TRANSMISSION GULLY PROJECT

TECHNICAL REPORT #9

Freshwater Habitat & Species:

Description & Values

August 2011

Front Cover Photo:
Two koaro (*Galaxias brevipinnis*) in the mid reaches of Duck Creek. These reaches are considered high ecological value with good cobble bottom, minimal sedimentation. The habitats found in each of the valued streams along the alignment have been described in detail to provide guidance for restoration and rehabilitation of streams following construction.

Bibliographic reference:
Boffa Miskell, 2010: Transmission Gully Project Technical Report 9 - Freshwater habitat and species: Ecological evaluation and assessment. Prepared by Boffa Miskell Ltd for NZ Transport Agency. Report No: W09034. 151 p.

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1 INTRODUCTION

1.1 BACKGROUND

This technical report is one of a series that report on ecological investigations being undertaken as part of NZTA 345PN Phase II Investigations, E&EA; work package "WS-08 Ecological Assessment, Survey, Modelling and Management (BML, 2009)". The purpose of Work Package 08 is to comprehensively map and describe the values of ecological systems, and to describe the distribution and abundance of native flora and fauna that occur along this route. From this work the potential environmental effects of both the construction and ongoing operation of the proposed "Transmission Gully Main Alignment" project (TGMAP, or *the project*) can be assessed and measures required to mitigate adverse effects can be developed (Technical report 13b).

The proposed "Transmission Gully Main Alignment project" is 27 km long. Map 1-1 shows the proposed route. It runs through a wide range of habitats from improved pasture, plantation forestry, shrublands, and scrub to forest remnants. It ranges from sea level to 280m in altitude and crosses eight catchments. Waterways from most of these catchments discharge to Pauatahanui Inlet, a nationally significant estuary and wildlife refuge.

This report describes the results of the freshwater habitat and species investigations undertaken along streams associated with the proposed TGMAP from October 2007 to March 2010. These studies covered freshwater fish, aquatic macro-invertebrates and physical habitat and provided data from which ecological values could be determined. These studies overlapped and co-ordinated with an extensive water quality study undertaken by SKM.

The objectives of the freshwater investigations for evaluation were:

- To describe the general biological values through identification of species and communities inhabiting the various waterway types within the project area and describing the physical nature of those habitats;
- To describe the biological values of streams that will be potentially subject to permanent loss due to culverting.
- To verify which native fish species are present within the affected stream reaches along TGMAP alignment to inform appropriate designs for fish passage at stream crossings, and habitat restoration where stream diversions occur.
- To identify all existing fish passage-related issues including the presence of existing perched culverts to assist in the development of mitigation packages and the design of new culverts.
- To investigate all streams and their physical nature that will potentially be diverted, so that the created streams can be formed in a way that mirrors the original habitat, hydrology, gradients and flows.
- Create the physical and biological (with SKM water quality results) template to assist post construction and operational condition monitoring.

This report:

- Describes the approach and methods undertaken to investigate freshwater ecological values;
- Describes the freshwater ecosystems, habitats and biota within the proposed road corridor, focusing on those that may be affected by construction and operation;
- Presents an ecological evaluation of freshwater ecosystems, habitats and biota.

1.2 ASSESSMENT FOCUS

Following the scoping stage of the ecological investigations of the TGMAP (described in an earlier preliminary report[1]), four topic areas were identified as being the critical aspects in relation to freshwater ecosystem management during construction and operation. These four topics are: aquatic habitat, sediment discharge, water quality (storm water) and fish passage. These matters together account for the greater part of the interaction between the proposed road alignment and freshwater ecosystems and thus became the focus of the detailed investigations and assessment/mitigation work.

The four topics guided the process of identifying different catchments or reaches as needing different levels of effort of study and sampling (for example, higher priority being given to reaches at higher risk of receiving high levels of sediment discharge or of being directly affected by diversion). Sampling and analysis methods applied were based on the way in which a reach or waterway was likely to be affected through one of these four areas (for example, SEV was used for reaches that were likely to have to be "re-created"). Finally, the topics were used to provide a focus for the mitigation effort (for example, treatment effort focusing on reaches where water quality is particularly high).

Recognising the importance of these topics to the freshwater ecosystem assessment, four "areas of focus" were used:

- Sediment discharge into freshwater systems, during construction and operation, has the potential to be the most significant impact of the proposal; it could affect the largest area/longest reach, having the greatest potential adverse effects on the most sensitive habitats, communities and species.
- Water quality of freshwater ecosystems could be affected by run-off from the construction area but to a large extent that is considered under sediment discharge, the operating highway however, through storm water runoff also has the capacity to discharge contaminants to the freshwater habitats. The characteristics of run-off are addressed by SKM2 and we use that data to make ecological commentary. The location and scale of effects on habitats and biota could be broad.
- Habitat will be directly affected (loss or degradation) to varying degrees at specific places or over discrete reaches but there are also options for habitat maintenance or enhancement (through restoration).
- Fish passage may be disrupted where the construction or operation of the State highway presents a physical or chemical barrier, but there are options for maintaining passage through good design and operation.

Figure 9-1 shows the alignment and study area which is defined by potentially affected catchments.

This report has also benefited from comments made by the RATAG's reviewer (Dr Boothroyd) and his commentary has assisted the final report.

[1] Boffa Miskell (2008): Stream Survey and Preliminary Ecological Valuation: Te Puka Stream, Horokiri Stream, and Duck Creek. Report prepared for NZTA

[2] SKM (2011): Technical Report 15 Assessment of Water Quality June 2011v8.

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NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

PROJECT CONTEXT

9.1

2 OVERVIEW / CONTEXT / SETTING THE SCENE

2.1 PHYSICAL ENVIRONMENT

Landform topography and geology

The Pauatahanui, Horokiri, Duck and Kenepuru Catchments and surrounding landscape topography are characterised by the South to North running hill range and ridge line that loosely enclose the Porirua harbour, with descending westward ridges and five main river valleys draining to the Porirua and Pauatahanui inlets (Kakaho, Horokiri, Pauatahanui, Duck, Kenepuru/Cannons and Porirua). The form is noted as a gently rolling landscape (a peneplain) (Healy 1980) not far above sea level (200-300m a.s.l.). A mature topography with rounded hills and valleys developed before the Pleistocene glaciations and influenced by the faults present, glaciations, river cut down and sea erosion.

The hills and rolling land is generally composed of Rimutaka undifferentiated formation comprising indurated mudstone, sand stone and silt stone. Smaller linear areas along the western valleys and hill toe areas south to north are Kaitoke Formation which is unsorted and sorted alluvium and loess. The Horokiri system has the greatest diversity of rock and sediment types and also includes Trentham (unsorted gravel and un-weathered loess), Hutt alluvium (with sands) and Judgeford material.

The parent rock is largely mud and sand stone with valleys of alluvial and loess material with some few sands and gravels especially in the Horokiri. Gravels, cobble (eroded sandstone) and sand show in prevalence in the stream beds.

Hydrology/Rainfall.

The normal annual rainfall for the catchment has been estimated at around 1200mm. The number of rainy days with over 1mm in 24 hours has been estimated at 177 (1980), or roughly half the year. The mean air temperature is around 13 degrees Celsius with a recorded minimum of 5.5 in July and maximum of 22 in January.

Solar radiation in the Pauatahanui catchment is higher than other Wellington catchments (Kelburn) measured at a mean daily total of 341 calories per square centimetre. The Pauatahanui area receives typically more sun shine hours than other, southern, parts of Wellington.

Land uses

The land resource and capacity was studied by Healy et al and published in 1980. The capability study shows most of the land as being Class IV land; not suitable for cropping; of medium potential for grazing and of high potential for forestry. The Horokiri Valley and Ration catchment has land class iii areas; these are of medium potential for cropping, and high potential for grazing and forestry.

Despite these capability classes most of the landscape is in pasture and variously grazed on small scale farm lets which include exotic shelterbelts or else in pine forest, such as the large regional forest in the hill country of the Horokiri catchment east. Few indigenous vegetation areas persist (see BML technical report #).

2.2 WATERWAYS OVERVIEW – WATERSHED / CATCHMENTS

For the purposes of describing the freshwater habitats, it is useful to divide the area into catchments and waterway sections. The TGMAP crosses at four of the major catchments of the Porirua inlet (shown on Figure 9-2).

The components that are of importance to ecological investigations are:

- Extensive earthworks in close proximity to streams;
- Large culverts and bridges; and
- Lengths of both temporary and permanent waterway diversion.

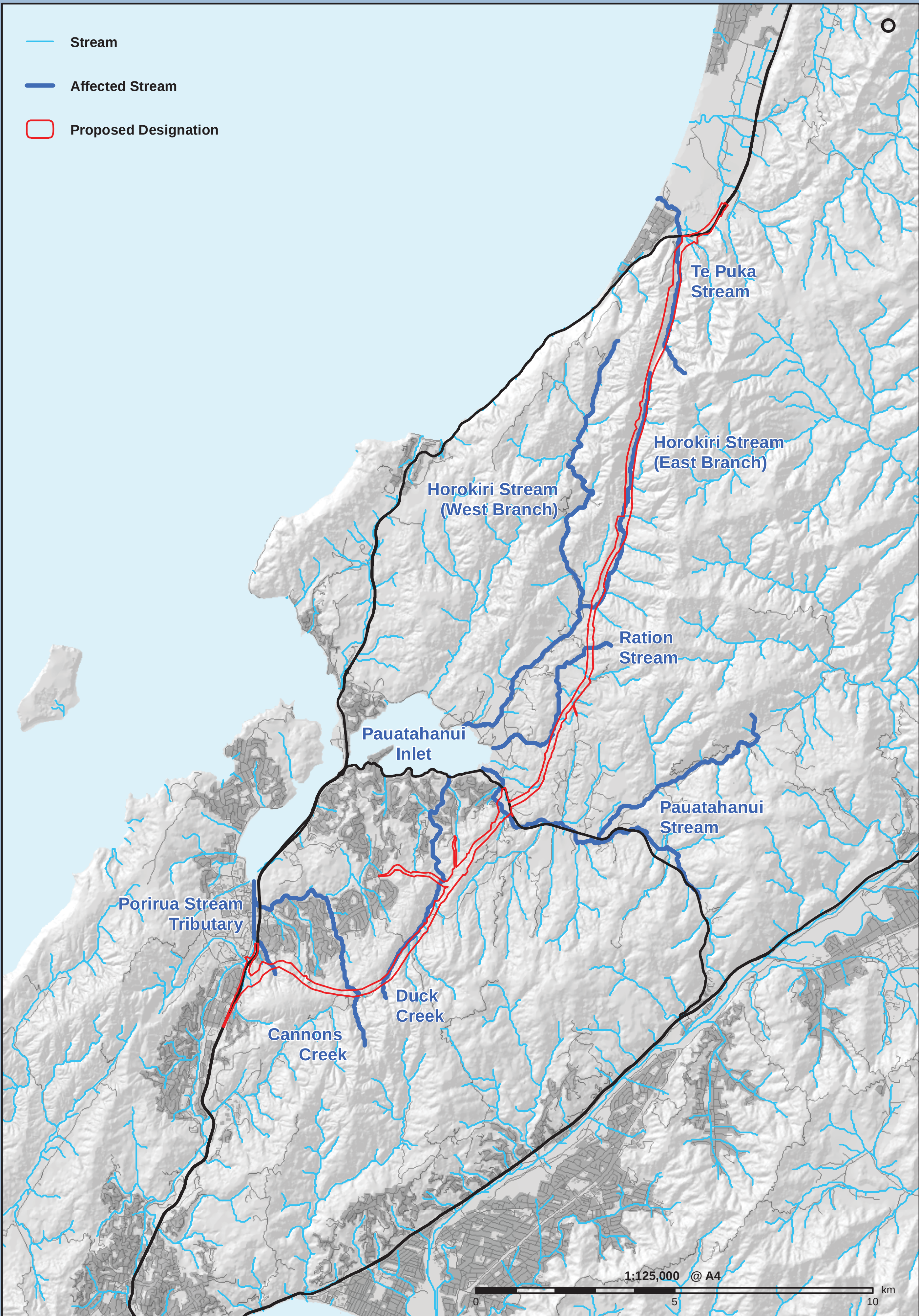
Ongoing operation will result in discharges of storm water to these streams, and ultimately to Porirua Harbour and Pauatahanui Estuary (the Porirua inlet).

For the purposes of the Ecological Impact Assessment and associated Technical Reports, the area was divided into the catchments around Porirua Harbour/ Pauatahanui Estuary. This report investigated streams in seven (7) catchments that are crossed by the proposed State highway, those areas are:

- Porirua Stream (a small tributary)
- Kenepuru Stream (specifically Cannons Creek)
- Duck Creek (most of the middle and lower reaches)
- Pauatahanui Stream (the lower portion)
- Ration Stream
- Horokiri Stream (most of the upper half)
- Te Puka Stream (most of the upper stream above SH1)

Figure 9-2 shows the waterways and their REC classification names.

The northern most affected stream, the Wainui Stream (North) was not studied in any detail. This was because the Road proposed is bridged over the stream, and this is the only point of interaction with that stream, and there is proposed to be little to no direct impact on the bed or waterway. Furthermore, the riparian condition is largely farm and pine plantation orientated and the only adverse effects of any potential note are those associated with earth disturbance downstream (where the Wainui Stream meets with the Te Puka) and the authors considered that the general earthworks sediment discharge management regime and EMP considerations covered what minor impacts might occur through bridge construction for the Wainui Stream.



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2.3 SOCIAL AND PLANNING CONTEXT

The TGMAP lies within Greater Wellington Region and predominantly in Porirua District. A small part at the northern end is in the Kapiti Coast District. (See Map 1-1) and small parts are also in the Upper Hutt City Council area and the Wellington City Council area.

The Greater Wellington Regional Freshwater Plan (operational -17th Dec 1999) identifies waterways of value (from a range of perspectives) and sets out objectives, policies and methods, including rules, for their management.

Porirua City identified "Ecosites" through a limited review in 2001 but these are not listed in its Operative District Plan.

Consultation has been undertaken with the Department of Conservation and Greater Wellington Regional Council through a series of meetings and workshops and the outcomes incorporated into methodologies and reporting as appropriate. Through this, the Department of Conservation (DoC) expressed concern on two matters. First, that the relative abundance and number of freshwater species found is likely to be under-estimated since only electric fishing was used. Secondly, the use of SEV is relatively untested and therefore the method has no test as of yet in the published literature. Both these concerns were addressed in developing and carrying out the methodology, and are discussed in Section 3 (methods) of this report.

3 METHODS AND SEARCH/SAMPLING EFFORT

3.1 APPROACH

A range of survey methodologies have been used including various national protocols (e.g. SEV3, Harding et al 2009, Stark et al 2001) and industry standard practices and modified variations of commonly used methods. Each method was tailored to the project, the site and to the purposes of the data collection. Following is an overview of the sampling strategy, the sites and areas sampled, and a catalogue of the methodologies employed for collection of the sets of data. More detailed aspects of the methodologies, including aspects that varied from published protocol are discussed further in subsequent sections of this report.

Four "sets" of data were collected for the project investigations over a period of three years to describe the aquatic habitats and their assemblages; and to allow regional importance and sensitivities to be assessed. The four are:

- physical habitat data, i.e. stream morphology, substrate type, riparian condition etc;
- water quality (collected in the main by SKM);
- water quantity (collected in the main by SKM); and
- Flora and fauna (primarily aquatic macro invertebrates, fish and aquatic macrophyte data).

Sampling and analysis methods were chosen that would:

- Describe the existing aquatic physical habitat (including water parameters);
- Differentiate between the basic aquatic habitat types in the project area;
- Identify similarities and differences between reaches within streams and across the main waterways in the project area;
- Supplement the existing data in describing the fish communities in the project area;

[3] "Stream Ecological Valuation (SEV), NIWA, Quinn, J.; Parkyn, S. (2006). NIWA report and modelling system produced for the ARC.

- Describe the existing the aquatic macro invertebrate communities;
- Identify rare and threatened species within the waterways;
- Assess the conservation/Regional significance of the species and communities present;
- Allow an evaluation of loss and change of aquatic habitats; and
- Enable identification of potential effects from mitigation proposals could be developed if the project were to proceed.

As part of this, a number of separate studies have been undertaken by Boffa Miskell Ltd on behalf of NZTA, since 2008 in aquatic systems and these are brought together here. They include:

- Stream Survey & Preliminary Ecological Valuation: Te Puka Stream, Horokiri Stream, and Duck Creek. Report June 2008. An SEV-focused survey;
- Additional Freshwater fisheries surveys 2009;
- Additional SEV surveys 2009;
- Additional correction SEV surveys to convert SEV to the new cobble bottom formulation (Technical changes to formulations by NIWA for GWRC), March 2010;
- Detailed physical habitat and substrate surveys of Horokiri and Te Puka, November 2009;
- Fish passage through culvert matrix, a matrix to determine culvert /fish passage requirements. File report 2010;
- Supplementary Environmental Management Plan, Horokiri Stream and Te Puka Stream considerations. Workshop July 2010;
- Mitigation rationalisation, internal report June 2010; and
- New Design suggestions for TGMAP for Providing Aquatic Habitat within Culverts, memo 2010.

Related reports produced by others, in conjunction with BML or separately, include a range of water quantity and quality reports and research undertaken by SKM. These include:

- Baseline Water Quality Monitoring Report (Malcolm & Wiseman 2009);
- Sediment Yield Calculations (Malcolm 2010);
- Construction Erosion & Sediment Control (Martell/ Adams/ Albrecht 2009);
- Generation of Daily Stream flow : time series for Selected Catchments (Hansford / Malcolm 2009);
- Modelling of Sediment in the Streams & Harbours (B. Fountain);
- Stormwater Management Devices (Albrecht/ Martell 2010);
- Peak flow Analysis for Culvert and Bridge Design (Martell/ Fountain/ Adams/ Heinemann 2009); and
- Assessment of Hydraulic Effects on Critical Streams (Fountain/ Adams/ Martell 2010).

Sampling effort and most research has focused on three of the 7 main waterways in the seven catchments likely to be affected to the greatest extent by the proposed road. These are Te Puka Stream, Horokiri Stream and Duck Creek. In the remaining four affected catchments (Ration, Pauatahanui, Cannons Creek, and Porirua), the scale of potential effects was considered (following scoping of effects) to be significantly less and sum to very little. For the three “affected” waterways the alignment travels parallel to and within 100m of (i.e. the proposed designation often includes the waterway) around 60% of the Te Puka stream, in similar proximity and affecting around 50% of Horokiri Stream and again around 50% of the Duck Creek. Whereas in the other waterways the road alignment runs at right angles to the waterway and may only cross that water way once, directly affecting perhaps only 200m of the waterway. The affect is primarily focused on downstream earthwork sediment discharge effects.

For example the Pauatahanui stream has around 500m (less than 10%) affected, and by a bridge crossing not infill for a culvert or a parallel earth-worked structure.

Ration Stream also has potentially around 500m (<10% linear length) and 4 or 5 first order tributaries bisected, while the Cannon and Ranui Heights un-named stream system (A Porirua tributary) are intersected by the proposed roading, and the interaction is a bisection of the stream. At these locations the waterways are in the extreme headwater, are intermittent in flow, and heavily modified by the land uses around them. In short it was considered that these systems are highly unlikely to maintain permanent aquatic life.

Therefore, the studies undertaken in those other waterways have not been as detailed as in the three main affected catchments.

Sampling throughout the three years has resulted in:

- 31 sites being fished by EFM at 40m reaches per sample (4 pass method[4]);
- 15 sites being sampled for aquatic macro invertebrates (three semi-quantitative kick net samples per site, totalling 45 samples);
- 15 full SEV protocol sample sites;
- stream geomorphology sample sites (totalling 2.6 km of surveyed stream morphology);
- 23 existing culverts surveyed for passage;
- 24 intermittent tributaries of the Horokiri and Te Puka walked and visually surveyed;
- 16 water quality sites regularly monitored;
- 4 permanent NTU logger sites established; and
- A total of around 50km of linear waterway walked, photographed and noted.

3.2 SCOPING OF SAMPLING EFFORT AND LOCATIONS

Based on an initial scoping survey, only three streams in three catchments where chosen for full assessments (Te Puka, Horokiri and Duck). These streams and catchments were those where significant variations in the alignment were possible at the start of work, and where the current and possible variation could have major positive or negative effects when compared with the original designated alignment. Sampling was undertaken in a range of other streams at specific locations and often for only one specific component, e.g. only fish sampling.

Sampling was undertaken at:

- Three sites in the Te Puka Stream;
- Seven sites in Horokiri Stream;
- Six sites in Duck Creek;
- Three in Cannons Creek;
- Two in Kenepuru Stream;
- One in Ration Stream; and
- One in Pauatahanui Stream.

Sites within each stream were selected to describe representative habitat types, and to provide reasonable geographical coverage of the study area. All sample site locations are listed in Table 9-1 below and shown on Figure 9-3 and sampling activities listed in Table 9-2. A range of sites were surveyed in additions to the 15 SEV (full) survey sites and these were electric fished to add to the

[4] There is and will currently be some debate over electric fish sampling methodology potentially referring to a new publication favouring a single pass over 150m system as opposed to other multiple pass systems. We greatly favour multiple pass systems since scientific literature shows that single pass sampling typically samples only 50% of the fish fauna present (habitat and species diversity dependent) (Jowett & Richardson 1996, Jacobs & Swink 1982, Price & Peterson 2010). Ideally mutli-pass and multi-method over several time periods should be employed for maximum potential recognition of all diversity. While a single pass system may create data better suited to the National data base that reason is not paramount for the sampling undertaken here and in most consent applications.

fish survey record and more basic observations made of the physical habitat and macrophyte presence.

No specific periphyton sampling was undertaken and macrophyte, being found infrequently and in low abundances, was not made a focus of specific survey.

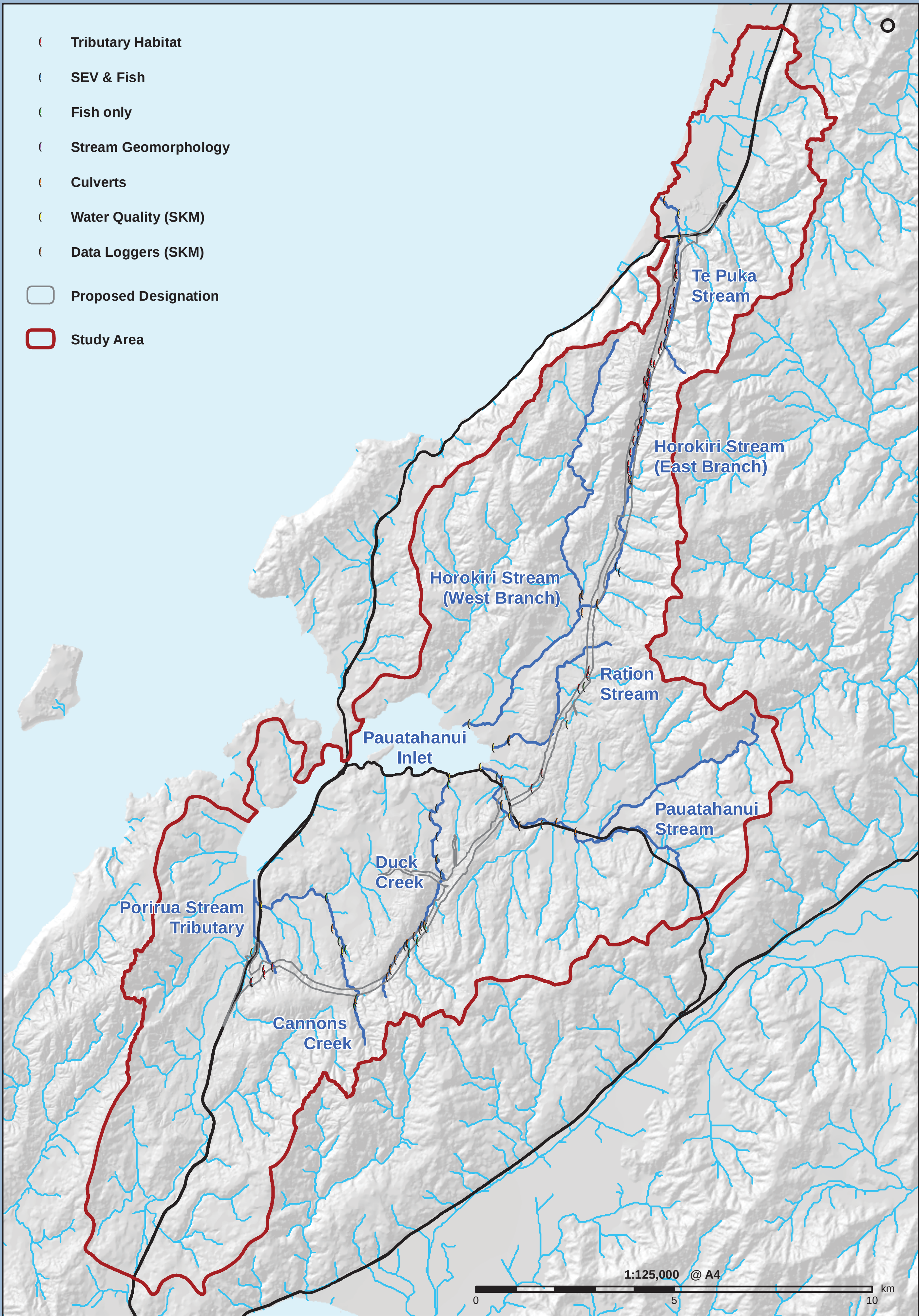
Table 9-1lists the sites by sample type and Maps in Figure 9-3 identify the various sampling efforts spatially. Figure 9-3 also includes the water quality sampling locations undertaken by SKM, as well as the data loggers installed to measure back ground water turbidity.

Table 9-1 Location of Sample Sites

Ref No. or code	Name	Northing (NZTM)	Easting (NZTM)	Altitude a.s.l.	Distance from Coast
1. TP-U	Te Puka Stream (Upper)	1764995	5458597	190 m	2,020 m
2. TP-M	Te Puka Stream (Mid)	1765241	5459521	118 m	1,730 m
3. TP-L	Te Puka Stream (Lower)	1765342	5460818	55 m	1,165 m
4. HK-U	Horokiri Stream (Upper)	1764585	5457133	205 m	11,520 m
5. HK-M	Horokiri Stream (Mid)	1764319	5456148	150 m	10,185 m
6. HK-L	Horokiri Stream (Lower)	1764155	5455070	115 m	8,975 m
	Horokiri West (control)				
	Horokiri east				
7. BH-M	Horokiri Stream (Battle Hill – main)	1763762	5452982	63 m	7,025 m
8. BH-T	Horokiri Stream (Battle Hill - Tributary)	1763843	5452952	67 m	6,835 m
9. DK-U	Duck Creek (Upper)	1758033	5442702	137 m	4,110 m
10. DK-M	Duck Creek (Mid)	1758559	5443594	97 m	3,975 m
11. DK-L	Duck Creek (Lower)	1758961	5444023	75 m	3,755 m
	Duck tributaries				
	Duck Creek Silverwood				
	Duck Creek Nth				
	Duck creek South				
	Pauatahanui Stream				
	Ration upper				
	Ration lower				
	Kenepuru Stream lower				
	Kenepuru Stream middle				
	Cannons upper				
	Cannons middle				
	Cannons lower				

Table 9-2 Type of Sampling at Each Site

Ref no.	Name	SEV & other	EFM (ONLY)	PHA.(ONLY)	Other (photo, site visit)
1. TP-U	Te Puka Stream (Upper)	Y		Y	
2. TP-M	Te Puka Stream (Mid)	Y		Y	
3. TP-L	Te Puka Stream (Lower)	Y		Y	
4. HK-U	Horokiri Stream (Upper)	Y		Y	
5. HK-M	Horokiri Stream (Mid)	Y		Y	
6. HK-L	Horokiri Stream (Lower)	Y		Y	
	Horokiri West (control)	Y			
	Horokiri east		Y		Y
7. BH-M	Horokiri Stream (Battle Hill – main)	Y		Y	
8. BH-T	Horokiri Stream (Battle Hill - Tributary)	Y		Y	
9. DK-U	Duck Creek (Upper)	Y		Y	
10. DK-M	Duck Creek (Mid)	Y		Y	
11. DK-L	Duck Creek (Lower)	Y	Y	Y	
	Duck tributaries		Y		
	Duck Creek Silverwood	Y	Y		
	Duck Creek Nth	Y	Y		
	Duck creek Sth	Y	Y		
	Pauatahanui Stream		Y		Y
	Ration upper		Y		Y
	Ration lower		Y		Y
	Kenepuru Stream lower		Y		Y
	Kenepuru Stream middle		Y		Y
	Cannons upper		Y		Y
	Cannons middle		Y		Y
	Cannons lower		Y		Y


Tributary Habitat
SEV & Fish
Fish only
Stream Geomorphology
Culverts
Water Quality (SKM)
Data Loggers (SKM)
Proposed Designation
Study Area
Te Puka Stream
Horokiri Stream (East Branch)
Horokiri Stream (West Branch)
Ration Stream
Pauatahanui Inlet
Pauatahanui Stream
Duck Creek
Porirua Stream Tributary
Cannons Creek
1:125,000 @ A4
0
5
10
km

3.3 FIELD AND ANALYSIS METHODS

3.3.1 AQUATIC PHYSICAL HABITAT

The measurement and evaluation of physical habitat

Aquatic physical habitat parameter measures methods followed those of Harding et al (2009), giving an array of basic measures and observations (e.g. basic water chemistry, substrate, riparian condition etc). Sampling was undertaken at 13 sites (11 route sites, shown on Table 9-2, and one in each of Hawkins Gully and in Belmont Stream, as reference sites). An important component was the scoring of the sample habitat based on the 1-20 in-field assessment system using a graded expert score. This assessment was first developed by the ARC (Maxted et al 2000) and is an adaptation of earlier unpublished field models (Stark 1985, 2000), Urban Stream Habitat Assessment (NIWA 1999). This system is also very similar to that used by Environment Canterbury in Meredith et al (2003) and now also promoted as a "national protocol" by Harding's et al 2009.

The criteria used in this assessment are:

- Aquatic habitat abundance,
- Aquatic habitat diversity,
- Hydrologic heterogeneity,
- Channel alteration,
- Bank stability,
- Riparian vegetation type
- Riparian zone width

Each of these factors is scored on a scale of 1-20, and the higher the total score for a stream or reach then the better are the habitat opportunities present for native aquatic fauna. The highest possible score using this system is 140 (perennial) or 80 (ephemeral). Any stream which scores less than 20% of the maximum is considered to have severe problems and / or limitations with regard to both the in-stream and riparian values.

Measurements of diversion reach geomorphology

At two reaches, each around 1km long, in the Horokiri and Te Puka streams, a detailed geomorphological assessment was undertaken in addition to the SEV data, the PHA data and casual observation notes. These data were collected specifically in the areas where engineered road embankment diversions are considered to be required. The purpose was primarily to describe, in some detail, the bank widths, morphologies and the substrates to enable the design of diversion channels to at least approximate the existing habitat (in particular run-riffle dynamics, widths and depths, substrate sizes).

Two upper-middle reaches of the Horokiri were chosen as areas near to or within proposed diversion reaches, which, following scoping, were also considered representative of the general habitat types of the wider stream area. Each site, starting from the most downstream site were visited, the start location fixed by GPS and photographed. One person made recordings, the other under took the measures. A length of around 500m of the stream was mapped and divided in to the standard hydrological habitat types: run, pool, step-pool, braid, cascade, step-riffle, riffle and run-step (these being the majority of hydrological habitat types). Each hydrological habitat type's length was measured by pacing (having determined the average length of the pacer's pace) and the habitat patterns and lengths mapped. Other aspects of note were taken (including periphyton abundance and macrophyte presence). Following this mapping 13 Horokiri and 3 Te Puka Stream cross sections were located based on incorporation of all of the hydrological habitats present and typifying them. Each cross sectional transect spanned the wetted width up to the dry bank. Notes were made of the banks character beyond including the riparian species composition. Across the wetted widths every 0.5m a depth measure was made (the stream width at these locations averaged 3m giving at least 6 measures).

At locations on the transect at each of the left and right banks and at the stream centre a fixed area quadrat (25 cm2) was set on the bottom (substrate) and all of the surface substrate (cobbles) removed to a bucket. Each substrate item (cobble sized and upwards) was then measured along its longest axis and at its widest (to allow measure to calculate an approximate area). The proportional cover of the substrate types (including sand, mud and gravels) was first made from the quadrats prior to removal of the large substrate items.

Lastly a velocity approximation was made using the average time taken for 5 floats to travel 10m. On site sketch maps approximated meander patterns, and these were later revised or confirmed using aerial photographs. Aquatic vegetation (submerged and emergent) and periphyton was recorded and the relative abundances noted.

The outputs of these measures were:

- a measure of the proportions of typical substrate types,
- substrate particle sizes for different habitats,
- velocities/habitat,
- wetted stream width dimensions,
- depth profiles across the bed,
- bank dimensions (widths and heights),
- a drawn cross sectional profile, and
- habitat length patterns and proportions.

Aquatic Macrophyte and Periphyton

Macrophyte densities and abundance and species richness were recorded during the physical habitat measurement process (including SEVs). However, there is a limited presence of these aquatic plant species. During aquatic surveys periphyton sampling is often undertaken to measure species richness and cover. These measures are important when studying food webs, problem algae, nutrient dynamics and general biology of the waterway; they are not often associated with value assessment. Early scoping surveys indicated a low presence and abundance of aquatic macrophyte and periphyton and therefore no particular survey to describe their presence and locations was deemed necessary for the evaluation process. Through the physical habitat surveys, SEV and geomorphological surveys observations were made of the presence of aquatic macrophyte species and if there were notable periphyton abundances or mosses and liverwort but this is the only record of these groups.

River environment classification (REC)

During the analysis the River Environment classification (REC, NIWA 2004) database was used to plot and measure the difference linear lengths of the different REC classes along the affected alignments of all of the waterways. Since the REC system does not recognise first order sections the NZMS 260 TOPO mapped streams were used (put in to our GIS layer) and a REC class zero was established to account for the intermittent/ephemeral stream passage ways.

Water sheds (catchment) were sized using GIS and topography layers to divide the terrain into the various sub-catchment and catchment areas. The catchment sizes were determined and these sizes assisted in the requirements for fish passage and presence of fish habitat matrices. The catchments figures are shared with SKM where they use them in sediment yield calculations.

The allocation of sites to a Habitat Reach Type.

In order to group sampled sites of the various streams according to characteristic aquatic habitat types, thus enabling a generalisation about values and effects across sub-catchment areas, a small array of physical stream characteristics were used to group the sites into reach types, i.e.: lowland, lower-middle, middle and upper reach. Each reach type describes a slight variation in river dimensions; presence/influence of sediment; inland distance; height in catchment; and land use. It is helpful in the description and evaluation of the habitats and communities present to consider them in a "river continuum" framework, rather than as separate individual stream sites. In this way individual waterways/catchments can be discussed, as well as similarities between habitat types found across the waterways in the project area.

To do this, a matrix of variables - altitude, average wetted width, channel depth and average velocity along with riparian condition - were considered. Each of these variables was plotted for each sampled site and the sites scored in numerical order. The plots were typically stepped in nature, separating into 3 or 4 steps (e.g. altitude < 50m, 50-150m, >150m). A matrix was then made combining the sites using the site reach type allocation, i.e. scores were 1-3 (Lower, Middle, High) for each variable and each sites score was then totalled. Following this the array of final scores were subjectively divided into a reach habitat class type (Table 9-3).

Table 9-3 Reaches allocated to aquatic habitat type, based on habitat type score.

Aquatic Habitat type	Site	Habitat type Score
upper	Horokiri upper	7
	Duck mid	8
	Te Puka lower	8
	Te Puka upper	8
middle	Battle trib	9
	Duck upper	9
	Belmont	10
	Horokiri mid	10
	Te Puka mid	10
lower-middle	Duck Silverwood	11
	Horokiri lower	11
	Duck lower	13
	Duck South	13
lower	Battle main	14
	Duck North	15
	Pauatahanui	15

3.3.2 WATER QUALITY

During the collection of the SEV and PHA data basic water quality data such as pH, dissolved oxygen and spot turbidity were collected in the field by BML. However, SKM has undertaken a complete and extensive water quality study of the seven catchments (Te Puka, Horokiri, Duck, Cannons, Kenepuru, Ration, and Pauatahanui) and all of the main streams and lower reaches. In their Baseline Water Quality Monitoring Report (Malcolm & Wiseman 2010, 2011) they discuss the findings from an extensive array of samplings. Below (Table 9-4) is an outline of their sampling protocol and regime which was developed in consultation with BML ecologists.

Table 9-4 Summary of water quality data collected and purpose

Purpose	Method	Parameters	Comments
Baseline water quality	Wet and dry weather grab samples (4rounds)	Field parameters, visual observations, heavy metals, nutrients, hydrocarbons	To provide an overall picture of water quality for the different streams to be used as a baseline for assessing effects.
Fine sediment deposition in streambeds	Quorer sampling (3rounds) and visual assessment of fine sediment (1 round)	Suspended inorganic and organic sediment	Assess current fine sediment quantities in stream substrate
Turbidity	Continuous turbidity sampling	Turbidity	Continuous logging of turbidity to input to the calibration of sediment yield estimations
Water quality during storm events	Automatic samplers	Total suspended sediment, turbidity, selected heavy metals	To determine water quality of selected streams during storm events – to distinguish differences between first flush concentrations and throughout the rest of the storm
Sediment quantity during storm events	Event sampling	Total suspended sediment, turbidity	Results to be used for calibration of sediment yield estimations

Source: Page 7 - Final Stream Baseline Water Quality Report

Wet and dry weather grab samples

The baseline monitoring programme consisted of four rounds of sampling that was conducted quarterly. One round of sampling was done in 'dry' flow events and the remaining three rounds in 'wet' flow events. 'Dry' flow events were defined as less than 5mm of rainfall occurring in the previous 24 hours. 'Wet' flow events were when at least 5mm of rainfall had occurred in the last 24 hours. This was measured at the nearest rainfall gauge to each sampling location

Quorer sampling

Three rounds of Quorer sampling were undertaken during 'dry' flow events. NIWA's method for estimating the quantity of deposited fine sediment in streams was used (NIWA, 2008). Sampling was done at six stream locations (Appendix C (C1) of SKM Report[5]). Seven samples were collected and transported to Hills Laboratories for analysis for volatile suspended solids and total suspended solids. This data was used to calculate areal and volumetric suspendable organic sediment and suspendable inorganic sediment for each sample. The geometric mean was then calculated for each site. The purpose of this data is to provide an indication of the amount of sediment currently deposited in the substrate of freshwater bodies in the study area.

