.6	1.2	0.0	5.0
TE09	Pool	22.5	7.1	34.2	21.1	15.1	0.0	0.0	0.0
TE10	Riffle	92.2	3.7	3.7	0.5	0.0	0.0	0.0	0.0
TE11	Run	7.8	62.2	18.6	6.5	4.9	0.0	0.0	0.0
TE12	Riffle	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TE13	Pool	3.8	24.5	27.0	20.0	14.8	9.9	0.0	0.0
TE14	Run	5.4	40.6	26.7	16.4	9.6	1.4	0.0	0.0
TE15	Pool	29.0	13.9	27.8	21.2	6.9	1.2	0.0	0.0
Pool Average	All Pools	13.1	22.6	28.7	20.2	11.9	2.2	0.0	1.3
Riffle Average	All Riffles	38.4	32.6	15.0	8.9	5.0	0.0	0.0	0.0
Run Average	All Runs	13.5	35.5	26.4	16.5	6.2	0.5	0.0	1.4
Reach Average	Weighted	23.4	30.3	22.5	14.6	7.5	0.8	0.0	0.8

Average reach hydraulics

Relationships between discharge, average depth, average velocity, and average wetted width are shown in Figure I-4 for Teawaotemutu Stream.

Average wetted width (m) is the same as 'Total Available Area Weighted Suitability (AWS)' (m^2/m) in Section 4, with total available instream habitat area (m^2) calculated by multiplying average wetted width and reach length.

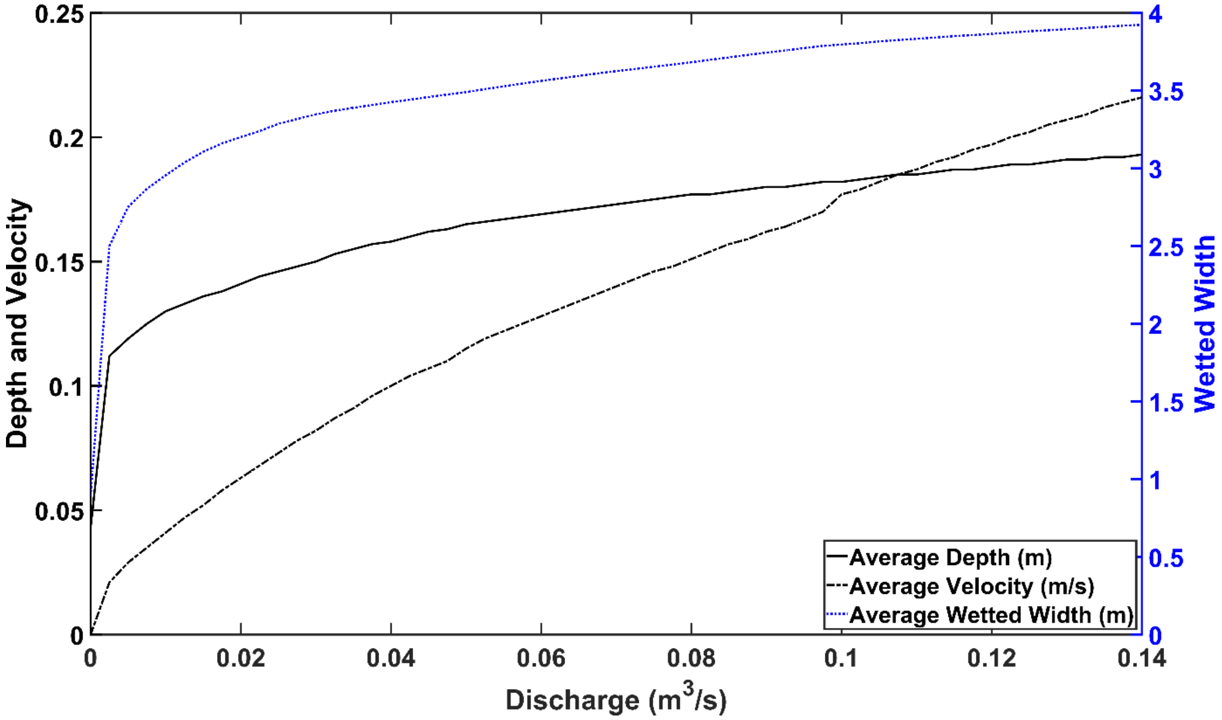

Figure I-4: Average reach hydraulics, showing average depth, average velocity, and average wetted width as a function of discharge for Teawaotemutu Stream.

Site photos and cross-sections

To provide context for interpretation of study results, example cross-sections from each habitat type are presented below for Teawaotemutu Stream.

Figure I-5: Teawaotemutu Stream – TE03 (Run), cross-section photo.

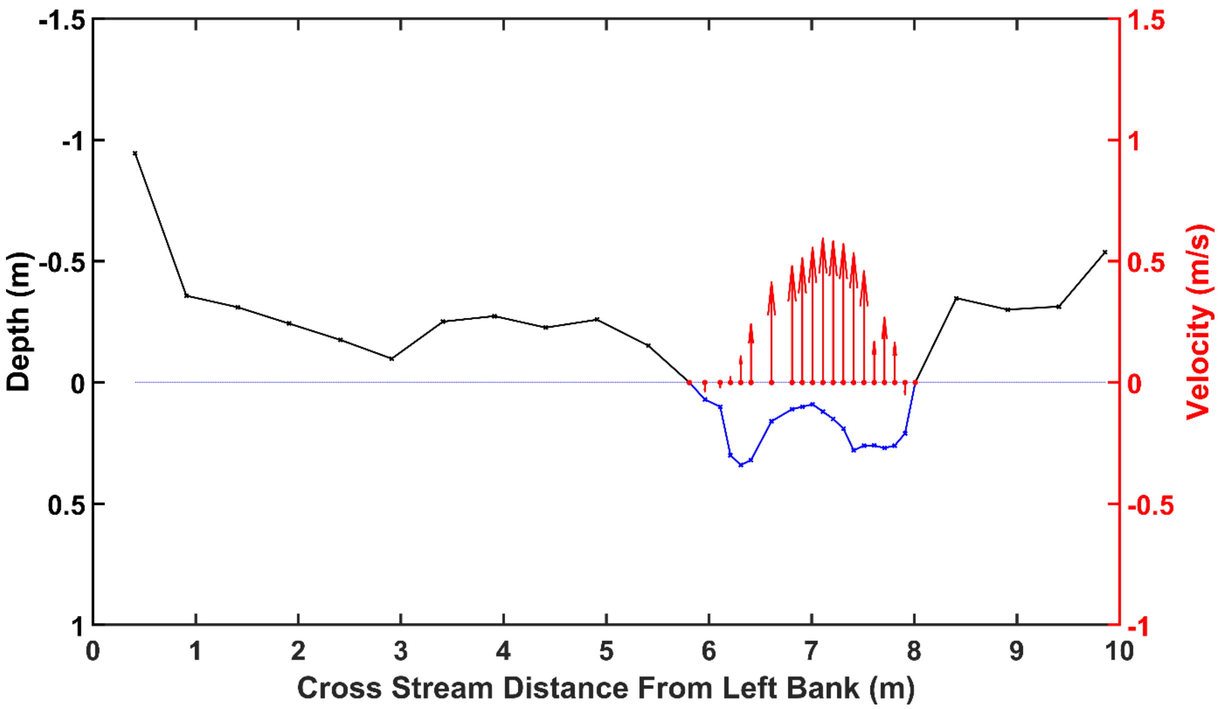

Figure I-6: Teawaotemutu Stream – TE03 (Run), cross-section of depth and velocity.

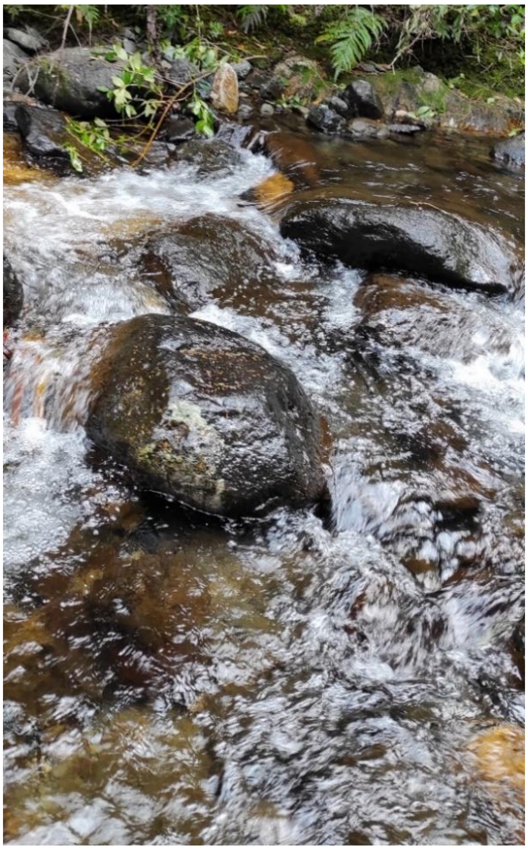

Figure I-7: **Teawaotemutu Stream – TE07 (Riffle), cross-section photo.**

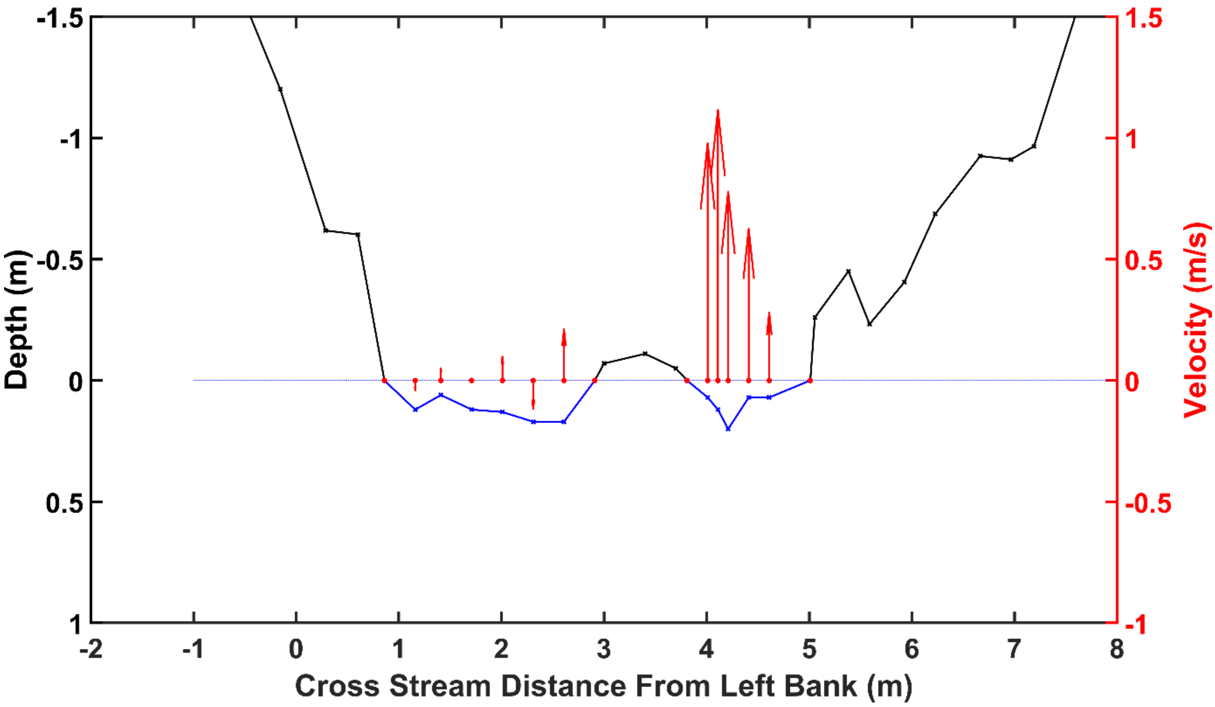

Figure I-8: **Teawaotemutu Stream – TE07 (Riffle), cross-section of depth and velocity.**

Figure I-9: **Teawaotemutu Stream – TE15 (Pool), cross-section photo.**

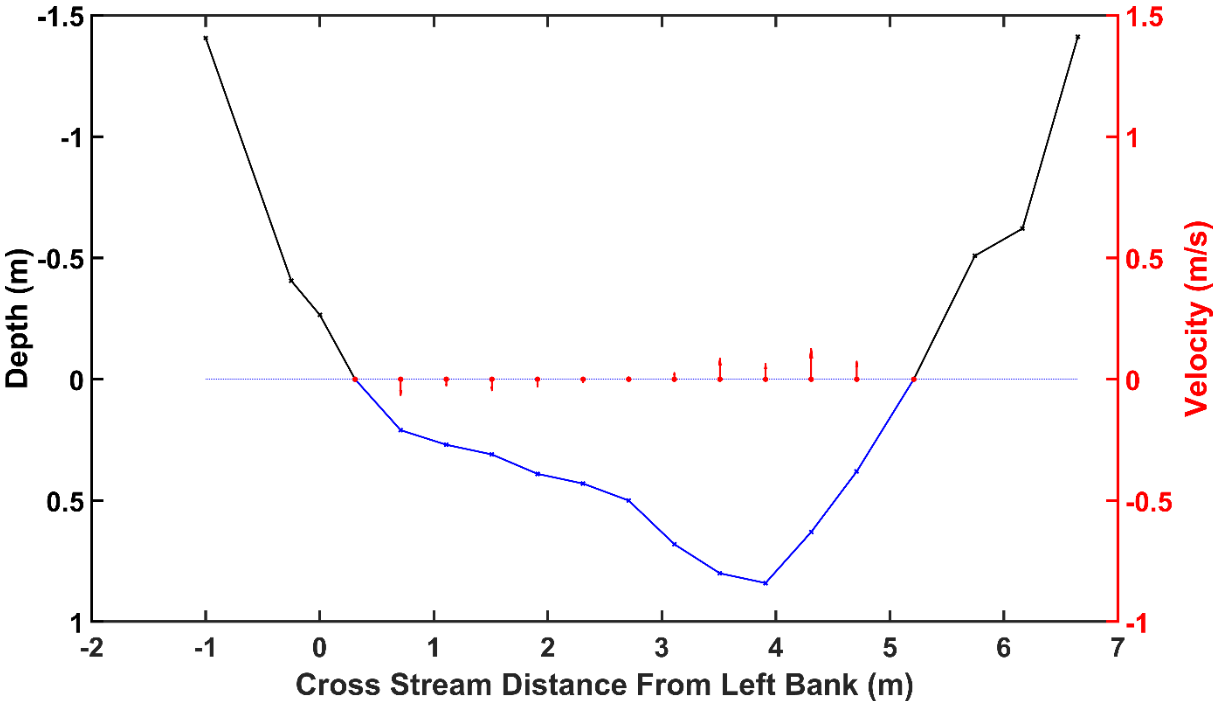

Figure I-10: **Teawaotemutu Stream – TE15 (Pool), cross-section of depth and velocity.**

Appendix J Thompson Stream – Habitat surveys, cross-section measurements, and site photos

Additional information on the distributions of habitat lengths, cross-section characteristics, and site photos are provided in this appendix for Thompson Stream.