Event Sampling

Eight grab samples were collected at the mouths of five of the streams that drain into the Porirua Harbour (Appendix C (C1) of SKM report). Event based sampling was carried out during or immediately following high rainfall events, where flow was expected to be high at these locations. Samples were collected and transported to Hills Laboratories for analysis for total suspended solids and turbidity.

[5] Baseline Water Quality Monitoring Report, March 2009, Malcolm & Wiseman, SKM

Continuous turbidity logging

These loggers have been in place from mid October 2009 and log turbidity every 15 minutes.

Relationships derived between total suspended solids and turbidity from both event and grab sample results have been used to estimate sediment concentrations during different flow events. This data has also been used to calibrate the sediment load modelling and sediment yield estimations for the modelling of sediment deposition in both the streams and the estuary. In this report, turbidity data has also been compared to gauged stream flow data (where available).

Automatic water sampling

Automatic water samplers triggered by a change in the rate of rise in the stream were installed at three locations for a period of three months.

3.3.3 SEV – HABITAT DESCRIPTIONS

At each of the 15 SEV sample sites, listed in Table 9-2, a range of physical habitat characteristics were recorded as is dictated by the SEV field sheet and data system. These characteristics included width, depth, velocity, and clarity of the stream, substrate composition, riparian vegetation and shade, temperature, dissolved oxygen, pH, and conductivity.

This data was combined with the other biological criteria and analysed using the Stream Ecological Valuation Worksheets (V.8 January 2008). Later, in 2010, these data were updated from additional field investigations to account for a change in the SEV system to account for a cobble bottomed stream system. Through 2009-2010 NIWA were working (on behalf of GWRC) to adapt the Auckland based SEV system to account for a primarily cobble based substrate system. This adaptation was completed in 2010.

Initially the “Stream Ecological Valuation” (SEV) was developed by NIWA for the Auckland Regional Council as a tool to provide standardised stream assessments, create a functional measure and provide a method for the calculation of off-setting mitigation based on stream quality. The SEV system calculates a stream quality score based on the comparison of stream function parameters between test and reference sites, the reference sites being comparable streams with low levels of disturbance by human activity (Rowe et al, 2008).

The ecological functions that are assessed are grouped into the following four categories:

- Hydraulic function – processes associated with water storage, movement and transport;
- Biogeochemical function – those related to the processing of minerals, particulates and water chemistry;
- Habitat provision functions – the types, amount and quality of habitats that the stream reach provides for flora and fauna; and
- Native biodiversity function – the occurrence of populations of indigenous native plants and animals that would normally be associated with the stream reach.

An overall SEV score is produced on a scale of 0 to 1, (where 0 = no function and 1 = full and proper functioning). A formula is provided for an Environmental Compensation Ratio, which indicates the relative amount of stream rehabilitation that might be required to replace functional values lost due to stream impacts. It should be noted that the formula calculates total replacement of functional values, based on a “no net loss” approach. While this is a sustainable approach, a satisfactory mitigation solution may be achievable at a lower threshold which recognises that some adverse effects may be inevitable.

SEV assessments were undertaken initially at each of the eleven sites: three sites in the Te Puka Steam, five sites in the Horokiri Stream catchment (including the main stream and a tributary at Battle Hill), and three sites at Duck Creek. Later in 2009 a further 4 sites were added, three in the Lower Duck Creek system and one in Horokiri. The streams were evaluated against reference sites and a representative Environmental Compensation Ratio was calculated.

Three reference sites from the Wellington Region were used. The first was Hawkins Gully, Makara Stream, for which an SEV was undertaken in October 2007 (BML, unpublished data). It had the highest SEV score of the six sites in that study. The second was Belmont Stream tributary, a native forest stream for which an SEV was able to be calculated from existing data (BML, unpublished data). The third was a hypothetical version of the Hawkins Gully stream with full native forest canopy, rather than the dense wetland vegetation actually present. This was the closest approximation that could be developed as a reference site representing an intact indigenous system. The various riparian vegetation parameters were adjusted to reflect an undisturbed forest environment, while the high in-stream habitat values were retained. Qualities seen and measured in the Te Puka headwaters were used to assist this “theoretical” SEV stream. However, only two reference sites were used in the final comparative analysis, those two measured sites. The particular values ascribed to the Reference sites can be viewed in Appendix 9.J.

Data was analysed in accordance with the methods described in the SEV manual (Rowe *et al*, 2008). The latest version of the SEV calculator was used (designated as Version 8.2, dated 28 February 2008). The only variation from this version was the calculation of the V-veloc function; an earlier version was used, which was current at the time of data collection. This was necessary because a different data collection methodology was required for the later version of the calculator.

3.3.4 FISH

Fish were sampled using an EFM300 backpack electro-fishing machine, which attracts and temporarily stuns fish so they can be captured. EFM sampling sites are listed in Table 9-2 and shown on Map 3-1, 3-2. At each sample reach a total of $40m^2$ was sampled. This reach area was sampled in 4m sequential lots using a two pass system. All fish netted were identified and measured, then stored in a bucket until the reach was fished, and then returned to their habitats.

We note that other fishing methods, especially night spot-lighting and baited trapping are also typical methods to ensure a full range of species are caught. We did not use any other method simply because we consider the effort and catch was sufficiently representative of the fauna present. The sampling returned 10 of the 17 historic species recorded in the freshwater fish database. Those not caught were lower reach species (yellow eyed mullet, triple fin, black flounder and smelt). We assume these are all present in the assessment. Those fish of higher catchment not caught but in the historic records were “rare” occurrences, i.e. short jaw kokopu, giant bully and lamprey. The Historic records report one capture of short jawed kokopu in 1989, one capture of giant bully in 1962, one capture of Lamprey in 1962 and two records of torrent fish (one in 1962, the other in 1997 all in the Horokiri. The records are by unrecorded persons using unrecorded methods. The torrent fish was recorded using electric fishing methods. While Lamprey, have only been recorded twice before, we are aware that this species can still periodically still be found migrating into the harbour tributaries on mass.

In our opinion the effects assessment is not basis or detracted by the absence of an extra fish sampling method and that we have made assumptions in regard to passage requirements and sediment discharge issues that cover off the presence of any of those “rare” species not sampled.

The significance of individual species was assessed using conservation threatened species lists prepared by Allibone et al 2010 and by evaluating their occurrence in the Wellington Region using data from the New Zealand Freshwater Fish Database (NIWA, 2007).

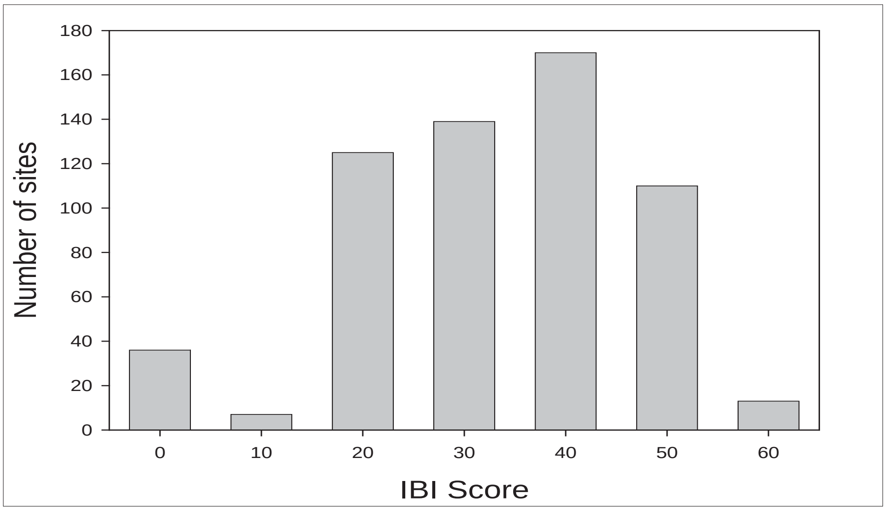
The value of the fish communities was assessed by comparison with other streams in the region. This included evaluation using IBI (the Fish Index of Biological Integrity, (Joy, 2005), and classification following the regional ranking system of Strickland and Quarterman (2001). The latter classification uses the threatened species classification of Molloy and Davis (1994), and was adapted to the updated classification of Hitchmough *et.al.* (2007) by defining Category A threatened species as equivalent to Acutely Threatened, Category B as Chronically Threatened and Category C as At Risk (Appendix 9.D)

It should be noted that the new classification evaluates threat of extinction, while the earlier Molloy and Davis prioritisation considered a wider range of criteria including human values (J. Molloy, pers. comm.)[6].

Table 9-5 Attributes and Integrity Classes for the Wellington IBI (after Joy, 2005)

Total IBI score	Integrity class	Attributes
50 – 60	Excellent	Comparable to the best situations without human disturbance; all regionally expected species for the stream position are present. Site is above the 97th percentile.
42 - 49	Very good	Site is above the 90th percentile of all Wellington sites species richness is slightly less than best for the region.
36 - 41	Good	Site is above the 70th percentile of Wellington sites but species richness and habitat or migratory access reduced some signs of stress.
28 - 35	Fair	Score is just above average but species richness is significantly reduced habitat and or access impaired.
18 - 27	Poor	Site is less than average for Wellington region IBI scores, less than the 50th percentile, thus species richness and or habitat are severely impacted.
6 - 17	Very poor	Site is impacted or migratory access almost non existent
0	No fish	Site is grossly impacted or access non existent

Figure 9-4 The distribution of IBI scores across the 600 sites used to calibrate the IBI in the Wellington region (from Joy, 2005)



[6] A review and new threat classification status has recently been published Allibone et al 2009.

Table 9-6 Stream Reach Importance rankings for fish in the Wellington Region. (Modified from Strickland and Quarterman 2001).

Ranking	Description	Criteria
Very important	Outstanding value. Both high conservation value AND high diversity.	Supports at least one acutely threatened species; OR at least one chronically threatened plus two at risk species; AND more than five native migratory fish.
Important	High value. Either high conservation value OR high diversity.	Supports at least one acutely threatened species; OR at least one chronically threatened plus two at risk species; OR more than five native migratory fish.
NE	Non-exceptional conservation or diversity values.	No acutely threatened species; less than one chronically threatened plus two at risk species; five or fewer native migratory fish.

3.3.5 AQUATIC MACROINVERTEBRATES

Aquatic macroinvertebrates (insects, snails, and worms) were surveyed in conjunction with the fish survey to provide further information on the ecological health of the streams. Samples were collected from each of the eleven sample sites listed in Table 9-1, and at each sample site three replicates were collected, giving 33 macro-invertebrate samples in total.

Communities were sampled using the MfE (2001) sampling protocol C1 (hard-bottomed, semi-quantitative). This involved the use of a 0.5 mm dip net, using the national standard kick-sampling protocol 'C1' described by Stark *et al* (2001). Species were identified to the lowest possible taxa (sufficient for MCI allocation) and abundances were recorded as coded abundances as per Stark 1998 protocol P1, coded abundance.

Six invertebrate indices (taxa richness, EPT taxa, total & EPT coded abundance, Macroinvertebrate Community Index (MCI), and Semi Quantitative MCI (SQMCI) were calculated for each replicate at each site. These biotic indices use the tolerances of New Zealand macroinvertebrate taxa for assessing the health of stony streams. All regional councils that undertake SoE monitoring use the MCI and/or SQMCI/QMCI for reporting results (Stark & Maxted 2007).

EPT taxa richness is the number of *Ephemeroptera* (mayfly), *Plecoptera* (stonefly), and *Trichoptera* (caddisfly) taxa in a sample. EPT are most diverse in natural streams and decline with increasing watershed disturbance. MCI (Stark, 1985, Stark & Maxted 2004) is an index based on the presence of invertebrate taxa, which has a score (1 to 10) based on their tolerance to organic pollution (1=highly tolerant, 10=highly sensitive). Streams with MCI scores greater than 120 are considered 'pristine' and streams with scores less than 80 are 'severely polluted'. QMCI (Stark, 1998, 2004) is similar to the MCI but also takes into account the coded abundance of each species. Where the MCI uses only presence-absence data, the SQMCI accounts for whether a species is rare or abundant in the sample.

3.3.6 HEADWATER "WETLANDS" AND SEEPAGES

While wetlands proper have been surveyed and described in the terrestrial flora reports those surveys did not treat small headwater seepage areas such as found at the top of the Horokiri and Te Puka streams at the Wainui saddle. In this freshwater report we have photographed many of these areas and supply a brief description of their extent, the primary vegetation cover and weather we considered them to have particular flora, fauna or functional values and therefore values to note.

Photo 9-1 The Wainui Saddle, headwaters of the Horokiri east.

4 RESULTS - DESCRIPTION OF FRESHWATER SYSTEMS, PATTERNS AND TRENDS

4.1 BASIC SYSTEM DESCRIPTIONS

The following are basic descriptions of the six waterways of the project area that are directly intersected and affected by the road alignment. The descriptions provide a rough idea of the catchment, the linear lengths the flows, a little on the appearance of the waterway and

Te Puka Stream

The Te Puka stream has a catchment area of some 3.7 Km2 (372ha) and drains through a very steep gradient from above and to the north of the Wainui saddle over 3 km to the South under the state highway and across the coastal plain through the Whaeroa Beach Surf Club Reserve to the coast.

The waterway in its headwaters is a poorly defined cobble and boulder base stream under a full forest canopy (the true right arm) or a narrow channelised intermittent creek from the Wainui saddle area. The larger perennial true right arm represents a very natural and pre-disturbance aquatic habitat type with sub-surface flows, appropriate organic matter and complex and simple habitat areas ideal for koaro and banded kokopu but less so for shortjawed kokopu. Below the headwater and out of the forest the stream widens and becomes semi-braided on a course cobble base with a relatively undefined channel set in wide banks. The habitat is very simple and relatively uniform. As the stream reaches the lower-middle portion it cuts through an old ridge and this cut forms a deep and enclosed gorge section (around 500m). This adds substantively to the habitat opportunity of the creek. Following the gorge the stream falls further a further 500m to the State Highway were the gradient falls to the coastal plain. This lower stream section is narrower, single channel and provides greater evidence of farming disturbance.

Average velocities in the middle to upper reaches range from 0.3 to 0.5 ms^{-1} in water depths typically around 0.05 to 0.1m (very shallow) in undefined wetted channels of around 3 to 4 m often in two channels in a bank to bank stream of 9 to 15m.

Riffle habitat makes up around 40% of the aquatic habitat with cascades, stepped riffles, and stepped pools making up equally the remaining general aquatic habitat types; all represent relatively shallow, “fast” water habitat.

Photo 9-2 Te Puka Head water stream section under native coastal broadleaf canopy

Photo 9-3 Wainui saddle headwater branch of the Te Puka

Photo 9-4 Upper Te Puka main stem showing flow type and substrate

Photo 9-5 Example of a true left Te Puka tributary, typically dry for most of the year.

Photo 9-6 Lower-middle reach of the main stem of the Te Puka Stream. Note the relatively uniform flow pattern, substrate and riparian situation.

Photo 9-7 Lowest section of the Te Puka Stream prior to passage under the existing State Highway. Note gradient flattened, uniform flow and substrate and adjacent farming influences.

Horokiri Stream

The Horokiri stream has a catchment area of some 34 Km^2 (3380) and drains from north to south from the Wainui saddle (at around 500m a.s.l) down into the Pauatahanui inlet between the Kakaho and the Pauatahanui catchments.

The waterway runs along an alluvial flat narrow bottom between steep and unstable hills to the west and east for most of its length (that length being around 12,900 m). As the stream reaches its middle reach the surrounding hills recede and the alluvial plain in which it sits opens into the Battle Hill Regional Park. The East branch of the Horokiri then meets the near equal sized west branch at about the Paekakariki Hill Road, doubling the size of the waterway. From here the river proceeds to the Pauatahanui Inlet reasonably directly and as a relatively slow and large lowland river type.

The upper headwaters of the Horokiri east are largely in rough pasture with the larger tributaries coming from the east and in native regenerating shrublands. The typical water velocity in the headwaters is around $0.2ms^{-1}$ but this can pick up to around $0.5m^{-1}$ in some of the steeper middle reaches. The water is clear, the substrate cobble and relatively clean but the riparian areas largely exotic pasture species and unprotected from stock.

The upper-middle reaches are characterised by a narrowing of the valley and an increase in native treeland type riparian vegetation (mahoe shrub) on steep banks and small terraces over a mild to deeply incised stream passage. Despite the vehicle and stock crossings the substrate and general form of the stream in this upper-middle section is relatively hydrologically and “benthically” unmodified, although there is now little wood debris or other forest associated habitat factors present.

The middle and lower-middle reach is deeply incised with native herbs and grasses adhering to the steep tall banks. The riparian top of the bank is largely pastoral grasses. The water generally runs clear in a wide deep set channel as a shallow run and riffle system.

The lowest reaches are of a much flatter gradient and the river larger and deeper with frequent pools and long runs. The water is often slightly sediment tainted (i.e. with colour) and sands and sediment are common on the benthos. The banks are largely exotic and mixed weeds (willow), shrubs and grasses.

Photo 9-8 Typical form of the Horokiri headwaters (upper reach). Note pastoral riparian condition, small and undefined channel and cobble substrate.

Photo 9-9 Upper-middle reach of the Horokiri after. Note a flat gradient section, pastoral influences, uniform cobble substrate, flood plain size and erodible bank profile.

Photo 9-10 Typical middle reach section of the Horokiri with a gorse mahoe riparian cover and a relatively uniform run flow pattern with medium cobble substrate.

Photo 9-11 Lower Reach of the Horokiri were logger installed. Low gradient, exotic vegetated.

Ration Stream

The ration system is one of the shorter waterways of the eight affected. It has a total catchment area of around 6.13 km^2 (nearly 20% of that of the Horokiri) and rises only to around 260 m.a.s.l. and is some 4,800m in length. The ration catchment divides the Horokiri from the Pauatahanui catchment and discharges off Ration point through a small oioi reed land into the Pauatahanui inlet. A generally flatter catchment, the majority of the middle reach is in plantation forestry, the lower reaches in life style farming and the upper reaches in beef and sheep pasture. The system has numerous intermittent or ephemeral tributaries that are largely covered in macrophyte (monkey musk, watercress, water pepper) and/or rushes and sedges in pasture (*Juncus effusus, Carex* sp). Water in this system is not necessarily flowing and is often in areas only found underneath long grass swards and wetland plants. An open channel with water flow is only obvious in the middle to lower reaches under pine plantation or through the farmlands near the inlet. The water is often clouded and nutrient and sediment levels can be very high (SKM water monitoring recorded Ration has having the highest Suspended inorganic sediment of the eight streams monitored over six months for the TG project and raised nitrogen and phosphate levels). Unlike the Horokiri there is a relative consistent and slow velocity of water (~0.2ms^{-1}). Unlike the Horokiri or Pauatahanui Ration does not have a catchment watershed in higher hill country with areas of native shrubland but instead in low hills with plantation forestry. This forestry is likely to be having an adverse effect on the hydrology of the system.

Photo 9-12 A middle reach view through the golf course of the ration. Note the deep set bur small flow and highly managed and modified riparian condition.

Photo 9-13 Lower reach condition of the Ration in a mixed (mahoe) native/exotic riparian situation. In these few examples the stream is slightly more representative of a low gradient coastal type expected of the area.

Photo 9-14 An upper reach example of the Ration this tends to be a wetland/pasture/stream flow pattern with soft substrates and coloured waters with little open water.

Photo 9-15 A 300mm giant kokopu caught (and released) in the lower Ration.

Pauatahanui Stream

The Pauatahanui catchment is the largest of the TG project area at around 43.4 km^2 (4200ha). The majority of the feeder tributaries arise in the south of the catchment from the hills at an altitude of around 430m a.s.l. The main stem has a linear length of around 9,600m.

The upper catchment area has pockets of bush and shrubland but the middle and lower catchment is largely in exotic shelter belts and pasture. The lower reaches, prior to discharge into the Pauatahanui inlet, are wide relatively deep sandy, gravely small cobble reaches typical of lowland streams with over hanging willows associated with pools and deep runs.

The river exits to the inlet through a large well formed oioi wetland.

Typically the riparian condition is one of rough pasture, pasture weeds and mixed exotic trees (willow being common) and in general there is a strong vegetative riparian cover in the middle and upper reaches, although generally the banks are unprotected and stock has free access to most areas. At and below the TG project affected area the Pauatahanui River is a relatively typical lowland stream with a relatively natural meander path, hydrologically natural flows and a substrate that while sediment affected still reflects a reasonably natural condition. Flows are reported at anywhere from 55 L/s to 25800 L/S an average around 1 cumec (940L/s).

Photo 9-16 Lower reach were logger was installed.

Duck Creek

The Duck stream has a catchment area of some 10 Km^2 (1000ha) and drains west through a very steep gradient from 490m a.s.l to sea level over a distance of around 7.2 Km (average channel slope of 0.037m/km).

By and large the upper catchment is in pasture, with the headwaters (4-5 tributaries) in scattered riparian native shrub and pasture. The middle-lower section has its contributing catchment land in plantation forest (Silverwood forest) until the river meets the Whitby Coastal estate urban area. The catchment is roughly 50% steep to very steep pastoral lands and 50% mixed age and type forest. The stream system includes narrow tributaries that have extensive and near vertical drops into the main stem from both the true left but mostly the true right and thus restricted to climbing fish only.

The main stem has shallow slow meanders in the flatter upper steps providing varied habitat from the steeper straighter sections. Generally the substrate is dominated by coarse gravel/cobble with little fine sediment. Depths vary from shallow upper areas around 0.1m and 3 to 4 m wide to middle reach areas around 0.3 to 0.5m deep and 5m wide to lower reaches of over 1m deep and 10m wide. In many lower and middle reach areas the stream has good in-stream habitat and varied riparian and wetland edge habitat. The upper stream is currently modified through three track crossing culvert systems which are all perched and do not provide a continuous up stream swimming passage. Flow velocities in the main stem average at 0.3 ms^{-1} while Flows are recorded in Healy as being from 16 L/S to 5890 L/s and averaging 230 L/s.

Photo 9-17 The upper Duck Stream condition of a mixed pastoral / tussock landscape with an undefined stream channel with a shallow and cobbled bed.

Photo 9-18 One of the three perched culvert arrangements currently in the upper Duck main stem

Photo 9-19 The middle reach of the Duck Stream showing enclosing steep valley sides, open pastoral landscape and riparian condition, uniform flow habitat and cobble substrate nature.

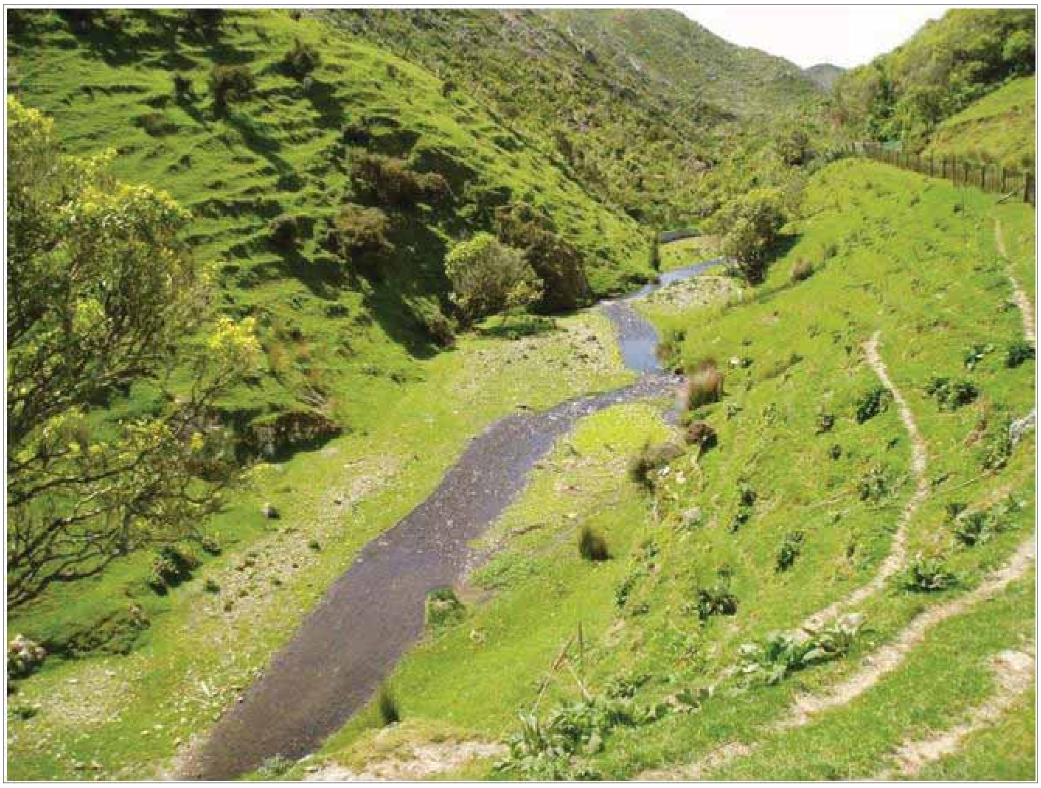


Photo 9-20 The middle reach of the Duck Stream as for Photo 19.

Photo 9-21 One of the true right perched side tributaries of the Duck system, in which banded kokopu can still be found.

Photo 9-22 Lower Pauatahanui Stream with blackberry, willows and rank pasture on the banks. Rafts of filamentous algae on the bed.

Cannons Creek / Kenepuru Stream

Cannons Creek is a tributary of Kenepuru Stream (total catchment area of around 13km^2 or 1300 ha) with a sub-catchment of around 390 ha. Its headwaters lie in Belmont Regional Park at an altitude of approximately 400m. The stream descends from its headwaters through farmland and regenerating bush for 3.6 km until it joins the Kenepuru.

The Cannons Creek system includes the Cannons Creek Lake Reserve which is a small narrow 7.5ha reserve that is situated at the point Cannons Creek enters Porirua East. The Lakes Reserve contains two artificial lakes; an upper southern lake and a lower northern lake.

Below the Lakes Reserve, Cannons Creek passes under Warspite Avenue and through Cannons Creek Park for a further 1.4km. Over this section it is contained within a concrete-lined channel or 'flume'. It then drops steeply down a series of large stepped concrete structures to join Kenepuru Stream at the base of the recently developed Aotea residential subdivision. Kenepuru Stream flows through Bothamley Park to eventually enter the Porirua Harbour approximately 3.0km from the Cannons Creek Lakes Reserve. The Cannons Creek Lakes are also fed by springs and storm water drains.

The two lakes were formed in the 1950s to act as flood detention ponds. The eastern perimeter of the lower lake is lined with stone. The upper lake is fringed by flax, wetland grasses and native tree and shrub. Both lakes are surrounded by mown lawns and beyond this with a band of native shrubs and trees along the gully slopes.

While the majority of the upper catchment consists of regenerating native vegetation and small areas of primary forest, the upper area of the catchment above the Takapu Road electricity substation is almost entirely in improved pasture managed by Landcorp. Water habitat in this upper reach is intermittent.

Photo 9-23 Upper Canons Creek. Note the open pastoral landscape, aquatic macrophyte edged waterway, flow and stream size.

Photo 9-24 Lower Cannons Creek (below ponds) Note a concrete lined “drain”

Photo 9-25 Lower Canons Creek concrete steps prior to a perched culvert release into the Kenepuru Stream.

Photo 9-26 The perched culvert releasing Canon's Creek stream to the Kenepuru Stream. (Fish passage barrier).

Porirua Catchment

Near the proposed beginning of the new route at the southern end the alignment traverses the top (head water) of an un-named tributary of the Porirua Stream. This short steep tributary is intermittent but has a good cover of mahoe indigenous secondary forest below the road alignment within the gully and is then surrounded by the pone forest plantation that covers the majority of the sub-catchment of this tributary. The stream width is typically 1 to 1.5m across, while depths (in the mahoe section) are less than 0.1m, flows small and total flow is estimated at survey to have been less than 10 L/S. While appearing (in the mahoe gully) to be of good physical habitat the aquatic macroinvertebrate fauna was very poor. Sections above the mahoe gorge become choked with gorse and monkey musk and generally rapidly decrease in water habitat.

Photo 9-27 Upper reach of the un-named Porirua tributary. Note deeply set stream with full canopy cover, heavy mahoe litter and small flow.

Table 9-7 Stream Flow summary

Stream System	Mean discharge (l/s) (*from Healy 1980*)	Linear length (km)	Catchment size (ha)
Horokiri (west)	848	47.6	1,518
Ration	126	19.4	617
Pauatahanui	939	149	4,225
Te Puka	100*	3.1	314
Duck	232	7.2	1,037
Canons Creek		3.6	390

*= Estimated on site by crude methodology at one time.

4.2 PHYSICAL HABITAT QUALITIES OF SPECIFIC AREAS OF INTEREST

Appendix 9.C presents the basic physical habitat parameter data in the SEV work sheets as well as other data collection systems.

4.2.1 CHANNELS

The average stream width and depth as measured from the geomorphological studies of three 500m reaches in the Te Puka and Horokiri systems are shown in Table 9-8. Other measures noted come from the SEV data collection system.

Typically upper reaches of the main stems of the waterways in the catchment have wetted channel widths that range from 1.5 to 3m wide. The channel and wetted width occupies, where in run or riffle habitat types, around 50% of the flood channel as defined by a significant bank structure (over 1m in height). Pools, chutes, falls and cascades typically are bounded by bed rock, large boulders or deep cut “gorge” like banks and often occupy 90-100% of the “flood” channel.

In middle stream reaches the average width of the wetted channel increases by around 0.5m, while at the lower reaches, approaching tidal areas, the streams expand to 3 or 4m (such as at the logger sites in the Pauatahanui Stream and Duck Creek). However, in these lower reaches the flood plain expands to over 100m wide (actual measures made of 100m-160m).

Duck Creek follows the same pattern as the Horokiri and Te Puka, ranging from 0.8m to 1.8m wide in the middle and upper section but expands to 2-3m in the lower sections (the golf course). Ration, Cannons and Kenepuru are even smaller and typically have a channel range of 0.5m in the upper reaches to 2m in the lower reach.

Te Puka Stream is unusual in its structure from the other streams of the project area in that it has a number of expanded multi-channel areas leading to wetted widths of 4-6m in a flood plain up to 20m wide. These areas are technically braids through a cobble gravel river bed.

Table 9-8 Averaged basic stream water parameters.

Middle Horokiri				
Micro-habitat	**Average depth (m)**	**Max depth (m)**	**Proportion wet**	**Wetted Total (m)**
Run	0.11	0.24	36.20%	3.22
riffle	0.10	0.16	44.99%	2.60
pool	0.39	0.67	49.78%	2.13
Upper Horokiri				
Run	0.14	0.09	44.65%	1.7
pool	0.35	0.25	55.26%	2.1
cascade	0.17	0.05	91.18%	3.1
Middle Te Puka				
Step/Riffle	0.19	0.11	41.11%	3.7
Run/Riffle	0.11	0.06	45.19%	6.1
Run	0.12	0.06	31.67%	1.9

Depth profiles are similar throughout the seven waterways. Upper reaches have between 0.1 and 0.2m of water averaged across the channel. A typical profile is either a graduated depth increase such as in the Te Puka and middle Horokiri either there is a beach of flat gradient dry bank and the waters depend from 0.0 to the centre at around 0.2m and again shallows to zero. Or as is the case in the middle-upper Duck and Pauatahanui streams the banks on the wetted channels are abrupt and the water depth is immediately 0.2-0.3m deep and is generally uniform across the channel. Riffles and cascades are typically the shallowest habitat averaging 0.1m; runs have a greater range 0.1-0.2 to 0.3-0.4 (in the lower reaches). Pools contain the deepest water habitats and averaged 0.3-0.4m in the middle Te Puka and Horokiri systems (the deepest pool encountered was around 0.7m)

4.2.2 VELOCITIES

Velocities varied generally between 0.3 and 0.7ms-1 for lower, middle and upper reaches. Table 9-9 shows the averages recorded from the various habitat types within the geomorphological reaches. Measures from the SEV data collection ranged from 0.3 through to 0.5ms-1 with the median velocity being 0.33ms-1. Typically these streams are relatively slow moving with only moderate velocities (0.3-0.4ms-1) rising at infrequent and small intervals to 0.7ms-1 at features such as a cascade, chute or other drop feature. The Te Puka stream has the highest general water velocity and highest specific velocity reaches. Several cascades and chutes in the upper Horokiri also have twice to three times the average stream velocity, but all are within native climbing fish tolerances given the physical habitat type in which these occur.

Table 9-9 Typical habitat velocities

Middle Horokiri		Upper Horokiri		Te Puka	
Micro-habitat	**Average velocity (m/s)**	**Micro-habitat**	**Average velocity (m/s)**	**Micro-habitat**	**Average velocity (m/s)**
run	0.36	run	0.23	step/riffle	0.30
riffle	0.68	pool	0.29	run/riffle	0.49
pool	0.43	cascade	0.44	run	0.26

4.2.3 SUBSTRATE

As with most Wellington coastal streams the streams of the project area are hard bottomed streams. Generally this means a range of cobble sizes and gravels and pebbles with some bed rock. High sediment, sand and clay beds are very uncommon and typically, in the region, not natural but a result of a cobble base inundated from land based disturbance generated sediment. The Cannons and Kenepuru middle and lower sections have soft substrate beds that are the results of land use patterns causing large scale sediment covering of the once cobble beds. Ration Stream, in the main stem, also shows a high sediment coating and embeddedness where typically 50% of the bed has a soft substrate layer over a cobble bed.

The Ration, Horokiri, Pauatahanui and Duck waterways all have a sandy lower reach component to their main stems, a factor of the tidal nature of these lower reaches.

The middle and upper reaches of the Horokiri, Te Puka, Duck (and Pauatahanui) systems are however, predominantly hard and cobble. Measures from the geomorphological surveys illustrate that in general the bed of these streams has a cover of 35% large cobble, 35% medium cobble, 20% small cobble, 20% pebble, 15% gravel (although pockets can dominant small slow flow areas in the lower middle reaches), and 15% sand[7]. In general the bed coverage is a complex of variously sized cobbles showing a normal but complete set of boulder to sand eroded profiles. Sediment was infrequently recorded and the bed habitat can be considered a diverse benthic substrate habitat.

[7] Note a greater than 100% cover is possible as gravels and sands were measured irrespective of the potential for large cobble to generally cover the obvious upper surface.

Where boulders occur they dominate the substrate; however, they only occur in a few specific habitat types (typically cascades, stepped pools, chutes and falls). Bed rock was very infrequently encountered.

Figure 9-5 shows the averaged proportional bed cover representation of each substrate type from the total samples for each of the three river types surveyed. The standard deviation error bars show the variability in cobble cover; generally however, the dominant cover falls between the three cobble size classes (large-small) with an underlying pebble structure.

Figure 9-5 Average cover (%) of substrate types in main waterways (error bars one standard deviation).

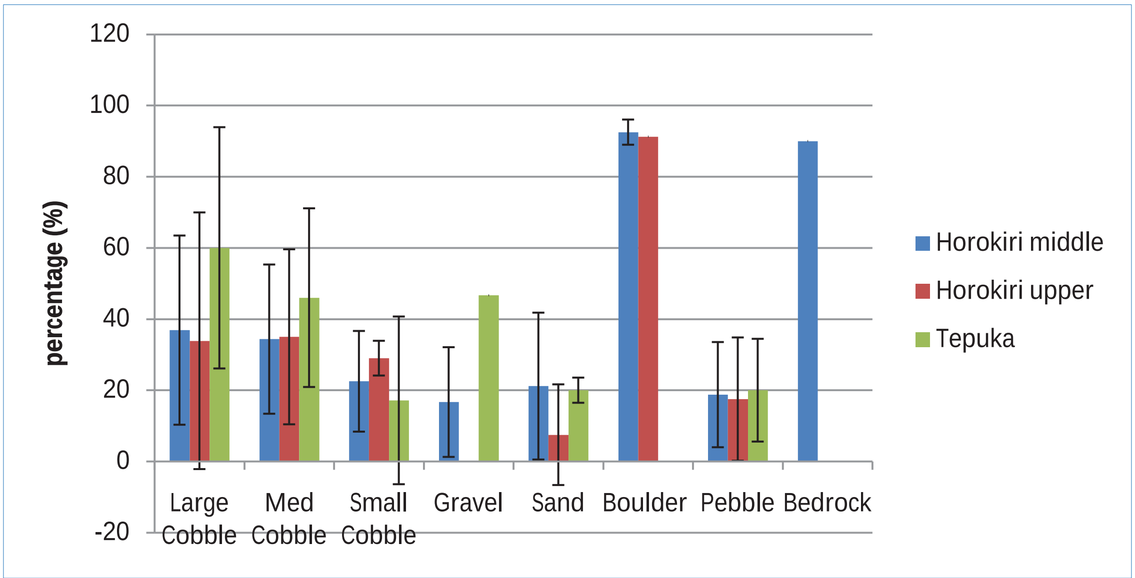
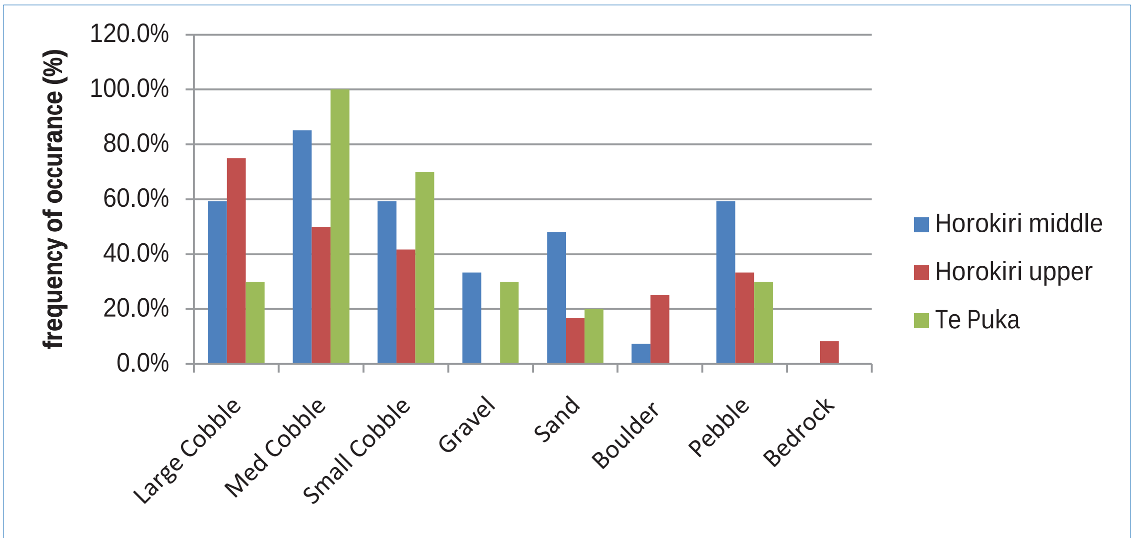


Figure 9-6 is a plot of the frequency of occurrence of different substrate types in the samples and indicates the chance of finding a specific substrate type at any one location on the Horokiri or Te Puka streams. In Te Puka medium sized cobbles are most commonly encountered with a regular decrease in frequency of medium to small cobble to pebble and finally sand. This would appear to be a good example of a reasonably uniform substrate degradation pattern. In the main this is the pattern for all of the four largest waterways in the project area.

Figure 9-6 Frequency of occurrence (%) of substrate types

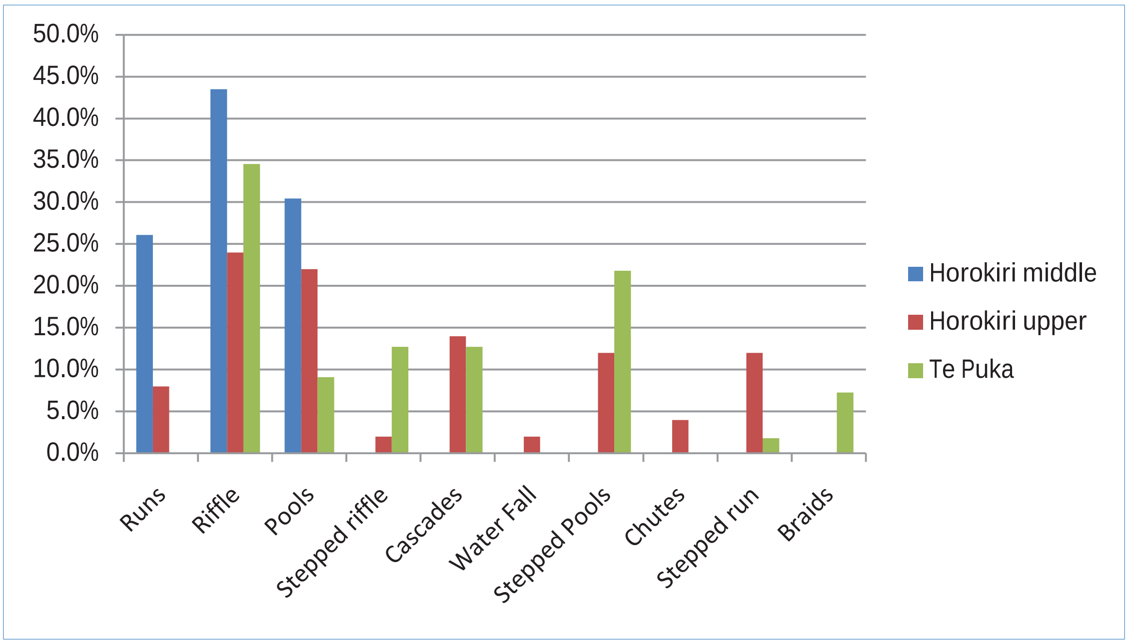


4.2.4 REACH HABITAT TYPES.

The various reaches of the various streams encountered had a variety of water habitat types. Most common are the "standard" run, riffle and pool types. In addition there are cascades, chutes and waterfalls, but also hybrids such as stepped pools (a descending series of small pools (1m by 1m) that over one metre by way of a steep riffle pass from one pool to the next and this series may occur over 20 or 30 or more metres. Similarly there are stepped riffles and stepped runs.

Figure 9-7 plots the frequency of occurrence of these features as measured from the 1.5km of reach measured in the Horokiri and Te Puka systems. The point of note is that the Te Puka system has a more diverse and complex set of water habitat types. The Horokiri middle reaches are made up, by and large, by riffles, pools and runs. Whereas the Te Puka system also has the more complex stepped pools, stepped riffles etc. The upper Horokiri includes one off examples of a chute and a waterfall and included cascades; however, in the Horokiri upper reaches these were narrower, defined boulder cascades unlike the wider, less defined cascades of the Te Puka.

Figure 9-7 Frequency of occurrence (%) of each habitat type from a 500m reach

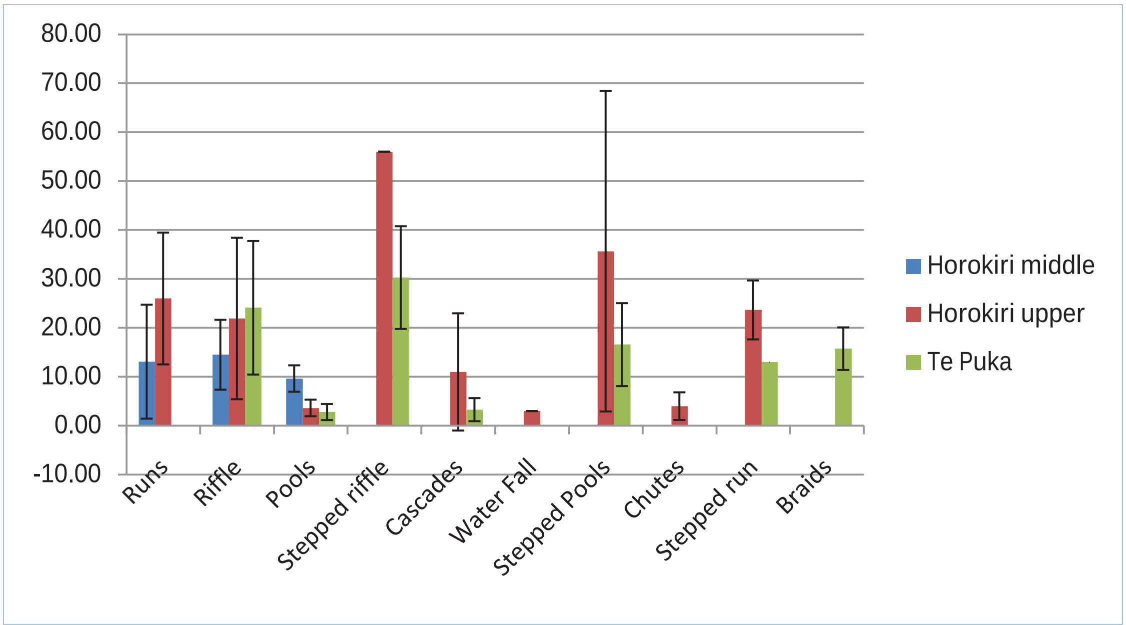


In the lower reaches, all of the main stems of the 5 larger streams (i.e. Te Puka, Horokiri, Ration, Pauatahanui, Duck,) reduce to runs and pools (largely expanded slower runs reaches).

Each 500m reach surveyed had around 50 habitat units (as seen in the data in Appendix 9.C). Of note was that over the 500m, this number of units was similar in each of the survey areas. Each unit was typed and its length measured until the unit type changed e.g. until a run changed to a riffle. Figure 9-8 plots the average length of the habitat types along a typical middle and upper reach. In the Horokiri middle reach, runs and riffles are typically 15m long and pools are long at around 8m. In the upper reaches the diversity increases and stepped pool and stepped riffles habitats persist over relatively long distances (35-50m). (These are excellent stonefly habitats). Pools are typically less than 5m long while runs and riffles are also typically over 20m. The upper reaches while having a wider number of habitat types have generally longer linear lengths of any one type than the middle reaches.

In the Te Puka Stream stepped riffles are typically 30m long with other habitats typically 15-20m long. A braid habitat is actually a parallel set of riffles.

Figure 9-8 Average linear length (m) of aquatic habitat types



4.2.5 RIPARIAN CONDITION

Most of lengths of stream in the seven catchments have no or little indigenous over reaching (shading) riparian vegetation. Most commonly, riparian vegetation consists of a mixture of short and long grasses with various native and exotic shrubs and pine plantation. The lower reaches of all of the streams are in urban or production landscapes with predominantly managed grass edges and exotic trees.

Riparian stream vegetation consists of:

Te Puka Stream

Te Puka Stream has around 5.5km of stream from its headwater tributary to the coast. Below State Highway 1, the land is urban and pastoral use and the stream entirely modified. Above the State Highway, the stream bed and flow path is relatively natural and remnants of the natural riparian cover persist; however, for the greater length, native riparian cover is limited. The upper headwater, however, has an entirely native and full riparian cover. This linear length is around 1.1km (20%).

Below the forest cover is a farmland reach which is a generally open, sometimes braided, section. While having steep slopes vegetated to the north (either in kohekohe coastal forest or, lower down pine) and occasional clusters of shrubs and trees, this is largely open gravels or has a riparian edge of long grasses .The length of this riparian cover type is around 1.5km or 27%. There is a further 1km (20%) of the stream with a loose or close native shrub and secondary forest tree cover either on one or both sides (such as the lower Te Puka gorge). Half of this is also surrounded by plantation pine, offering strong riparian influence. Around 200m of the stream has a pine tree riparian influence. Below the SH, 900m (16%) of the stream has no riparian cover (short grass), 250m (4.5%) has a loose treeland (exotic), and a further 300m (5%) has a dense canopy made up of exotic, mixed species, forest cover. In general then, 40% of the Te Puka Stream maintains some native functional riparian cover; some 40% is without functional riparian cover and 20% has an exotic functional riparian cover.

Horokiri Stream

Horokiri Stream is a long system of around 13.8km. Approximately 8,400m of this is in pastoral grasses, either rural or semi-rural (life style), making up around 61% of the riparian influence. A further 3,400m (25%), predominantly in the lower reaches (below the Battle Hill Regional Park), has a riparian cover of mixed density and mixed-species exotic treeland. Only around 1,800m (13%) of the system has a loose, native shrub (mahoe, *Pseudopanax* sp, tauhinu) riparian influence and this primarily in the middle reaches, in the rural land in one more or less continuous band. Some 200m of the tidal area has a salt marsh riparian edge. The predominant influence on the stream in this catchment is pasture, stock and tauhinu shrubland covered hill slopes.

Ration Stream

Below the proposed alignment route, 300m of the lower Ration Stream is in oioi/wiwi salt marsh, 250m is in open grass land, 810m is in exotic woodland cover (from dense canopy to scattered), and 1.5km of pine plantation/ exotic shrub cover. Through the alignment, the riparian cover is 300m of grassland, and 60m of shrubland/wetland. Above the alignment, the cover is 200m of shrub/wetland, 200m of grassland and 600-900m (depending on the headwater reach) in pine plantation.

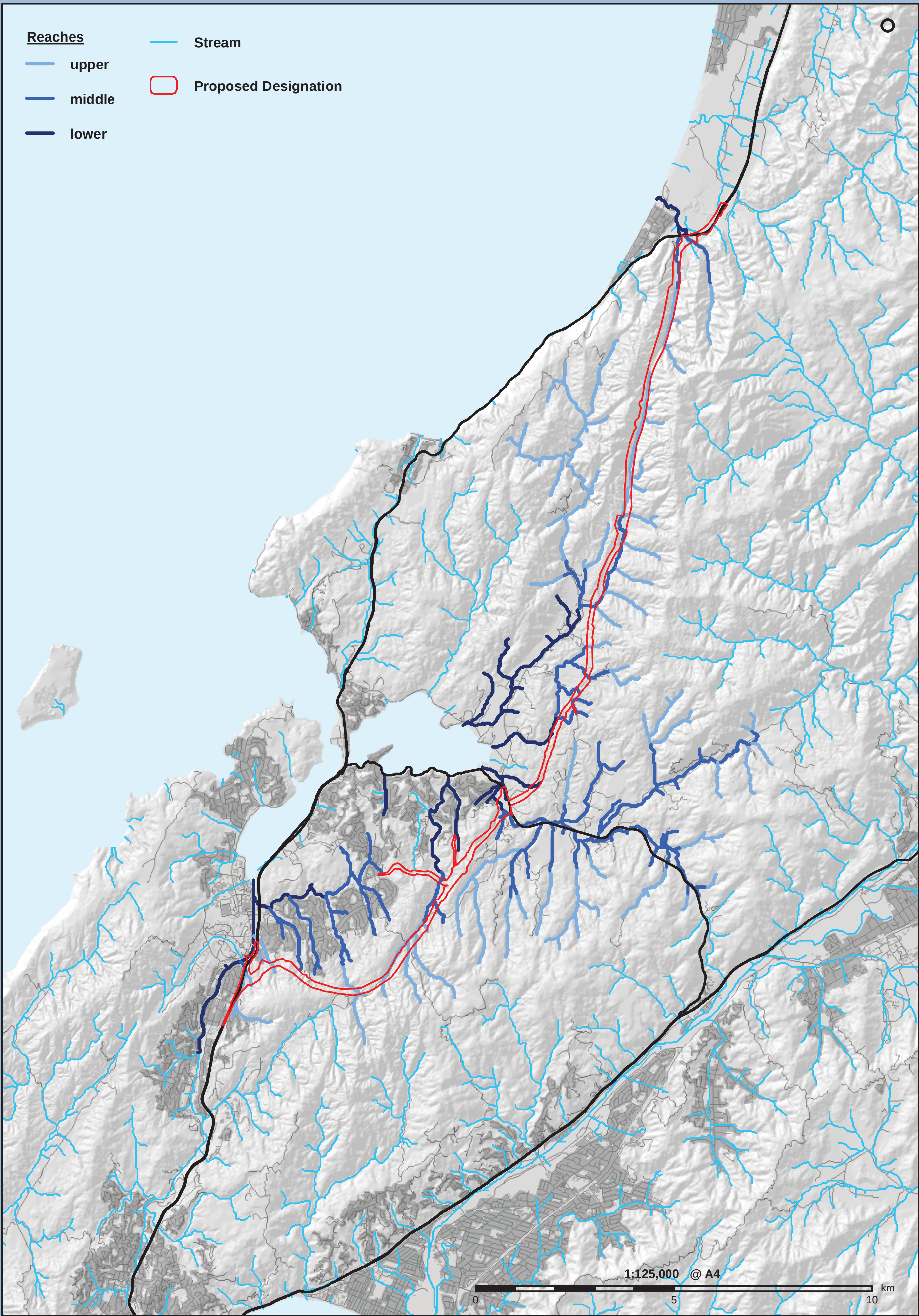
Of the approximately 4.5km of the main stem of the Ration Stream some 53% of the riparian cover is pine plantation involving exotic shrubland/vineland and pine trees, 20% is exotic treeland (shelter belts etc) including poplar, oak etc, around 17% is open pasture and 6% salt marsh; the remaining 4% is a mixture of shrubland/wetland.

Pauatahanui Stream

Pauatahanui Stream has only been considered in the downstream section from the road crossing. This encompasses 2.2km of waterway. 1000m of this system (45%) is in open pasture grasses and has no over-arching riparian influence; 900m (41%) is in mixed exotic treeland and shrubland, with groups of willows, oaks etc and exotic (primarily) and native shrubs forming an influential but incomplete riparian cover. The lower 14% (300m) of the river is within an oioi salt marsh.

Duck Creek

Duck Creek main stem system is approximately 8km long. Like the Horokiri it has little remaining native riparian cover but this is remnant / regenerating native shrub and secondary (mahoe) forest at the intermittent headwaters, which extends for about 900m (8.5%). In the middle reach is a steeper-sided gorge-like reach which is ex-pine plantation. This area (some 1,800m or 20%) is a mixture of shrublands with exotic and native components as well as wild herbaceous areas with long (rough) grass. The middle to upper reaches is dominated by rough pasture grasses (some 2,000m or 22%). The lower reaches (the flatter lowland slopes) are a mixture of rough pasture and treeland over pasture through the golf course. In this lower area there are around 1,800m of rough pasture, and 950m of treeland with 100m in native sedgeland and a further 100m in pockets of mahoe. In total, around 50% of the main stem has a rough grass riparian influence, 12% has a treeland influence, 11% has a native canopy secondary influence, 25% has a mixed shrubland influence, and 2% is salt marsh and 1% native sedgelands.



Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

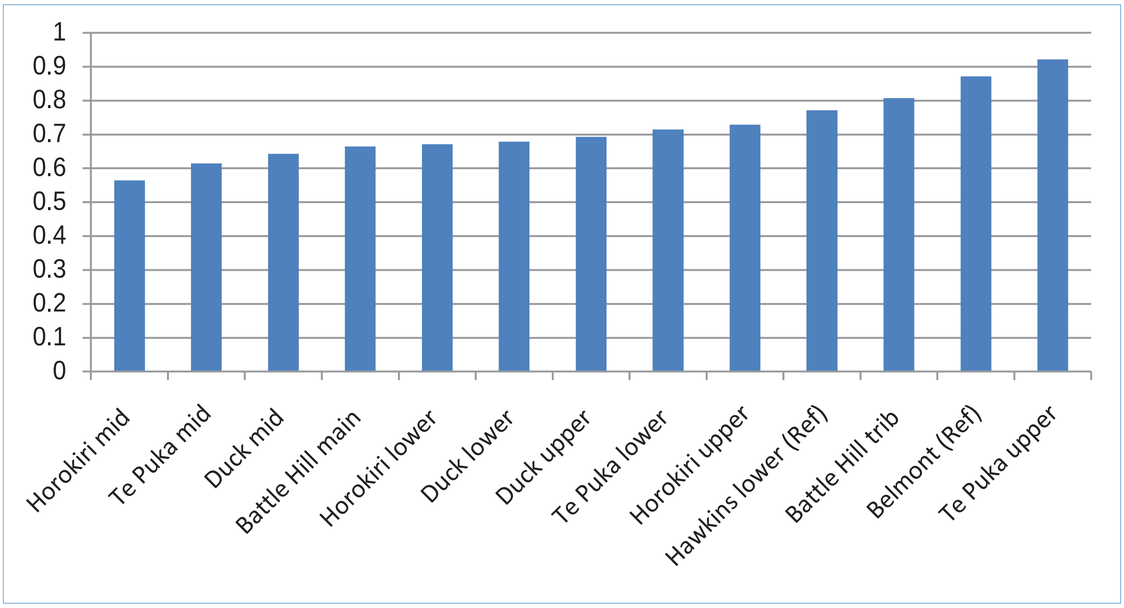
AQUATIC HABITATS

4.2.6 PHYSICAL HABITAT ANALYSIS (PHA) SCORING.

Combining the measures and observations to form the aquatic habitat score for 12 of the sites on three of the main waterways results in the outcome shown on Figure 9-10. The field records and calculation of aquatic habitat score are set out in Appendix 9.C. The PHA scores reflect a level of disturbance and are loosely correlated with Habitat "type" as modification tends to be in the lower to middle reaches before the lowest and upper most reaches. The PHA scores reflect that the lower-middle reaches are most modified.

All surveyed sites score over 50% of their maximum potential. Scores generally are high at typically over 60%, for rural and urban land use pattern catchments. The Te Puka upper site, predictably, was near the maximum score and certainly represents the natural case for a pre-development headwater stream. The three reference sites (each of which show levels of modification and effects of wider land development) were more than 75% of their possible maxima. All other surveyed and potentially affected sites were between 55 and 75%. Of some note is that it is typically the middle reaches and not the lower reaches that are in the poorest condition relative to the reference sites or maximum score possible.

Figure 9-10 Physical Habitat Assessment scores (Maximum score = 1)



4.3 WATER QUALITY

This section provides comment on the ecological aspects of the SKM water quality report findings (See Appendix 9.B). While SKM sampled the same streams as are addressed by ecological investigations, the sampling sites were not always the same. However, these differences were reviewed and considered to not affect the ecological findings or assessment. The potential effects of changes in water quality are discussed in the AEE.

4.3.1 HEAVY METALS

Grab sample results

Understanding levels of heavy metals in freshwater is important because heavy metals can be both acutely and chronically toxic to fauna.

Total and dissolved arsenic, cadmium and nickel from all sample sites were always below ANZECC guideline concentrations. Chromium and lead concentrations, however, were occasionally above guideline values at some sites, but this was usually the total rather than the dissolved concentration. Copper and zinc concentrations at above guideline levels were noted within all catchments. Exceedences tended to occur more frequently at downstream sites and usually were for total rather than dissolved concentrations.

The dissolved fraction represents a greater risk than the total in terms of ecological impacts as it relates to the more bio-available metal fraction. Therefore, poor water quality and risk of toxicity effects on aquatic organisms is better highlighted by exceedences of dissolved metals in relation to guideline values.

There were particularly high dissolved concentrations of Zinc at both Porirua sites (Cannons stream) and Total Copper was above the guideline value at a number of sites (Kenepuru, Cannons Duck, Pauatahanui, Ration, Horokiri, Wainui). Particularly high Dissolved Copper concentrations were often sampled at Kenepuru and the Porirua sites (Cannons Creek) and there was one exceedence at a lower Duck Stream site.

Automatic sample results

The quality of 'first flush' and 'composite' samples were generally different and in some instances the 'first flush' had higher contaminant loadings. This is likely to be due to the nature of the source of the metals in the catchment (i.e. roads, storm water, sediments etc.) and is an expected result.

SKM found that data collected by automatic samplers had higher dissolved and total metal concentrations on average than in grab samples. Contaminant load was found to vary significantly over the storm event. Median Total and Dissolved Zinc concentrations for Horokiri were below guideline levels, while total and Dissolved Copper at Horokiri was above guideline values.

There are, in most catchments, Copper and Zinc contaminant levels of note and contaminant levels of biological concern in the Kenepuru, Cannons, Pauatahanui and lower Duck and Horokiri systems.

4.3.2 NUTRIENTS

Nutrient levels are important in freshwater systems because at raised levels they lead to excessive growth of plants, many of which can be unwanted organisms (e.g. periphyton). Over a longer time period changed nutrient levels cause changes in the food web of a freshwater ecosystem and can affect plants, animals, communities and habitats.

Nutrients, as indicated by Total Nitrogen and Total Phosphorus, were often elevated above the guideline values. In both 'dry' and 'wet' sample events almost all catchments had median Total Nitrogen and Dissolved Reactive Phosphorus concentrations above ANZECC guideline values. Again Kenepuru, Cannons and Pauatahanui stand out as most enriched.

Apart from the natural/background level of phosphorus and nitrogen in soils, levels can be elevated by addition of fertiliser on farm land.

4.3.3 TURBIDITY

Turbidity levels are important in freshwater systems because high levels of sediment in water can reduce light levels reaching plant and thus reduce photosynthetic activity as well as smother animals.

Total Suspended Sediments and Turbidity data were collected in grab samples and by automatic samplers (fixed position data loggers) in the Horokiri, Porirua and Pauatahanui catchments. These loggers had been sampling for over 6 months.

Generally concentrations of both TSS and Turbidity increased with storm rainfall intensity and stream flow. Flows between 2 and 8 cumecs resulted in a generally linear increase in TSS. The measures illustrate that those three main streams often rose to TSS of 300 g/m^3 (between 250 and 350 NTU). The largest recorded result was 1400 gm^3 when flows were around 9 cumec.

The data loggers showed that between January 2010 and May 2010 13 events raised the levels of TSS in Horokiri Stream (measured at Horokiri -west) over 200 gm^3, the largest at around 900 gm^3. Horokiri east (main stem) had at least 21 events over 200 gm^3, two of which were over 1000 gm^3. Both these catchments are predominantly rural sheep and beef farming. The logger in the Pauatahanui lower reach recorded less extreme TSS conditions with 11 events over 40 gm^3 and the highest TSS recording of around 130 gm^3. In Duck Creek there were 23 events over 50 gm^3, four events over 200 gm^3, and the largest event was near 400 gm^3.

The TSS data gathered so far suggests that all of the streams in the project area experience a number of raised TSS conditions throughout each year. In the Horokiri Stream, events can be very large (>1000 gm^3) and quite frequent, whereas in other catchments events are more typically 50-100 gm^3.

Table 9-10 Summary of turbidity recordings

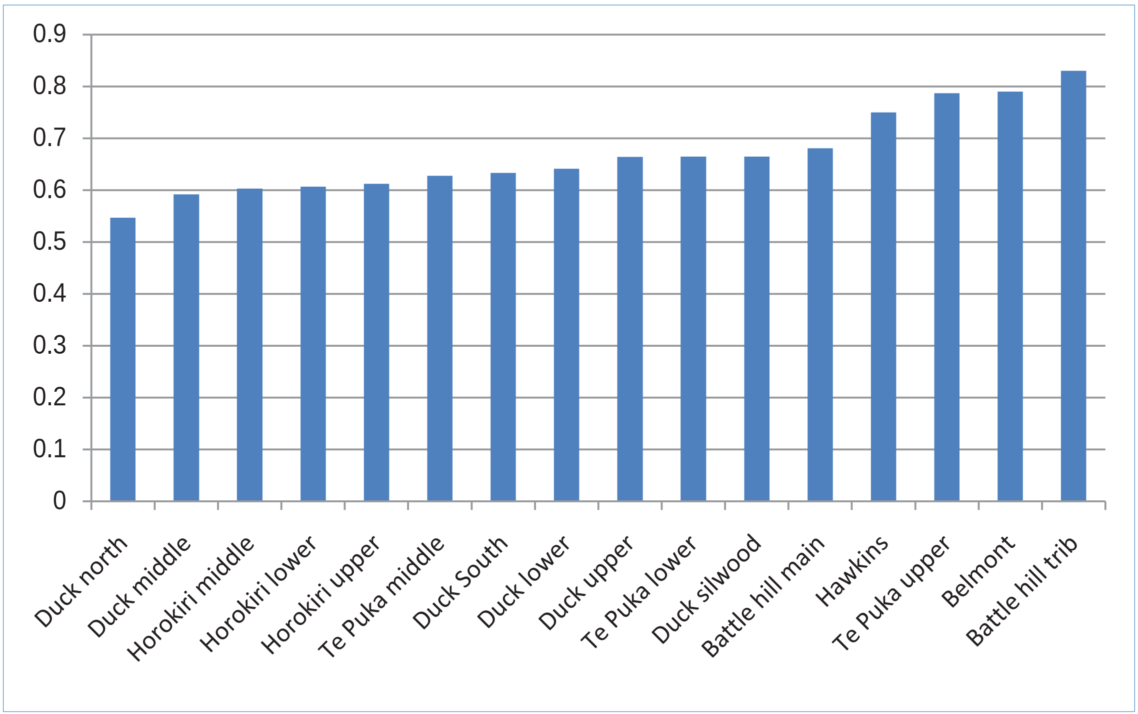
Site name	Data length	Turbidity (NTU)	
		Mean	Median
Duck 2	28/10/09 - 22/7/10	8.9	7.3
Horokiri 3	22/12/09 - 13/7/10	12.2	4.2
Horokiri 4	11/12/09 - 13/7/10	13.6	5.7
Pauatahanui 2	18/11/09 - 28/7/10	24.3	2.8

Ration stream showed very high (and the highest) Suspended inorganic sediments

4.4 STREAM ECOLOGICAL VALUATION (SEV)

Summary SEV analysis sheets are provided in Appendix 9.J and shown in Figure 9-11 below.

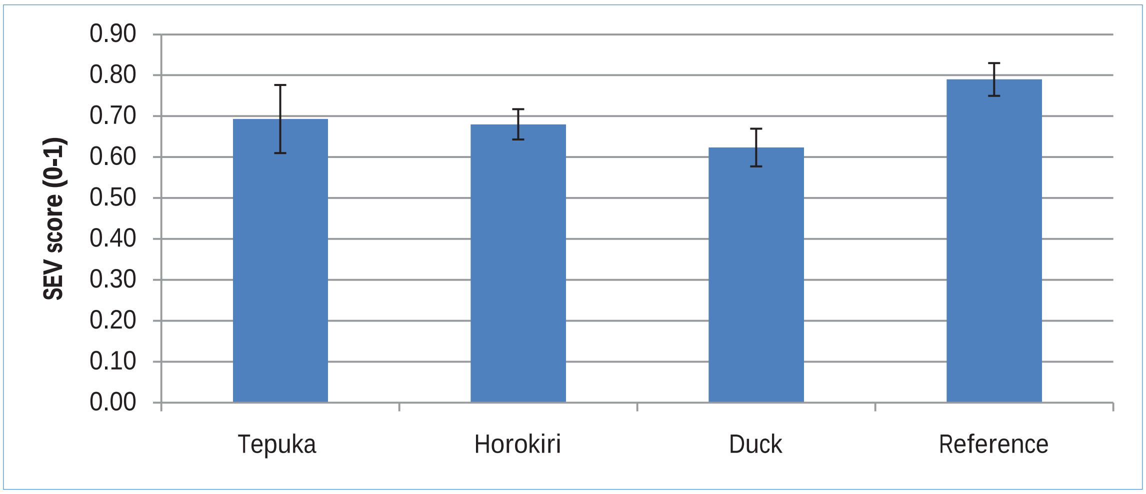
Figure 9-11 Calculated total SEV scores (reference sites = Belmont, Te Puka upper, Hawkins)



SEV scores across the general sample sites of the three main affected catchments (Te Puka, Horokiri and Duck) ranged from 0.547 to 0.681 with the reference sites (Belmont and Battle Hill tributary) scoring between 0.75 and 0.83. It should be noted that the upper Te Puka also falls into the 0.75-0.83 range.

The average SEV scores for each of the main affected catchment streams (Te Puka, Horokiri and Duck) as well as the reference sites are shown in Figure 9-12 (Error bars are one standard deviation of the mean). The reference sites' average is likely to be statistically significantly higher than the affected catchment streams, Te Puka's average being greatly boosted by the one upper headwaters site which is of high enough quality to be considered as a reference site.

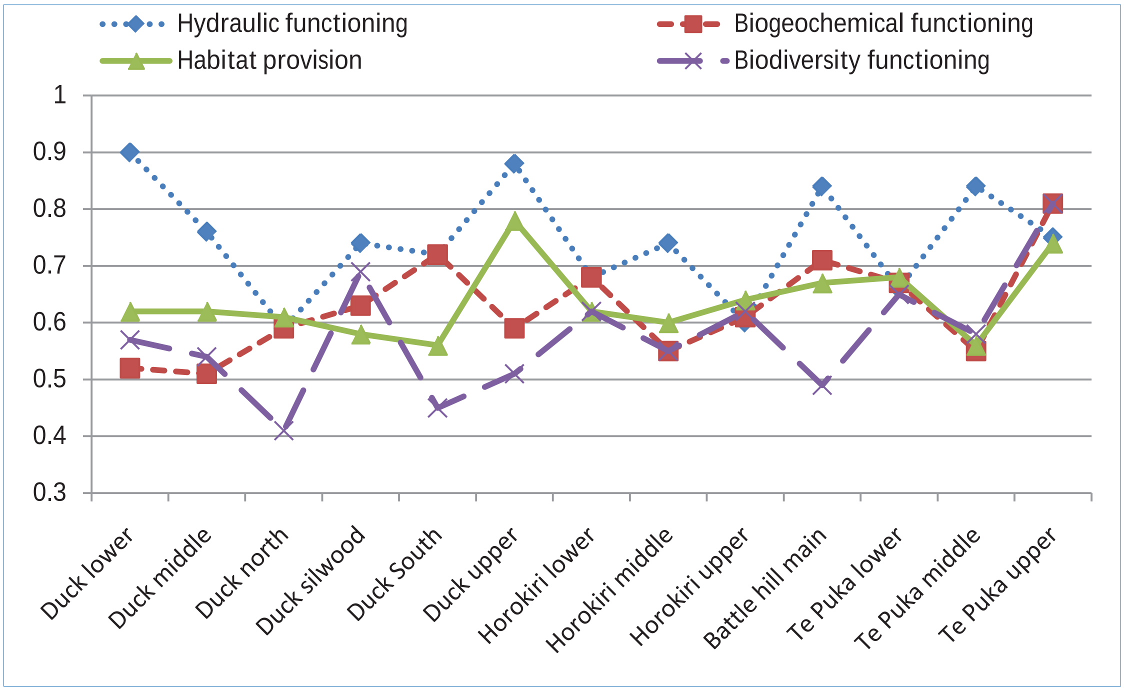
Figure 9-12 Catchment average SEV scores



Examination of the four principal SEV factors (hydraulic function, biogeochemical functioning, habitat provision and biodiversity function) illustrates, across the surveyed sites, the variations in scoring for these attributes. Figure 9-13 shows the pattern of these four variables ranked from low to high. The individual functions are plotted separately in Appendix 9.J.

Biodiversity functioning was the poorest scoring factor with several sites scoring below 0.5. The lowland reaches of Duck and Horokiri where poorest in respect to biodiversity function followed by other Duck sites and middle Horokiri sites. Unusual was that the Duck Stream at Silverwood site scored significantly differently and higher than the other Duck sample sites. The reference sites scored highest with Te Puka upper and Duck Silverwood the best “affected” stream reaches. With regard to habitat provision, there are three general bands: the lowest value sites (<0.6) are the middle reaches of the Te Puka, Horokiri and two of the lower Duck sites. An apparent contradiction between the biodiversity function and habitat provision is the low score of habitat provision at Duck Silverwood against the high score of biodiversity function. The highest values (>0.7) were the reference sites and Te Puka upper.

Figure 9-13 SEV factors at each reach (y axis 0-1)



Generally biodiversity function factors are drawing down many of the sites in their total SEV score while, and often at odds with other scores, it is the hydraulic score that is driving total scores upward. This is especially so for Duck lower (a middle-lower reach) and Duck upper, Te Puka middle and Battle Hill main. Without these apparent anomalies in hydraulic function, most sites would score far below the reference sites (and the upper Te Puka) and form a more regular pattern, of increasing “value” from lowland to middle reaches.

4.5 FRESH WATER FISH

4.5.1 FRESHWATER FISH DATABASE (FFDB)

Prior to this survey, the **Horokiri Stream** had been sampled on 25 recorded occasions between 1962 and 2005 (NIWA, 2007). Nineteen species, including koura, had been recorded, the maximum on a single occasion being 13 species in 1962. No acutely threatened species have been recorded. Chronically threatened species previously recorded were lamprey (recorded on seven occasions), giant kokopu (recorded on seven occasions), and long fin eel (recorded on twenty occasions). An “at risk” species (short jaw kokopu) was recorded on one occasion.

Sites on the **Te Puka Stream** had been sampled twice, in 1989 and 2002, with four fish species (shortfin and longfin eel, banded kokopu, and redfinned bully) plus koura being recorded. The only threatened species in this stream was longfin eel (chronically threatened).

Duck Creek had been sampled on nine occasions between 1983 and 2005. Ten fish species (no koura) were recorded, with a maximum of seven species being recorded on two occasions. No exotic fish species or marine wanderers (such as mullet or flounder) had been recorded. Three chronically threatened species were recorded, with those being lamprey (recorded on one occasion), giant kokopu (three occasions), and longfin eel (seven occasions). No acutely threatened or at risk species were recorded.

Note that the Freshwater Fisheries Database (FFBD) records include sample sites along the full length of these catchments from the stream mouths at Pauatahanui Inlet to their headwaters. A number of species such as marine wanderers would not occur in the mid and upper stream reaches sampled in this study. Table 9-1 lists distance from sea for each sample site.

4.5.2 TGMAP INVESTIGATIONS

General

Seventeen species of fish have been recorded in the FFDB from the seven catchments of the project area (Table 9-11). Four of these species are typically found in the lowest reaches (smelt, flounder, mullet, triple fin) and are often associated with tidal parts of the habitat as well as the lower freshwater. They were not been targeted by the sampling regime for this project and are assumed to be present permanently or periodically in all of the tidal reaches of the streams of the study area. Of the remaining 13 species, the sampling programme for this project has recorded nine. Those not recorded by EFM sampling were lamprey, torrent fish, shortjawed kokopu and giant bully.

Table 9-11 Fish recorded in project area

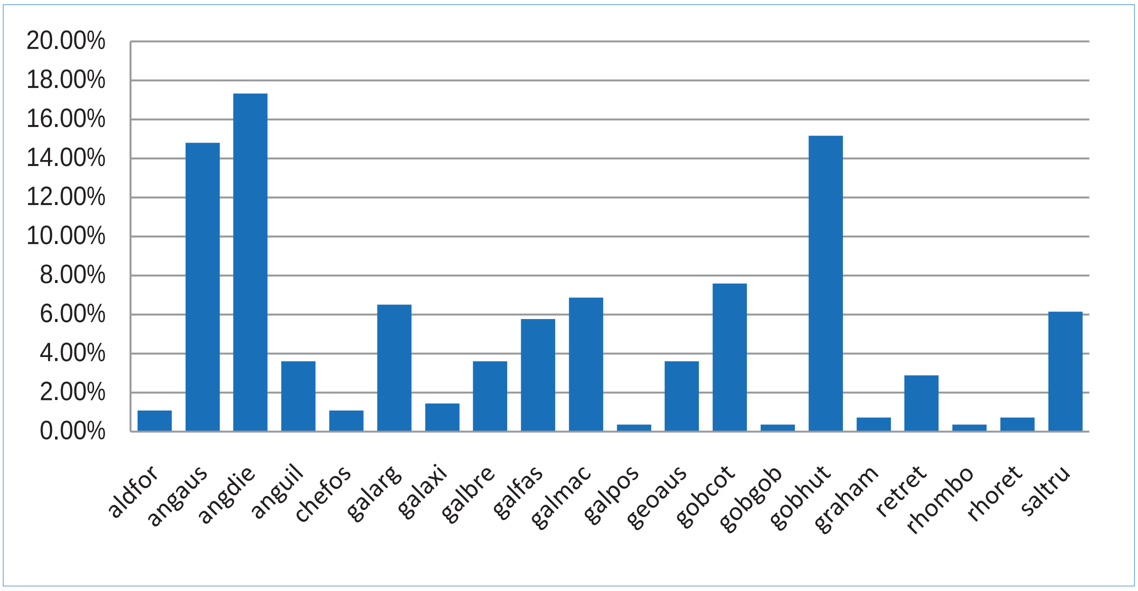
Technical Name	Common Name	Found in this study
Aldrichetta forsteri (tidal)	Yellow eye mullet	N(*)
Anguilla australis	Short fin eel	Y
Anguilla dieffenbachii	Long fin eel	Y
Cheimarrichthys fosteri	Torrent fish	N
Galaxias argenteus	Giant kokopu	Y
Galaxias brevipinnis	Koaro	Y
Galaxias fasciatus	Banded kokopu	Y
Galaxias maculatus	Inanga	Y
Galaxias postvectis	Shortjaw kokopu	N
Geotria australis	Lamprey	N

Gobiomorphus cotidianus	Common bully	Y
Gobiomorphus gobioides	Giant bully	N
Gobiomorphus huttoni	Red fin bully	Y
Grahamina sp. (tidal)	Estuarine triplefin	N(*)
Retropinna retropinna	Smelt	N(*)
Rhombosolea retiaria	Black flounder	N(*)
Salmo trutta	Brown trout	Y

(*) sampling typically not targeting these species and records therefore maintop recognise their presence.