Habitat mapping surveys

Histograms of the measured habitat lengths are provided below, with summary statistics found in Section 4.4.1.

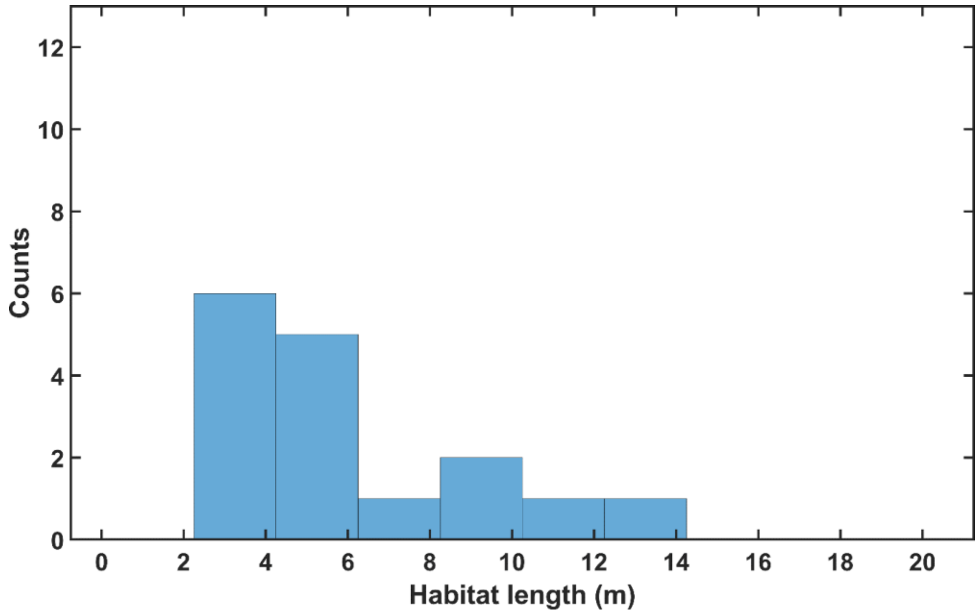

Figure J-1: Histogram of pool lengths in Thompson Stream.

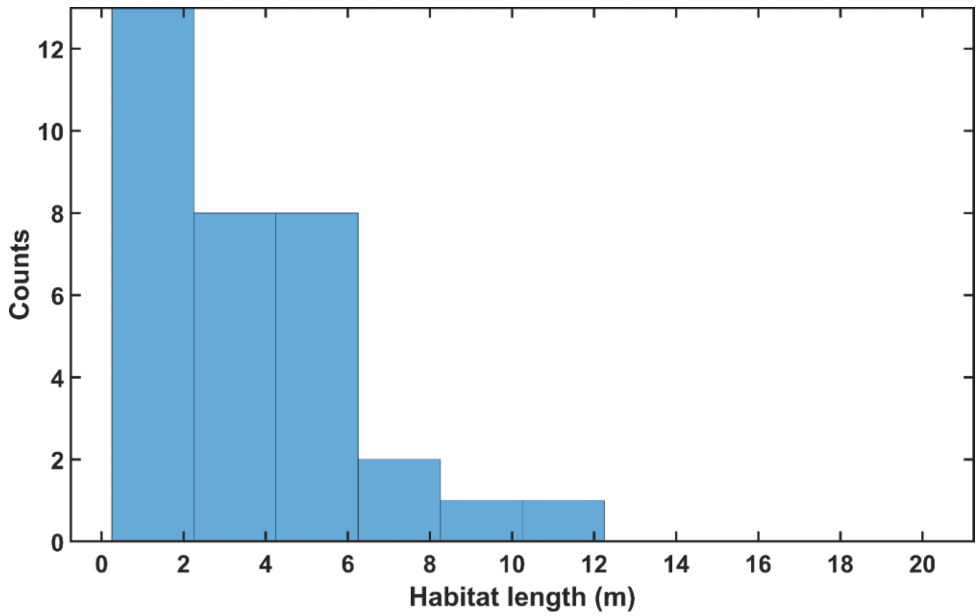

Figure J-2: Histogram of riffle lengths in Thompson Stream.

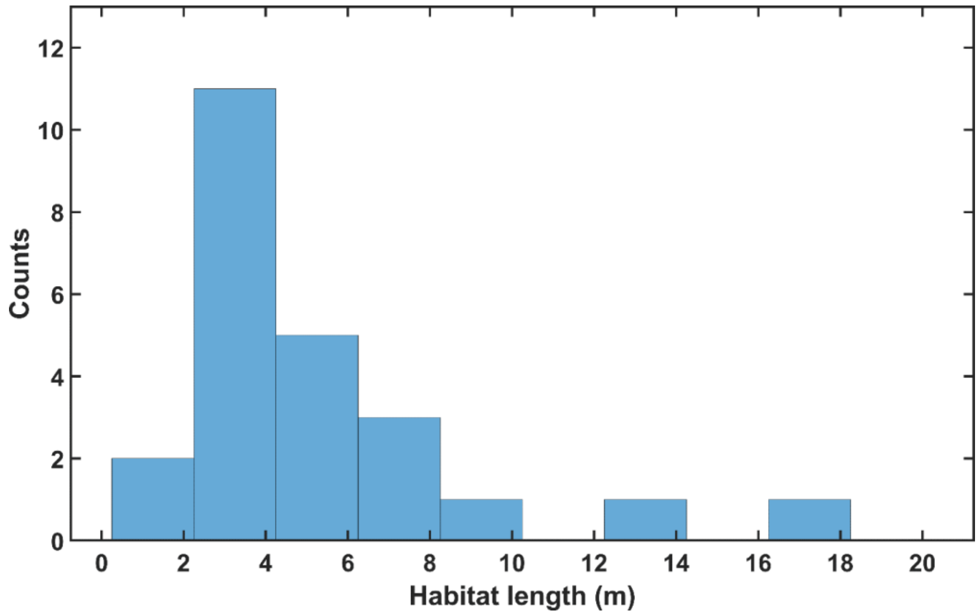

Figure J-3: Histogram of run lengths in Thompson Stream.

Cross-section surveys of depth, velocity, and substrate

Physical habitat in Thompson Stream is summarised in Table J-1 for the survey reach. Pool, riffle, and run weightings from the habitat mapping surveys (Section 4.4.1) are used to generate the 'Reach Average' physical habitat parameters. Substrate in Thompson Stream is summarised in Table J-2. Only wetted instream areas are used for the summary since we focused on instream habitat at low flows (i.e., 7-day MALF) and out of channel substate that was dry at the time of survey will not form instream habitat at these flows.

Table J-1: Thompson Stream physical habitat summary from cross-section surveys.

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
TH01	Riffle	2.050	0.147	0.072	0.142
TH02	Run	2.280	0.244	0.107	0.086
TH03	Pool	3.500	0.462	0.132	0.045
TH04	Riffle	3.300	0.173	0.052	0.121
TH05	Pool	3.900	0.507	0.130	0.041
TH06	Run	2.250	0.280	0.124	0.075
TH07	Riffle	1.700	0.058	0.034	0.359
TH08	Run	2.250	0.226	0.101	0.093
TH09	Pool	3.250	0.853	0.262	0.025
TH10	Run	1.900	0.242	0.127	0.087
TH11	Run	3.900	0.356	0.091	0.059
TH12	Riffle	2.900	0.157	0.054	0.134
TH13	Pool	3.690	0.550	0.149	0.038
TH14	Pool	2.300	0.421	0.183	0.050
TH15	Riffle	1.050	0.055	0.052	0.382

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
Pool Average	All Pools	3.328	0.559	0.171	0.040
Riffle Average	All Riffles	2.200	0.118	0.053	0.228
Run Average	All Runs	2.516	0.270	0.110	0.080
Reach Average	Weighted	2.626	0.295	0.107	0.121

Table J-2: Thompson Stream substrate summary (percentages) from cross-section surveys.

	Cross-section Type	Bedrock	Boulders	Cobbles	Coarse Gravel	Fine Gravel	Sand	Silt/Mud	Vegetation
TH01	Riffle	0.0	42.2	23.7	14.0	12.1	8.1	0.0	0.0
TH02	Run	0.0	23.3	30.2	17.0	9.0	6.2	0.0	14.3
TH03	Pool	0.0	39.2	21.5	14.5	14.5	10.3	0.0	0.0
TH04	Riffle	18.2	47.7	16.5	6.8	2.0	1.1	0.0	7.7
TH05	Pool	0.0	39.2	24.6	11.2	8.1	8.9	0.0	8.0
TH06	Run	0.0	30.4	28.6	18.3	13.0	9.0	0.0	0.7
TH07	Riffle	0.0	30.3	19.0	24.3	17.4	7.4	0.0	1.8
TH08	Run	0.0	42.0	26.5	15.3	9.6	3.7	0.0	2.9
TH09	Pool	0.0	37.8	24.6	12.5	2.2	1.1	1.1	20.7
TH10	Run	0.0	67.4	19.6	9.6	2.6	0.8	0.0	0.0
TH11	Run	0.0	22.3	26.5	17.7	14.0	4.6	1.7	13.1
TH12	Riffle	0.0	42.8	31.1	13.8	6.7	1.7	0.0	3.9
TH13	Pool	0.0	48.1	24.8	9.8	6.8	2.5	0.0	8.0
TH14	Pool	0.0	48.0	25.2	9.7	4.3	4.1	0.0	8.6
TH15	Riffle	0.0	42.6	31.7	14.0	6.7	5.0	0.0	0.0
Pool Average	All Pools	0.0	42.5	24.1	11.5	7.2	5.4	0.2	9.1
Riffle Average	All Riffles	3.6	41.1	24.4	14.6	9.0	4.7	0.0	2.7
Run Average	All Runs	0.0	37.1	26.3	15.6	9.7	4.9	0.3	6.2
Reach Average	Weighted	1.3	40.0	25.0	14.1	8.7	4.9	0.2	5.7

Average reach hydraulics

Relationships between discharge, average depth, average velocity, and average wetted width are shown in Figure J-4 for Thompson Stream.

Average wetted width (m) is the same as 'Total Available Area Weighted Suitability (AWS)' (m^2/m) in Section 4, with total available instream habitat area (m^2) calculated by multiplying average wetted width and reach length.

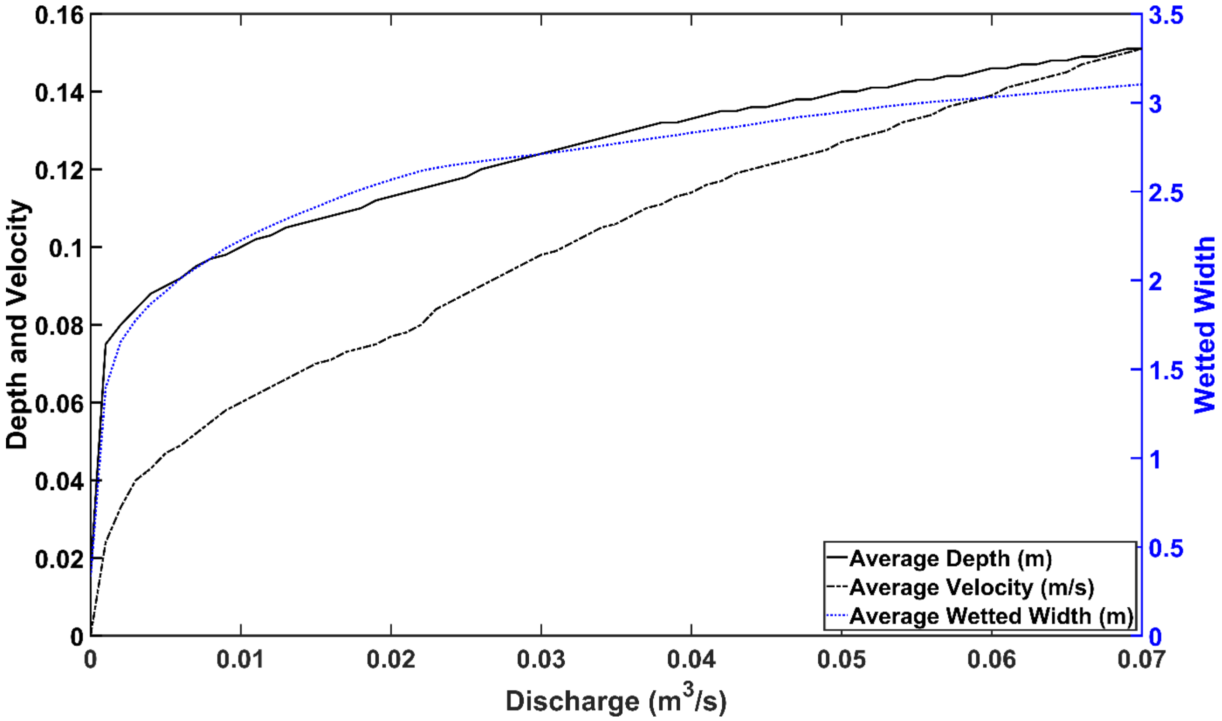

Figure J-4: Average reach hydraulics, showing average depth, average velocity, and average wetted width as a function of discharge for Thompson Stream.

Site photos and cross-sections

To provide context for interpretation of study results, example cross-sections from each habitat type are presented below for Thompson Stream.

Figure J-5: Thompson Stream – TH02 (Run), cross-section photo.

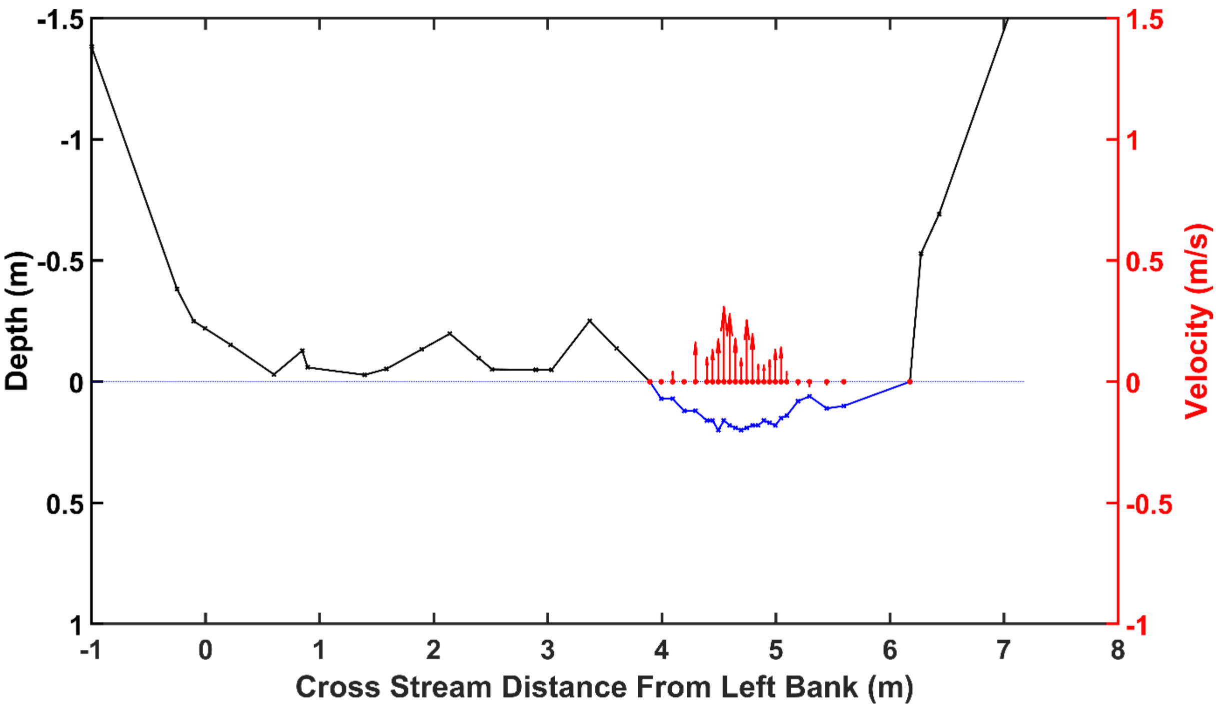

Figure J-6: Thompson Stream – TH02 (Run), cross-section of depth and velocity.

Figure J-7: Thompson Stream – TH07 (Riffle), cross-section photo.

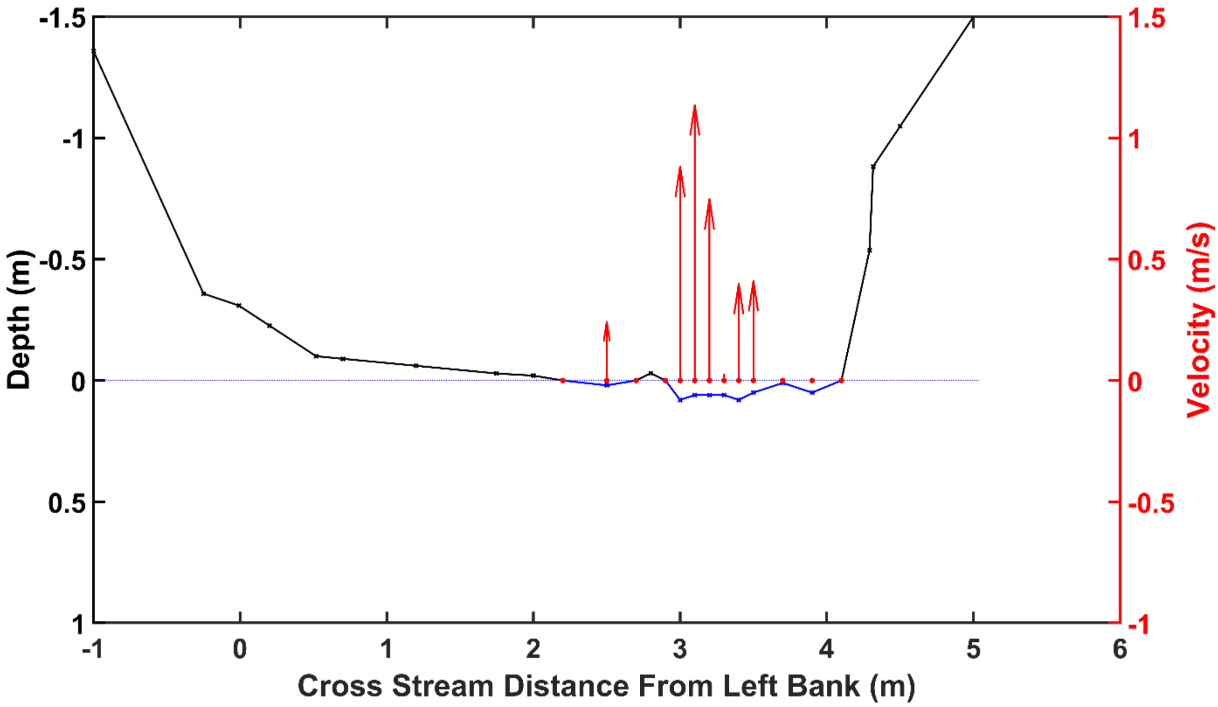

Figure J-8: Thompson Stream – TH07 (Riffle), cross-section of depth and velocity.

Figure J-9: Thompson Stream – TH14 (Pool), cross-section photo.

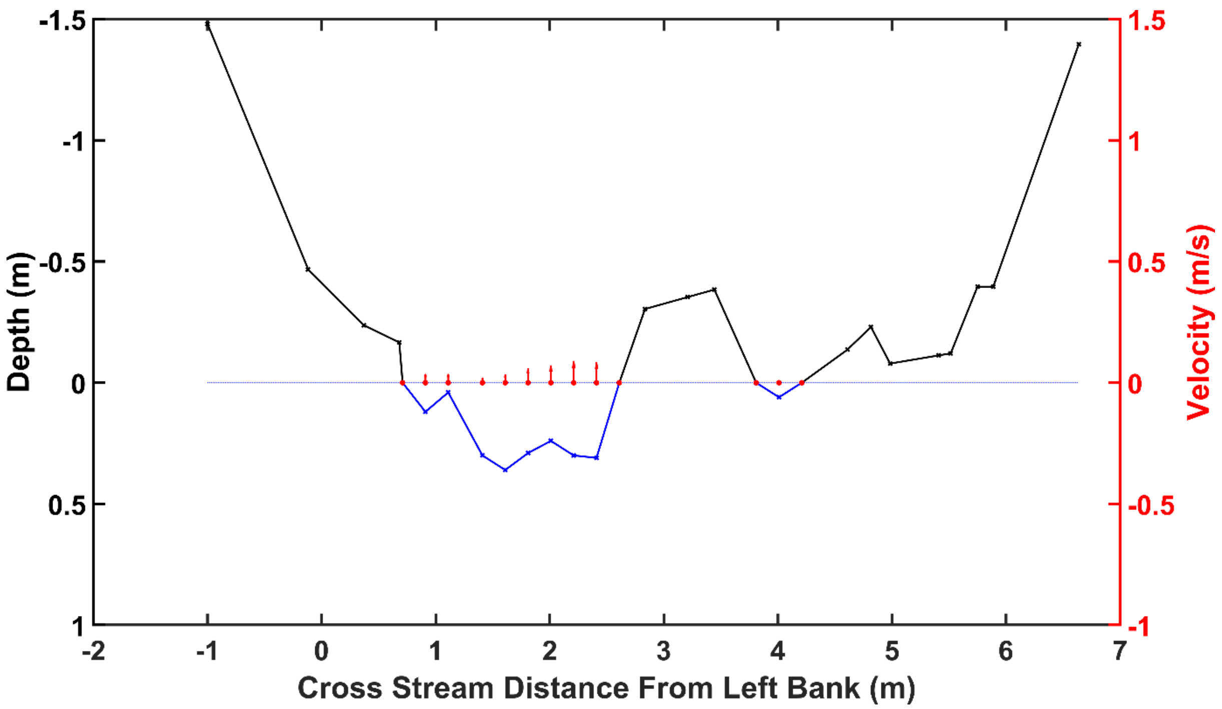

Figure J-10: Thompson Stream – TH14 (Pool), cross-section of depth and velocity.

Appendix K Tributary-R – Habitat surveys, cross-section measurements, and site photos

Additional information on the distributions of habitat lengths, cross-section characteristics, and site photos are provided in this appendix for Tributary-R.

Habitat mapping surveys

Histograms of the measured habitat lengths are provided below, with summary statistics found in Section 4.5.1.

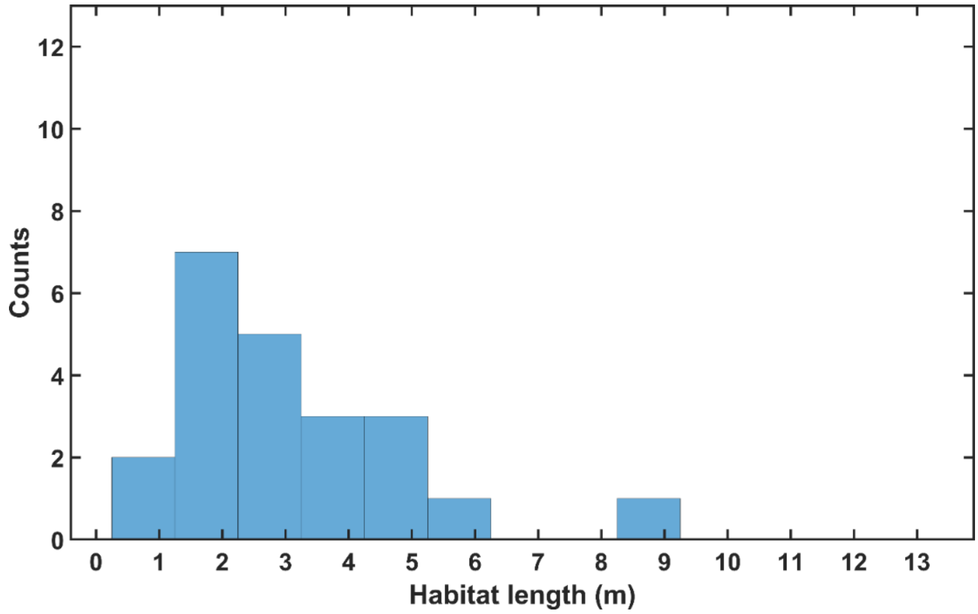

Figure K-1: Histogram of pool lengths in Tributary-R.