Plotting the frequency of occurrence in the records of each fish species (Figure 9-14) shows that the two species of eel and red fin bully are, by far, the most frequently encountered freshwater fish. Lamprey, torrent fish, shortjawed kokopu and giant bully are infrequently found (that is, in less than 1% of records) as are the tidal species.

Figure 9-14 Frequency of occurrence of fish species in records



The focus therefore has been on middle and upper river fish to understand their distribution within the catchment and to understand any current and potential passage / barrier issues.

Table 9-12 summarises the number of fish taxa sampled at each site during project investigations, and ranked according to the allocated reach habitat type.

Table 9-12 Distribution of fish taxa across catchments

Site	Habitat	Number of taxa
Battle main	lower	4
Ration lower	lower	3
Pauatahanui	lower	8
Duck Nth	lower	8
Horokiri lower	lower-middle	3
Horo West-low	lower-middle	4
Horo East -lower	lower-middle	3
Duck lower	lower-middle	6
Duck Silwood	lower-middle	8
Duck Sth	lower-middle	9
Cannons lower	lower-middle	4
Kenepuru lower	lower-middle	2
Te Puka mid	middle	3
Horokiri mid	middle	3
Duck upper	middle	3
Cannons upper	middle	2
Cannons mid	middle	3
Kenepuru mid	middle	2
Battle trib	middle	5
Te Puka upper	upper	2
Te Puka lower	upper	3
Horokiri upper	upper	3
Ration upper	upper	1
Duck tribs	upper	5
Duck mid	upper	4

The species distribution data by site is provided in Appendix 9.F.

Table 9-13 Summary of species caught within each river system sampled by EFM.

Catchment	Fish species (with threat status indicated)
Te Puka	Koaro*, red fin bully*, long fin eel*
Horokiri	Banded kokopu, koaro*, red fin bully*, common bully, long fin eel*, short fin eel
Ration	Giant kokopu*, long fin eel*, short fin eel, white bait (?)
Pauatahanui	long fin eel, short fin eel, inanga*, common bully
Duck	Banded kokopu, koaro*, Giant kokopu*, Inanga*, red fin bully*, common bully, long fin eel*, short fin eel
Cannons	Banded kokopu, Giant kokopu*, Inanga*, red fin bully*, long fin eel*, short fin eel

*-"At Risk" (Townsend et al 2008) "Declining" (Allibone et al 2010)

Most of the galaxids and long fin eel and red fin bully present are recognised as "declining" species (Allibone et al 2010) meaning all of the streams carry "at Risk" species.

Some lower reach sites had the expected number of fish (less the tidal species and infrequent species) (i.e. 5-10). Duck Stream, in its lowest reaches in particular, had a relatively rich fauna. The summarised separated catchments fish fauna are shown in Table 9-13 against the FWDB fauna records.

Table 9-14 Comparison of FFDB and current fish sampling records

	Te Puka	Horokiri	Ration	Pauatahanui	Duck	Cannons	Kenepuru
Taxa sampled	3	6	4	8	11	6	2
Taxa FWDB less estuarine species	8	13	.	9	10	2	6
Percentage sampled of fauna recorded	37.5%	46%	.	88.9%	110.0%	300.0%	33.3%

The current surveys show that sampling in the Pauatahanui and Duck Streams has found all of the historically recorded species. In Cannons Creek and Ration Stream, new records have been added to the database. In Kenepuru, bully and inanga were not found. This is not considered to be an error or issue related to sampling methodology issue since bully are recognised as being sampled well by EFM.

Only half the species recorded in the records for the Horokiri were sampled in these surveys. The species not found, but historically recorded, included lamprey, giant bully, torrent fish and shortjawed kokopu, that is, those fish described earlier as very infrequent in the records. Setting aside the records for these fish (bring the expected total assemblage to 9, similar to the Pauatahanui and Duck Streams) the surveyed species are all those species recorded as typical. The species not sampled in the Horokiri were brown trout giant kokopu and inanga; all these are species generally able to be sampled by a backpack EFM, and all generally lower stream species.

Assemblage similarity across the Catchments

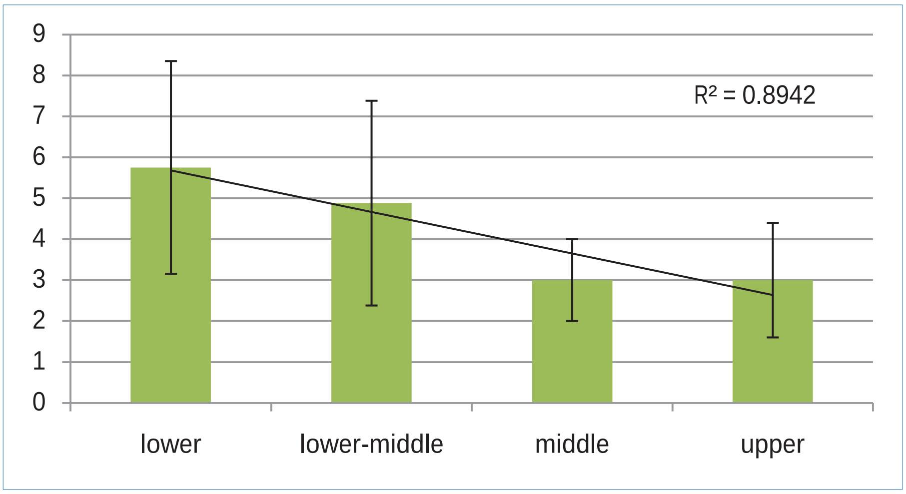
A similarity of fish faunal composition analysis was done using a Pearson correlation matrix working on species richness. This was assessed to determine if any reach or site stood out in any way from others (See Appendix 9.F). This analysis shows the proportion of the total possible similarities based on a correlation factor of > 0.7 – this figure was chosen since it was felt that a level of 0.7 similarity represented an appropriately high level. Five stream areas (Horokiri east lower, Te Puka lower, Cannons, Horokiri upper and battle main) have fish communities in common with over 25% of all sites; seven areas have assemblages of fish that are relatively unique, due largely to low numbers of taxa than having notably taxa, within the project area. Most sites are relatively dissimilar in their fish species fauna composition.

The Horokiri middle reaches are all very similar in respect of their fish assemblage (Horokiri East is very similar in species composition to, Horokiri lower, Horokiri upper, Battle Hill main stem) but also to Te Puka lower, Duck upper, Duck lower and others. Te Puka is very similar to Horokiri middle reaches and Kenepuru middle reaches. But the assemblages of the lower Duck sites, Pauatahanui, Ration, cannon upper and Kenepuru lower are all very different and typically either for the low diversity of fish or the very high diversity.

Habitat and Reach patterns

Using the site to habitat reach allocation described in Section 3 (Methods) a plot was done of average number of taxa by habitat reach (Figure 9-15). A regression line was fitted to the mean taxa richness and that fit showed a positive linear relationship ($r^2>0.5$) between fish taxa richness and distance from the coast.

Figure 9-15 Average species richness in four habitat reach types



The average middle reach in these catchments has less species than expected. The pattern of fish distribution inland however, does follow observations noted by Jowett & Richardson 1995[8] and supports the notion that there are two distinct fish communities: lowland and upland. Lowland communities typically contained the highest density and diversity of fish, whereas upland communities are often dominated by one or two species. Both Jowett & Richardson (1996) and Hays and Leathwick (1989)[9] have noted that the overriding feature influencing patterns of fish distribution is diadromy in the fauna with species varying in their ability to penetrate upstream. This is also the pattern for the major streams of this project area, especially the Duck, Horokiri and Te Puka.

4.6 AQUATIC MACROINVERTEBRATES

4.6.1 INTRODUCTION

The following results are set out as follows: species richness of the sites and streams and catchments are shown and discussed, followed by an examination of the mean richness by habitat reach type looking for patterns related to reach. The EPT taxa alone are examined as this group of taxa is a habitat quality indicator. Abundances are only discussed for the EPT groups as data is presented in terms of coded abundance[10] and there are recognised difficulties in interpretation of coded abundance that can lead to incorrect patterns and conclusion (Duggan et al 2003).

The MCI and SQMCI metrics are then examined, acknowledging that the MCI metric is influenced by the effect that rare taxa with sensitivity scores at either end of the spectrum can have, while the SQMCI suffers from the approximations associated with the coded abundance numerical partitioning. Using the MCI and species assemblages and the coded abundance, the interpretation of community sensitivity can be sufficiently made without the SQMCI.

Lastly this section looks at the species assemblages - the proportional make up of the communities, again avoiding the abundance data to the greater extent. A similarity matrix is used (from Pearson Correlation matrix on proportional taxa richness profiles per site) to establish how similar across

[8] Jowett, I.; Richardson, J. 1996. Distribution and abundance of freshwater fish in New Zealand rivers. New Zealand Journal of Marine and Freshwater Research, Volume 30, Issue 2 pages 239 - 255

[9] John W. Hayes, John R. Leathwick 1989. Fish distribution patterns and their association with environmental factors in the Mokau River catchment, New Zealand. New Zealand Journal of Marine and Freshwater Research, Volume 23, Issue 2 , pages 171 - 180

[10] “Coded abundance” means that ranges of richness are grouped and assigned a value for further analysis; for example 1 = 0-5 species; 2= 6-9 species.

the catchments and reaches the benthic communities are. This is repeated using the coded abundance data as much of the difference lies in the numerical proportional differences and not in the taxa present.

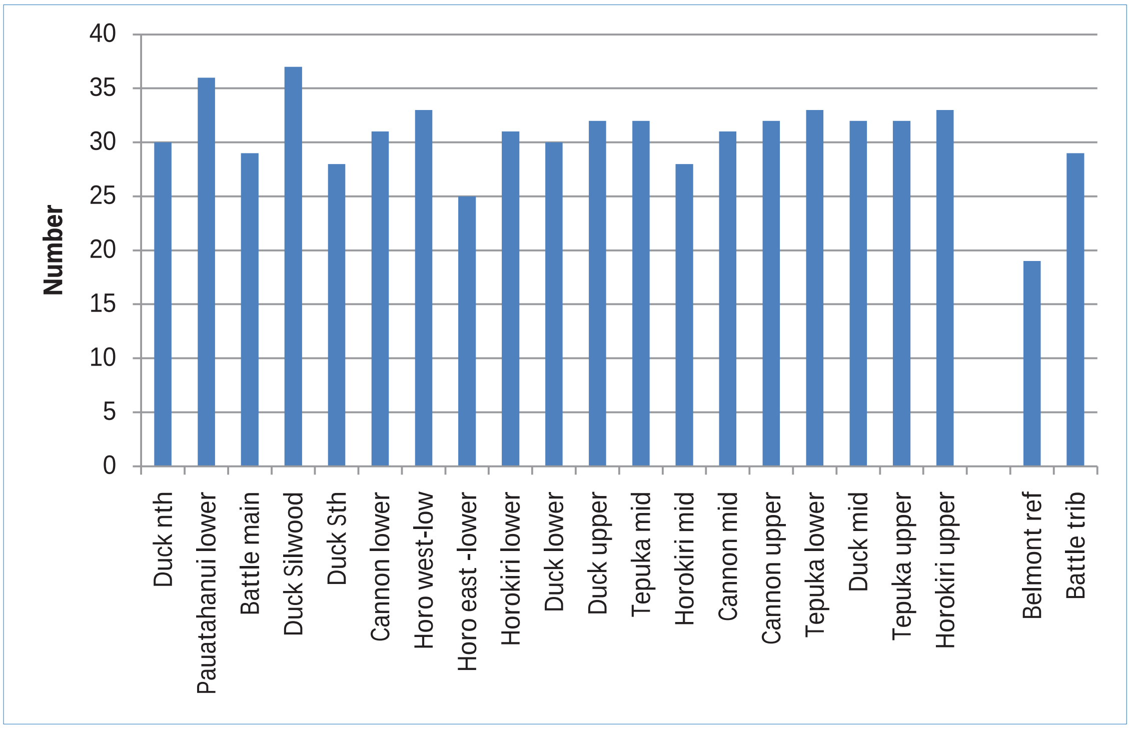
4.6.2 SPECIES RICHNESS

In total 81 different aquatic invertebrate taxa were sampled from the seven catchments of the project area. A range could not be identified to the species level, so that in practice, this section looks at "taxa richness". These are:

- 5 molluscs,
- 1 mite,
- 1 worm,
- 1 flat worm,
- 6 *Crustacea*,
- 1 *Lepidoptera*,
- 1 *Megaloptera*,
- 21 fly (*Diptera*),
- 1 *Neuroptera*,
- 2 *Odonata*,
- 4 beetle,
- 1 bug (*Hemiptera*),
- 6 stonefly (*Plecoptera*),
- 20 caddisfly (*Trichoptera*) and
- 10 mayfly (*Ephemeroptera*).

Sites returned consistently around 30 taxa across all of the sampling sites, (taking an average of the three samples). Figure 9-16 plots the average of the three samples per site. Of some note is that generally the surveyed project sites have greater taxa richness than the two reference sites.

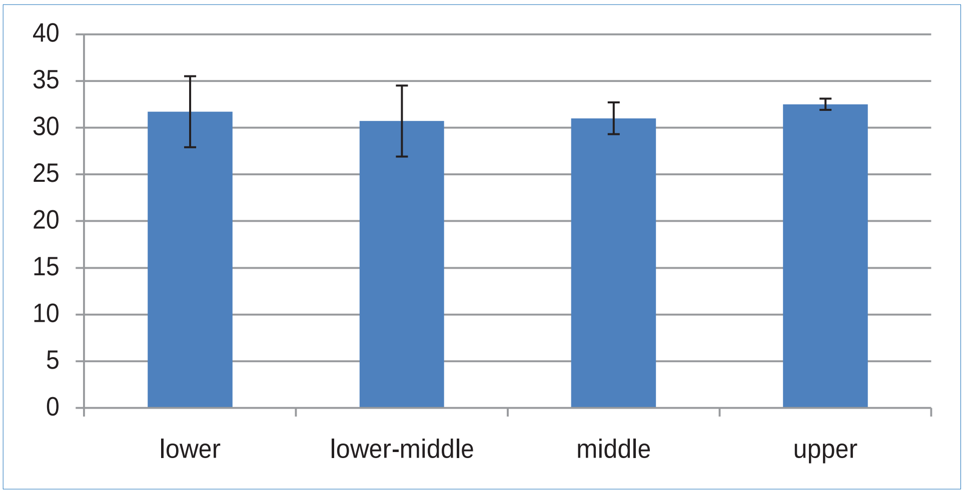
Figure 9-16 Total number of taxa at each sample site



In Figure 9-17 individual site results are pooled with sites fitted into each reach class, and the mean taxa richness plotted by reach class.

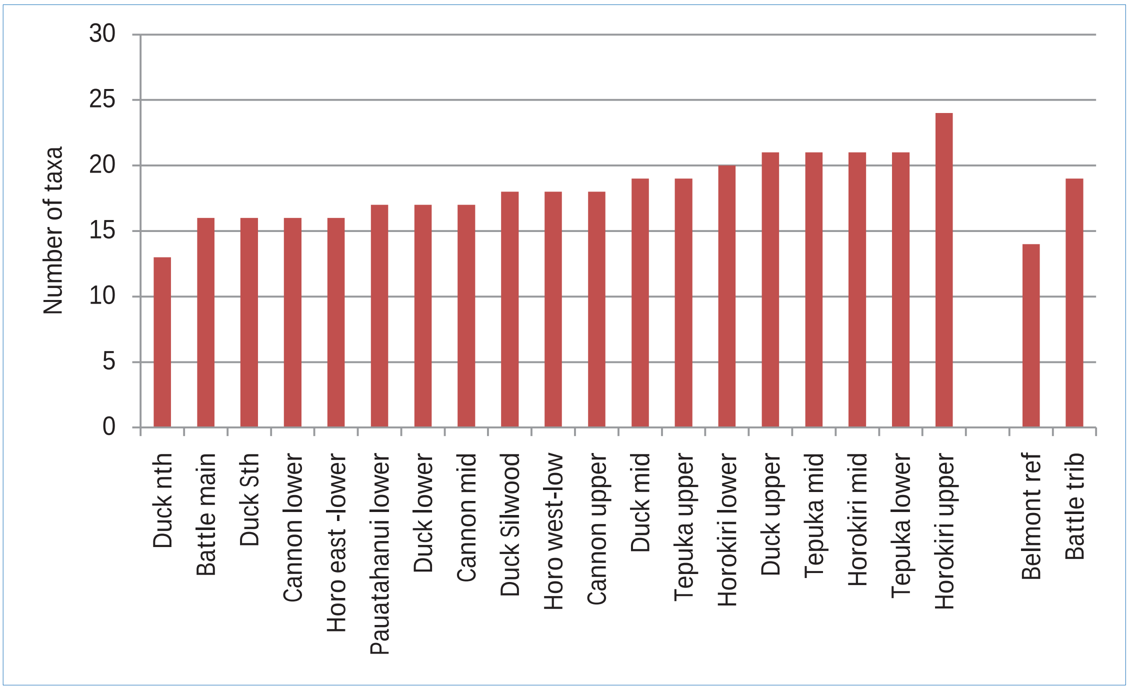
Compared to the national kick net median sample taxa richness (14/kick sample (10-90% range 7-20 Quinn & Hickey 1990)) the streams sampled in the project area are rich in benthic invertebrate species. Figure 9-17 shows no pattern or statistically significant differences in aquatic invertebrate community taxa richness.

Figure 9-17 Mean taxa richness in different reach classes



Inspection of the EPT (*Ephemeroptera*, *Plecoptera* and *Trichoptera*) taxa shows that all sample sites have over 10 EPT taxa and a typical range of between 15 and 20 taxa with 5 stream sites having over 25 EPT taxa (see Figure 9-18). In contrast to the EPT taxa of the reference sites (Belmont and Battle tributary) the communities in the project sites have generally similar numbers and ranges of EPT taxa.

Figure 9-18 Number of EPT taxa at sample sites



The EPT taxa groups were pooled and the frequency of encounter plotted (Table 9-15).

Ten taxa of mayfly were recognised. In the seven catchments *Deleatidium* are the mostly commonly encountered mayfly (100%) along with *Coloburiscus*. These two taxa are caught in over 80% of the 63 samples. Four other taxa, while less common, were also typical of the streams in general, they are: *Nesameletus*, *Austroclima*, *NeozephEblia*, and *Acanthophlebia*. Around 41% of the mayfly fauna caught across the seven catchments were either *Deleatidium* or *Coloburiscus* species.

Six taxa of stonefly were recognised. *Zelandoperla*, *Zelandobius* and *Stenoperla* stonefly were caught from around 50% of the samples, with the other taxa much less commonly present. Furthermore over 80 % of the records of stonefly are in these three taxa and these three taxa typify the stonefly community in the wider catchment.

Caddisfly were the most taxa rich group of the EPT with 20 taxa recognised. Eight taxa were found in over 50% of sampled and five in over 70%. *Olinga* was the most commonly found taxa along with *Pycnocentrodes*, *Aoteapsyche*, *Psilochorema* and *Hydrobiosella*. However, no single taxon within the group dominated in terms of proportion of recordings.

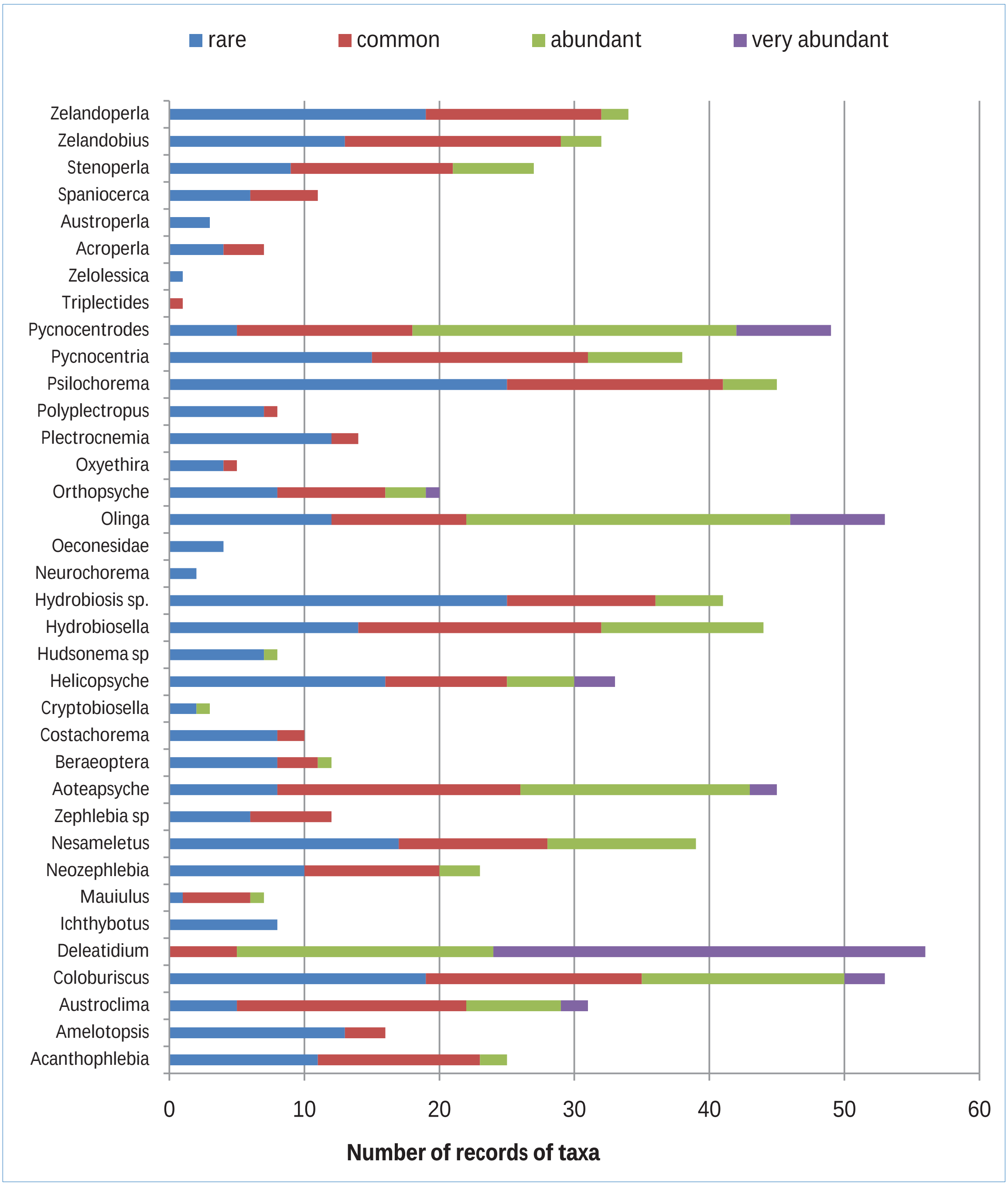
Table 9-15 EPT taxa frequency in sampling (pooled samples - Total sample number = 63)

Taxa group and species	Frequency of catch	Proportion of taxa group
Ephemeroptera		
Mauiulus	11.1%	2.5%
Ichthybotus	12.7%	2.9%
Zephlebia sp	19.0%	4.3%
Amelotopsis	25.4%	5.8%
Neozephlebia	36.5%	8.3%
Acanthophlebia	39.7%	9.0%
Austroclima	49.2%	11.2%
Nesameletus	63.5%	14.4%
Coloburiscus	84.1%	19.1%
Deleatidium	100.0%	22.7%
Plecoptera		
Austroperla	6.3%	3.4%
Acroperla	11.1%	5.9%
Spaniocerca	17.5%	9.2%
Stenoperla	46.0%	24.4%
Zelandobius	52.4%	27.7%
Zelandoperla	55.6%	29.4%
Trichoptera		
Triplectides	1.6%	0.2%
Zelolessica	1.6%	0.2%
Neurochorema	3.2%	0.5%
Cryptobiosella	4.8%	0.7%
Oeconesidae	6.3%	0.9%
Oxyethira	7.9%	1.1%
Hudsonema sp	12.7%	1.8%
Polyplectropus	12.7%	1.8%
Costachorema	15.9%	2.3%
Beraeoptera	19.0%	2.7%
Plectrocnemia	22.2%	3.2%
Orthopsyche	33.3%	4.8%
Helicopsyche	52.4%	7.5%
Pycnocentria	60.3%	8.7%
Hydrobiosis sp.	65.1%	9.3%
Hydrobiosella	71.4%	10.3%

Psilochorema	71.4%	10.3%
Aoteapsyche	73.0%	10.5%
Pycnocentrodes	77.8%	11.2%
Olinga	84.1%	12.1%

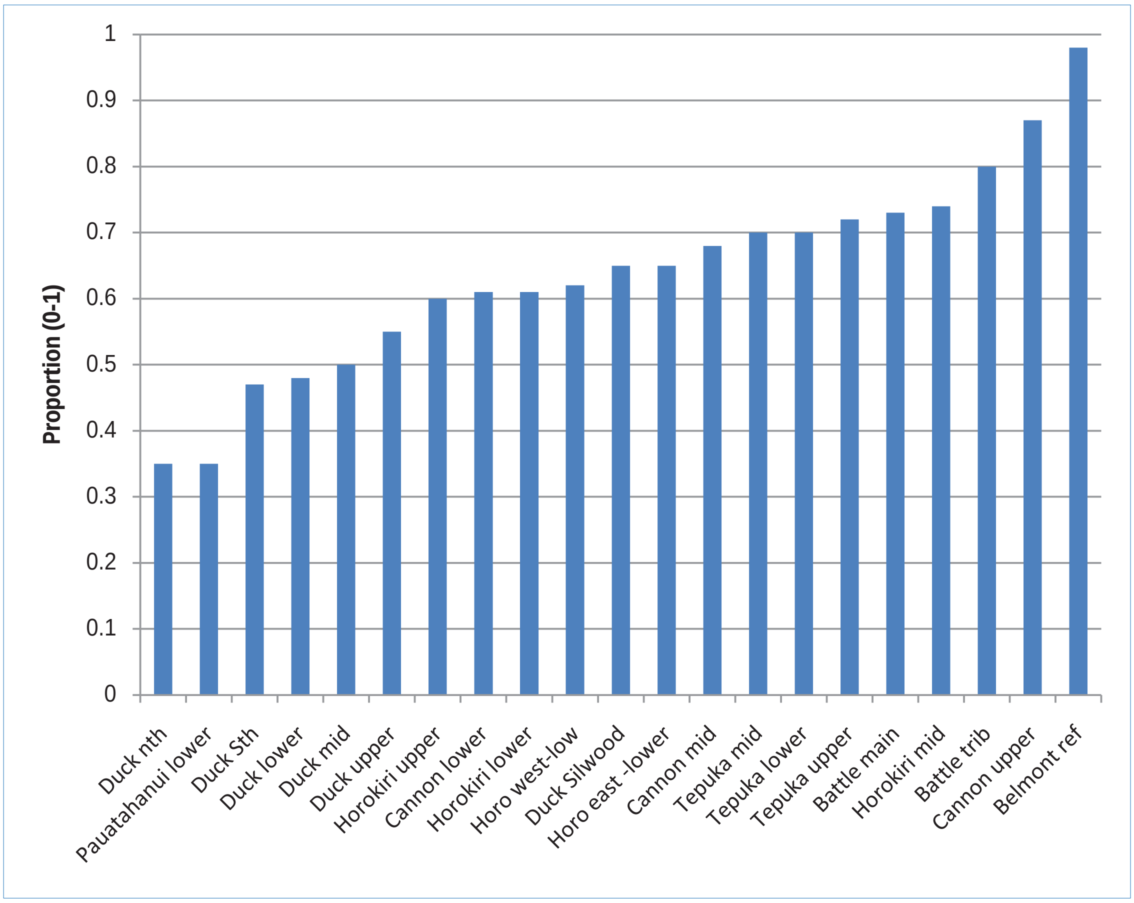
Abundances of these groups are given in coded abundances and the occurrence of any individual taxon can be seen in the data presented in Appendix 9.H. Figure 9-19 shows the proportional frequency of recording of taxa in terms of four coded abundance classes. Clearly *Deleatidium* is most frequently encountered in vary abundant numbers. Less frequently *Olinga, Pycnocentrodes, Coloburiscus* and *Helicopsyche* are also found in very abundant numbers. The same taxa are also often abundant.

Figure 9-19 Frequency of occurrence of taxa in different abundances categories.



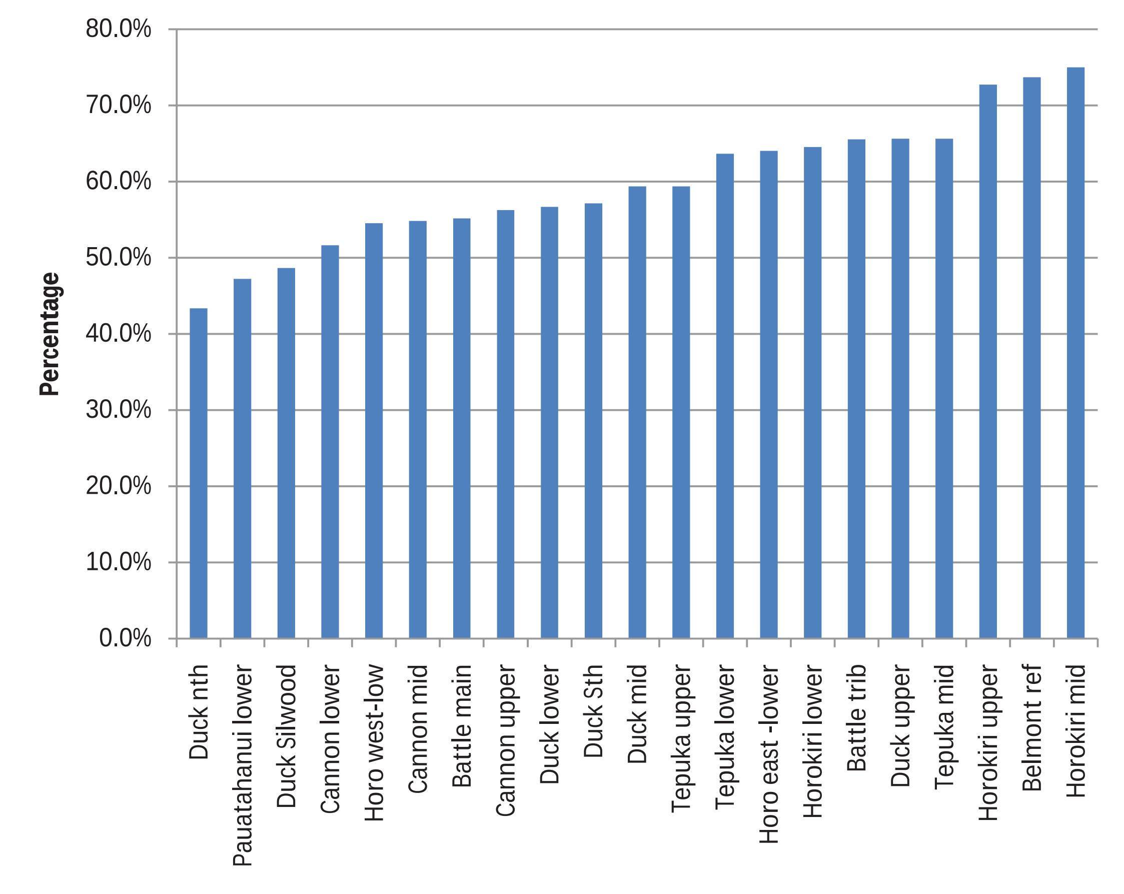
Plotting the mean coded abundance of EPT fauna as a proportion of the total community abundance by site illustrates (Figure 9-20) that middle and upper reach sites, except in Duck Creek, have EPT fauna as a large or dominant proportion of their faunal community (in terms of numbers of individuals). The reference sites and Cannons Creek upper site have the highest proportion of EPT.

Figure 9-20 The average abundance of EPT taxa as a proportion of the total community average abundance.



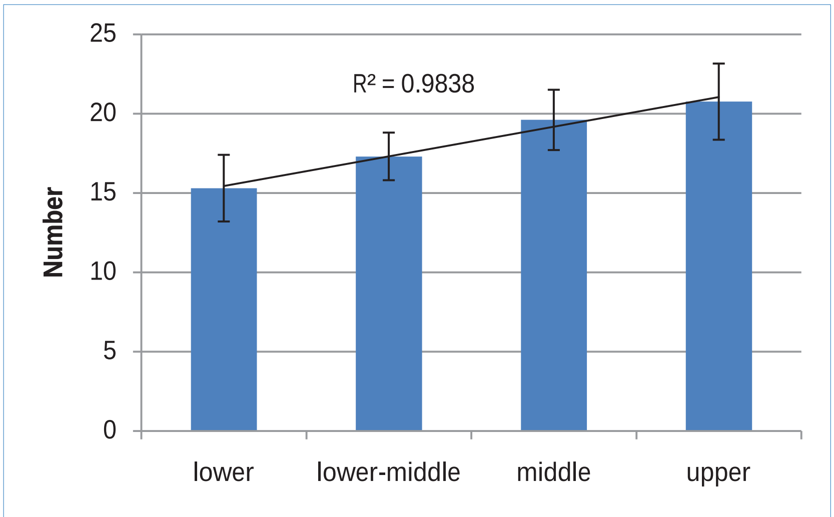
A commonly used comparative biometric is the percentage of a community's richness or abundance that is EPT. Figure 9-21plots the percentage representation of the total taxa richness which is made up of ETP taxa (%EPT). It shows that for most sites over 50% of the community's species belong to one of the three EPT groups. The lowland sites of Duck Creek and Pauatahanui are the only sampled sites that have less than 50% representation. Two project sites (Horokiri middle and Horokiri upper) and one of the reference sites (Belmont) have over 70% of the taxa present belonging to the EPT groups.

Figure 9-21 The proportion that the EPT taxa makeup of the total taxa present at each site



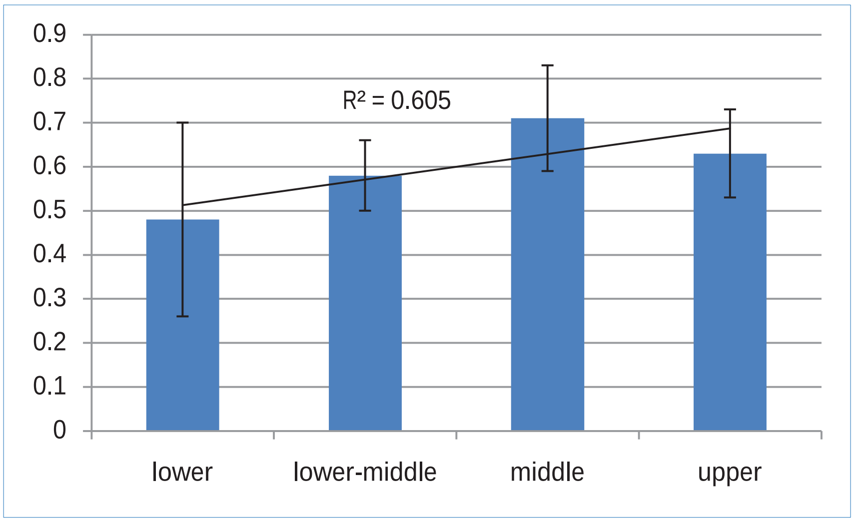
There is a positive trend in increasing EPT representation in the fauna from lowland to upland (Habitat Reach Type) reaches (Figure 9-22). The regression line is a very good fit at $r^2>0.9$.

Figure 9-22 EPT taxa richness and habitat reach classes



Also there is a positive trend in the proportions of the total aquatic communities made up by EPT taxa (Figure 9-23).

Figure 9-23 Proportion of EPT taxa in the communities of each reach class



4.6.3 SENSITIVITY INDICES

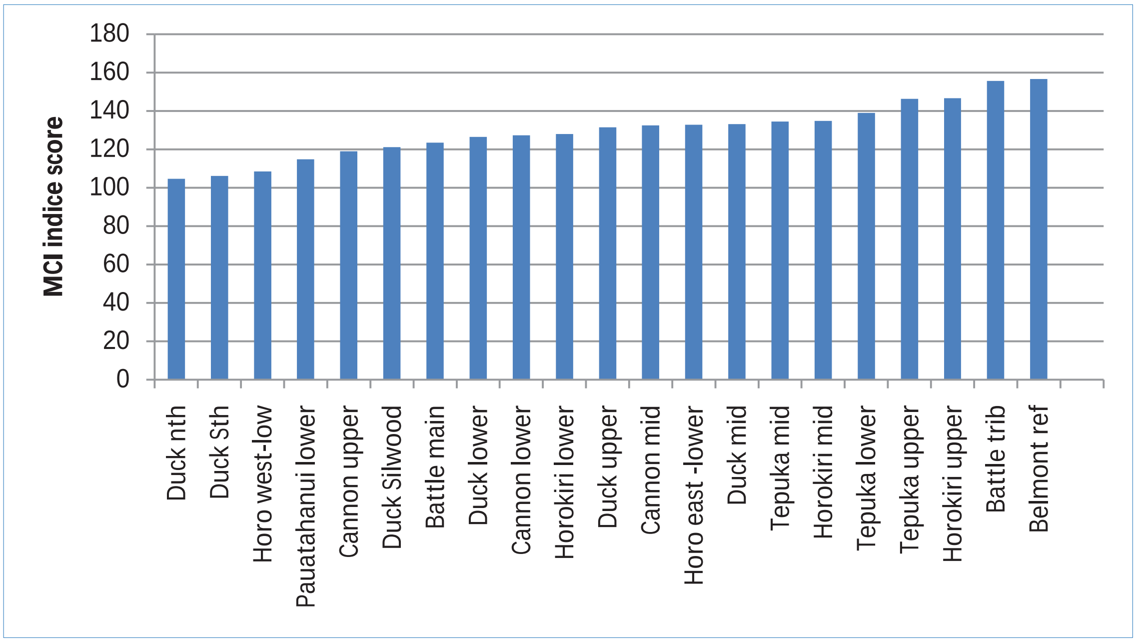
Stark & Maxted's (2004) guide to interpretation of the MCI indices score are given in Table 4-7 below.

Mean MCI scores in the project area sites were generally high, greater than 100 and typically over 120 (Figure 9-24). It can be seen that all sites measured qualify as being "Good" quality with only "possible mild pollution", while the majority of sites (> 17) quality as being of "Excellent" quality in terms of their MCI scores (i.e. clean).