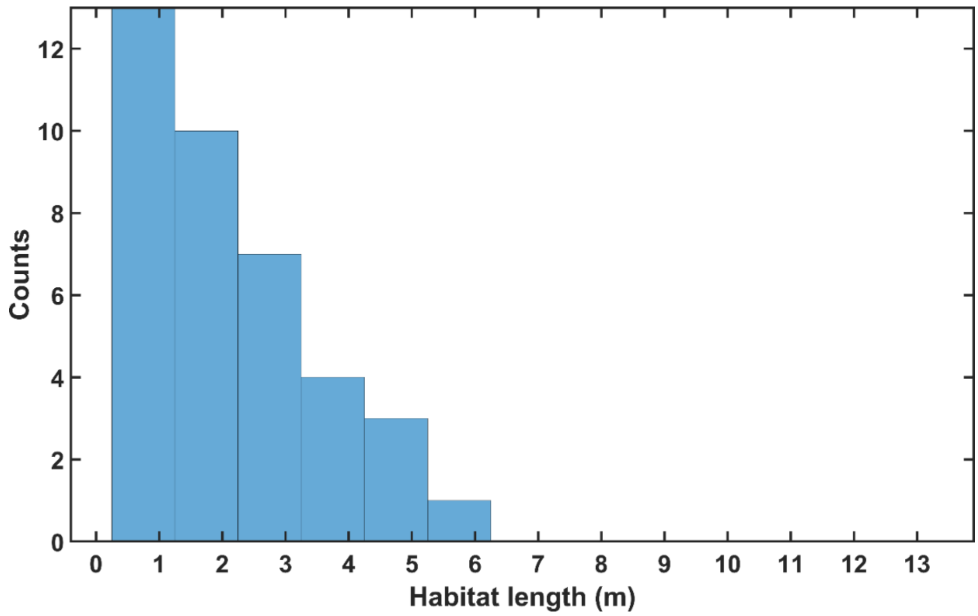

Figure K-2: Histogram of riffle lengths in Tributary-R.

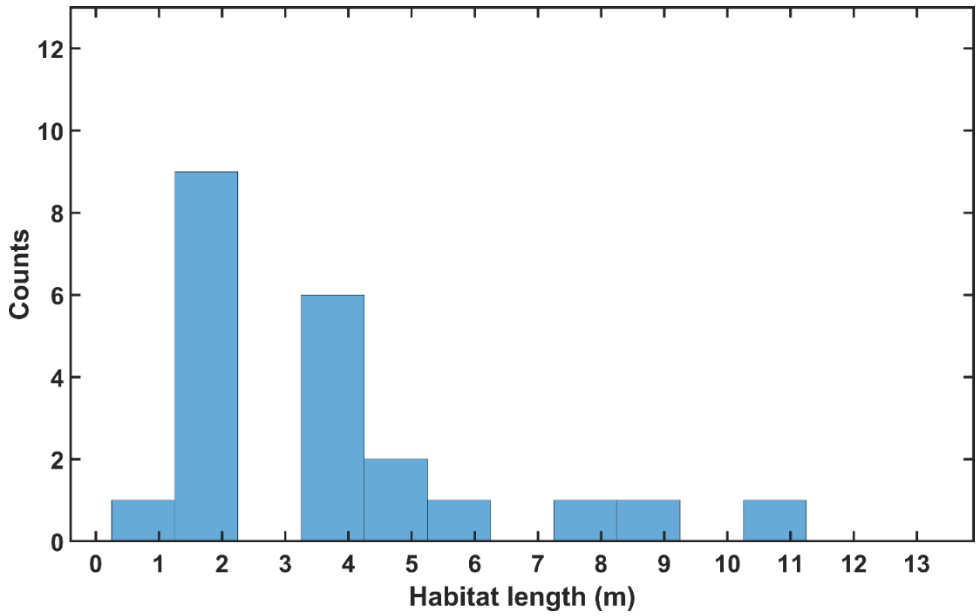

Figure K-3: Histogram of run lengths in Tributary-R.

Cross-section surveys of depth, velocity, and substrate

Physical habitat in Tributary-R is summarised in Table K-1 for the survey reach. Pool, riffle, and run weightings from the habitat mapping surveys (Section 4.5.1) are used to generate the 'Reach Average' physical habitat parameters. Substrate in Tributary-R is summarised in Table K-2. Only wetted instream areas are used for the summary since we focused on instream habitat at low flows (i.e., 7-day MALF) and out of channel substate that was dry at the time of survey will not form instream habitat at these flows.

Table K-1: Tributary-R physical habitat summary from cross-section surveys.

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
TR01	Pool	1.260	0.131	0.104	0.038
TR02	Run	1.500	0.187	0.124	0.027
TR03	Pool	1.160	0.222	0.191	0.023
TR04	Riffle	1.150	0.065	0.056	0.077
TR05	Run	1.260	0.061	0.048	0.083
TR06	Run	1.835	0.146	0.080	0.034
TR07	Riffle	0.550	0.017	0.030	0.302
TR08	Run	1.080	0.082	0.076	0.061
TR09	Pool	1.090	0.172	0.158	0.029
TR10	Riffle	2.190	0.152	0.070	0.033
TR11	Run	1.250	0.088	0.070	0.057
TR12	Pool	2.600	0.528	0.203	0.009
TR13	Riffle	0.270	0.017	0.064	0.287
TR14	Pool	2.100	0.255	0.122	0.020
TR15	Riffle	1.050	0.031	0.029	0.163

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
Pool Average	All Pools	1.642	0.262	0.156	0.024
Riffle Average	All Riffles	1.042	0.056	0.050	0.172
Run Average	All Runs	1.385	0.113	0.080	0.052
Reach Average	Weighted	1.339	0.136	0.091	0.086

Table K-2: Tributary-R substrate summary (percentages) from cross-section surveys.

	Cross-section Type	Bedrock	Boulders	Cobbles	Coarse Gravel	Fine Gravel	Sand	Silt/Mud	Vegetation
TR01	Pool	0.0	20.8	20.8	27.9	8.4	6.7	7.4	7.8
TR02	Run	0.0	16.0	26.3	19.0	21.3	15.3	0.7	1.3
TR03	Pool	0.0	12.1	32.8	11.4	14.4	8.7	0.0	20.5
TR04	Riffle	0.0	43.5	21.3	10.0	8.3	11.7	5.2	0.0
TR05	Run	0.0	18.8	32.1	18.9	12.7	12.8	0.0	4.6
TR06	Run	0.0	8.0	18.9	18.1	19.9	24.8	0.0	10.3
TR07	Riffle	0.0	59.6	12.6	21.5	0.0	0.0	0.0	6.3
TR08	Run	0.0	13.1	47.3	19.1	13.6	6.9	0.0	0.0
TR09	Pool	0.0	42.6	18.4	21.1	8.6	9.3	0.0	0.0
TR10	Riffle	0.0	41.7	21.2	18.0	11.5	2.2	0.0	5.4
TR11	Run	0.0	19.4	19.4	20.3	13.4	23.6	2.9	1.0
TR12	Pool	0.0	39.6	14.2	11.9	10.8	12.1	3.1	8.3
TR13	Riffle	0.0	44.6	17.7	12.3	12.7	12.7	0.0	0.0
TR14	Pool	0.0	56.0	5.7	11.8	11.6	14.1	0.0	0.9
TR15	Riffle	0.0	21.7	25.7	18.8	16.7	15.2	1.0	1.0
Pool Average	All Pools	0.0	34.2	18.4	16.8	10.8	10.2	2.1	7.5
Riffle Average	All Riffles	0.0	42.2	19.7	16.1	9.8	8.4	1.2	2.5
Run Average	All Runs	0.0	15.1	28.8	19.1	16.2	16.7	0.7	3.4
Reach Average	Weighted	0.0	30.2	22.6	17.4	12.4	11.9	1.3	4.3

Average reach hydraulics

Relationships between discharge, average depth, average velocity, and average wetted width are shown in Figure K-4 for Tributary-R.

Average wetted width (m) is the same as 'Total Available Area Weighted Suitability (AWS)' (m^2/m) in Section 4, with total available instream habitat area (m^2) calculated by multiplying average wetted width and reach length.

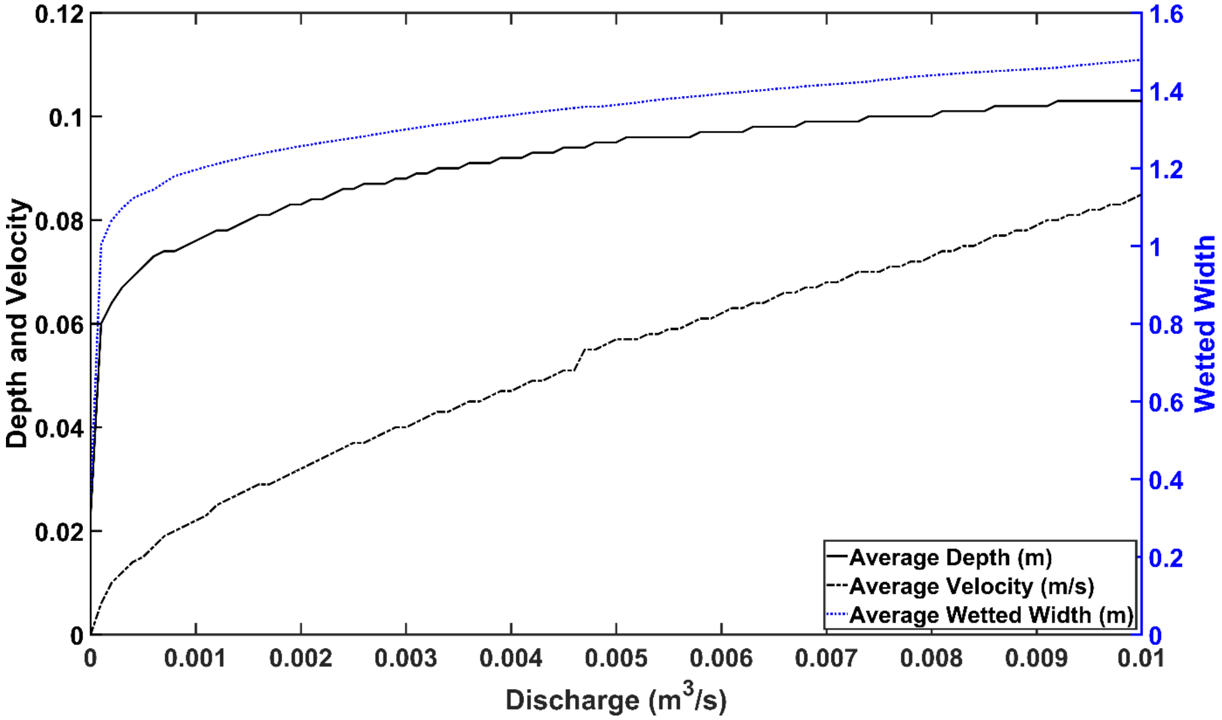

Figure K-4: Average reach hydraulics, showing average depth, average velocity, and average wetted width as a function of discharge for Tributary-R.

Site photos and cross-sections

To provide context for interpretation of study results, example cross-sections from each habitat type are presented below for Tributary-R.

Figure K-5: **Tributary-R – TR03 (Pool), cross-section photo.**

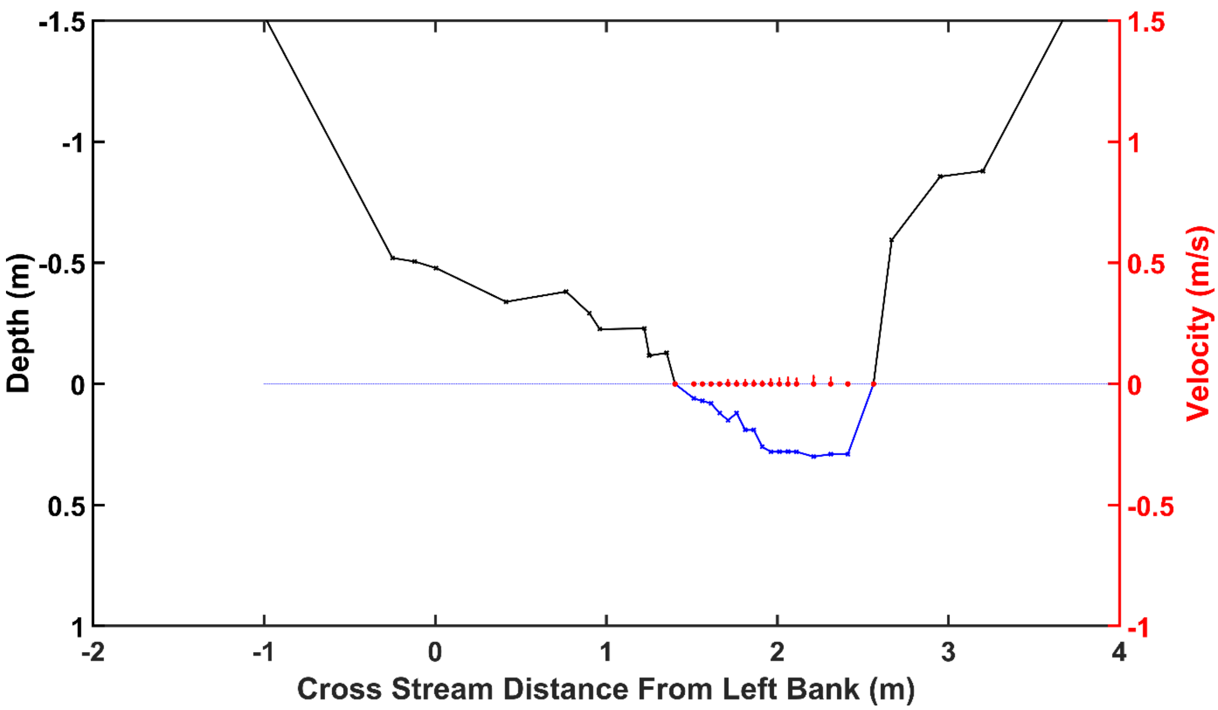

Figure K-6: **Tributary-R – TR03 (Pool), cross-section of depth and velocity.**

Figure K-7: Tributary-R – TR11 (Run), cross-section photo.