Table 9-16 MCI & QMCI score classification meanings (from Stark and Maxted 2004)

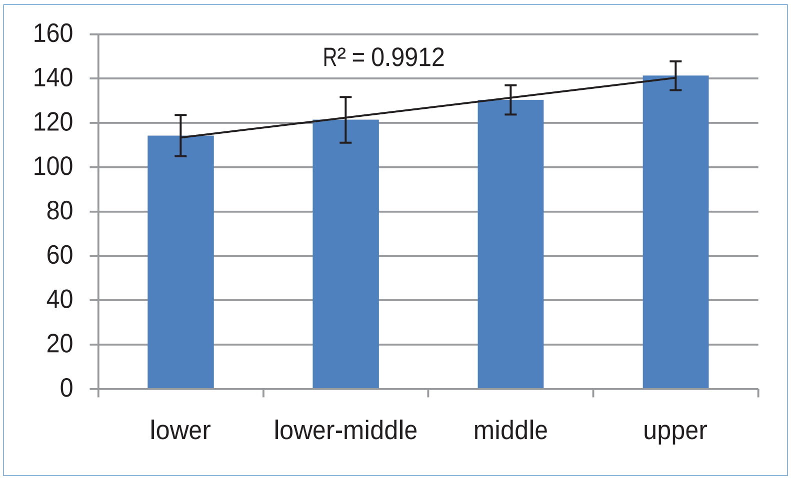
Quality Class	Stark (1998) description	MCI	QMCI
Excellent	Clean	>120	>6.0
Good	Possible mild pollution	100-120	5-6
Fair	Probable moderate pollution	80-100	4-5
Poor	Probable severe pollution	<80	<4

Figure 9-24 Average MCI Score from each sampling site arranged in order of increasing score



There is also a distinct trend of lower reach sites having lower MCI scores than upper reach sites (Figure 9-25).

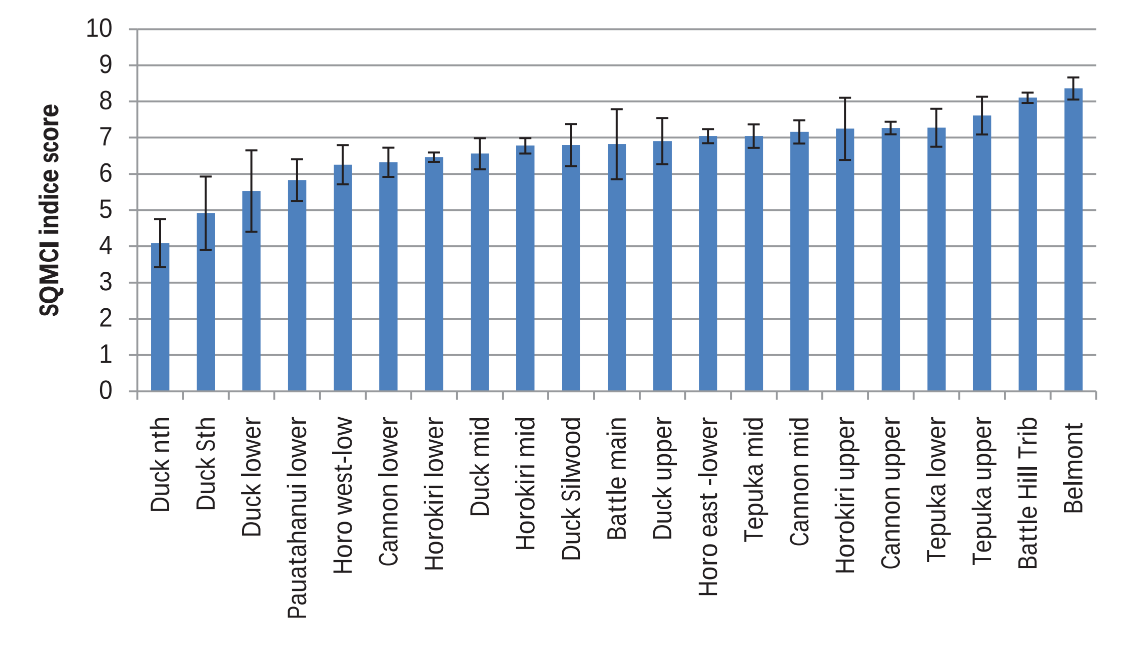
Figure 9-25 MCI scores and habitat reach class



The SQMCI, which accounts for the abundance of the sensitivity scoring taxa (weighting the score in favour of the most abundant taxa) accounts for the effect of single (or low number of) taxa of very high or low MCI scores on the final score. This metric is best used with full count data but coded abundance is sufficient to gain a numeric community sensitivity score. Those scores are plotted in Figure 9-26. The range is from 4 ("fair" - Probable moderate pollution) through to over 8.

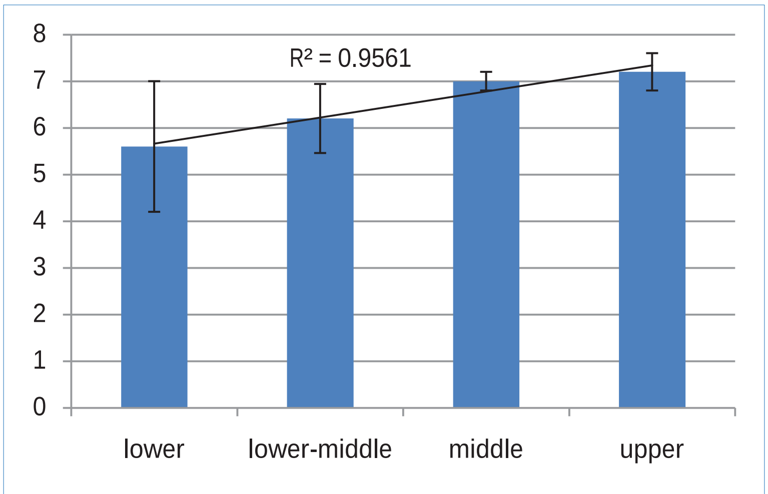
Only 4 sites produced a score of < 6. Scores > 6 are interpreted as "Excellent" quality, clean sites. Duck Nth, Sth and Pauatahanui lower sites responded to both MCI and SQMCI in the same ranked way. However, Duck lower's MCI score indicated an "excellent" quality while the SQMCI indicates a good quality (with variance from fair to Excellent). This suggests that the sensitive taxa at that site are not numerically dominant in the community assemblage.

Figure 9-26 Mean SQMCI scores for sampled sites (error bars 1 Std Dev).



As with the MCI there is also a distinct linear relationship between SQMCI score and river reach position (Figure 9-27).

Figure 9-27 SQMCI scores for habitat reach classes



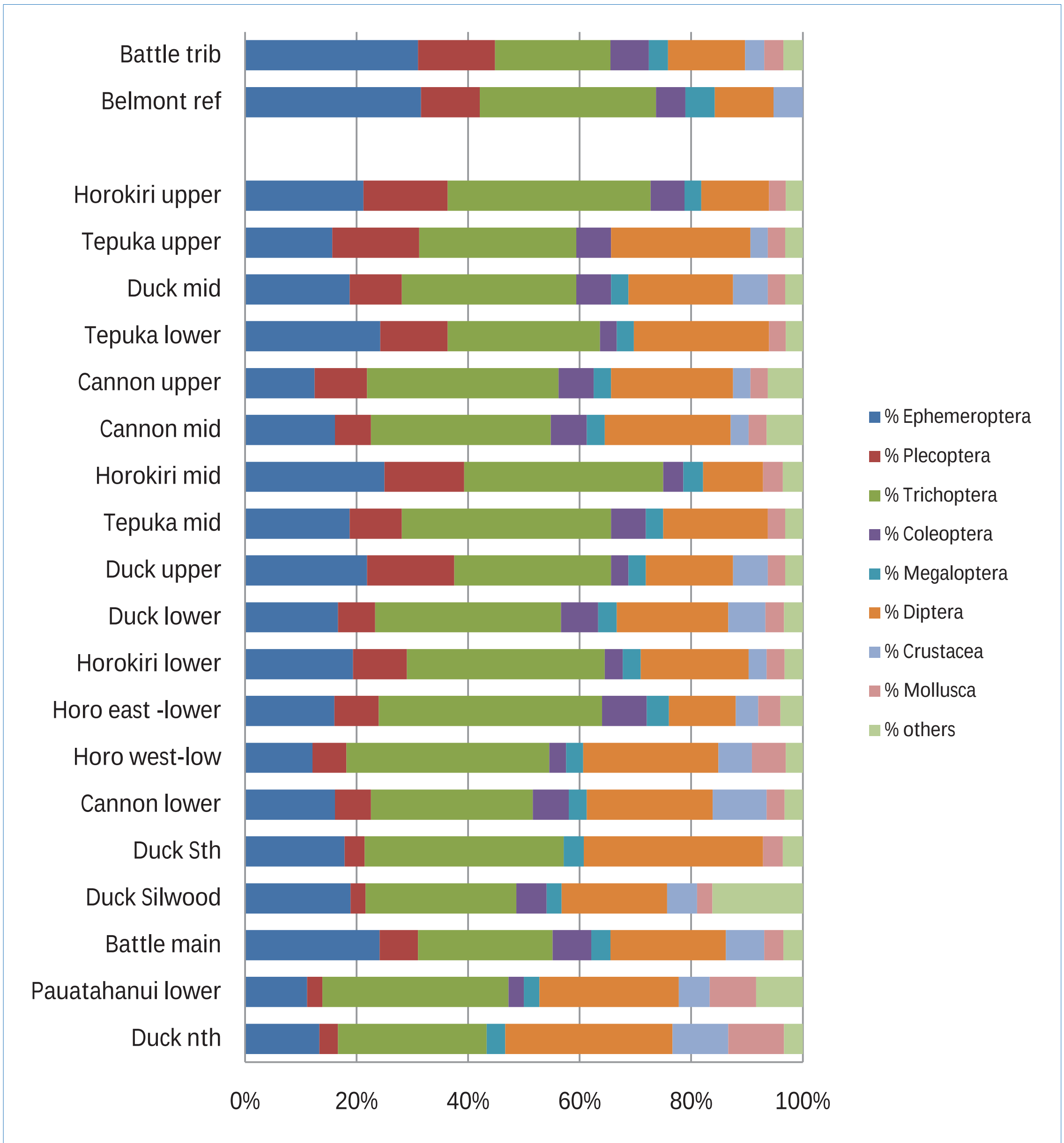
Both sensitivity indices strongly suggest the aquatic benthic macroinvertebrate fauna across and throughout the seven catchments are in very good to excellent condition with sensitive taxa prominent or dominant in the benthos of those streams.

4.6.4 COMMUNITY ASSEMBLAGE

Inspection of the proportions of a community's taxa groups can reveal a lot about the habitat condition and the primary drivers of that habitat: the substrate type, periphyton growth, light levels, water flows etc. There are two aspects: the proportional composition of species groups in the taxa present and the proportional abundances of the different taxa groups. Figure 9-28 shows the percentage of the total number of taxa present that fall into each of the groups (as listed in the legend). The sites are arranged in no particular order other than the two reference sites are at the top.

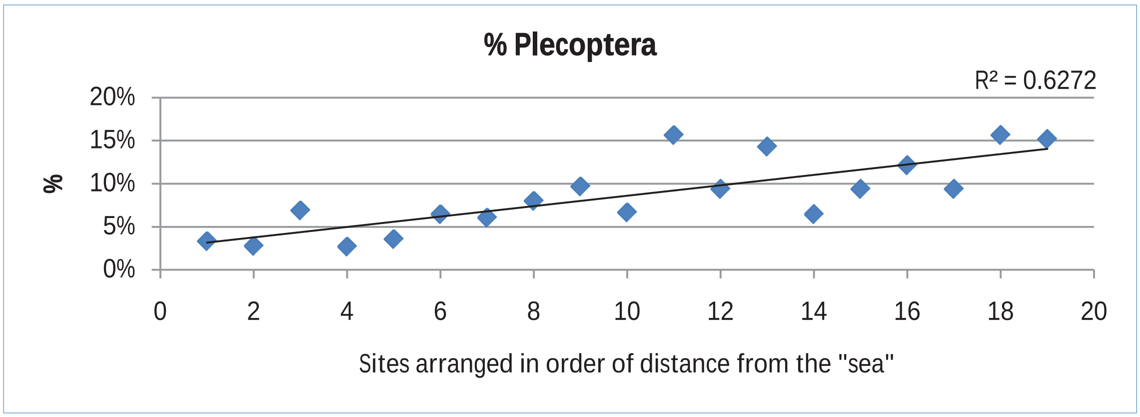
By and large there are no notable patterns other than those already noted in relation to the EPT fauna (such as greater numbers of taxa in the stonefly group in the upper reach sites). Duck Silverwood, Duck Nth and Pauatahanui are the most different in that these sites have a greater representation of "other" fauna (mites, worms, amphipods and Crustacea).

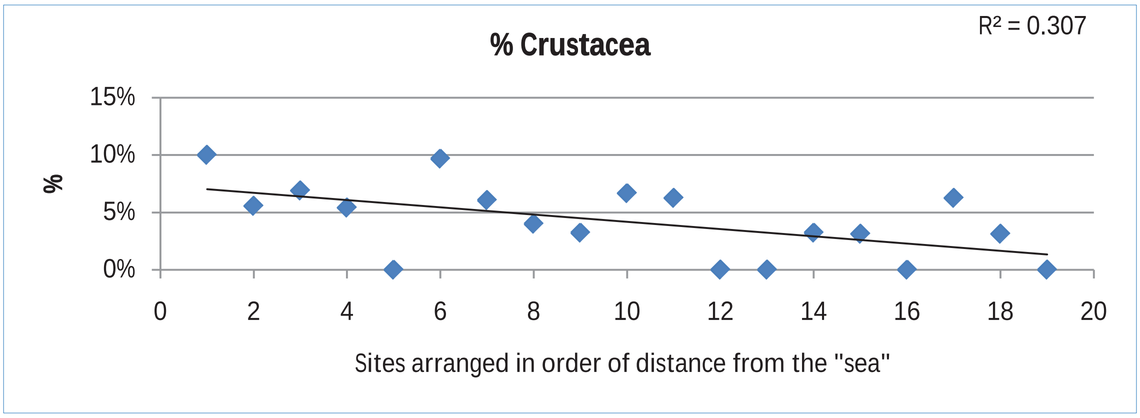
Figure 9-28 Macroinvertebrate community composition at each sampled site.

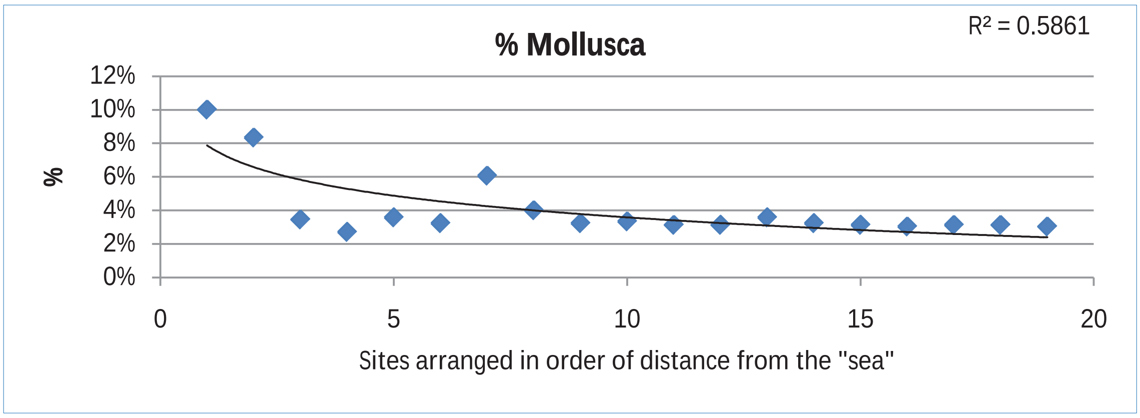


Scatter plots of each taxa group against reach position (lower to upper) are presented in Figure 9-29 a, b & c. The three plots that revealed reach related relationships were stonefly, Crustacea and snails. Stoneflies have a linear relationship with stream catchment reach position, increasing in the upper reaches. Crustacea have the opposite relationship, although the data were too variable for a good linear fit. The snail relationship with reach is logarithmic, declining rapidly away from the lowest reaches.

Figure 9-29 A, B & C. Relationship between taxa group and reach position







The similarity of assemblages across the sampled sites (streams) was examined using a Pearson Correlation matrix[11] testing the different taxa grouping percentage compositions. Generally all sites are very similar to all other sites with typically >90% similarity.

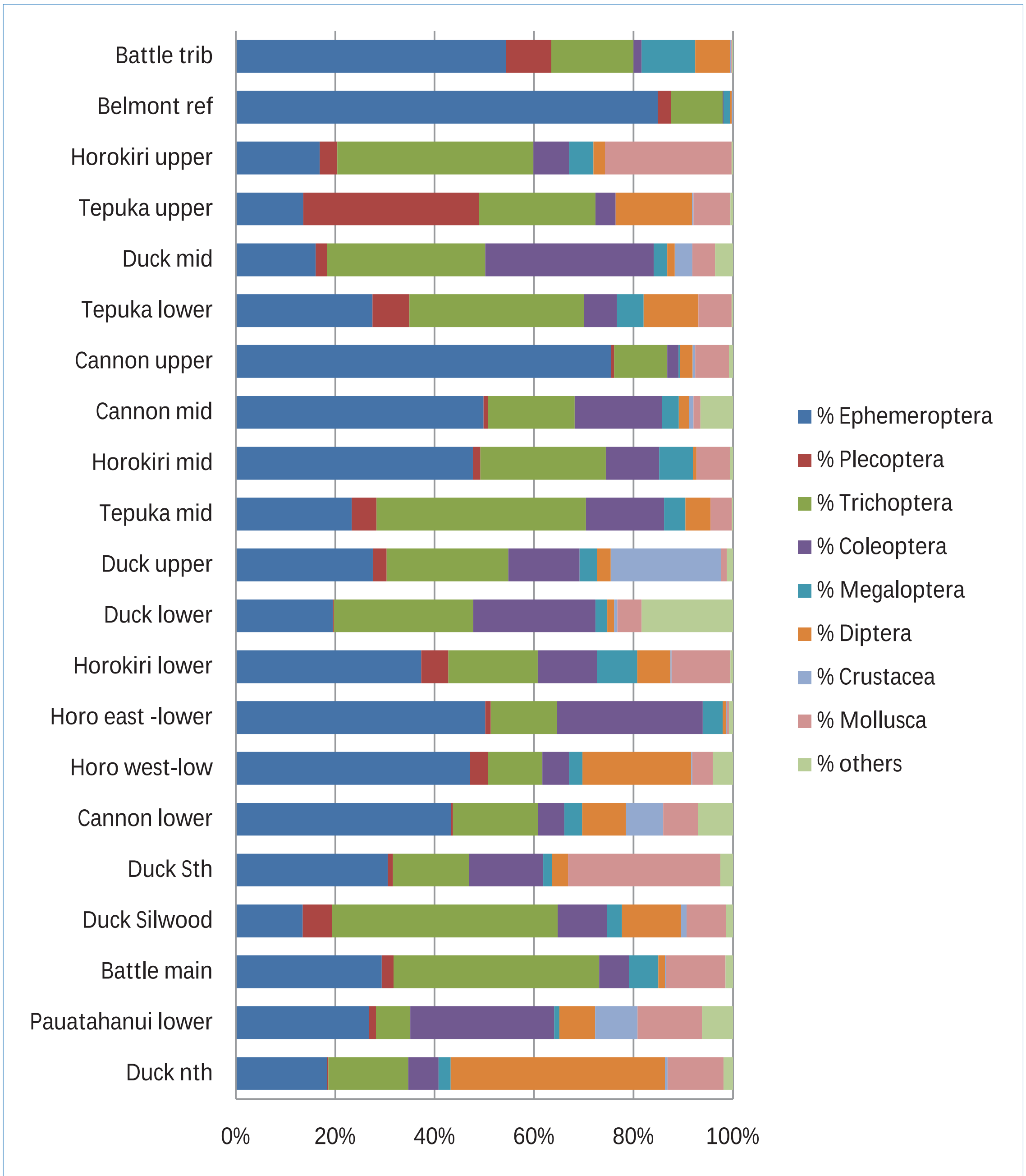
Only Battle Hill tributary (Battle tributary) and to a much lesser extent Duck North (Duck Nth) showed any assemblage differences from the whole. At Duck North this is due to its snail and

[11] Table of outcomes presented in Appendix XX

crustacean groups and at the Battle tributary site because of the reduced caddisfly assemblage and more evenly balanced proportions of taxa groups.

If abundance by taxon group data is examined, a different pattern and perspective emerges. While the taxa assemblages may be very similar (i.e. what species are present in what proportions), their abundances (even by coded measures) are different. Figure 9-30 shows that the Belmont reference site is numerically dominated by mayfly, as is the Cannons upper site. Duck north has a noticeably high proportion of Diptera; while the lower reach sites in general have fewer mayflies (which correspond to a change in the substrate to gravels and sands).

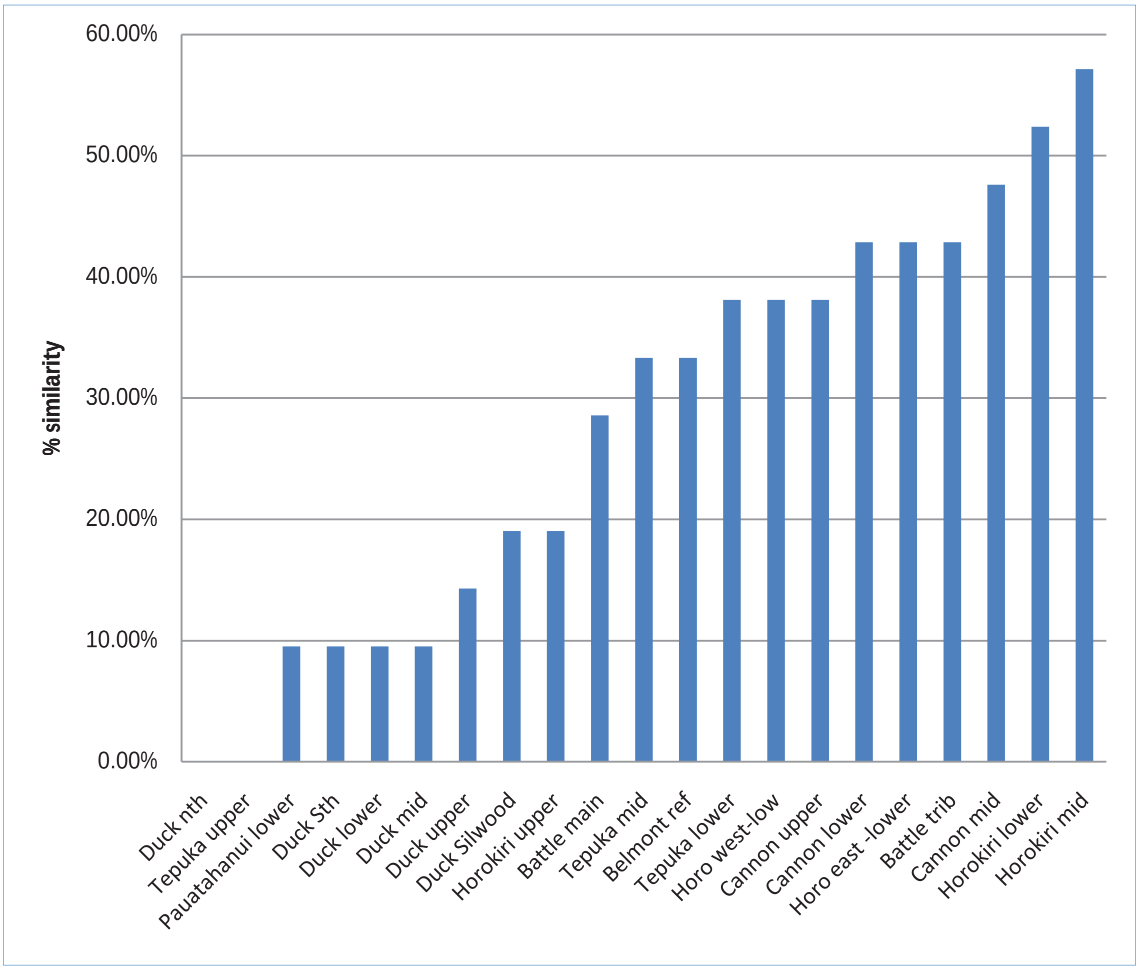
Figure 9-30 Abundance of macroinvertebrate taxa at different sites.



The similarity correlation matrices showed that virtually all of the sites are less than 50% similar to any other site although two sites are unique in terms of their numeric taxa proportions (Duck Nth & Diptera, and Te Puka upper & stonefly).

As a general trend the lower reach sites are more different from the other reaches in the catchments and the middle reaches with most "uniform" abundance distributions across the taxon groups. The implications of these similarity measures are that by and large the faunal composition is similar throughout the seven waterway systems and differences relate to differences in proportional abundances rather than which taxa are present. There are no streams of any notable uniqueness.

Figure 9-31 Similarity level of abundances of taxa groups at each sample site



4.7 EPHEMERAL HEADWATER "WETLANDS".

A variety of headwater tributaries in the farmlands of the upper Te Puka, Horokiri, Ration and Duck Creek have plant species adapted to a periodically-submerged or standing water / wet soil habitat which may be thought of as wet riparian or as wetland-seepage. These wetland systems were not treated in the terrestrial ecological technical report, which did address wetlands in general but those larger features more distinguishable as "stand alone" wetland. These small, linear stream interrelated ones are instead addressed and assessed here as a component of the stream systems. While these features may be found as components of nearly any side tributary with some area of flattish gradient, they are most noticeable, numerous and, from a functional aspect, most important in the Wainui saddle area dividing Te Puka and the Horokiri.

The following is a general description of the structure and species composition of these areas and while these wetland/seepage features are variable in terms of the extent of indigenous species within them, they are dominated by exotic pastoral orientated species affected by grazing and do not, as far as the surveys of several of the most prominent ones in the upper Horokiri and Te Puka systems have identified contain any threatened or conservationally important species.

One of the larger of these features is at the true right headwaters of the Horokiri at the Wainui saddle. It arises as one of the headwaters of the Horokiri Stream in a wide flattish forked gully which is wet and boggy across its width. The area is unfenced and exposed to stock but contains an assortment of wet adapted grasses, rushes and sedges.

Predominantly the vegetation consists of creeping buttercup, cocks foot, Yorkshire fog, Juncus species (such as J. australis, J. planifolius, J. edgerae, J. effuses), as well as less frequent but not uncommon: Centella spp., Luzula pieta, Hydrocotyle moschata, Dichronda brevifolia, Gonocarpus micranthus, Polygonum salcifolium, lemna minor, Azolla filiculoides, Myriophyllum propinquum, Carex virgata, Plantago raoulia, Blechnum filiforme, B. Minus and Rytidosperma unarede.

While the above list is generic it is also representative of the general structure and composition of all of these stream edge boggy features in the Ration, Duck system and Te puka system also. We note that in virtually all cases, to our knowledge, these seepage/wetland features are largely beyond the road designation boundaries, i.e. above the alignment. There are 16 ephemeral tributaries in the Tepuka, 11 of which are on the southern side and bisected by the Road in their lower reaches, 33 such ephemeral tributaries in the Horokiri, 16 on the western side and crossed by the Road, 18 ephemeral tributaries between the Horokiri and Ration crossed by the Road, 4 within the Ration system, 2 within the Pauatahanui and 2-3 with the Duck (most of the Duck tributaries are intermittent or perennial).

Each of these ephemeral watersheds have a range of "wetland" features such as described above. All of the tributaries of the Te Puka on the true left, and the tributaries on the true right of the Horokiri have been walked and visually assessed, as have those on the Duck. Only three locations were accessible on the Ration and one associated with the Pauatahanui. The Cannon (three tributaries) and the tributaries of the Porirua have also been fully assessed).

The GWRC Freshwater Plan lists in Appendix 3, Part B Nationally threatened aquatic or semi-aquatic plant species. This list includes Isolepis basilaris Juncus holoschoenus, Myriophyllum robustum Myosurus minimus, and Leptinella dioica spp monoica, Ophioglossum petiolatu, Anogramma leptophylla and the moss Fissidens berteroi. All species that potentially could persist in the riparian boggy headwater tributaries wetlands of the project area. None of these threatened plants have been recognised from survey to date within the projects designation area (or wider surveyed areas). Given the condition of the "wetlands" observed and the land use prevalent it is unlikely that any of these rarer plants are present.

Photo 9-28 Example of a typical headwater seep in pasture in Horokiri, Ration, Duck, Cannon's or the Porirua un-named tributary.

No faunal sampling was carried out in any ephemeral headwater, despite there being the potential for seepage adapted snails, beetles and flys. We note however, that there is no unusual geomorphology or water chemistry associated with those ephemeral tributaries, two factors that strongly influence the presence of unusual seepage fauna (Collier & Brian 2006). We consider that the probability of such fauna being present is very low.

5 EVALUATION OF SYSTEMS, HABITATS AND BIOTA

5.1 INTRODUCTION

Freshwater ecosystems, habitats and species have been evaluated against a number of benchmarks. The statutory benchmark is set out in the Greater Wellington Regional Freshwater Plan (operative 17th Dec 1999). However, evaluations of species and communities have also been done to assess the ecological importance of the waterways within the project area. This is important in setting priorities for protection and mitigation, and resource allocation. Data collected for GWRC's State of the Environment monitoring, is also used in evaluation.

5.2 STATUTORY CONTEXT

The Greater Welling Regional Freshwater Plan seeks to recognise waterways of significance to the Region. It includes appendices that list river mouths (Plan Appendix 1); wetlands lakes and rivers (and their margins) which have a high degree on natural character (Plan Appendix 2); and Water Bodies with Nationally Threatened Indigenous Fish Recorded in the Catchment and Nationally Threatened Indigenous Aquatic Plants (Plan Appendix 3).

River mouths recognised in Appendix 1:

- Pauatahanui Stream The landward edge of Pauatahanui Inlet Wildlife Management Reserve at NZMS 260 R27 708 095
- Horokiri Stream The seaward side of Pauatahanui Road Bridge at NZMS 260 R26 702 107

Wetlands, Lakes and Rivers and their Margins, with a High Degree of Natural Character (from Appendix 2):

The Plan recognises two groups within this category:

"Part A: Surface Water to be managed in its Natural State" for which "Policy 5.2.1 provides direction on water quality for the management purposes of the water bodies listed….." No sites in the project area are listed in Part A.

But several are listed in "Part B: Surface Water to the Managed for Aquatic Ecosystem Purposes" for which Policy 5.2.6 "provides guidance on water quality for all water bodies not listed in Appendix 7. This includes water bodies that are being managed for other purposes in accordance with Policies 5.2.2 to 5.2.5"Project area sites on this list are:

- "All water bodies and river beds within the catchment of the Horokiri Stream and the Ration Stream upstream of the respective coastal marine boundaries at R26 702 107 and R26 707 103;
- All water bodies and river beds within the catchment of the Pauatahanui Stream upstream of the coastal marine area boundary at NZMS R27 708 095."

Appendix 3. Water Bodies with Nationally Threatened Indigenous Fish Recorded in the Catchment and Nationally Threatened Indigenous Aquatic Plants includes the following project area sites:

"Part A: Water Bodies with Nationally Threatened Indigenous Fish Recorded in the catchment:

- The Horokiri Stream and the Ration Stream and their tributaries upstream of the respective coastal marine boundaries at R26 702 107 and R26 707 103, (Species recorded are: Shortjawed Kokopu, Giant Kokopu, and Banded Kokopu)

- The Pauatahanui Stream and its tributaries upstream of the coastal marine area boundary at R27 708 095, (Species recorded are: Giant Kokopu and Banded Kokopu)"
- "Duck Creek and its tributaries upstream of the coastal marine area boundary at R26 095 696, (Species recorded are: Shortjawed Kokopu, Giant Kokopu, and Banded Kokopu)"
- "The Wainui Stream and its tributaries upstream of the coastal marine area boundary at R26 750 241, (Species recorded are: Giant Kokopu)."

No Part B (threatened plant sites) in the project area is listed. Nor are any streams recognised for trout spawning values, water quality values or amenity values.

The waterways listed in Part A are habitats of significant indigenous fauna and therefore will typically qualify as "significant" using typical "significance" criteria (ticking the rarity criterion) of the District or Regional Plan or of one of several commonly used methods (Whaley et al 1995, Norton, Roper-Lindsay 2004).

Porirua City identified "Ecosites" through a limited review in 2001 but these are not listed in its Operative District Plan.

In its submission on designation for the Western Corridor, Porirua City (2005) records Ecosites which are "potentially affected by the TGMAP[12]. Only one of these is associated with a freshwater/riparian habitat: "Site 199, Transmission Gully Riparian Area" which is 1.877 ha of unreserved public land. In 2005 this lay within the "Transit designation". In 2005 the likely impact of highway development on this site was ranked at 3 (out of a maximum impact ranking of 6). This was based on the site having a low Ecosite significance rank (5) but likely to experience "very significant adverse effects resulting in the ecological values of the site being largely lost". This site is addressed in Technical Report 11.

A short length of Horokiri Stream at the north end of the TGMAP route lies in Kapiti Coast District. The Kapiti Coast District Plan lists "Ecological Sites" but none are freshwater/riparian vegetation or habitats likely to be affected by the highway development.

5.3 SENSITIVITY AND TOLERANCES

Presence in general of Ephemeroptera, Plecoptera and Trichoptera (EPT) (species dependent) is indicative of good water quality (and aquatic habitat), and through that of better quality freshwater habitat. Generally the assemblages in the project waterways have strong EPT representation. Those EPT taxa are significant in terms of their proportional representation in the total numbers (abundance) of individuals in the sampled communities – this is illustrated in Figure 9-30. The summary of MCI and SQMCI scores presented in Table 5-1 shows that the macroinvertebrate fauna represent good to excellent water quality habitats with numerous sensitive taxa. Only the lower reaches of Duck Creek had some assemblages that indicate some minor water quality issues. Similarity measures also support a view of a relatively common aquatic faunal assemblage with small differences in proportional abundances related to reach position (distance in land).

Overall the streams of the area have fauna sensitive to organic water pollution and their sensitivity is considered as relatively high, or sensitive to contaminants.

[12] "Ecosites" were identified by Boffa Miskell Ltd in 2001 in "*Inventory of ecological sites in Porirua City".* In 2005, Dr Paul Blaschke reviewed the inventory to assess which sites were potentially affected by the proposals as they stood at that time.

Table 9-17 Summary of MCI and SQMCI scores for sampled sites

Site/stream	MCI	QMCI
Duck Nth	Good	Fair
Duck Sth	Good	Fair
Duck lower	Excellent	Good
Pauatahanui lower	Good	Good
Horo West-low	Good	Excellent
Cannon upper	Good	Excellent
Cannon lower	Excellent	Excellent
Horokiri lower	Excellent	Excellent
Duck mid	Excellent	Excellent
Horokiri mid	Excellent	Excellent
Duck Silwood	Excellent	Excellent
Battle main	Excellent	Excellent
Duck upper	Excellent	Excellent
Horo East -lower	Excellent	Excellent
Te Puka mid	Excellent	Excellent
Cannons mid	Excellent	Excellent
Horokiri upper	Excellent	Excellent
Te Puka lower	Excellent	Excellent
Te Puka upper	Excellent	Excellent
Battle Hill Trib	Excellent	Excellent
Belmont	Excellent	Excellent

5.4 ECOLOGICAL SIGNIFICANCE/ECOLOGICAL CHARACTERISTICS

Introduction

Two primary methods have been used to test the regional value of the reaches and streams affected by the proposal. The fish IBI has been calculated for the sites sampled and compared to the general condition of other waterways in the Region (Appendix 9.D). A comparison has also been made of how the %EPT, QMCI and MCI values rank relative to the data on these same factors published by GWRC as part of their SOE programme (Perrie 2008).

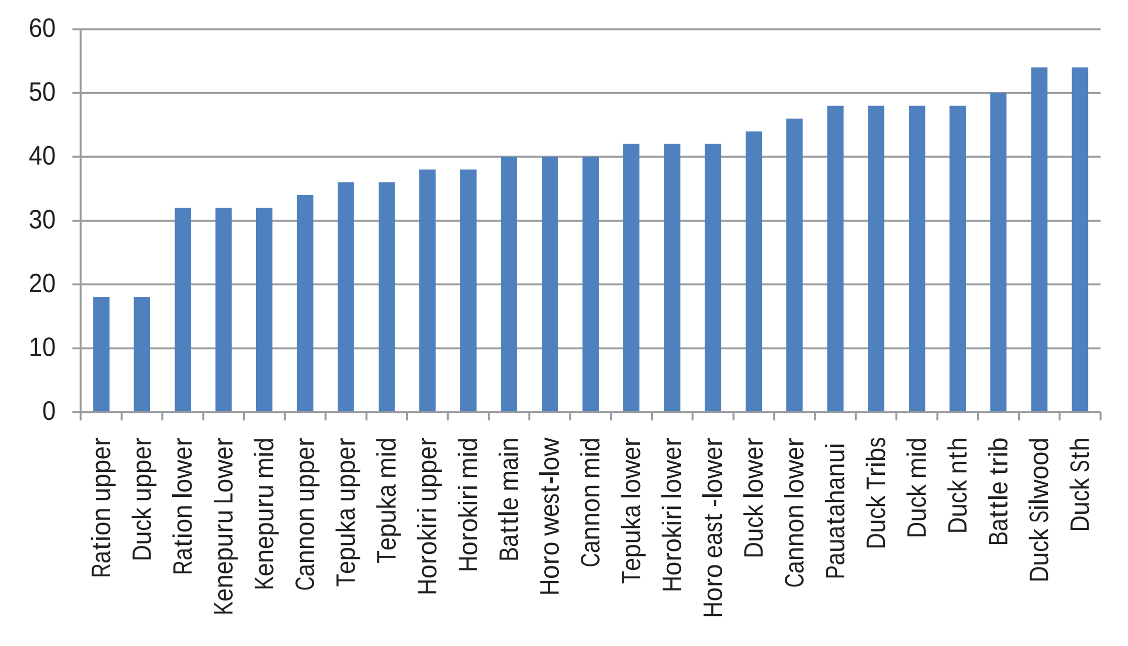
There are no comparative metrics for the physical habitat. However, the SEV outputs have been examined in relation to the project reference sites. Project reference sites had to be established since currently there are no recognised or "designated" Regional Council reference sites.

Fish communities.

An IBI score was calculated for each site based on the presence/absence of fish taxa and set against the Regional background. The Regional background was developed by calculating the IBI for 99 streams in the region (Appendix 9.D) using the model developed by the Centre for Freshwater Ecosystem Modelling and Management, Massey University (Joy 2009).

The IBI scores for the surveyed sites of the project area are shown in Figure 9-32. The scores ranged from below 20 to over 50.

Figure 9-32 Summary of Integrated Biodiversity Index (IBI) scores for sampled sites.



Following the IBI methodology these scores give rise to the following Regional IBI rating (Table 5-2).

Table 9-18 IBI Wellington Regional Rating (adapted from Joy)

Site	Rating
Ration upper	Poor
Duck upper	poor
Ration lower	Fair
Kenepuru Lower	Fair
Kenepuru mid	Fair
Cannons upper	Fair
Te Puka upper	Fair
Te Puka mid	Fair
Horokiri upper	Good
Horokiri mid	Good
Battle main	Good
Horo West-low	Good
Cannons mid	Good
Te Puka lower	Good
Horokiri lower	Good
Horo East -lower	Good
Duck lower	Good
Cannons lower	Good
Pauatahanui	Very Good
Duck Tribs	Very Good
Duck mid	Very Good
Duck Nth	Very Good
Battle trib	Very Good
Duck Silverwood	Excellent
Duck Sth	Excellent

The regional modelling included 14 records (15 sites) from the Horokiri and its tributaries. Of these 15 sites, five were "fair" or worse, five were "good", one "very good" and four were "excellent". This illustrates the benefits of using multiple measures rather than single factors (such as presence of rare species).

Of the full suite of waterway sites in the regional data base used, only seven stream sites returned an excellent score (scores of > 50) (2 of which were sites on the Duck Stream). There can be no doubt that in terms of fish assemblages the Duck Stream (and tributaries) is a very important system on the west coast of the Wellington Region. This is tempered, of course, by the fact that it is the lower reaches that are the most important areas, having the most fish species. Based on the assemblages recorded and the IBI scores (IBI score 52) the lower Duck Creek (at least) must also be considered one of the best fisheries also on the west coast of the Wellington Region.

It is of interest that Te Puka Stream rates only as fair in the regional assessment, with few species recorded. All of the streams become less important in terms of fish taxa richness the higher up the catchment, which is as expected since the IBI analysis does not distinguish well the natural decline in species richness occurring in headwaters.

The fish diversity in the Horokiri and Duck systems (and its maintenance) is of very high ecological value and importance at the Regional scale.

Threatened fish species .

Threatened fish species were caught in all of the sub-catchemnts of the Pauatahanui surveyed and all of the main waterways sampled (Porirua stream also has threatened species although not in the tributaries affected). Typically giant kokopu were sampled in the lower reaches and below direct affected areas, koaro where sampled in the upper reaches, especially in the Duck upper tributaries, red fin bully and long fin eel are commonly present throughout.

Catchment	Threatened fish species (Allibone et al 2010)
Te Puka	Koaro, red fin bully, long fin eel
Horokiri	koaro, red fin bully, long fin eel
Ration	Giant kokopu long fin eel
Pauatahanui (lower)	long fin eel, inanga
Duck	koaro, Giant kokopu, Inanga, red fin bully, long fin eel
Cannon (upper & lower)	Giant kokopu, Inanga, red fin bully, long fin eel

-"At Risk" (Townsend et al 2008) "Declining" (Allibone et al 2010)

As noted in the Regional Policy Statement, and the Regional Freshwater Plan, the presence of six native species and or threatened species makes these streams significant habitat for native aquatic fauna and therefore also habitat of greater importance.

Aquatic macroinvertebrate fauna regional comparisons

Alton Perrie's Regional Council State of the Environment (SOE) publication 2007/2008[13] has been used to fit the various sampled stream sites into a Regional context. This SOE reporting programme reports on a variety of water quality and macroinvertebrate sampling outcomes for 58 repeatedly (annually) measured stream sites around the Region.

[13] Annual freshwater quality monitoring report for the Wellington region, 2007/08. GW/EMI-G-08/161. October 2008 Welling Regional Council Publication.

A summary of the metrics taking the Regional mean of their values is provided below in Table 9-19 and they are compared with the average values for each metric of each of the project's streams that involved aquatic macroinvertebrate sampling.

Table 9-19 Regional Means for selected metrics

Biometric	Regional Mean	Te Puka mean	Horokiri mean	Duck mean	Cannons mean
QMCI	5.55	7.31	6.77	5.80	6.92
MCI	106.26	139.90	129.00	120.46	126.24
Richness	20.05	23.7	21.2	23.4	22.2
%EPT	43.21%	62.88%	64.33%	55.13%	54.23%

In regard to all SOE metrics, benthic invertebrate fauna values for the project area streams are above the Regional average values.

In Figure 9-38 to Figure 9-41 (Appendix 9.E) the project sample site results for each of the above standard aquatic indicator metrics are shown alongside the results for each of the 58 Regional streams monitored. This makes it possible to see the place of the project area streams against the Regional situation and to separate out those project area streams with obviously high or low ranking. The SOE programme had two of the project streams within its scope: the Horokiri (at Snodgrass) and the Pauatahanui, both of which are represented in the following charts as a green bars, while the other project sites are in red bars.

In regard to SQMCI, the project sites cluster in the upper 3rd of the Regional list, with only the three lower reach Duck sites in the lower half of the regional ranking.

The project sites are generally in the middle and upper 3rd in terms of taxa richness (i.e. typical) although the Duck middle site is notably high and the Cannons upper and Horokiri East sites are notably low.

%EPT rankings are around the average and most sites fall in the central chart area. However, in general the project sites have higher MCIs than the regional average, many falling in the top ¼ but again with Duck Nth, Duck Sth, as well as Horokiri West falling in the lower 3rd.

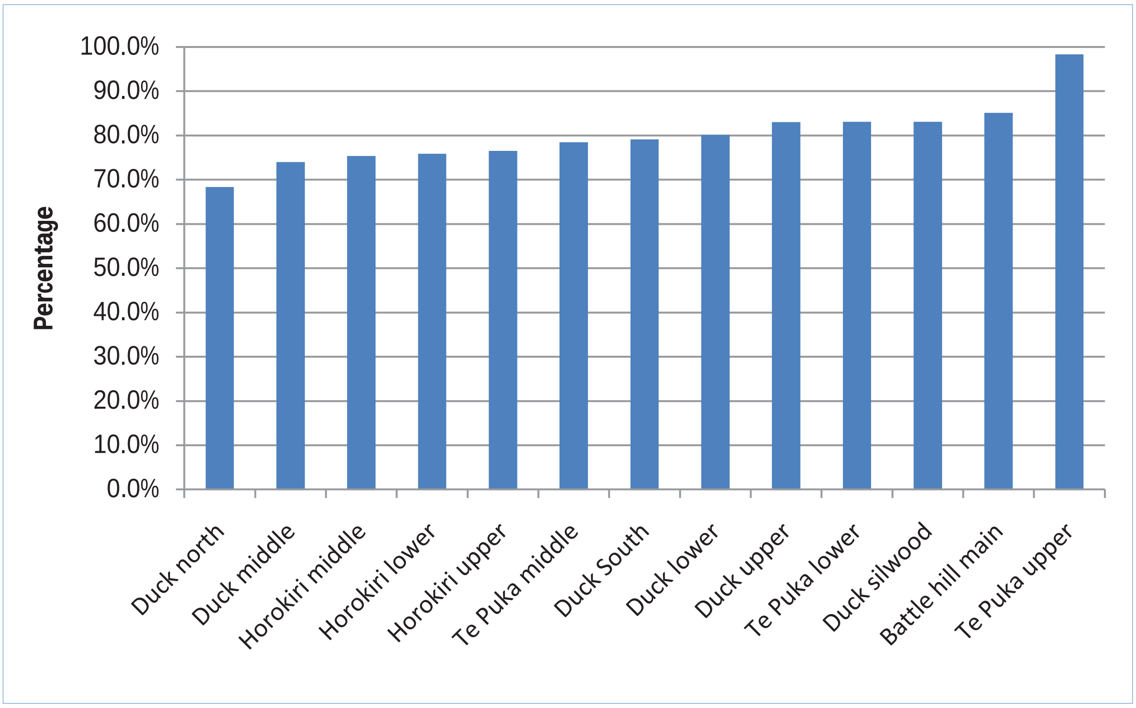
In summary, over all four of these measures, Horokiri from the lower to upper reaches, and the Te Puka above the State Highway both fall generally in the top 25% for all metrics and both systems must be seen as significant to the Region in terms of aquatic macroinvertebrate fauna.

Middle and upper reaches of Duck Creek and Cannons Creek also have high value in terms of their aquatic benthic macroinvertebrate fauna.

Overall sev scores

The total calculated SEV scores have been divided by the average reference site score (0.8) and plotted in Figure 9-33. This shows that even the "poorest" sites in the lowest reaches of Duck Creek still exhibit 68% of the habitat condition of the reference site. Most reaches studied show over 75% of the condition they could be expected to have if in "good" condition for the landscape they remain in. Te Puka is such high quality that in its head waters "Te Puka upper" is for all intents and purposes a "reference" condition site.

Figure 9-33 Final SEV scores as a proportion of the Averaged reference score



5.5 WATER QUALITY

The water quality data (SKM 2011) illustrates that several catchments have heavy metal issues and that most catchments currently have nutrient enrichment. The catchments most contaminated (with Copper and /or Zinc) are Porirua, Cannons, Kenepuru, Duck, Pauatahanui, Ration, Horokiri and Wainui i.e. most of the waterways. However only the Kenepuru and Cannons have notable high Dissolved Copper contaminant and it is the dissolved material that is most ecologically of issue. Again it is the Kenepuru-Cannons and Pauatahanui systems that have the greatest nutrient enrichment[14].

The TSS data gathered suggests that all of the streams in the project area experience a number of raised TSS conditions throughout each year. In the Horokiri Stream, events can be very large (>1000 gm^3) and quite frequent, whereas in other catchments events are more typically 50-100 gm3.

In all cases it appears that benthic macroinvertebrate fauna and fish indicative of good waterway quality persist with this current level of contaminant. However, in the absence of data over a prolonged period of time, it is not known whether these conditions and values are trending downwards.

5.6 REGIONAL CONDITION AND VALUE CONCLUSION

Project sampling and limited regional and historical data show that overall the streams of the TGMAP area support fauna that are sensitive to organic water pollution and sensitive to contaminants. This is in spite of a general nutrient enrichment condition, a low background of copper contamination and a discernable copper and zinc contamination in the lower reaches of

[14] See SKM Technical Report Water quality Malcolm & Wiseman (2010)

Kenepuru, Cannons, Duck and Pauatahanui waterways. The absence of systematic data collection over a long time means that it is not possible to identify any trends in fauna communities or condition of the physical environment.

Maintenance of diversity in the lower reaches of the Horokiri and Duck systems is of very high ecological value and importance at the Regional scale. In terms of aquatic habitat most reaches maintain over 75% of the condition they could be expected to have if in “good” condition for the landscape they remain in.

At a Regional scale the aquatic fauna and physical habitat of the Duck, Horokiri and Te Puka systems, while apparently deteriorating in the lower reaches and potentially trending down with land use practices, are considered to be Regionally significant. The lower reaches of Ration and Pauatahanui are also considered to be of high value (although the Ration is not of Regional importance) despite their modifications as they too still retain important fauna species. The Kenepuru, Porirua tributary and Cannons systems are of lower value although they still support an array of values, notably components of the macroinvertebrate fauna.

Table 9-20 Tabulated summary of Values.

Regionally significant in terms of Ecology	PHA (SEV)	Fish	Aquatic invertebrates	Compilation result
Lower-middle Tepuka	H	M	H	H
Upper Tepuka	H	M	H	H
Lower Horokiri (east)	M	H	H	H
Middle Horokiri (east)*	M	H	H	H
Upper Horokiri (east)*	M	M	H	M
Lower Ration	L	M	L	L
Middle Ration	L	L	L	L
Lower Pauatahanui	L	H	M	M
Lower Duck	M	H	M	M
Middle Duck	M	H	H	H
Upper-Middle Duck	H	M	H	H
Upper Cannon	M	M	H	M
Porirua tributary (Linden)	L	L	L	L

*Considers only the western tributaries, not the eastern tributaries which are in much better riparian condition and are expected to have greater value.

Table conclusion: Regionally significant in terms of Aquatic Ecology: Horokiri, Duck Creek, Te Puka.

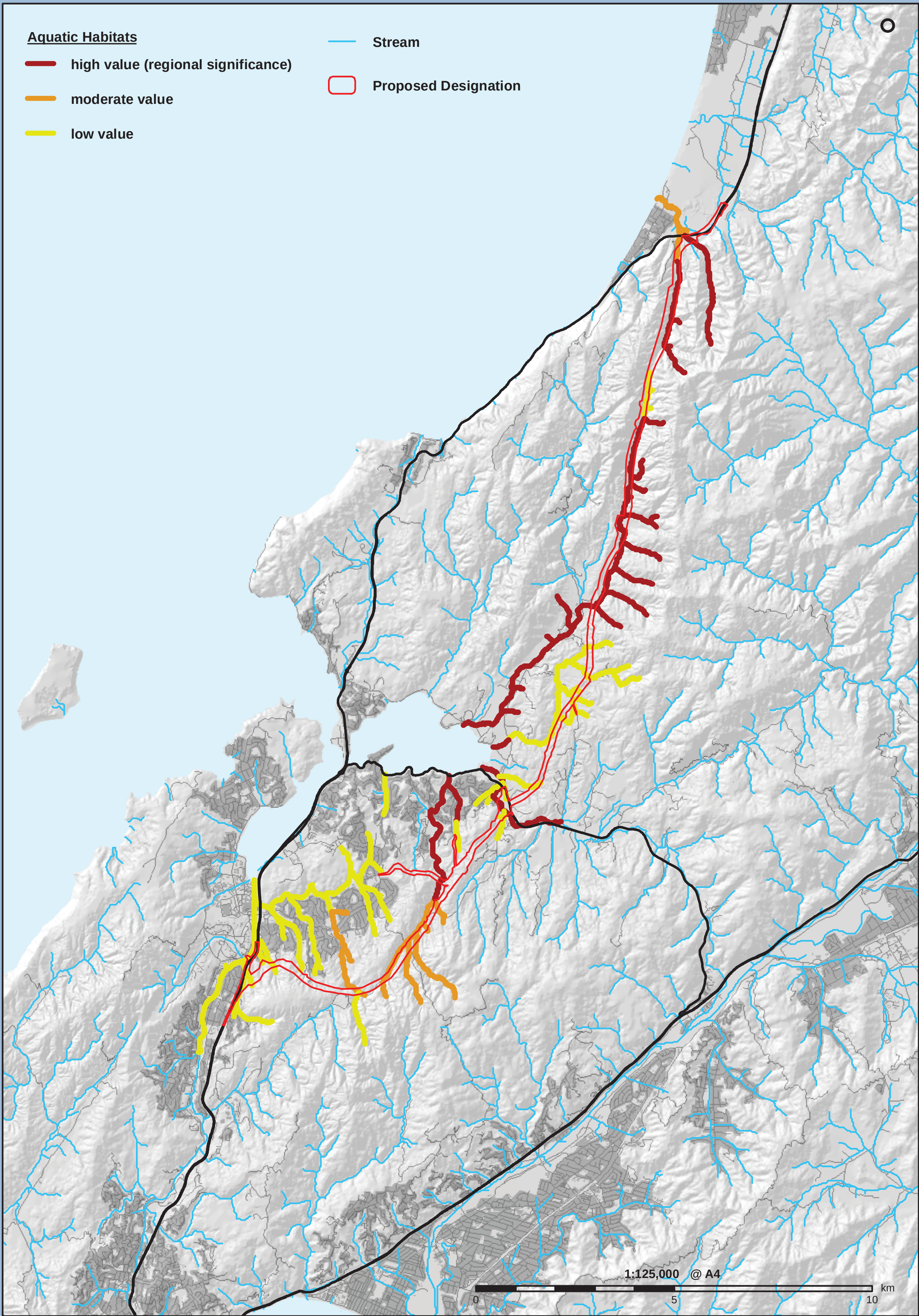
5.7 COMPARISON WITH APPENDIX 2 OF THE REGIONAL FRESHWATER PLAN

Without question the Horokiri has the ecological and Natural Character (ecology aspects) values to be listed in Appendix 2 of the GWRC Freshwater Plan.

The Pauatahanui however, is more modified and has a reduced character and pattern and process. Nevertheless, it too, retains attributes and biodiversity and processes that (at a Regional level) would cause it to still be retained in Appendix 2 of the GWRC Freshwater Plan

The Ration stream most certainly does not have the attributes, character and quality to be included in Appendix 2 of the plan.

Summary Values maps (Map 3-1) show those areas of each stream which have been classified as above and are inclusive of decisions made for all of the waterways and tributaries not just those broader areas described in the above tables.



Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

AQUATIC HABITAT VALUES

6 DISCUSSION

6.1 INTRODUCTION

The Transmission Gully project will have a range of effects on riparian and aquatic habitat and on freshwater fauna. The following discussion provides some context to the components of the freshwater aquatic environment that are critical to their health and functioning. It is intended to assist in assessing potential effects, determining appropriate mitigation, and guiding ongoing management and monitoring.

6.2 FISH PASSAGE IN CULVERTS

6.2.1 ISSUES

Seasonal fish movement

Many indigenous freshwater fish are migratory and must spend part of their lifecycle in the sea (diadromous). They require streams and rivers that are relatively unmodified from the mouth to the headwaters. If passage along a stream is prevented, populations of some species upstream of the barrier will eventually die out. The Freshwater Fisheries Regulations (1983) require that passage must be provided for indigenous fish.

At main stem diversions the design needs to not only consider fish passage but must match velocities with the original stream to ensure resident fish can maintain themselves in the new channel and utilise the habitat.

Also each fish has different climbing and burst swimming abilities and so the species of resident fish must be known to ensure the design caters to these requirements.

There is a well established toolbox for design and installation of fish friendly culverts (Boubee et.al. 2000) and these can ensure fish passage is maintained under most circumstances. Using these methods there is also the opportunity in Duck Creek to upgrade existing culverts to reopen the catchment to missing fish species.

In addition there is a range of methods for creating or maintaining habitat within culverts that can offset some of the effects of lost habitat.

Low gradient stream culverts

Generally the provision of fish passage in low gradient streams can be readily achieved through careful design.

Sampling and the NZFFDB indicate that main stem culverts of all streams must facilitate the passage of juvenile and adults of whitebait of several fish species that are relatively poor climbers including *Galaxias argenteus* (Giant kokopu) and *G.brevipinnis* (Koaro).

For the movement of fish identified in these streams any culvert or stream diversion needs to have the following design criteria:

- A velocity at or around 0.5m/s (but certainly less than 1 m/s);
- A water depth of at least 0.1m but preferably 0.2 m;
- The base needs to be roughened and with velocity abatement devices;
- The invert (both in and out) must be below the stream invert and the structures conducive to gravel movement into and along the culvert.

High gradient stream culverts

Investigations have identified the need for design features that take into account the steep fall on tributary streams, while providing a surface for climbing fish. Sampling and the NZFFDB indicate that these streams must facilitate the passage of juvenile and adults of whitebait of native fish that are excellent climbers including *G. brevipinnis* and *G. fasciatus* as well as both eel species.

Providing for fish passage in steep culverts can be problematic. It is difficult or impossible to maintain stream bed habitat through the culvert and so a range of devices are often retrofitted to the culvert to provide additional roughening and rest and refuge areas for migrating fish. These devices, however, can affect culvert flow capacities, are abraded and damaged by gravels and boulders during storm events, and require continual maintenance.

6.2.2 TRANSMISSION GULLY STREAMS

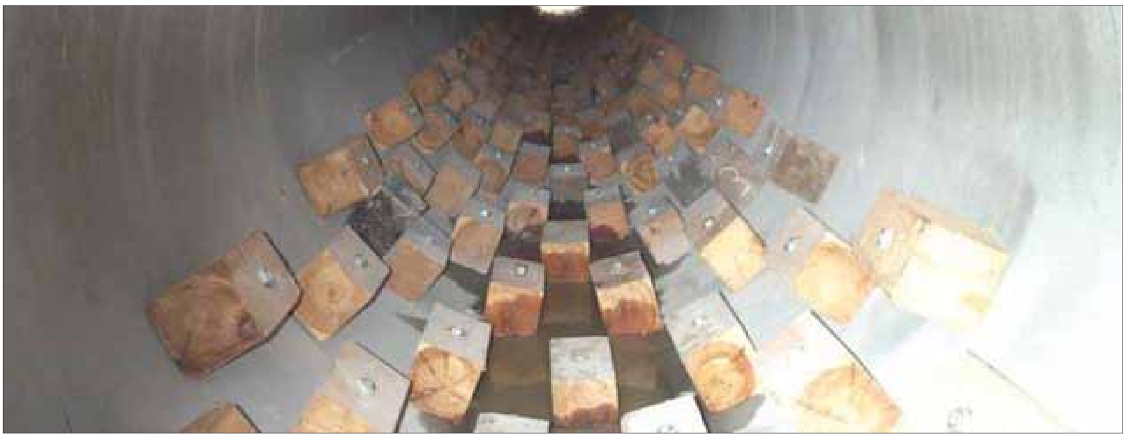
The tributaries of the Te Puka, Horokiri and Duck Creek, which will be affected by the alignment and require both culverts and fish passage, share similar characteristics. They are steep to very steep; have single and loose, rocky substrates, often with intermittent surface flows and generally have small headwater catchments that (generally because of the presence of a forest fragment) provide habitat for small numbers of koaro, banded kokopu and eel species.

The tributaries in question generally have sections between the upper pool and forest headwaters (the desired habitat) and the main stem which are steep and stepped, form a cascade, and provide shallow water over a cobble/moss/lichen/macrophyte surface of varying steepness, with a small but important hyporehic zone. Through this surface and sub-surface the juvenile banded kokopu, koaro and eel currently move using a combination of swimming, wriggling and climbing.

The challenge is to provide climbable fish passage in the steep and high water velocity environment through a smooth pipe surface over distances, often up to 100m and where the inlet or outlet, may become disconnected to the stream bed through periodic erosion.

The current support to swimming fish (typically in burst mode) is to provide a corrugated pipe, or to retrofit the culvert base with various plastic screw-in moulds such as “stand pipes” (Stephenson & Baker 2009; Slaven & De Longe 2007). These are extremely expensive over any distance, require ongoing maintenance, and have not been used to cover entire culvert bottoms on steep slopes. Typically, retrofitting of culverts has entailed bolting or gluing on stones, or wood blocks in various patterns to affect flow on low gradient flows. All of this facilitates movement for swimming fish.

Photo 9-29 Example of wooden blocks bolted into a culvert.



However, recent West Wind wind farm experience with a retrofitted culvert (30m long 5-6% gradient) is that the wooden blocks were shorn off in the first high flows (Ewen Robertson pers com). Our view is that, because of the velocities and quantities of gravels and loose material that will be flushed through the step culverts along Transmission Gully, in pipe solutions in Horokiri, Te Puka and, to a lesser extent, Duck tributaries, the same problem would arise.

New options

Recent studies on climbing fish (David, Hamer & Collier 2009) in the Waikato examining the use of UV treated mussel spat ropes as ladders for climbing fish has presented a possible solution. Research by David et al, 2009 (although early experimentation) has shown that over a 0.5m vertical height over 90% of juvenile banded kokopu successfully climbed a spat rope and accessed a "pool" above the set up. They did so within three hours. The researchers suggest that all of the climbing galaxiids and eel are likely to perform as well as the banded kokopu. The experimenters tested two types of rope: "Russet Loop" and "Super Xmas Tree" (Donaghys Industries, New Zealand). Both rope types are constructed by the manufacturer using ultraviolet (UV) stabilised polypropylene yarn. They used 3 ropes of 0.25 m diameter as a multi-rope ladder.

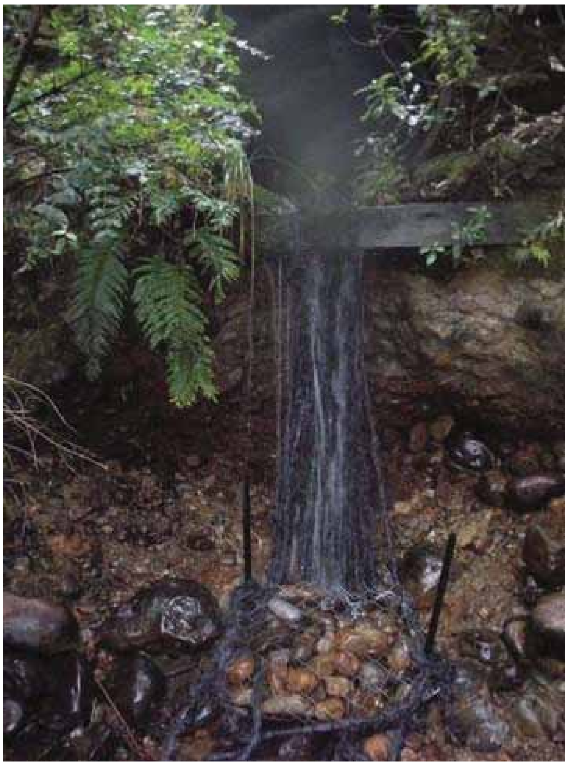


Photo 9-30 Example of the use of spat ropes in a natural situation to add access to an otherwise difficult or impossible climb (Taken from Stevenson & Baker. (2009), photo courtesy of B. David, Environment Waikato).

The use of mussel spat ropes appears to offer some advantages as a structure promoting fish passage. The ropes are relatively cheap ($NZ 1–2/m, $NZ500 m roll), are available as UV stabilised ropes, and so they are less perishable than other available ropes. They can be simply replaced as required.

We believe this might be a workable solution In the Transmission Gully situation. Several design options are possible. One option would be to install a small diameter pipe (200mm) pipe parallel to the main stormwater pipe. Three (or four) strands of mussel spat rope would be inserted with sufficient length emerging to lie some 0.5m of length in the down slope pool. The upper ends would have flush attachment so as to remain in place and afford "dismount" of the fish into the water.

In his study, David et al noted the following matters that will require consideration if this method is to be considered:

1. *The likely size and life stage of fish when they reach the structure (which can affect climbing capability) and the complexity of the route.*

In the Transmission Gully proposals, the distances from the Coast to the head of the systems are: Te Puka - 4km; Horokiri – 10km; Ration – 3km; Pauatahanui – 4km; Duck – 9km; Porirua – 5km. For Te Puka, Horokiri and Duck the route up the catchment is relatively straight forward and it is anticipated that juveniles swimming up the catchment would cover the 5-10km in short time, be held up infrequently and arrive as young juveniles, having spent little time maturing prior to reaching the tributaries of the headwaters. Thus it is anticipated that early juvenile stages which are the better climbers than older fish will use the structures.

2. *The motivation of fish when they reach the obstacle (both size and motivation could vary with distance inland).*

Given the low water quantities and minor habitats on the eastern tributaries it is likely that motivation will be low and the numbers attempting passage also very low.

3. *What species they are (different species have different climbing capabilities). From sampling and records*

It is known that koaro, banded kokopu and both eel species are present and reach the headwaters of most of the streams present (certainly the Horokiri, Te Puka and Duck). IT is also known from records that there are seven common species in the upper catchments and a slim chance that short jaw kokopu could also be present, the greatest potential for short-jaw in the project area being associated with the Horokiri and Te Puka systems. However, in both cases the headwaters that might draw these fish are on the north-eastwards side of the alignment (the true left tributaries of the Horokiri and true right of the Te Puka) and not affected by passage issues aside from in the main stem. The galaxids and eel present and requiring passage are good climbers (including short jaw). The bully present do not require passage in the steep small tributary habitats.

4. *The range of velocity/discharge of water running down the ropes.*

In the Transmission Gully tributaries, storm events the velocity of water through the culvert will greatly exceed 2ms-1; during normal flow times and given the limited water, velocities down the rope pipe (which might be at 30o or more) are likely to be limited by the ropes.

5. *The vertical height of the ropes and the manner in which they have been installed (the length and gradient of the inner pipe).*

Installing the ropes loosely within a pipe, but occupying most of the pipe should protect the ropes and prolong their functional life, and it may help concentrate the wetted areas, and sustain a wetted system in summer. However, travel distance on these "ladders" has not been tested beyond 0.5m. Under the current design it is likely that these passages may be over 100m in order to pass under the road and batter slopes. Galaxids are known to climb that type of distance; however there is as yet little empirical proof that they will sustain such a passage on a rope ladder in a pipe.

6. *The possibility of debris entanglement and periphyton accumulation on the ropes.*

Where the pipe is 200mm or more and the pipe largely filled with three ropes and a stone guard grill placed over the top, there will be limited chance of a blockage of water and passage. However, such potential blockages may require an annual inspection to ensure that prior to the main migration season the passage is functional.

6.3 DIVERSIONS

6.3.1 ISSUES

Significant diversions are likely in the upper Te Puka Stream, and the upper and mid reaches of the Horokiri Stream, with the original stream bed being reclaimed. With careful design it can be possible to emulate the original physical habitat conditions of the original channel. Section 4.2 provides a comprehensive description of these streams with the intention of guiding diversion design. The following discussion highlights key issues with regard to diversion formation and design and current knowledge of the requirements of freshwater fauna.

6.3.2 HABITAT TYPES –RUN /RIFFLE /POOL

Currently the freshwater ecological literature suggests that banded kokopu, koaro and short jawed kokopu are species typical of inland and upland native forested stream systems in good condition, in first and second order systems, with small pool and cascade habitat types. It is recognised that these habitat types may be all that is left to them rather than the extent their habitat preference. Hayes suggests koaro, for example, would and do inhabit large pool systems and drift feed were it not for competition for such habitat and predation in such habitat by large trout (Hayes 1996). Therefore an array of aquatic habitat should be considered, especially where added diversity can be achieved.

The affected habitat in the Te Puka is quite uniform with 55% of the habitat in either riffle or stepped riffle and doesn't have the cover (in stream or riparian) conducive to either the banded kokopu, eel or the possible presence of shortjawed kokopu. While the riffle habitat in general is good for bully, torrent fish and juvenile eel (as shown by Jowett & Richardson (1995), and reproduced in Table 9-21 below), more complex water habitat are required by the Galaxid species present in the Te Puka. Currently sampling shows only bully species to be in the open braided riffle reaches of the upper Te Puka.

Table 9-21 Percentage of fish by habitat type (Jowett & Richardson 1995).

	% in riffle	% in run
Longfinned eel	77.7	23.9
Shortfinned eel	76.1	22.3
Upland bully	43.6	56.4
Common bully	59.1	40.9
Redfinned bully	63.1	36.9

In regard to Horokiri Stream the habitat within the general area of the upper reach diversions is more complex than in the Te Puka with areas of cascade, water fall, chutes and runs. This will be the most complex habitat to carry out habitat restoration. The lower reaches of the diversion area are however, more simple being largely run and pool systems.

Table 9-22 provides the proportion of occurrence of each habitat type in the Te Puka and Horokiri. In the Te Puka riffles and stepped pools are the most frequently encountered habitat types. In the lower Horokiri riffles are twice as common as either runs or pools while in the upper Horokiri there is a varied array of habitat none of which can be said to be substantially more frequent in occurrence than any other.

In terms of lengths of each habitat to recreate, and accepting that there will be construction limitations, the data from the sites shows that stepped riffles in the Te Puka and upper Horokiri are the longest habitat types, with riffles also occupying substantive linear lengths between 14 and 24 m. Waterfalls, chutes and cascades are generally short at less than 5m.

Table 9-22 Habitat type proportions (%) in the diversion reaches of the Horokiri and Te Puka.

	Run	Riffle	Pool	Stepped riffle	Cascade	Water Fall	Stepped Pools	Chute	Stepped run	Braid
Te Puka		35	9	12	12		22		2	8
Horokiri upper	8	24	22	2	14	2	12	4	12	
Horokiri middle	26	44	30							

The above array of data will allow detailed planning of diversions to replicate the existing conditions.

6.3.3 DEPTHS OF WATER

Depths and velocities together influence species preference and acceptance of habitats. Generally native fishes are thought to prefer shallow water over deeper water however, it is generally accepted that due to the high level of modification of the lower reaches of rivers and changes to access and predation in lakes that the data is skewed in terms of where native fish are currently found and existing patterns of distribution with depths may not indicate preferences but rather reflect limited choices.

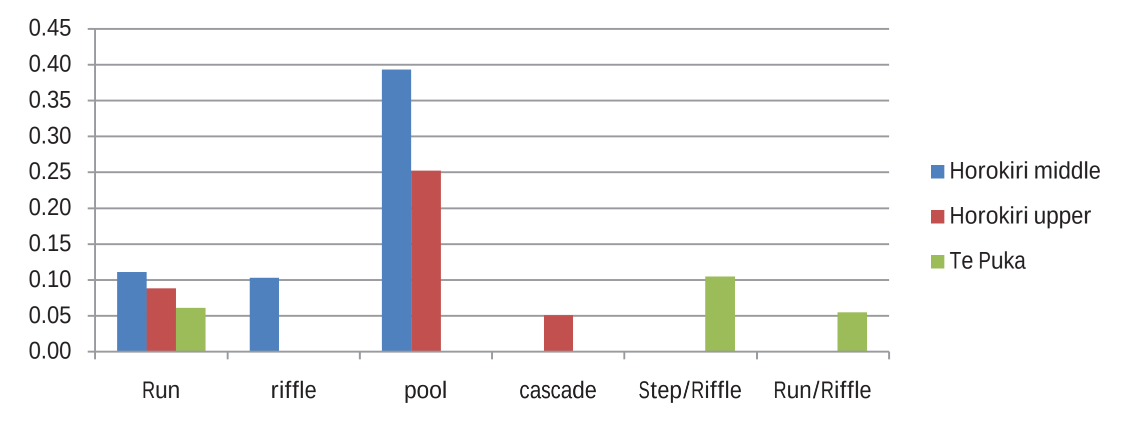
Jowett and Richardson surveyed are wide range of habitats and discovered that native fish are found in a range of depths including from 0.05 to 0.67 m (but this does not consider lakes). They found that the distribution of native fish with water depth varied between species (Table 9-23). Blue gilled bullies and torrent fish were more common in deeper water (0.25-0.5 m), whereas half or more of the short finned eels, upland bullies, and common river galaxias occurred in water < 0.125 m deep. There sampling did not include koaro, banded kokopu, short jawed kokopu, giant kokopu and some of the other fishes relevant to the Horokiri, Te Puka systems.

Table 9-23 Percentage fish-use by water depth for fish species

	Depth (m)			
Species	**<0.125**	**0.125-0.25**	**0.25-0.5**	**>0.5**
Longfinned eel	37.0	35.9	20.6	6.5
Shortfinned eel	53.2	25.7	17.3	3.9
Torrentfish	16.1	37.6	39.4	6.9
Upland bully	56.6	28.1	8.2	7.1
Redfinned bully	36.7	43.4	15.1	4.7
Bluegilled bully	13.8	45.8	35.2	5.2
Common river galaxias	50.0	30.1	13.7	6.2
Common bully	44.6	30.1	14.5	10.8
Average of all species	**38.5%**	**34.6%**	**20.5%**	**6.5%**

In the Horokiri and Te Puka systems we found depth profiles as illustrated in the following graph:

Figure 9-35 Average depth in various habitat types (m)



As is to be expected pools were the deepest features averaging between 0.25 and 0.4m (but there were pools upward of 1m). While most other features averaged between 0.05 and 0.1m (i.e. very shallow). The current habitat is typically very shallow, and without the native forest canopy, prone to summer temperature issues. However, in general the depths are those preferred by many native fish species.

We therefore propose that the depths of all features other than pools target a range of 0.05 and 0.3. Riffle depths should aim to be 0.05-0.15, cascade depths range from 0.0.05, Runs should range from 0.05-0.3 m. Target depth for pools should be 0.25 to 0.5.

6.3.4 SUBSTRATE SIZES

Substrate sizes and the spaces between substrates provide for, and even govern, the species suited to the habitat. Eel and lamprey prefer the softer substrates such as silts, sands and gravels, bullies are found in abundance in s mall to middle sized cobbles, galaxids in larger cobbles and often in boulder – cobble habitat. Koaro and banded kokopu are often in bed rock or solid bottom pools and boulder chute habitat. Table 9-24 illustrates some measured “preferences” by Jowett and Richardson (1995).

Table 9-24 Percentage fish-use of habitat units based on substrate size for fish (Jowett & Richardson 1995).

	Substrate size (mm)			
Species	**<32**	**32 - 46**	**64-128**	**>128**
Longfinned eel	7.3	37.4	30.4	24.9
Shortfinned eel	77.7	15.0	5.7	1.6
Torrentfish	45.6	36.7	13.6	4.2
Upland bully	13.5	53.1	26.7	6.7
Redfinned bully	0.0	24.6	27.8	47.6
Bluegilled bully	0.7	81.1	11.8	6.5
Common river galaxias	39.9	15.9	44.2	NS
Common bully	63.0	25.2	0.0	11.8
All above species	**38.1**	**38.9**	**13.7**	**9.3**

Throughout the Horokiri and Te Puka, from the diversion location habitats we have measured the substrate types, their sizes and proportion composition. Table 9-25 shows that the most common substrate type in the Te Puka is cobble, medium sized is ubiquitous but large cobble is also common. Gravels sand and pebble are also frequently present and therefore a wide substrate type is available. The upper Horokiri includes some bed rock and boulders, but is dominated by large cobble whereas lower down the catchment (the middle Horokiri) medium cobble dominant and sand and pebbles are common.

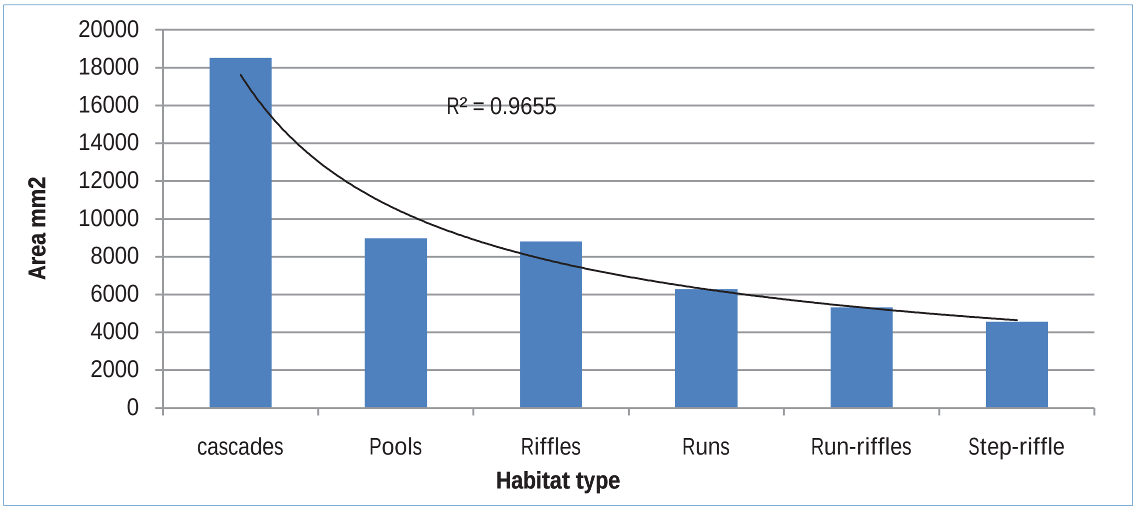
Table 9-25 Average % cover of the different substrate types.