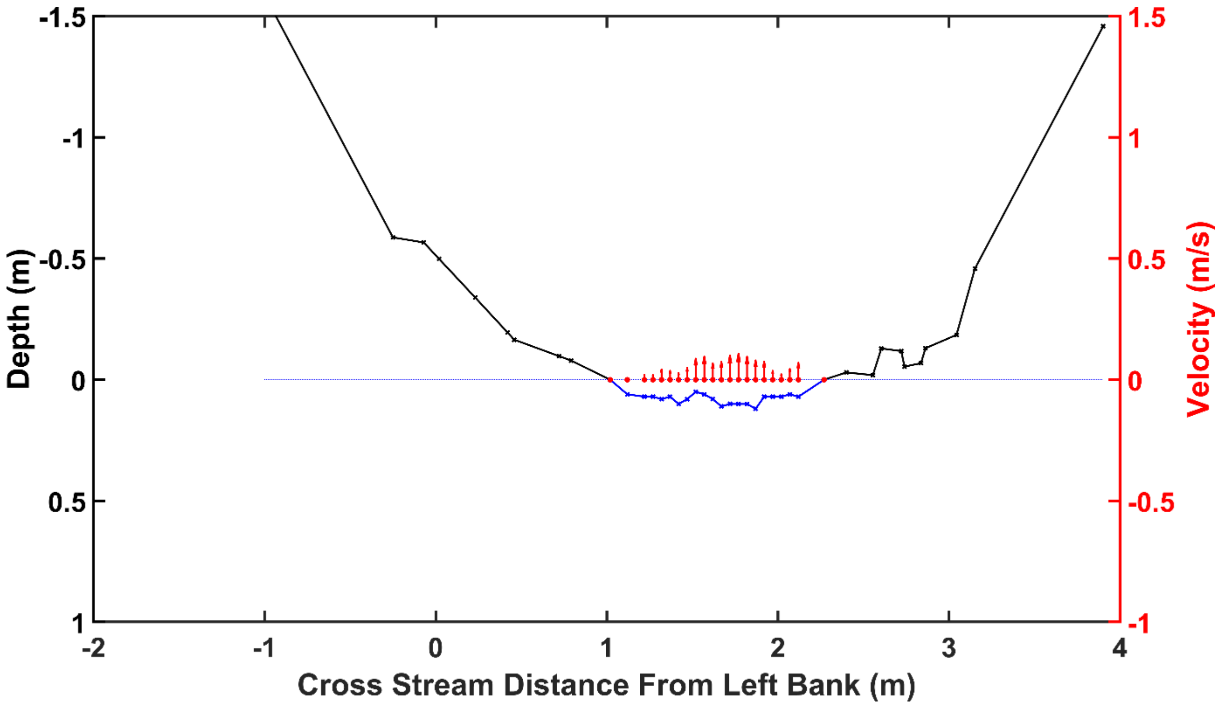

Figure K-8: Tributary-R – TR11 (Run), cross-section of depth and velocity.

Figure K-9: Tributary-R – TR15 (Riffle), cross-section photo.

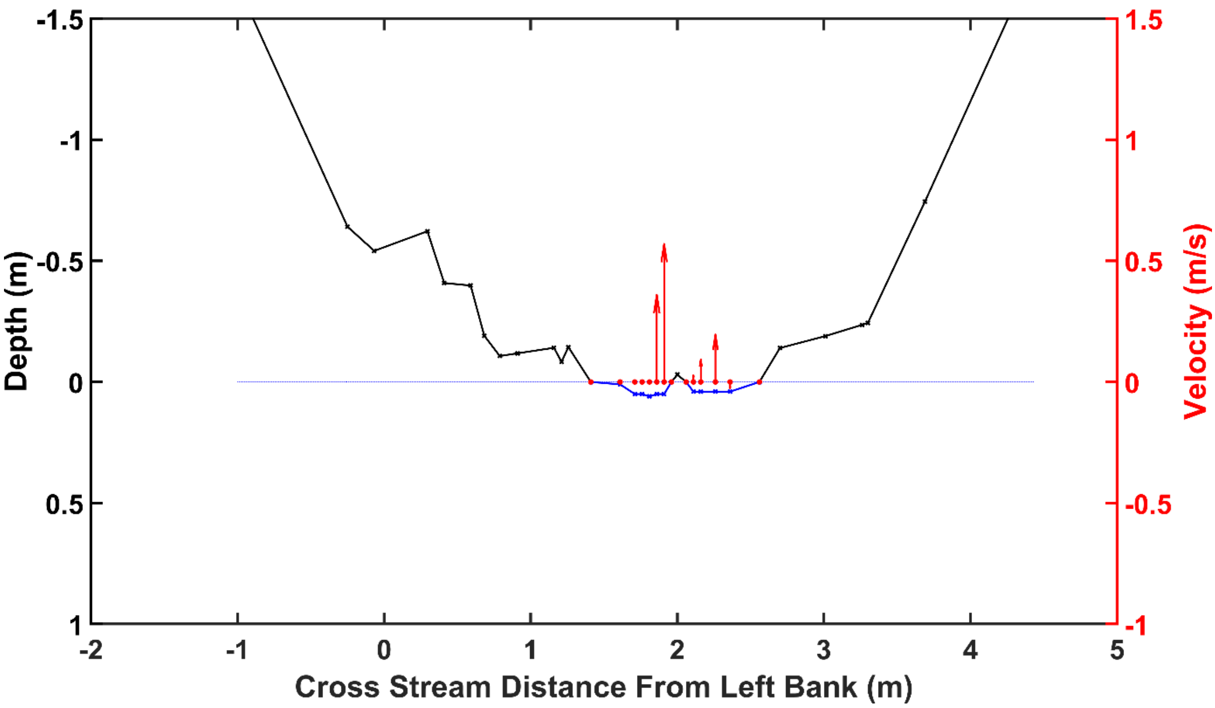

Figure K-10: Tributary-R – TR15 (Riffle), cross-section of depth and velocity.

Appendix L Wharekirauponga Stream - Downstream Site (WKP1) – Habitat surveys, cross-section measurements, and site photos

Additional information on the distributions of habitat lengths, cross-section characteristics, and site photos are provided in this appendix for Wharekirauponga Stream - Downstream Site (WKP1).

Habitat mapping surveys

Histograms of the measured habitat lengths are provided below, with summary statistics found in Section 4.6.1.

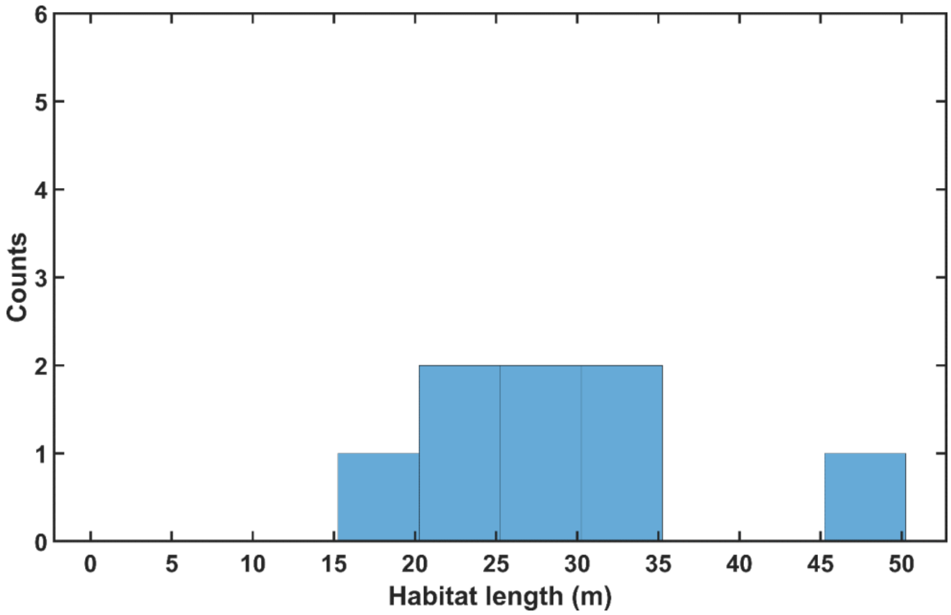

Figure L-1: Histogram of pool lengths in Wharekirauponga Stream - Downstream - WKP1.

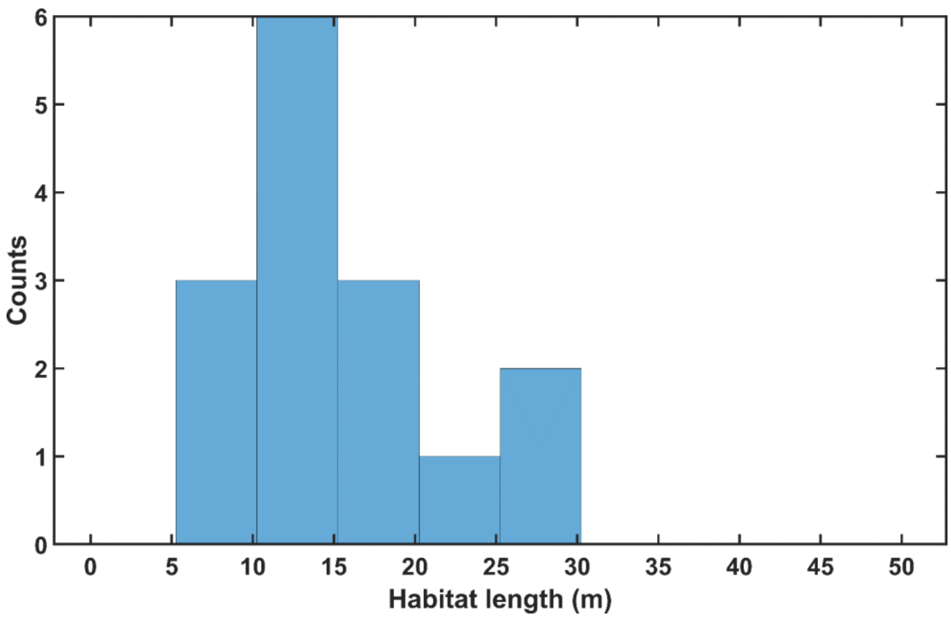

Figure L-2: Histogram of riffle lengths in Wharekirauponga Stream - Downstream - WKP1.

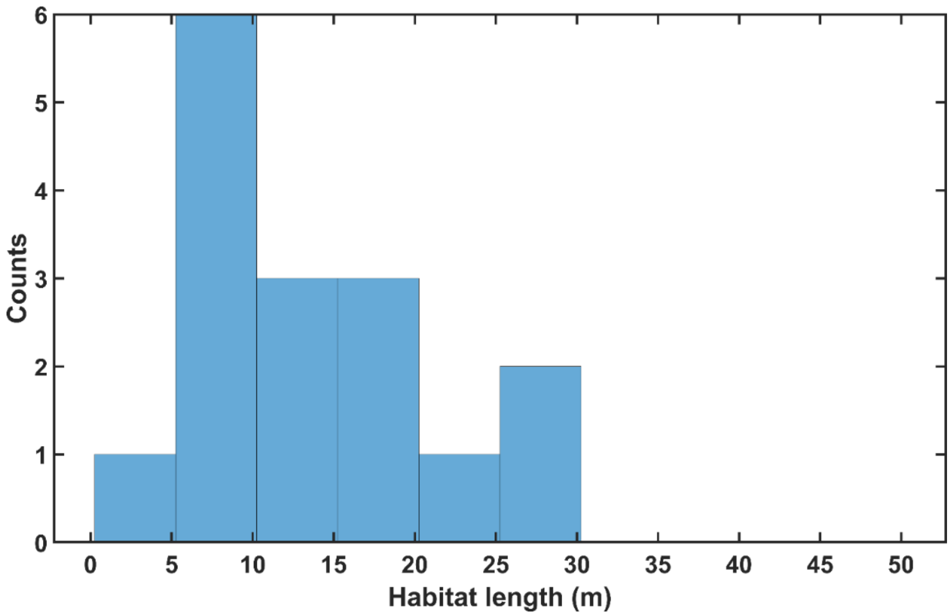

Figure L-3: Histogram of run lengths in Wharekirauponga Stream - Downstream - WKP1.

Cross-section surveys of depth, velocity, and substrate

Physical habitat in WKP1 is summarised in Table L-1 for the survey reach. Pool, riffle, and run weightings from the habitat mapping surveys (Section 4.6.1) are used to generate the 'Reach Average' physical habitat parameters. Substrate in WKP1 is summarised in Table L-2. Only wetted instream areas are used for the summary since we focused on instream habitat at low flows (i.e., 7-day MALF) and out of channel substate that was dry at the time of survey will not form instream habitat at these flows.

Table L-1: Wharekirauponga Stream - Downstream - WKP1 physical habitat summary from cross-section surveys.