	Large Cobble	Medium Cobble	Small Cobble	Gravel	Sand	Boulder	Pebble	Bedrock
Horokiri middle	59.3%	85.2%	59.3%	33.3%	48.1%	7.4%	59.3%	
Horokiri upper	75.0%	50.0%	41.7%		16.7%	25.0%	33.3%	8.3%
Te Puka	30.0%	100.0%	70.0%	30.0%	20.0%		30.0%	

Of note is the near absence of soft fines and silts in the Horokiri or Te Puka.

The actual sizes of the substrates were measured and the following graph plots the mean substrate class size (as an Area mm^2).

Figure 9-36 Mean substrate particle size by habitat feature (mm^2) in the Horokiri and Te Puka catchments.



These proportions should guide the recreation of the new diversion beds to be made.

6.3.5 HYPORHEIC ZONE

An important component of substrate size is the presence and extent of a hyporheic zone. The hyporheic zone is a region beneath and alongside a stream bed, where there is mixing of shallow groundwater and surface water. The flow dynamics and behaviour in this zone is recognized to be important for surface water/groundwater interactions, as well as fish spawning, among other processes.

Currently the depth of this zone in the Horokiri and Te Puka is unknown but it is anticipated that the cobble and gravel will be at least 1m deep. For practical purposes we propose that in the Horokiri diversions that a hyporheic zone of, on average 1m, be created using a range of cobble sizes similar to that recorded on the surface.

6.3.6 STREAM VELOCITIES

The third major component of habitat preference is water velocity. Fish especially but also aquatic macroinvertebrates and aquatic plant life have tolerances to particular flows as well as preferences. Species swimming abilities and (for the establishment of habitat preference curves) species "preference" flows have been researched and modelled by a number of NIWA researchers. Native fish species have differing abilities to cope with deferent velocities, some velocities are preferred others result in avoidance behaviours, some can only be passed through short bursts of extreme energy, some can be passed through sustained swimming. Jowett, Mitchell and others have researched for a range of fish species those velocities in laboratory situations. The following Table 9-26shows some preference velocities based on studies of were fish are found from a range of surveyed rivers about New Zealand.

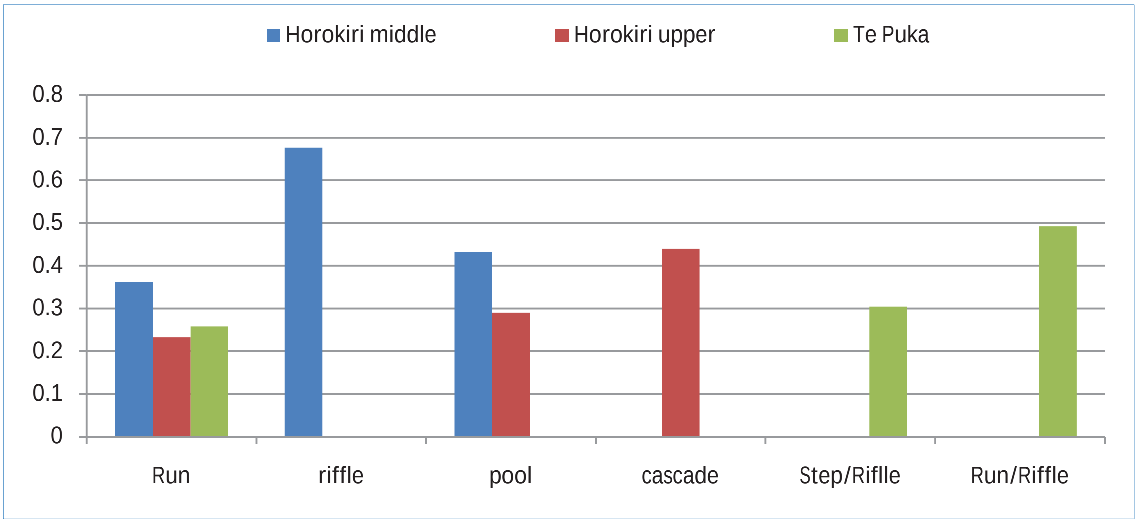
Table 9-26 Percentage fish-use by velocity for native fish species. Velocity (m s-').

	Velocity (ms^{-1})			
Species	**<0.15**	**0.15-0.3**	**0.3-0.6**	**>0.6**
Long finned eel	21.1	22.7	21.2	35.0
Short finned eel	10.4	30.3	25.5	33.8
Torrent fish	0.3	5.8	23.5	70.3
Upland bully	43.1	35.7	16.5	4.7
Red finned bully	38.6	39.7	18.4	3.2
Blue gilled bully	0.8	7.5	20.8	70.9
Common river galaxias	38.5	30.0	13.5	18.0
Common bully	13.4	44.8	29.3	12.4

Native fish typically are found in velocities under 0.3ms-1, but of course can be found in velocities much higher than this where there are refugia or sub-habitats out of the "central" flow. Note, some fish such as blue gilled bully, successfully manage quite high velocities. Again, as with the depths, introduced species competition and predation may be squewing these results.

Velocity measures from the Horokiri and Te Puka systems are illustrated in Figure 9-37.

Figure 9-37 Average velocities within Te Puka and Horokiri Streams by habitat feature



These show that the Te Puka middle reach has average velocities between 0.25 and 0.5 ms^{-1}, the upper Horokiri with 0.22 to 0.42 ms^{-1} and the middle Horokiri with velocity average ranges between 0.3 and 0.5 ms^{-1}. The fastest velocities measured throughout was 0.72 ms^{-1} (in the middle Horokiri), the most common velocity measured was 0.41ms^{-1}.

Velocities of the diversion reaches therefore should be contained below 0.5 ms^{-1} and preferably 0.2 to 0.4 ms^{-1}, and drop structures preferred to move down the catchment rather than steep reaches of fast runs or riffles. In attaining these velocities small waterfalls and chutes are recommended to be constructed with a climbing fish surface focus.

6.3.7 RIPARIAN PLANTING

Currently the majority of the stream lengths in the Horokiri and Te Puka systems lack riparian vegetation other than rank grasses and areas where beds of aquatic weeds have formed. There are small sections of the middle to lower Horokiri with mahoe fringes. Generally though, the streams gravel beds lie in open country, surrounded by grazed pasture.

Riparian cover provides a wide range of benefits for aquatic habitat. It reduces daily and seasonal temperature fluctuations including summer peaks which can be debilitating for some species of fish. Native riparian trees, shrubs and tussocks have evolved fast growing, strong and fibrous root systems which stabilise stream banks reducing stream bank erosion. They also reduce flood flow velocities when streams overtop their banks and flow across adjacent terraces. This also reduces erosion. A forest canopy contributes organic matter, leaves and small branches, for detritus feeders. And a 'rain' of insects which provide food for carnivorous fish and macroinvertebrates. Branches and trees that fall into the stream provide snags and create debris dams which are extremely important habitats and refugia for stream fauna. And appropriate riparian vegetation provides spawning habitat for several species of native fish. Revegetation of these streams with appropriate species can therefore provide significant ecological benefits.

Key Physical Properties of Riparian Colonising Plant Species

The following table lists the top 10 riparian species identified by Landcare and provides a ranking of their key strengths across a range of key attributes (Marden et.al. 2005). For example lacebark ranked top for root strength and canopy spread. Lemonwood ranked top for root spread.

Table 9-27 Key features of 10 native riparian plants

	Root strength (1-4mm)	Root spread (5 yrs)	Root depth (5 years)	Plant biomass (5 years)	Height	Canopy spread
Lacebark	1	6	5		1	
Kowhai	2					
Kanuka	3					
Kohuhu	4	4		6		
Fivefinger	5					
Cabbage tree	6	5	1	1	3	
Lemonwood		1		5		
Tutu		2	4	2		1
Ribbonwood		3	2	3	2	
Karamu			3	4		2

Recommended Riparian Plant Species

Originally these streams would have flowed through podocarp mixed broadleaf forest and the fauna present in them would have reflected this habitat. Where riparian planting is proposed for mitigation, it should therefore be aimed at returning a broad leaf canopy (mahoe, five finger, pigeon wood and Coprosma sp.). Initial planting should include riparian species recognised for their rooting strength to stabilise the site.

Once stable vegetation has developed this broadleaf planting should be enriched with podocarp and hardwood species such as kahikatea, pokaka, hinau, titoki, kohekohe and matai.

Riparian planting should focus on a zone of no less than 10m either side of the waterway. It should have a medium term target of 80% stream canopy cover with woody vegetation.

Table 9-28 Recommended Riparian Species & Growth Rates

	Common name	Botanical name	Growth rate	Mature Height (m)	Height at 5 years	Height at 10 years	Height at 20 years (m)
RIPARIAN WET							
Initial planting (stream bank erosion protection)	Toetoe	Cortaderia toetoe	Fast	3	n/a	n/a	overtopped
	Lowland flax	Phormium tenax	Fast	3	n/a	n/a	overtopped
	Umbrella sedge	Cyperus ustulatus	Fast	1.5	n/a	n/a	overtopped
	Sedge	Carex geminata	Fast	1.5	n/a	n/a	overtopped
	Cabbage tree	Cordyline australis	Fast	15	3.75	7.5	15
Initial planting (wet terraces)	Koromiko	Hebe stricta var. stricta	Fast	4	3.75	7.5	overtopped
	Karamu	Coprosma robusta	Fast	5	3.75	5	overtopped
	Kowhai	Sophora microphylla	Fast	8	3.75	8	overtopped
	Kotukutuku (tree fuchsia)	Fuchsia excorticata	Fast	10	3.75	7.5	10
	Fivefinger	Pseudopanax arboreus	Fast	10	3.75	7.5	10
	Houhere (narrow-leaved lacebark)	Hoheria angustifolia	Fast	10	3.75	7.5	10
	Tarata (lemonwood)	Pittosporum eugenioides	Fast	10	3.75	7.5	10
	Manatu (lowland ribbonwood)	Plagianthus betulinus	Fast	15	3.75	7.5	15
Year 3 enrichment	Putaputaweta	Carpodetus serratus	Slow	10	1.25	2.5	5
	Turepo	Streblus heterophyllus	Slow	12	1.25	2.5	5
	Swamp maire	Syzygium maire	Slow	15	1.25	2.5	5
Year 5 - 8 enrichment	Pukatea	Laurelia novae-zelandiae	Slow	30	1.25	2.5	5
	Kahikatea	Dacrycarpus dacrydioides	Slow	40	1.25	2.5	5
RIPARIAN DRY							
Initial planting	Rangiora	Brachyglottis repanda	Fast	6	3.75	7.5	overtopped
	Karamu	Coprosma robusta	Fast	5	3.75	7.5	overtopped
	Koromiko	Hebe stricta var. stricta	Fast	4	3.75	7.5	overtopped
	Makomako (wineberry)	Aristotelia serrata	Fast	8	3.75	7.5	overtopped
	Ngaio	Myoporum laetum	Fast	8	3.75	7.5	overtopped
	Houhere (lacebark)	Hoheria sexstylosa	Fast	8	3.75	7.5	overtopped
	Kohuhu	Pittosporum tenuifolium	Moderate	10	2.5	5	10
	Kanuka	Kunzea ericoides	Moderate	15	2.5	5	10
Year 3 enrichment	Fivefinger	Pseudopanax arboreus	Fast	10	3.75	7.5	10
	Mahoe	Melicytus ramiflorus	Moderate	10	2.5	5	10
	Broadleaf (kapuka)	Griselinia littoralis	Moderate	15	2.5	5	10
	Heketara	Olearia rani	Slow	8	1.25	2.5	5
	Pigeonwood	Hedycarya arborea	Slow	8	1.25	2.5	5
Year 5 - 8 enrichment	Titoki	Alectryon excelsa	Slow	15	1.25	2.5	5
	Nikau	Rhopalostylis sapida	Slow	10	1.25	2.5	5
	Hinau	Elaeocarpus dentatus	Slow	20	1.25	2.5	5
	Tawa	Beilschmiedia tawa	Slow	25	1.25	2.5	5

Growth rates are from Landcare (2010).

- Slow: 1-25 cm/yr
- Moderate: 25-50 cm/yr
- Fast: > 50 cm/yr

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9 APPENDICES

Appendix 9.A Glossary of Terms

TGMAP Initials standing for Transmission Gully Main Alignment Project.

PHA Abbreviation for Physical Habitat and term used to describe aspects of the aquatic habitat involving the bank, substrate, water and riparian condition.

SEV Stream Evaluation system. A system devised to regulate data collection and allow through formulae to establish a range of biological values relating to stream habitat function, condition etc.

Substrate The ground or floor material of a water course (typically rocky, gravelly, sandy or muddy).

Riparian Edges immediately along the banks of a waterway. The riparian zone is that 3 Dimensional area adjacent that directly interacts with the waterway (eg shades it or drops material into it).

Turbidity A measure of the amount of suspended matter in the water column. Turbidity is often considered to be how "dirty" the water is and looks. It is a different measure from clarity and from direct measures of suspended solids. There is a strong correlation between turbidity and suspended solids up to around 350 NTU.

NTU Nephelometric Turbidity Unit – A measure of how much light reflects from particulates in a column of water.

IBI Index of Biological Integrity

Taxa A less discriminate word for species. Taxa may also mean genera, sub-species etc.

Taxa richness The number of identifiably different "species".

EPT An abbreviation for Ephemeroptera, Plecoptera and Trichoptera (mayfly, stonefly and caddisfly).

Macroinvertebrate. An aquatic invertebrate above "micro".

MCI A biometric – an index score - "Macroinvertebrate Community Indices". A summation of scores allocated to various taxa based on their measured sensitivity to water organic contaminants.

QMCI A biometric –an index scare - "Quantitative Macroinvertebrate Community Indices" a measure of the influence of each taxa based on its numerical abundance in the community on the "sensitivity score" (the NCI).

Biometric a biological measure typically a number describing a quantum of a feature or features or a score or index value.

Appendix 9.B SKM Water Reports

Work stream 12 – Report Headers

Report Header	Author
Baseline Water Quality Monitoring Report	Michelle Malcolm / Ian Wiseman
Sediment Yield Calculations	Michelle Malcolm
Construction Erosion & Sediment Control	Craig Martell / Jessie Adams / Petja Albrecht
Generation of Daily Stream flow Time series for Selected Catchments	John Hansford / Michelle Malcolm
Modelling of Sediment in the Streams & Harbours.	Ben Fountain
Stormwater Management Devices	Petja Albrecht / Craig Martell

Work stream 4 – Report Headers

Report Header	Author
Generation of Storm Rainfall Isohyets	John Hansford
Peak flow Analysis for Culvert and Bridge Design	Craig Martell / Ben Fountain / Jesse Adams / Konrad Heineman
Stormwater Management Devices	Combined with WS 12 as above
Construction Erosion & Sediment Control	Combined with WS 12 as above
Assessment of Hydraulic Effects on Critical Streams	Ben Fountain / Jesse Adams / Craig Martell

Appendix 9.C PHA & stream morphological Data

Horokiri 1

		Depth in cm across the waterway at 0.5m intervals						Bank Total width	Total wetted
1	Riffle	0.12	0.145	0.155	0.155	0.001		4.8	2.3
2	Pool	0.67	0.66	0.39	0.14	0		5.4	2.5
3	Run	0.02	0.1	0.16	0.15	0.12	0.02	5.2	3.05
4	Pool	0.26	0.5	0.5	0.44			3.6	2
5	Run	0.15	0.12	0.1	0.11	0.05		14.7	3.3
6	Riffle	0.02	0.135	0.12	0.09	0.085		5.7	2.6
7	Run	0.24	0.13	0.08	0.09	0.13	0.125	12	3.3
8	Riffle	0.02	0.05	0.15	0.15	0.15	0	7	2.9
9	Pool	0.56	0.51	0.34	0.12			4	1.9

Horokiri 1

Time over distance measures for Velocity calc (repeat measures)								
1	Riffle	10m	14.5	13.4				
2	Run	6m	24.7	20.1	20.3	33.8		
3	Pool	5m	8.46	8.5	9.2			
4	Pool	8m	17.8	22.01	16.14	18.3	16.06	17.7
5	Run	10m	20.5	21.3	22.06	23.07		
6	Riffle	4m	5.8	6.2	5.26			
7	Run	5m	11.99	12.04	13.1	13.64	13.28	14.07
8	Riffle	5m	7.085	8.07	8	9.53	7.95	7.9
9	Pool	6m	21.4	24.4	19.2	19.2	21.9	23.9

Horokiri 1

Hydro Habitat type lengths (m)		
Runs	**Riffle**	**Pools**
8	14	9
42	18	8
9	15	15
7	3	11
8	6	10
8	6	11
10	21	14
8	21	8
5	24	10
10	15	10
9	21	10
33	10	5
	12	6
	6	8
	14	
	33	
	11	
	12	
	15	
	13	

Horokiri 1 - Substrate cover (%)

		Large Cobble	Med Cobble	Small Cobble	Gravel	Sand	Boulder	Pebble
1 Riffle	L		30			10		60
	M	70		20				10
	R	45	50		5			
2 Pool	L		50		30	20		
	M	60	30					10
	R		80	10				10
3 Run	L		10		50	30		10
	M	10	20	40				20
	R	20	30	20		10		20
4 Pool	L	25	25	30	10	10		
	M	80	10	10				
	R						90	10
5 Run	L	20	25	10	10	30		5
	M	50	25	15		10		
	R		25	60	5	10		
6 Riffle	L		80	20				
	M	25	30	35				10
	R		20	30	25			25
7 Run	L	15	65			10		10
	M	20	20	25		10		25
	R	10	30	20				40
8 Riffle	L	20	35			5		
	M		5				95	
	R	25	65		5			5
9 Pool	L			10	10	80		
	M		30			40		30
	R	95		5				

Horokiri 2

		Depth in cm across the waterway at 0.5m intervals						Bank Total width	Wetted Total
1	Run	0	0.04	0	0.135			4.5	1.7
2	Pool	0	0.35	0.3	0.29	0.07		3.8	2.1
3	Cascade	0	0	0.01	0.01	0.065	0.17	3.4	3.1
4	Run	0	0.085	0.14	0.13			3.3	1.7

Horokiri 2

Horokiri 2 Substrate cover (%)								
	Run	4m	13.3	19.1	13.4	12.7		
1 Run	Pool	4m	17.8	11.5	11.4			
	Cascade	3m	5.8	4.2	4.7	9.9	9.6	
	Run	2m	9.8	11	11.7	12.3	7.3	

Horokiri 2 Substrate cover (%)

		Boulder	Large Cobble	Med Cobble	Small Cobble	Pebble	Gravel	Sand	Bedrock
1 Run	L		10	20	70				Heavey
	M	90	10						
	R		20	80					
2 Pool	L		10	40	20	30			
	M	100	95			5			
	R	75							
3 Cascade	L		10	40	20	30			
	M		95			5			
	R	100							
4 Run	L		90	10					
	M		30	40	20			10	
	R		20	20	25	30		5	

Horokiri 2 Substrate cover (%)

		Boulder	Large Cobble	Med Cobble	Small Cobble	Pebble	Gravel	Sand	Bedrock
1 Run	L		10	20	70				Heavy
	M	90	10						
	R		20	80					
2 Pool	L		10	40	20	30			
	M	100	95			5			
	R	75							
3 Cascade	L		10	40	20	30			
	M		95			5			
	R	100							
4 Run	L		90	10					
	M		30	40	20			10	
	R		20	20	25	30		5	

Horokiri 2

Hydro Habitat length measures (m)					
Step/Riffle	**Run**	**Cascades**	**Riffle**	**Pool**	**Water Fall**
56	10	2	10	4	3
	30	30	15	3	
	22	4	18	3	
	42	2	35	2	
		26	30	3	
		10	65	3	
		3	8	4	
Run/Step		Chutes	20	5	
25		2	5	8	
22		6	12	2	
20			15	3	
22			30	Stepped Pools	
18				22	
35				17	
				10	
				80	
				75	
				10	
				(15 pools)@1m each wide	

Te Puka

		Depth in cm across the waterway at 0.5m intervals							Bank Total width	Wetted Total
1	Step/Riffle	0.08	0.13	0.06	0.065	0.19			9	3.7
2	Run/Riffle	0.02	0.05	0.1	0.04	0.11	0.01	10.025	13.5	6.1
3	Run	0.055	0.12	0.06	0.01				6	1.9

Te Puka

Time over distance measures for Velocity calc (repeat measures)							
1	Step/Riflle	2m	10.4	5.3	5.1	5.5	
2	Run/Riffle	2m	4.5	4.1	3.4	4.4	3.9
3	Run	2m	10	5.5	10	5.5	

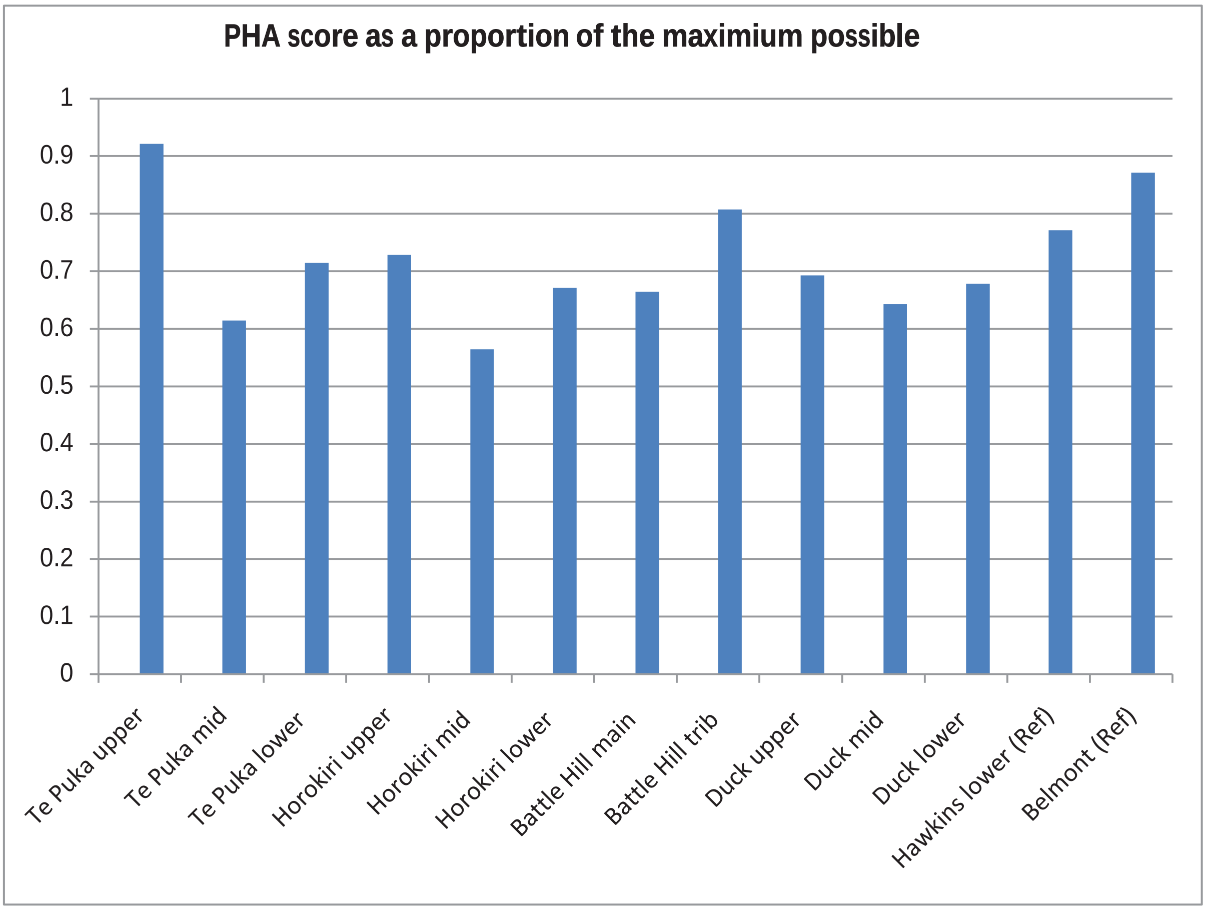
Te Puka substrate cover (%)

		Boulder	Large Cobble	Med Cobble	Small Cobble	Pebble	Gravel	Sand	Bedrock
1 Step/Riffle	L		90	10					
	M			80	10		10		
	R			20			80		
2 Riffle	L			50	20			30	
	M		70	30					
	R			70	10	10		10	
Run				40	20	40			
3 Run	L			30	20		50		
	M			30	20				
	R		10	50	20	10			

Te Puka - Braided Sections (lengths of hydro-habitat types (m)

Step/Run	Riffle	Cascades	Step Riffle	Braids	Step/Pool	Pool
13	30	5	30	10	20	2
	22	2	30	15	8	1
	13	2	50	20	11	5
	50	8	28	18	28	4
	60	2	31		26	2
	8	2	29		10	
	15	2	14		10	
	20				24	
	28				23	
	8				10	
	28				4	
	26				25	
	30					
	17					
	34					
	27					
	7					
	20					
	15					

Te Puka upper	Te Puka mid	Te Puka lower	Horokiri upper	Horokiri mid	Horokiri lower	Battle Hill main	Battle Hill trib	Duck upper	Duck mid	Duck lower	Hawkins lower (Ref)	Belmont (Ref)
129	86	100	102	79	94	93	113	97	90	95	108	122
0.9214	0.614	0.714	0.729	0.56	0.671	0.664	0.80714	0.69	0.6	0.68	0.77	0.871



Data Substrate size and area estimates from in stream measurements. Measures were taken on the true right, middle of syem and true left. Two measures were made, longest axis and axis perpendicular to that as a rough estimate to calculating cobble area (size).

Sample Site HK 8520 (Mark 08)

Cobbles Sizes (mm)

true right		**Area (mm2)**	**middle (mm)**		**Area (mm2)**
127	153	19431	160	175	28000
90	101	9090	175	134	23450
104	125	13000	116	113	13108
124	91	11284	143	125	17875
118	107	12626	120	160	19200
113	88	9944	95	82	7790
145	108	15660	64	68	4352
87	105	9135	67	68	4556
95	85	8075	62	76	4712
114	90	10260	85	55	4675
92	74	6808	81	61	4941
82	86	7052	66	54	3564
70	71	4970	67	50	3350
73	53	3869	88	85	7480
66	104	6864	55	52	2860
78	63	4914	63	72	4536
73	90	6570	52	70	3640
58	59	3422			
58	67	3886			
66	53	3498			
61	62	3782			
62	51	3162			

Sample Site HK 8520 (Pool)

true left		**Area**	**Cobbles true right**		**Area**
51	69	3519	150	132	19800
50	50	2500	153	107	16371
43	50	2150	96	84	8064
55	43	2365	97	75	7275
85	70	5950	120	77	9240
48	48	2304	78	60	4680
70	56	3920	145	118	17110
70	63	4410	127	92	11684
57	58	3306	75	73	5475
54	46	2484	88	83	7304
57	43	2451	120	120	14400
70	55	3850	77	63	4851
55	48	2640	93	70	6510
68	46	3128	108	82	8856
60	55	3300	200	131	26200
48	52	2496			
73	60	4380			
84	53	4452			
85	51	4335			
87	53	4611			
58	48	2784			
52	55	2860			
41	54	2214			
58	64	3712			
67	46	3082			
54	67	3618			

58	44	2552
64	45	2880
56	42	2352
52	43	2236

Sample Site HK 85200 (Run)

true right		Area	middle		Area
123	96	11808	92	64	5888
92	73	6716	104	68	7072
98	85	8330	88	62	5456
93	76	7068	92	68	6256
100	62	6200	68	56	3808
86	80	6880	95	76	7220
107	54	5778	71	52	3692
60	83	4980	66	56	3696
73	76	5548	48	48	2304
88	67	5896	62	50	3100
63	58	3654	50	50	2500
79	66	5214	122	109	13298
117	118	13806	117	72	8424
161	118	18998	119	84	9996
86	63	5418	77	71	5467
73	59	4307	93	72	6696
68	45	3060	88	68	5984
58	51	2958	66	95	6270
59	51	3009	101	58	5858
62	55	3410	71	59	4189
59	44	2596	63	73	4599
51	42	2142	73	55	4015

Sample Site 8950 (Pool)

true right		Area	middle		Area
150	230	34500	200	160	32000
102	87	8874	176	107	18832
82	69	5658	173	130	22490
135	173	23355	140	108	15120
140	109	15260	160	174	27840
143	78	11154	128	148	18944
90	77	6930	135	87	11745
85	69	5865	82	71	5822
67	108	7236	86	66	5676
98	65	6370	74	75	5550
130	91	11830	75	73	5475
123	89	10947	79	78	6162
86	77	6622	65	48	3120
103	59	6077	92	65	5980
100	185	18500	78	73	5694
132	93	12276	85	89	7565
112	112	12544	67	97	6499
94	78	7332			
144	122	17568			
93	72	6696			
72	75	5400			
95	63	5985			
73	120	8760			
76	55	4180			
60	72	4320			

Sample Site 8950 (Run)

true right		Area	middle		Area
190	210	39900	98	87	8526
162	129	20898	95	126	11970
89	99	8811	108	82	8856
145	95	13775	115	90	10350
95	100	9500	116	93	10788
101	61	6161	106	75	7950
103	72	7416	117	92	10764
95	76	7220	94	86	8084
68	69	4692	100	81	8100
70	55	3850	76	59	4484
79	52	4108	70	64	4480
63	108	6804	65	54	3510
72	59	4248	66	59	3894
66	60	3960	88	71	6248
60	48	2880	84	84	7056
59	56	3304	60	52	3120
60	52	3120	69	53	3657
84	54	4536	59	74	4366
83	66	5478	59	60	3540
60	57	3420	70	54	3780
76	51	3876			

Sample Site 8950 (Riffle)

true right		Area	middle		Area
138	110	15180	113	92	10396
85	81	6885	96	87	8352
135	107	14445	87	65	5655
83	91	7553	102	57	5814
95	81	7695	130	130	16900
139	95	13205	81	56	4536
83	68	5644	69	64	4416
165	122	20130	70	55	3850
99	59	5841	55	77	4235
60	82	4920	60	51	3060
58	90	5220	60	56	3360
66	56	3696	96	80	7680
80	80	6400	55	48	2640
85	71	6035	49	64	3136
107	82	8774	64	63	4032
93	76	7068	99	74	7326
98	75	7350	58	46	2668
112	74	8288	68	51	3468
71	63	4473			
79	58	4582			
73	60	4380			
96	84	8064			
73	57	4161			
84	57	4788			
102	83	8466			

Sample Site 8750 (Run)

true left		Area	middle		Area
132	104	13728	92	89	8188

112	97	10864	89	81	7209
97	77	7469	87	78	6786
90	80	7200	68	58	3944
87	69	6003	71	56	3976
116	85	9860	75	62	4650
96	58	5568	71	50	3550
88	56	4928	75	48	3600
69	54	3726	73	55	4015
84	69	5796	60	69	4140
65	57	3705	75	62	4650
71	49	3479	80	62	4960
105	83	8715			
70	50	3500			
55	47	2585			

Sample Site 8750 (Riffle)

true left		Area	middle		Area	true right		Area
151	120	18120	147	124	18228	157	111	17427
116	87	10092	200	320	64000	126	75	9450
115	66	7590				120	81	9720
106	80	8480				94	74	6956
230	160	36800				94	66	6204
90	82	7380				131	101	13231
73	58	4234				133	89	11837
110	74	8140				84	64	5376
77	64	4928				89	84	7476
72	65	4680				84	72	6048

Sample Site 8750 (Pool)

middle		Area	true right		Area	
88	92	8096	165	220	36300	
75	45	3375	160	200	32000	(5 x boulders - all similar size)
100	85	8500	170	250	42500	
68	65	4420	155	220	34100	
88	39	3432	180	230	41400	
75	58	4350	160	210	33600	
91	42	3822				
78	78	6084				
71	47	3337				
47	23	1081				
58	20	1160				
44	40	1760				
45	28	1260				
9	48	432				
44	22	968				
75	42	3150				
39	25	975				
69	33	2277				
65	31	2015				
25	20	500				

Sample Site 6375 (Run)

true left		Area	middle		Area	true right		Area
160	105	16800	148	111	16428	109	103	11227

90	63	5670	500	300	150000	150	98	14700
146	68	9928				67	46	3082
85	68	5780				59	44	2596
73	59	4307				67	63	4221
45	28	1260				59	42	2478
48	25	1200				31	24	744
47	45	2115				42	26	1092
64	37	2368				49	28	1372
59	36	2124				50	31	1550
35	21	735				29	20	580
37	33	1221						
53	54	2862						
60	42	2520						
37	27	999						
47	36	1692						

Sample Site 6375 (Cascade)

true left		**Area**	**middle**		**Area**	**true right**		**Area**
82	98	8036	220	109	23980	440	350	154000
94	56	5264	160	105	16800	200	400	80000
101	113	11413	83	41	3403	340	280	95200
113	72	8136	46	34	1564			
73	63	4599	62	36	2232			
62	53	3286	31	18	558			
25	87	2175	70	43	3010			
89	72	6408	80	55	4400			
73	65	4745	63	46	2898			
58	35	2030	127	126	16002			
48	25	1200						
44	35	1540						

Sample Site 6370 (Run)

true left		**Area**	**middle**		**Area**	**true right**		**Area**
116	109	12644	123	111	13653	83	62	5146
85	63	5355	150	81	12150	157	101	15857
148	135	19980	95	88	8360	142	85	12070
210	160	33600	105	92	9660	67	60	4020
			67	50	3350	52	33	1716
			79	40	3160	50	32	1600
			54	44	2376	30	30	900
			64	45	2880	39	35	1365
			52	30	1560	77	27	2079
			53	19	1007			
			98	45	4410			
			48	46	2208			
			94	74	6956			
			50	24	1200			

Sample Site Te Puka (Step Riffle)

true left		**Area**	**middle**		**Area**	**true right**		**Area**
105	91	9555	136	55	7480	83	68	5644
190	160	30400	69	38	2622	141	80	11280
124	93	11532	68	47	3196	61	48	2928
			89	70	6230	48	24	1152
			70	28	1960	43	35	1505
			58	33	1914			

47	38	1786
80	54	4320
110	82	9020
68	48	3264
66	27	1782
160	111	17760
44	41	1804
59	19	1121
37	34	1258
45	22	990
52	46	2392
39	23	897
67	46	3082
55	35	1925
95	42	3990
63	41	2583
53	41	2173
41	20	820
57	44	2508
47	28	1316
39	28	1092
47	25	1175

Sample Te Puka (Braid Run/Riffle)

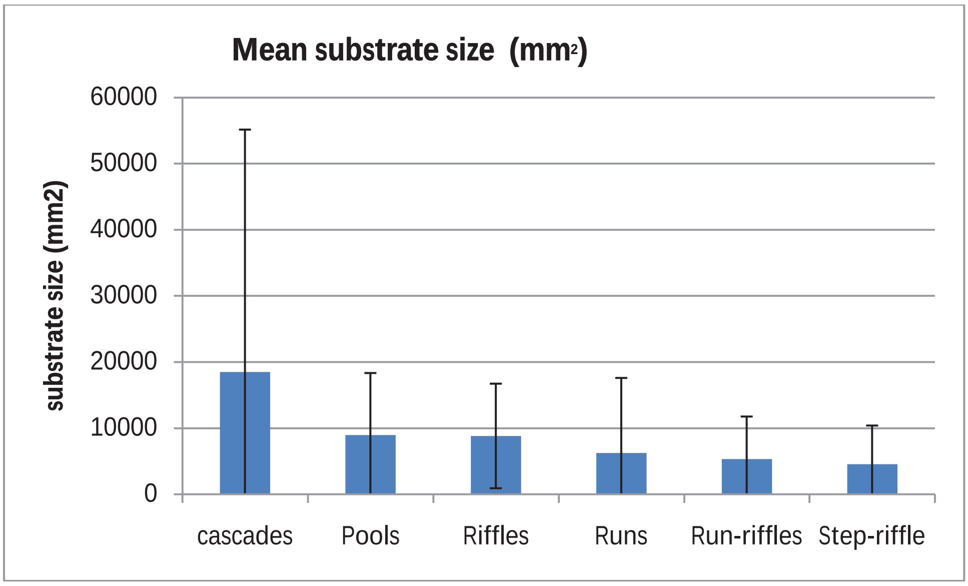
true left		**Area**	**middle**		**Area**	**true right**		**Area**
102	75	7650	131	93	12183	112	67	7504
62	53	3286	141	101	14241	60	48	2880
44	26	1144	118	91	10738	54	45	2430
44	50	2200	205	145	29725	111	85	9435
50	48	2400	157	94	14758	60	27	1620
48	18	864				60	39	2340
61	34	2074				48	39	1872
64	33	2112				33	22	726
56	36	2016				34	25	850
71	53	3763				48	37	1776
125	89	11125				35	30	1050
						29	25	725
						39	22	858

Sample Site Te Puka (Run)