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
WD01	Riffle	4.452	0.539	0.121	0.434
WD02	Run	6.831	1.436	0.210	0.163
WD03	Pool	8.010	2.866	0.358	0.082
WD04	Riffle	8.319	1.081	0.130	0.217
WD05	Run	7.000	1.318	0.188	0.178
WD06	Pool	6.200	2.694	0.435	0.087
WD07	Run	3.250	0.626	0.192	0.374
WD08	Pool	5.650	2.490	0.441	0.094
WD09	Riffle	4.999	0.627	0.125	0.373
WD10	Riffle	5.800	0.691	0.119	0.339
WD11	Pool	9.664	4.744	0.491	0.049
WD12	Run	6.100	1.181	0.194	0.198
WD13	Riffle	4.700	0.680	0.145	0.344
WD14	Run	3.750	0.925	0.247	0.253
WD15	Pool	17.444	9.480	0.543	0.025
Pool Average	All Pools	9.394	4.455	0.453	0.067
Riffle Average	All Riffles	5.654	0.723	0.128	0.341

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
Run Average	All Runs	5.386	1.097	0.206	0.233
Reach Average	Weighted	6.848	2.121	0.265	0.213

Table L-2: Wharekirauponga Stream - Downstream - WKP1 substrate summary (percentages) from cross-section surveys.

	Cross-section Type	Bedrock	Boulders	Cobbles	Coarse Gravel	Fine Gravel	Sand	Silt/Mud	Vegetation
WD01	Riffle	14.4	40.5	24.5	12.3	5.0	1.8	0.0	1.5
WD02	Run	5.9	37.2	16.3	13.4	17.8	9.5	0.0	0.0
WD03	Pool	0.0	37.6	15.3	14.7	17.6	13.1	1.5	0.1
WD04	Riffle	0.0	41.1	35.4	16.6	5.8	1.2	0.0	0.0
WD05	Run	0.0	29.3	40.6	15.2	6.2	6.8	0.3	1.6
WD06	Pool	28.2	20.8	20.8	14.9	8.6	6.7	0.0	0.0
WD07	Run	35.8	22.6	22.7	12.6	4.8	1.5	0.0	0.0
WD08	Pool	43.2	3.8	9.6	22.1	11.5	9.2	0.6	0.0
WD09	Riffle	6.5	64.0	21.1	6.1	2.2	0.1	0.0	0.0
WD10	Riffle	0.0	36.8	40.0	14.7	7.0	1.3	0.0	0.3
WD11	Pool	1.5	11.3	15.1	16.9	12.7	9.9	24.7	7.9
WD12	Run	0.0	34.9	38.8	15.9	6.1	2.8	0.0	1.4
WD13	Riffle	0.0	38.9	35.4	15.6	8.2	1.9	0.0	0.0
WD14	Run	0.0	31.7	28.2	25.9	10.7	2.7	0.7	0.0
WD15	Pool	10.0	14.8	12.2	11.6	9.2	12.5	19.4	10.2
Pool Average	All Pools	16.6	17.7	14.6	16.0	11.9	10.3	9.2	3.7
Riffle Average	All Riffles	4.2	44.2	31.3	13.1	5.6	1.2	0.0	0.3
Run Average	All Runs	8.3	31.1	29.3	16.6	9.1	4.7	0.2	0.6
Reach Average	Weighted	9.8	30.9	24.9	15.2	8.9	5.4	3.2	1.6

Average reach hydraulics

Relationships between discharge, average depth, average velocity, and average wetted width are shown in Figure L-4 for Wharekirauponga Stream - Downstream - WKP1.

Average wetted width (m) is the same as 'Total Available Area Weighted Suitability (AWS)' (m^2/m) in Section 4, with total available instream habitat area (m^2) calculated by multiplying average wetted width and reach length.

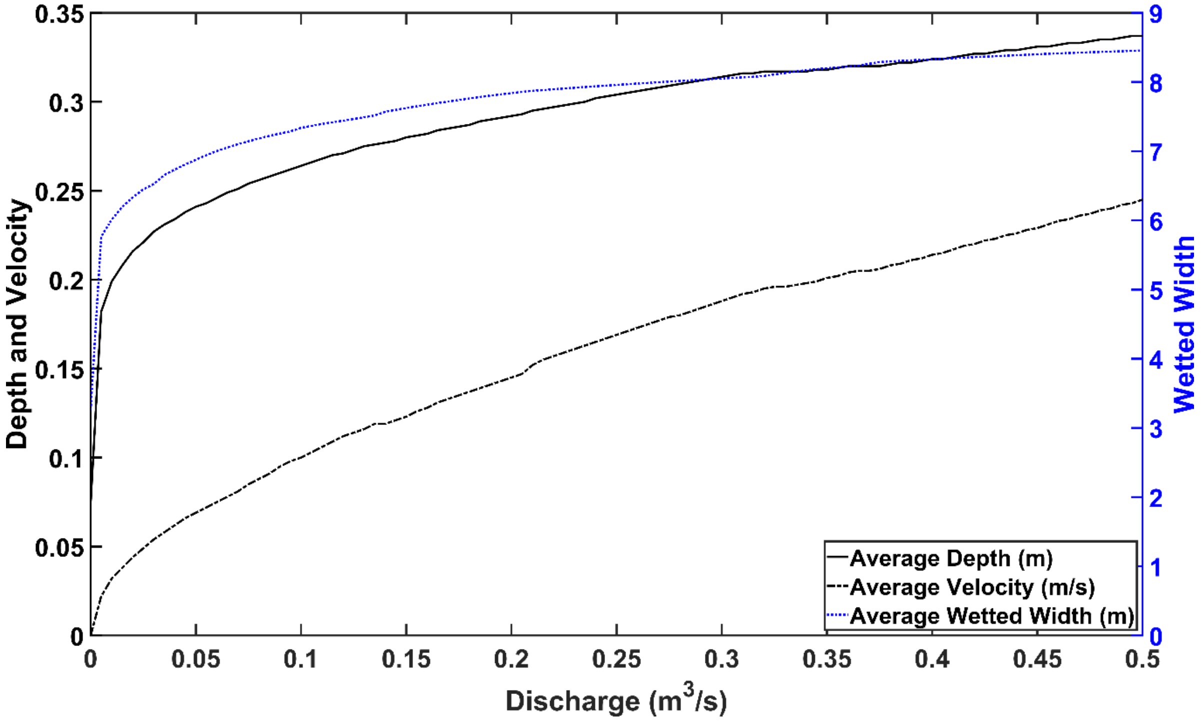

Figure L-4: Average reach hydraulics, showing average depth, average velocity, and average wetted width as a function of discharge for Wharekirauponga Stream - Downstream - WKP1.

Site photos and cross-sections

To provide context for interpretation of study results, example cross-sections from each habitat type are presented below for Wharekirauponga Stream - Downstream - WKP1.

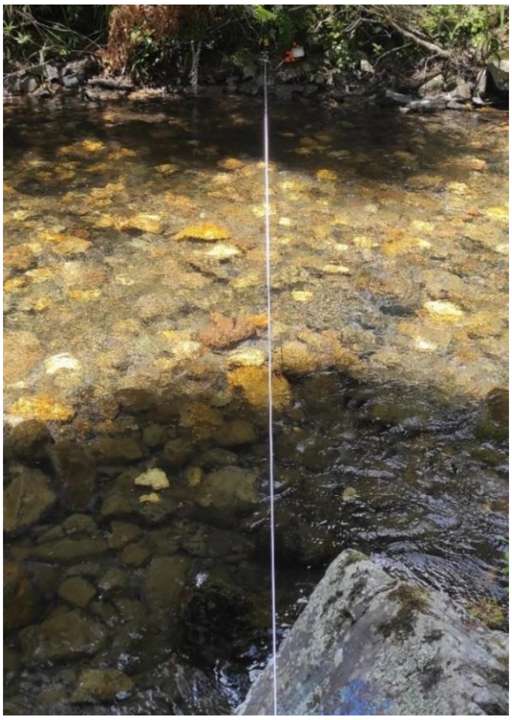

Figure L-5: Wharekirauponga Stream - Downstream Site (WKP1) – WD05 (Run), cross-section photo.

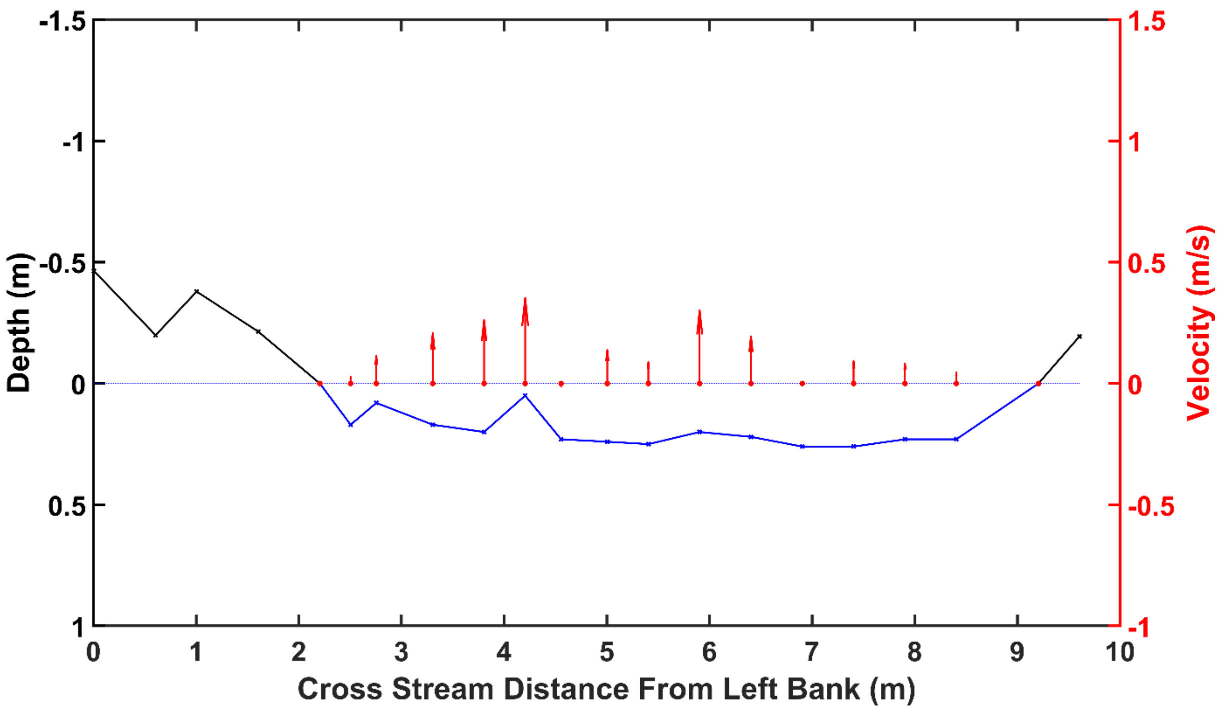

Figure L-6: Wharekirauponga Stream - Downstream Site (WKP1) – WD05 (Run), cross-section of depth and velocity.

Figure L-7: Wharekirauponga Stream - Downstream Site (WKP1) – WD06 (Pool), cross-section photo.

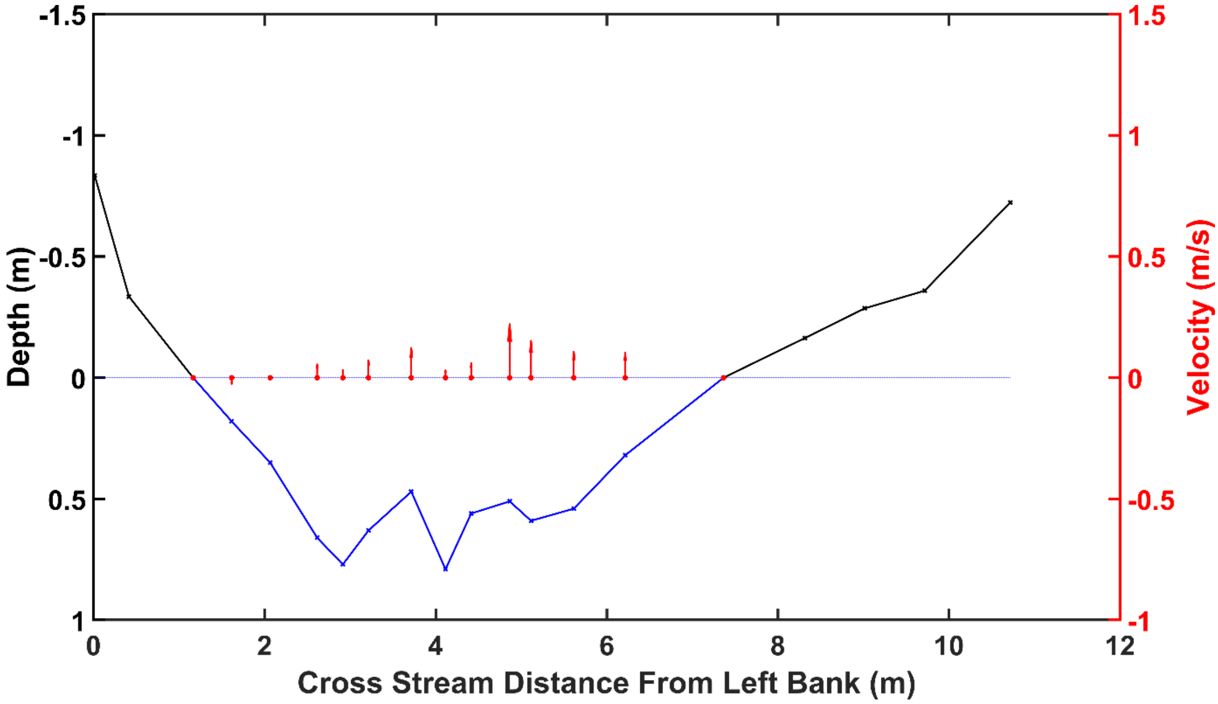

Figure L-8: Wharekirauponga Stream - Downstream Site (WKP1) – WD06 (Pool), cross-section of depth and velocity.

Figure L-9: Wharekirauponga Stream - Downstream Site (WKP1) – WD09 (Riffle), cross-section photo.

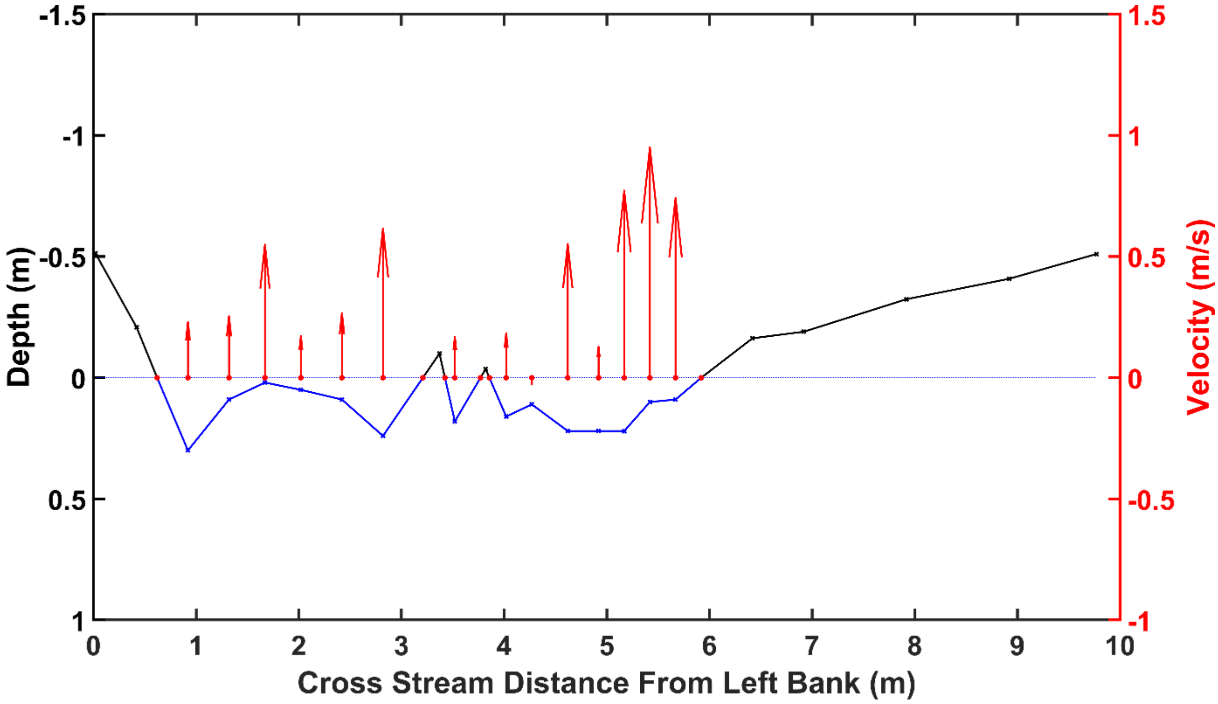

Figure L-10: Wharekirauponga Stream - Downstream Site (WKP1) – WD09 (Riffle), cross-section of depth and velocity.

Appendix M Wharekirauponga Stream - Upstream Site (WKP2) - Habitat surveys, cross-section measurements, and site photos

Additional information on the distributions of habitat lengths, cross-section characteristics, and site photos are provided in this appendix for Wharekirauponga Stream - Upstream - WKP2.

Habitat mapping surveys

Histograms of the measured habitat lengths are provided below, with summary statistics found in Section 4.7.1.

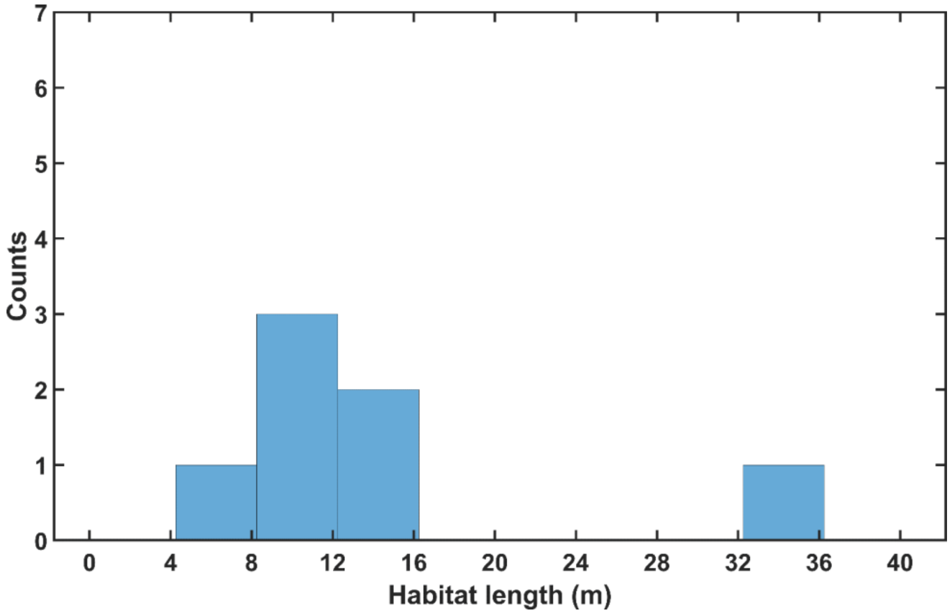

Figure M-1: Histogram of pool lengths in Wharekirauponga Stream - Upstream - WKP2.

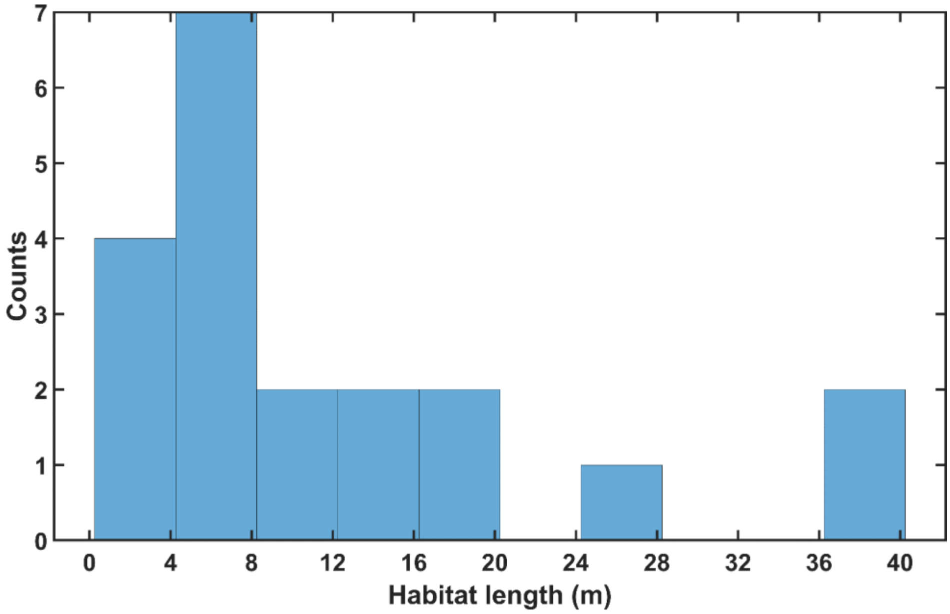

Figure M-2: Histogram of riffle lengths in Wharekirauponga Stream - Upstream - WKP2.

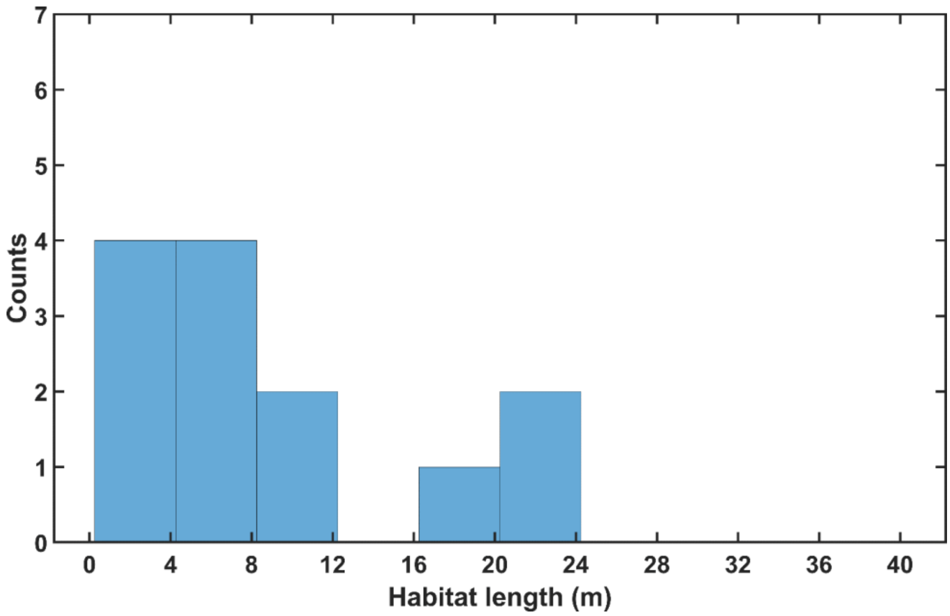

Figure M-3: Histogram of run lengths in Wharekirauponga Stream - Upstream - WKP2.

Cross-section surveys of depth, velocity, and substrate

Physical habitat in WKP2 is summarised in Table M-1 for the survey reach. Pool, riffle, and run weightings from the habitat mapping surveys (Section 4.7.1) are used to generate the 'Reach Average' physical habitat parameters. Substrate in WKP2 is summarised in Table M-2. Only wetted instream areas are used for the summary since we focused on instream habitat at low flows (i.e., 7-day MALF) and out of channel substate that was dry at the time of survey will not form instream habitat at these flows.

Table M-1: Wharekirauponga Stream - Upstream - WKP2 physical habitat summary from cross-section surveys.

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
WU01	Riffle	6.160	0.799	0.130	0.229
WU02	Run	6.150	2.241	0.364	0.082
WU03	Riffle	3.900	0.620	0.159	0.295
WU04	Pool	5.350	2.120	0.396	0.086
WU05	Run	8.200	2.556	0.312	0.072
WU06	Riffle	4.100	0.582	0.142	0.314
WU07	Pool	6.300	1.822	0.289	0.100
WU08	Riffle	6.600	0.580	0.088	0.315
WU09	Run	8.550	1.180	0.138	0.155
WU10	Pool	7.500	1.468	0.196	0.125
WU11	Riffle	4.510	0.641	0.142	0.286
WU12	Run	3.470	0.741	0.214	0.247
WU13	Run	7.280	1.943	0.267	0.094
WU14	Pool	6.150	2.227	0.362	0.082
WU15	Pool	5.640	3.332	0.591	0.055

	Cross-section Type	Wetted Width (m)	Cross Sectional Area (m^2)	Average Depth (m)	Average Velocity (m/s)
Pool Average	All Pools	6.188	2.194	0.367	0.090
Riffle Average	All Riffles	5.054	0.644	0.132	0.288
Run Average	All Runs	6.730	1.732	0.259	0.130
Reach Average	Weighted	5.737	1.265	0.216	0.204

Table M-2: Wharekirauponga Stream - Upstream - WKP2 substrate summary (percentages) from cross-section surveys.

	Cross-section Type	Bedrock	Boulders	Cobbles	Coarse Gravel	Fine Gravel	Sand	Silt/Mud	Vegetation
WU01	Riffle	0.0	66.4	24.5	8.1	0.8	0.0	0.0	0.2
WU02	Run	8.9	47.7	13.9	11.2	12.7	5.6	0.0	0.0
WU03	Riffle	1.4	84.7	12.2	1.7	0.0	0.0	0.0	0.0
WU04	Pool	32.0	34.1	7.6	13.1	4.9	1.8	0.0	6.6
WU05	Run	0.0	44.8	20.8	15.9	8.0	3.2	0.0	7.4
WU06	Riffle	0.0	40.9	27.9	17.8	8.7	4.7	0.0	0.0
WU07	Pool	28.3	26.8	20.6	13.8	3.1	0.5	0.0	6.9
WU08	Riffle	0.0	38.5	29.8	22.9	8.1	0.8	0.0	0.0
WU09	Run	0.0	42.7	30.6	16.1	8.2	2.3	0.0	0.2
WU10	Pool	0.0	61.3	11.6	13.6	9.3	4.2	0.0	0.0
WU11	Riffle	0.0	73.7	16.4	7.8	2.2	0.0	0.0	0.0
WU12	Run	0.0	73.6	16.4	8.2	1.3	0.0	0.0	0.4
WU13	Run	2.0	49.4	21.9	18.8	7.2	0.8	0.0	0.0
WU14	Pool	0.0	50.6	21.8	17.6	5.6	4.0	0.0	0.4
WU15	Pool	39.4	23.6	18.0	3.5	5.5	9.6	0.0	0.6
Pool Average	All Pools	19.9	39.3	15.9	12.3	5.7	4.0	0.0	2.9
Riffle Average	All Riffles	0.3	60.8	22.1	11.7	4.0	1.1	0.0	0.0
Run Average	All Runs	2.2	51.6	20.7	14.0	7.5	2.4	0.0	1.6
Reach Average	Weighted	5.1	53.7	20.4	12.4	5.2	2.1	0.0	1.1

Average reach hydraulics

Relationships between discharge, average depth, average velocity, and average wetted width are shown in Figure M-4 for Wharekirauponga Stream - Upstream - WKP2.

Average wetted width (m) is the same as 'Total Available Area Weighted Suitability (AWS)' (m^2/m) in Section 4, with total available instream habitat area (m^2) calculated by multiplying average wetted width and reach length.

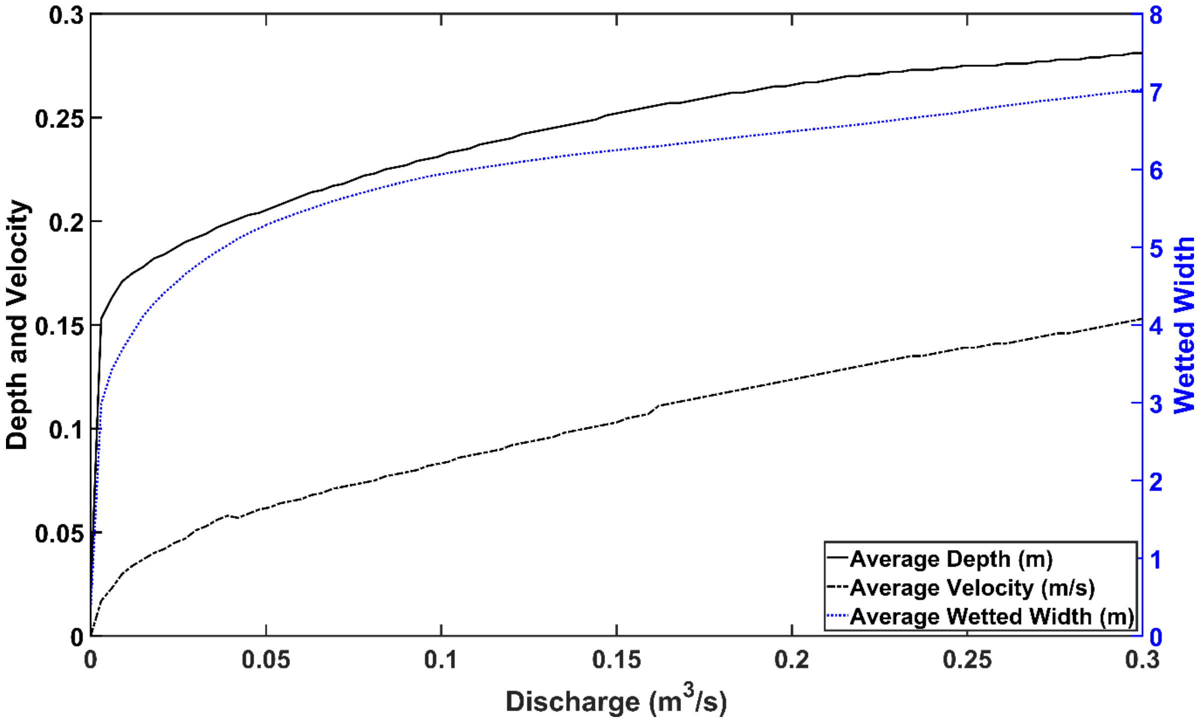

Figure M-4: Average reach hydraulics, showing average depth, average velocity, and average wetted width as a function of discharge for Wharekirauponga Stream - Upstream - WKP2.

Site photos and cross-sections

To provide context for interpretation of study results, example cross-sections from each habitat type are presented below for Wharekirauponga Stream - Upstream – WKP2.

Figure M-5: Wharekirauponga Stream - Upstream Site (WKP2) – WU05 (Run), cross-section photo.

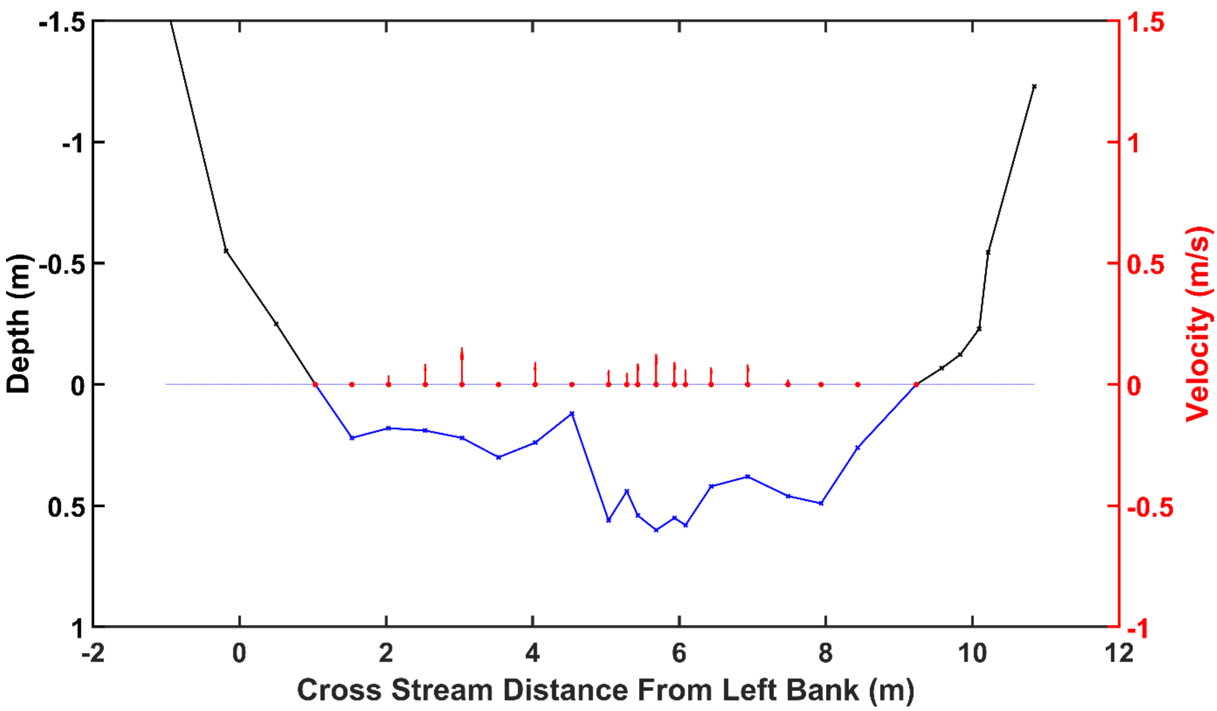

Figure M-6: Wharekirauponga Stream - Upstream Site (WKP2) – WU05 (Run), cross-section of depth and velocity.

Figure M-7: **Wharekirauponga Stream - Upstream Site (WKP2) – WU11 (Riffle), cross-section photo.**

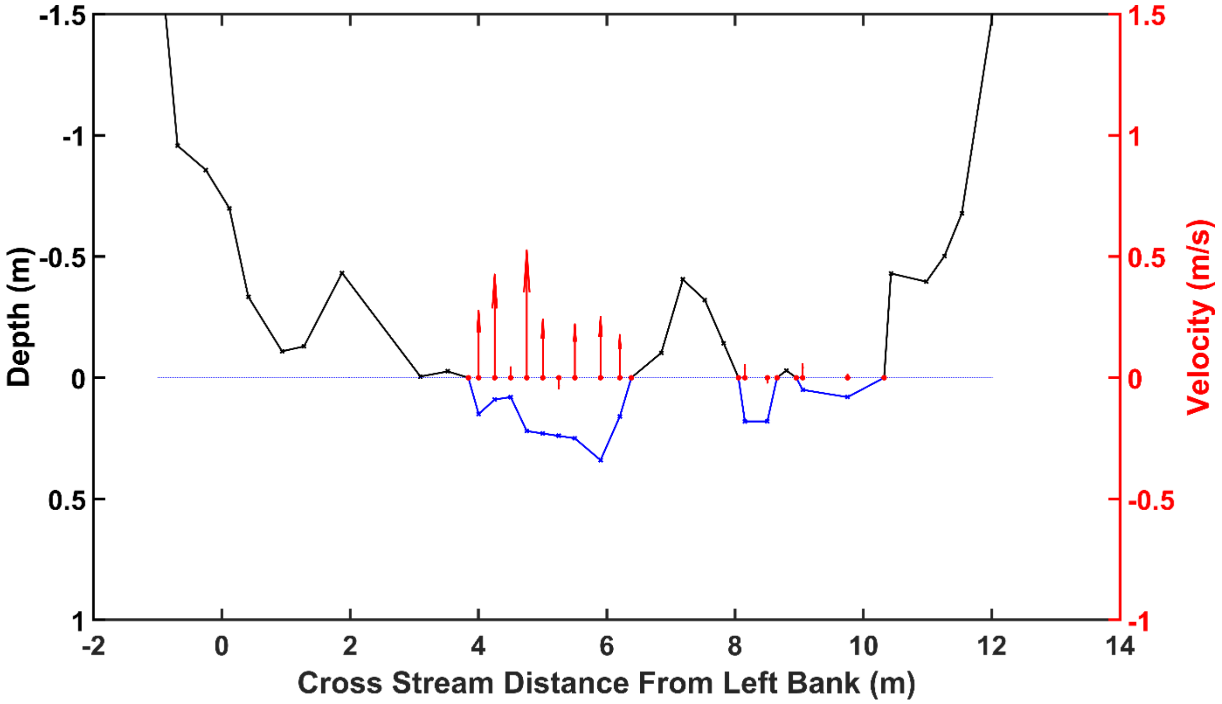

Figure M-8: **Wharekirauponga Stream - Upstream Site (WKP2) – WU11 (Riffle), cross-section photo.**

Figure M-9: Wharekirauponga Stream - Upstream Site (WKP2) – WU15 (Pool), cross-section photo.

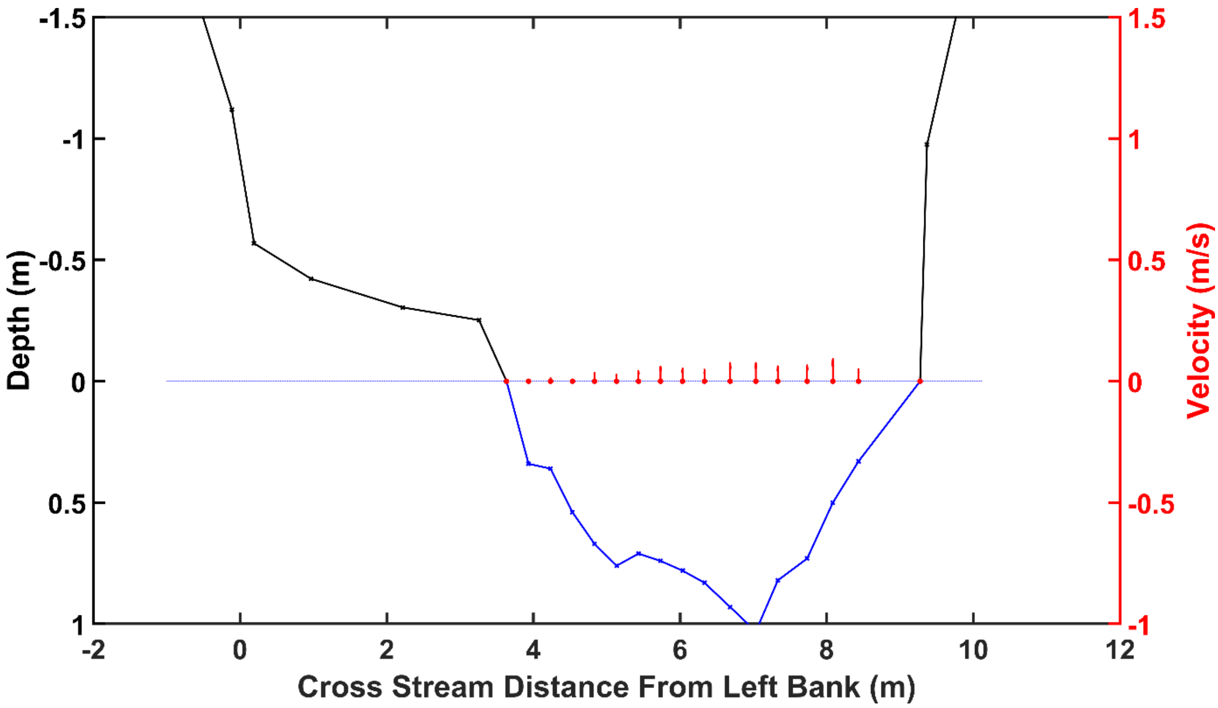

Figure M-10: Wharekirauponga Stream - Upstream Site (WKP2) – WU15 (Pool), cross-section of depth and velocity.