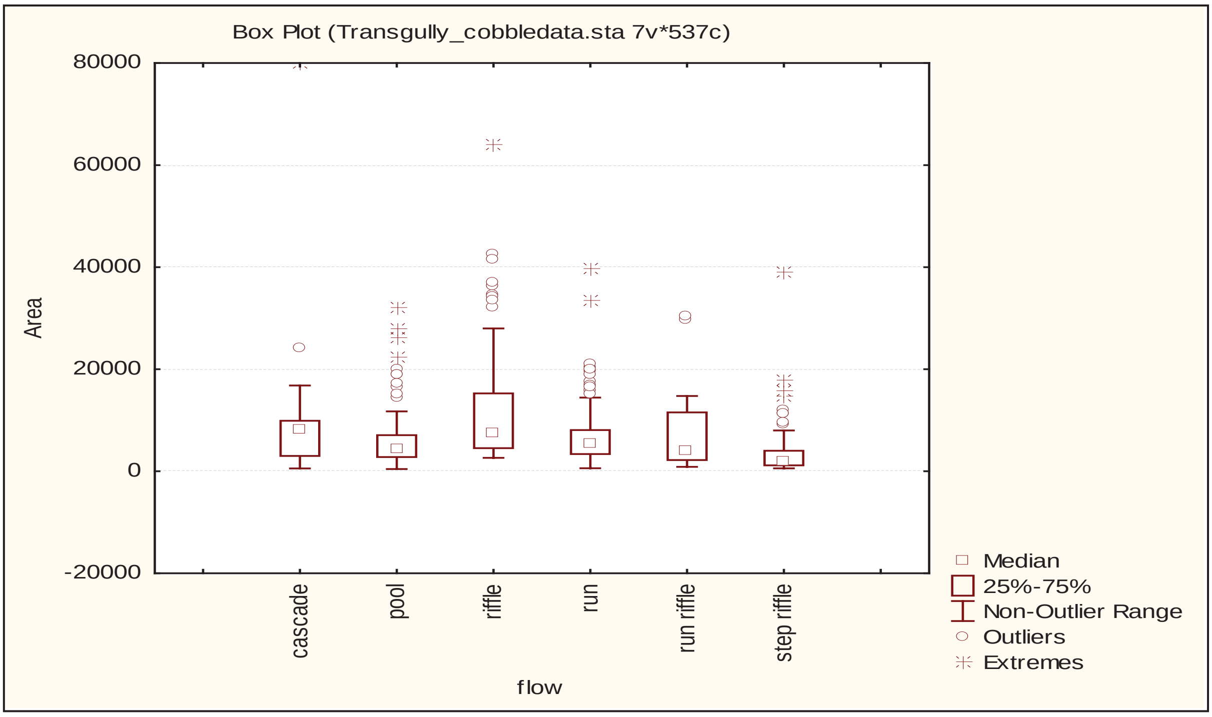
true left		**Area**	**middle**		**Area**	**true right**		**Area**
130	73	9490	108	55	5940	63	36	2268
78	58	4524	101	68	6868	40	22	880
72	62	4464	49	41	2009	62	33	2046
39	30	1170	59	48	2832	90	51	4590
93	74	6882	63	39	2457	29	32	928
51	33	1683	39	32	1248	45	35	1575
66	43	2838	66	34	2244	33	22	726
89	62	5518	39	43	1677	23	26	598
65	58	3770	59	44	2596	100	80	8000
33	22	726	58	25	1450	35	28	980
54	20	1080	58	28	1624	156	250	39000
58	48	2784	66	44	2904			
45	31	1395	35	27	945			
46	37	1702	36	18	648			
55	20	1100	37	25	925			
32	31	992	35	18	630			

22	27	594
52	24	1248

	Mean substrate size (mm2)	Sdev
cascades	18515.16	36614.64
Pools	8976.177	9352.22
Riffles	8813.029	7905.749
Runs	6283.259	11301.84
Run-riffles	5322.241	6428.39
Step-riffle	4568.222	5820.247

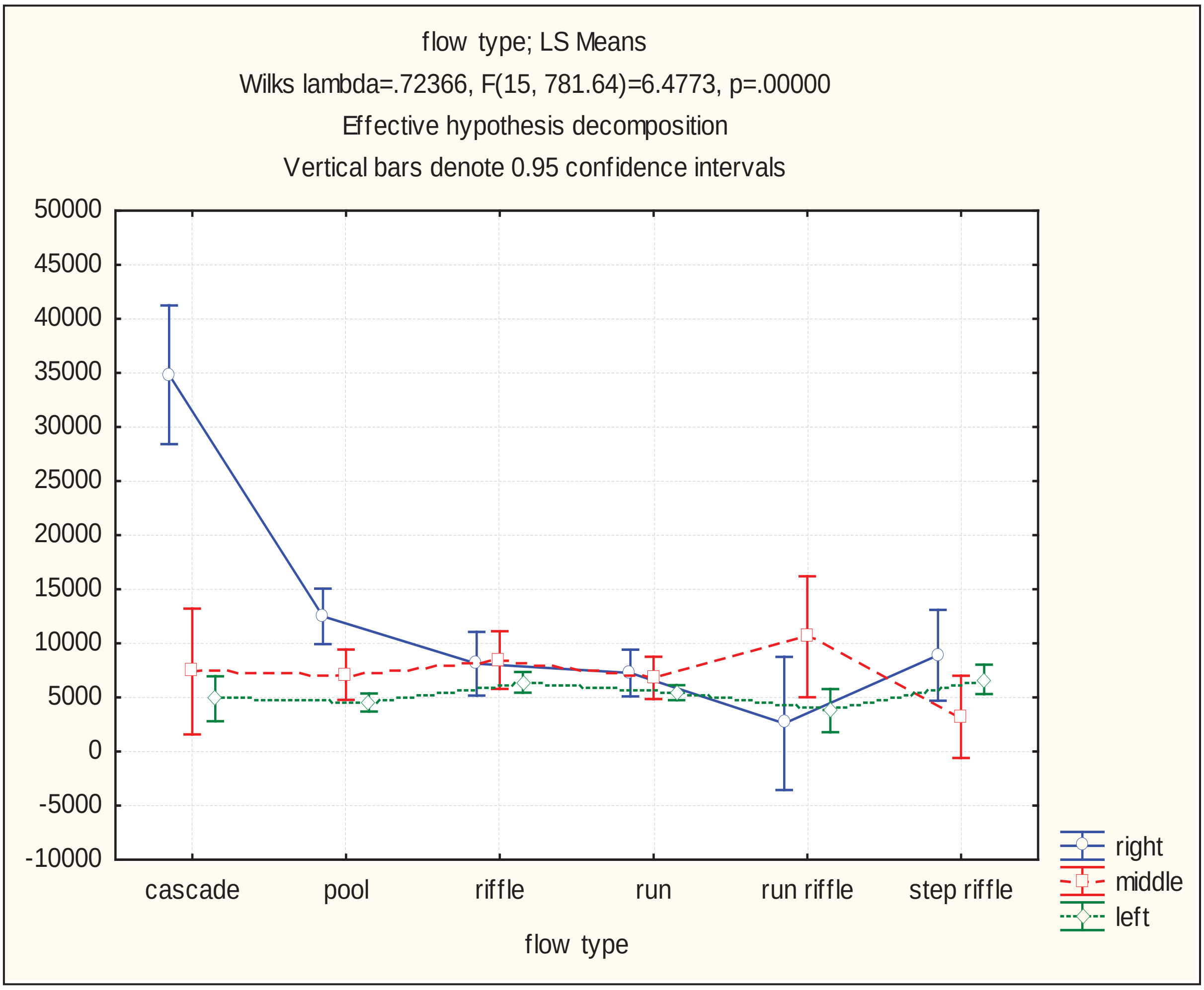


cascade	Mean	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Area	16479.58	558.0000	154000.0	1.018707E+09	31917.19	5556.070
pool	Mean	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Area	6520.100	432.0000	32000.00	37829327	6150.555	648.3254
riffle	Mean	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Area	12005.44	2640.000	64000.00	138516480	11769.30	1332.611
run	Mean	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Area	6927.157	594.0000	150000.0	111903874	10578.46	688.5993
run/riffle	Mean	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Area	8257.857	864.0000	30400.00	72500469	8514.721	1858.064
step/riffle	Mean	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Area	3950.590	580.0000	39000.00	30325947	5506.900	623.5336



Factorial ANOVA

	Test	Value	F	Effect df	Error df	p
Intercept	Wilks	0.338906	107.2867	3	165.0000	0.000000
location	Wilks	0.173271	1.1121	354	495.8928	0.138363
flow type	Wilks	0.598099	6.2201	15	455.8937	0.000000
location*flow type	Wilks	0.030290	1.370956	306	189.9270	0.008927



Appendix 9.D IBI Base Analysis

Index of Biological Integrity - Wellington Region : Fish
Centre for Freshwater Ecosystem Modelling and Management, Massey University

Site	IBI score	Rating
Akatarawa River	48	Very Good
Taepiro Stream	48	Very Good
Kahikatea Stream	18	Poor
Waiorua Stream	22	Poor
Waiorua Stream	26	Poor
Te Kahuoterangi Stream	16	Very Poor
Te Rere Stream	16	Very Poor
Maraetakaroro Stream	22	Poor
Wharekohu Stream	18	Poor
Kaiwharawhara Stream	20	Poor
Te Mimiorakopa Stream	26	Poor
Muaupoko Stream	30	Fair
Korokoro Stream	36	Fair
Bull Stream	42	Good
Waikanae River tributary	40	Good
Waikanae River tributary	48	Very Good
Waikanae River	36	Fair
Horokiri Stream tributary	32	Fair
Waikanae River	42	Good
Waikanae River	48	Very Good
Horokiri Stream tributary	30	Fair
Wainui Stream	20	Poor
Waikanae River	26	Poor
Waikanae River	26	Poor
Horokiri Stream	56	Excellent
Horokiri Stream	52	Excellent
Horokiri Stream	56	Excellent
Horokiri Stream tributary	56	Excellent
Horokiri Stream tributary	38	Good
Horokiri Stream tributary	46	Good
Horokiri Stream tributary	50	Very Good
Waimeha Stream	32	Fair
Horokiri Stream	42	Good
Horokiri Stream tributary	22	Poor
Horokiri Stream	34	Fair
Horokiri Stream	42	Good
Horokiri Stream	46	Good
Horokiri Stream	34	Fair
Wainui Stream tributary	26	Poor
Maungakotukutuku Stream	48	Very Good
Maungakotukutuku Stream	48	Very Good
Waikanae River	40	Good
Waikanae River	24	Poor
Ngatiawa River	22	Poor
Reikorangi Stream	28	Poor
Waikanae River	40	Good
Waikanae River	28	Poor
Waikanae River	34	Fair
Waikanae River	28	Poor
Waikanae River	34	Fair
Waikanae River	36	Fair
Waikanae River	30	Fair

Waikanae River	56	Excellent
Ngarara Stream	38	Good
Waimeha Stream	36	Fair
Ngarara Stream	28	Poor
Ngarara Stream tributary	28	Poor
Ngarara Stream	28	Poor
Ngarara Stream	22	Poor
Waikanae River	40	Good
Tui Stream	36	Fair
Taupo Stream	20	Poor
Whakatikei River tributary	48	Very Good
Bull Stream	28	Poor
Wainui Stream	40	Good
Wharemauku Stream tributary	36	Fair
Taupo Stream tributary	18	Poor
Taupo Stream	18	Poor
Taupo Stream	28	Poor
Wainuiomata River	36	Fair
Wainuiomata River	32	Fair
Mukamukaiti Stream	26	Poor
Mukamuka Stream	18	Poor
Ohau River	50	Very Good
Otaki River	36	Fair
Mangahao River tributary	44	Good
Mangahao River	36	Fair
Mangatangi Stream	48	Very Good
Otaki River tributary	32	Fair
Otaki River tributary	34	Fair
Otaki River tributary	20	Poor
Mangaore Stream	44	Good
Waikawa Stream	42	Good
Ohau River	50	Very Good
Makorokio Stream	52	Excellent
Lake Papiatonga tributary	26	Poor
Mangatainoka River tributary	40	Good
Mangatainoka River	48	Very Good
Tramway Creek	32	Fair
Mangaone Stream	24	Poor
Mangaone Stream	30	Fair
Mangaone Stream	26	Poor
Mangaore Stream tributary	34	Fair
Mangaore Stream	34	Fair
Waikawa Stream	44	Good
Waiti Stream	48	Very Good
Makahika Stream	40	Good
Ohau River	44	Good
Makorokio Stream	56	Excellent

Index of Biological Integrity - Wellington Region : Fish
Centre for Freshwater Ecosystem Modelling and Management, Massey University

Site	IBI score	Rating
1 TP-U	36	Fair
2 TP-M	40	Good
3 TP-L	40	Good
4 HO-U	38	Good

5 HO-M	36	Fair
6 HO-L	40	Good
7 BA-M	40	Good
8 BA-T	48	Very Good
9 DU-U	28	Poor
10 DU-M	44	Good
11 DU-L	52	Excellent

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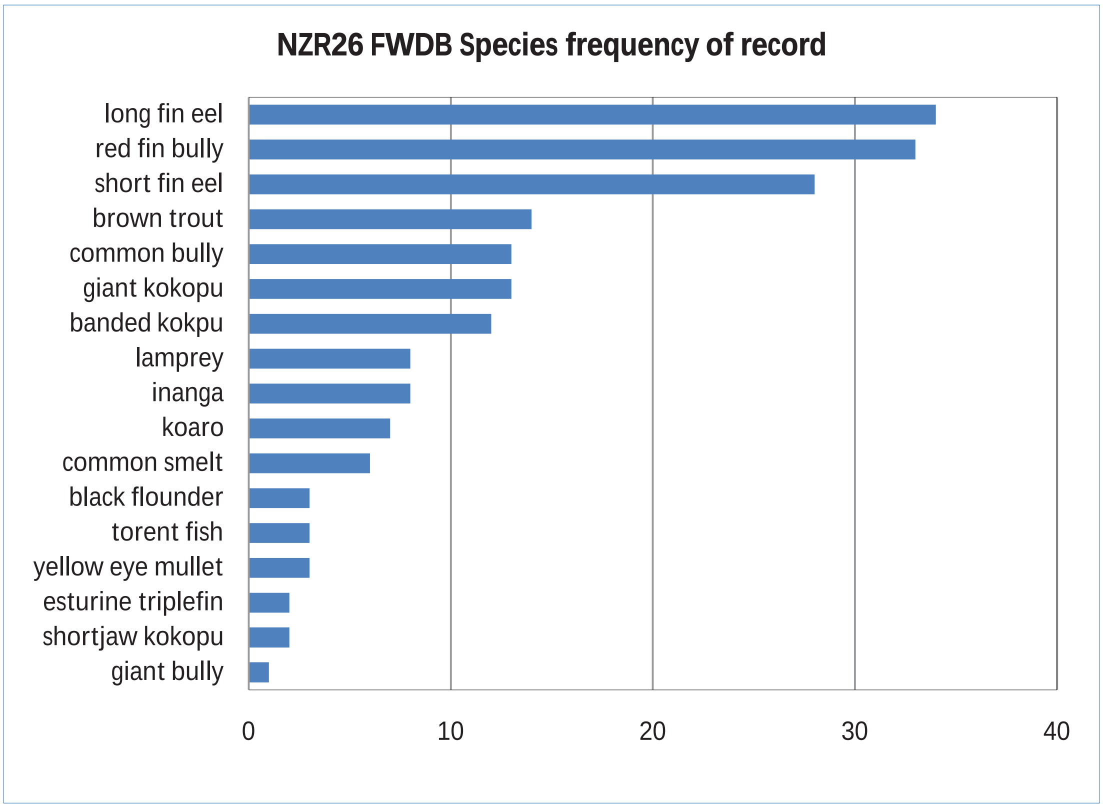


Appendix 9.E Regional Rivers Macroinvertebrate Metrics

data from Regional Council (Perrie 2008)

GWRC - Regional Biometrics				
	QMCI (2009)	Taxa richness (2009)	%EPT (2009)	MCI (2007)
Site Name	Mean QMCI	Mean taxa richness	mean %EPT	Mean MCI
Mangapouri S at Rahui Rd	4.05	20.33	9.0%	87.1
Mangapouri S at Bennetts Rd	4.54	13	7.0%	70
Waitohu S at Forest Pk	8.22	28.33	90.3%	138.2
Waitohu S at Norfolk Cres	4.72	14.7	0.0%	101.4
Otaki R at Pukehinau	7.76	17.3	95.0%	124.1
Otaki R at Mouth	5.15	18	37.5%	110
Mangaone S at Sims Rd Br	4.7	16.7	0.0%	60.6
Ngarara S at Field Way	4.76	10.3	1.8%	74.2
Waikanae R at Mangaone Walkway	7.95	23	86.0%	139.6
Waikanae R at Greenaway Rd	5.97	22.7	51.0%	118.2
Whareroa S at Waterfall Rd	6.24	28.3	56.0%	114.6
Whareroa S at QE Park	4.83	18	8.0%	74.6
Horokiri S at Snodgrass	7.09	18.3	75.8%	112.1
Pauatahanui S at Elmwood Br	7.31	21.3	11.8%	91.3
Porirua S at Glenside	3.26	21.7	9.5%	91.1
Porirua S at Wall Park (Milk Depot)	2.9	14.3	1.9%	92.8
Makara S at Kennels	4.4	17.7	10.4%	95.7
Karori S at Makara Peak	4.05	20.7	29.3%	87.6
Kaiwharawhara S at Ngaio Gorge	3.41	21	5.5%	94.7
Hutt R at Te Marua Intake Site	7.93	22.7	89.8%	143.5
Hutt R opp. Manor Park G.C.	4.93	19.3	41.0%	104.3
Hutt R at Boulcott	4.39	18.3	31.8%	99
Pakuratahi R 50m d/s Farm Ck	6.77	25.3	84.0%	129
Mangaroa R at Te Marua	4.88	22.3	56.0%	112.7
Akatarawa R at Hutt confl.	6.93	23.3	81.0%	124.3
Whakatikei R at Riverstone	6.91	23.3	70.0%	120.5
Waiwhetu S at Wainui Hill Br	3.83	7.7	0.0%	82.4
Wainuiomata R at Manuka Track	7.16	29.7	79.0%	133.5
Wainuiomata R u/s of White Br	3.61	19.7	27.0%	96.4
Orongorongo R at Orongorongo Stn	6.57	14.3	51.0%	99.6
Ruamahanga R at McLays	8.06	20.7	87.6%	149.3
Ruamahanga R at Te Ore Ore	6.87	15.3	68.0%	112.7
Ruamahanga R at Gladstone Br	5.68	15.3	23.5%	109.1
Ruamahanga R at Pukio	5.28	14.7	26.4%	108.7
Mataikona Trib at Sugar Loaf Rd	5.79	30	80.0%	124
Taueru R at Castlehill	5.15	22	66.0%	125.8
Taueru R at Gladstone	4.15	24.7	9.4%	88.7
Kopuaranga R at Stewarts	4.54	26.3	45.4%	107.7
Whangaehu R 250m u/s confl.	3.73	16.7	3.0%	61.3
Waipoua R at Colombo Rd Br	4.96	26	56.4%	108.9
Waingawa R at South Rd	6.34	17.7	54.0%	120.9
Whareama R at Gauge	3.96	14.3	2.0%	71.8
Motuwaireka S at Headwaters	6.97	26	63.5%	127.9
Totara S at Stronvar	5.3	21.3	63.0%	96.6
Parkvale Trib at Lowes Res.	5.19	18.3	19.0%	101.4
Parkvale S at Weir	3.71	17	4.4%	88.6
Waiohine R at Gorge	7.89	18.3	92.0%	136.8
Waiohine R at Bicknell's	7.18	13	74.0%	106
Beef Ck at Headwaters	7.85	29.3	81.0%	132.6

Mangatarere S at SH	5.53	19.3	43.0%	105.8
Huangarua R at Ponatahi Br	4.2	24.3	51.0%	104.3
Tauanui R at Whakatomotomo Rd	5.77	26.3	69.0%	119.3
Awhea R at Tora Rd	4.32	16	0.0%	85.8
Coles Ck Trib at Lagoon Hill Rd	4.04	21	4.4%	107.8
Tauherenikau R at Websters	6.12	17	46.6%	109.7
Waiorongomai R at Forest Pk	6.93	20.7	91.0%	116
Mean	5.54875	20.05	43.21%	106.26
Median	5.235	20.01	46.00%	107.75

TRANSMISSION GULLY BIOMETRICS				
	QMCI (2009)	**Taxa richness (2009)**	**%EPT (2009)**	**MCI (2007)**
Site Name	**Mean QMCI**	**Mean taxa richness**	**mean %EPT**	**Mean MCI**
Duck nth	4.10	30	43.3%	104.62
Duck Silwood	6.80	37	48.6%	121.11
Duck Sth	4.92	28	57.1%	106.09
Duck lower	5.53	30	56.7%	126.40
Duck upper	6.91	32	65.6%	131.38
Duck mid	6.56	32	59.4%	133.13
mean	5.80	31.5	0.55	120.46
Pauatahanui lower	5.83	36	47.2%	114.83
Horo west-low	6.26	33	54.5%	108.39
Horo east -lower	7.05	25	64.0%	132.82
Horokiri lower	6.47	31	64.5%	127.94
Battle main	6.82	29	55.2%	123.37
Horokiri upper	7.25	33	72.7%	146.65
Horokiri mid	6.78	28	75.0%	134.81
mean	6.77	29.8	0.64	129.00
Cannon lower	6.33	31	51.6%	127.27
Cannon mid	7.16	31	54.8%	132.49
Cannon upper	7.27	32	56.3%	118.96
mean	6.92	31.3	0.54	126.24
Tepuka upper	7.61	32	59.4%	146.30
Tepuka lower	7.28	33	63.6%	139.00
Tepuka mid	7.05	32	65.6%	134.40
mean	7.31	32.3	0.63	139.90
Belmont ref	8.11	19	73.7%	156.55
Battle trib	8.36	29	65.5%	155.53

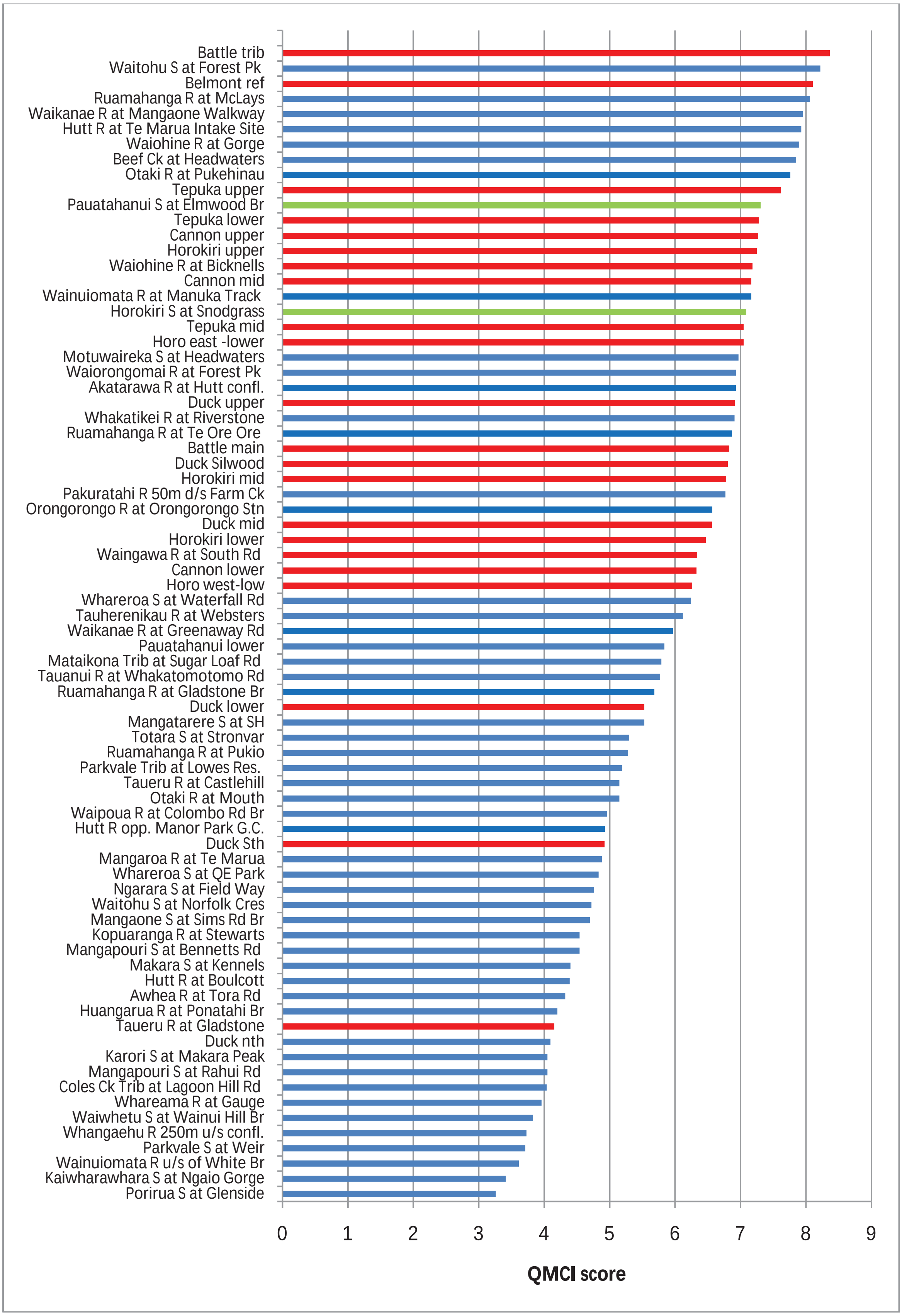


Figure 9-38 Mean Regional QMCI measures

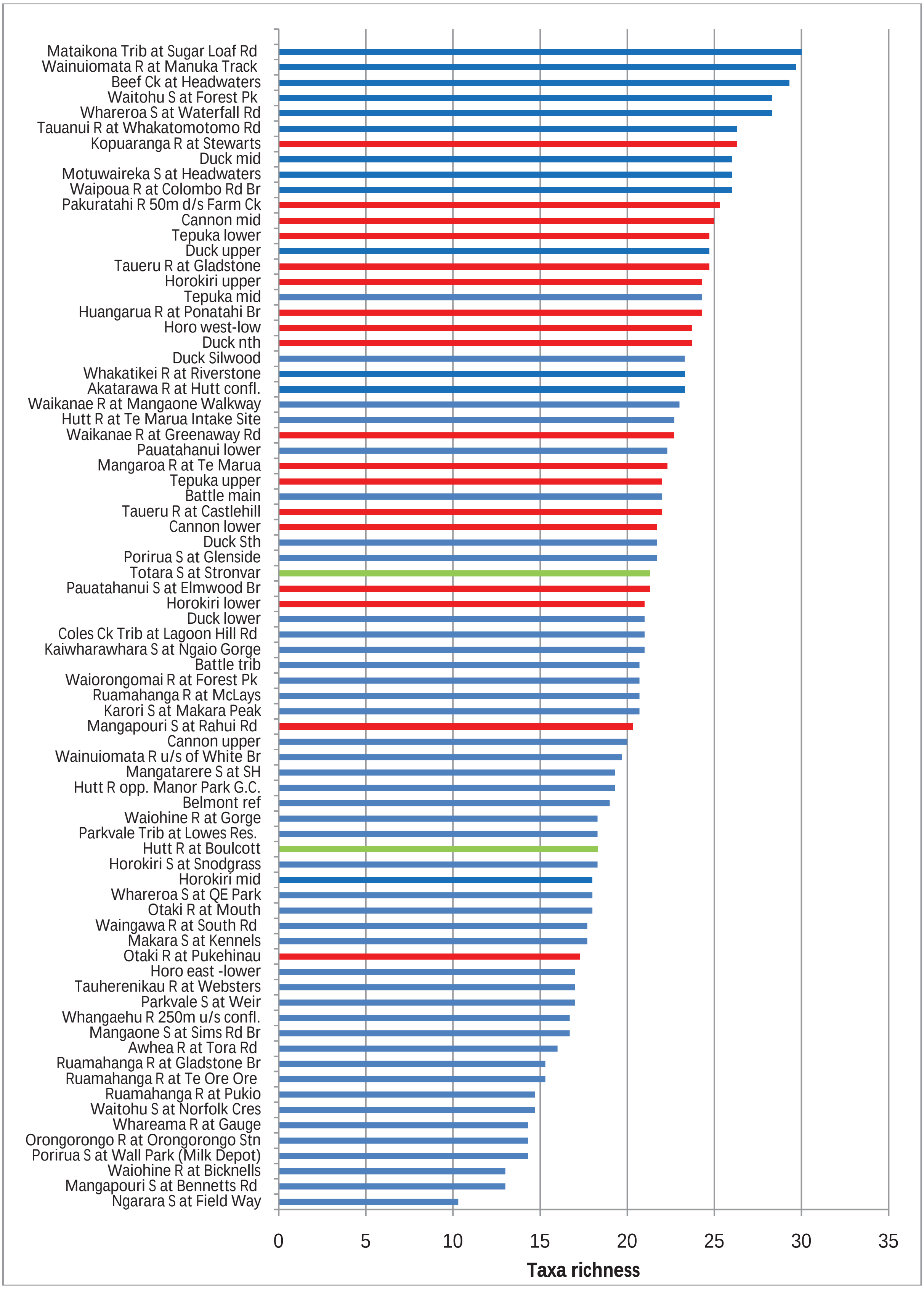


Figure 9-39 Mean Regional taxa richness

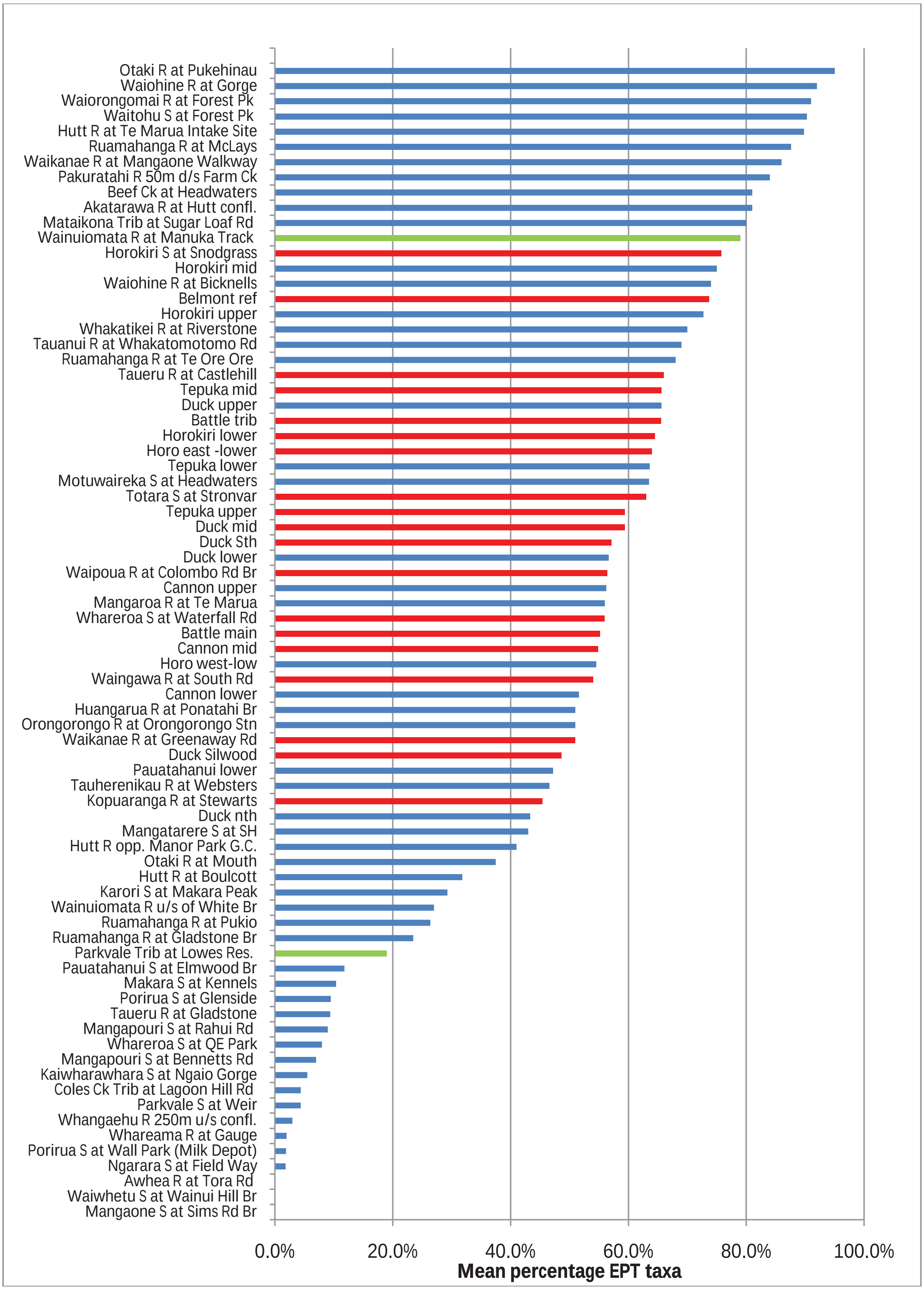


Figure 9-40 Mean Regional %EPT

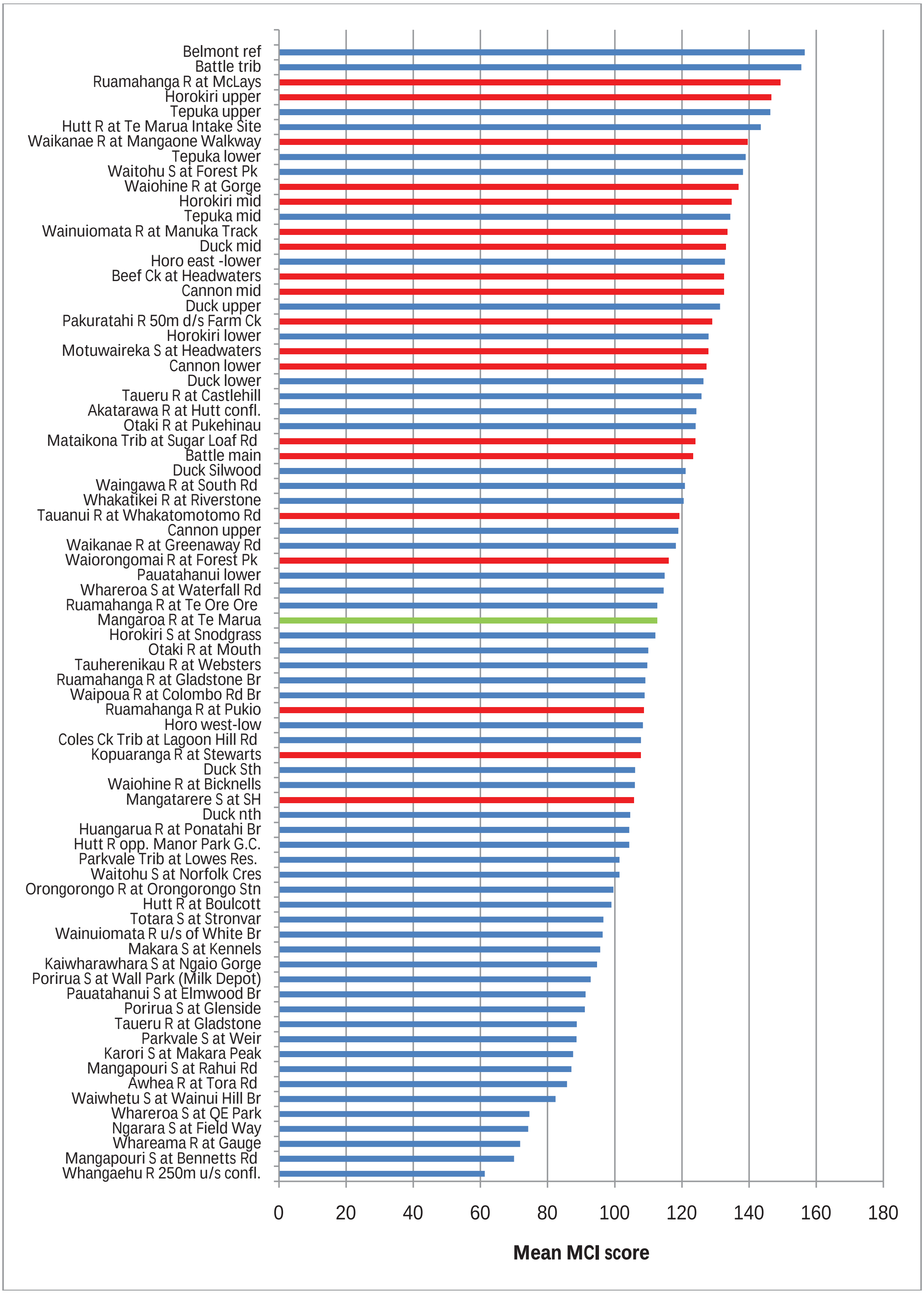


Figure 9-41 Mean Regional MCI

Appendix 9.F Fish Survey Results

SUMMARY RESULTS

Habitat	Site	# taxa	Total # Fish
lower	Battle main	4	29
Lower	Ration lower	3	8
Lower	Pauatahanui	8	85
lower	Duck nth	8	60
lower-middle	Horokiri lower	3	6
Lower-middle	Horo west-low	4	12
Lower-middle	Horo east -lower	3	24
lower-middle	Duck lower	6	55
lower-middle	Duck Silwood	8	34
lower-middle	Duck Sth	9	58
lower-middle	Cannon lower	4	36
lower-middle	Kenepuru Lower	2	16
middle	Tepuka mid	3	20
middle	Horokiri mid	3	15
middle	Duck upper	3	3
middle	Cannon upper	2	16
middle	Cannon mid	3	17
Middle	Kenepuru mid	2	12
middle	Battle trib	5	19
upper	Tepuka upper	2	4
upper	Tepuka lower	3	39
upper	Horokiri upper	3	6
upper	Ration upper	1	1
upper	Duck Tribs	5	10
upper	Duck mid	4	10

SITE RESTULSTS

	Te Puka			Ration		
	Te Puka upper	Te Puka mid	Te Puka lower	Ration lower	Ration upper	Pauatahanui
	TP-U	TP-M	TP-L	R - L	R-U	PT
Longfin eel	1	1	9		1	6
Shortfin eel				4		33
Koaro	3	10	4			
Redfin bully		9	26			
Common bully				3		7
Banded kokopu						
Giant kokopu				1		
Inanga						1
Lamprey						
Common smelt						
Elver sp						4
Eel sp (unidentified)						11
White bait						21
Brown trout (juvenile)						2
Total # Fish	**4**	**20**	**39**	**8**	**1**	**85**
Total No. taxa	**2**	**3**	**3**	**3**	**1**	**8**

	Horokiri						
	Horokiri upper	Horokiri mid	Horokiri lower	Battle main	Battle tributary	Horokiri west-low	Horokiri east -lower
	HK-U	HK-M	HK-L	BH-M	BH-T	HK-West	HK-East
Longfin eel	1	9	2	11	1	1	12
Shortfin eel	2	5		4	3	5	
Koaro			1		8		4
Redfin bully	3	1	3	13	4	5	8
Common bully				1		1	
Banded kokopu					3		
Giant kokopu							
Inanga							
Lamprey							
Common smelt							
Elver sp							
Eel sp (unidentified)							
White bait							
Brown trout (juvenile)							
Total # Fish	**6**	**15**	**6**	**29**	**19**	**12**	**24**
Total No. taxa	**3**	**3**	**3**	**4**	**5**	**4**	**3**

	Duck Creek						
	Duck Upper	Duck Tributary	Duck Mid	Duck Lower	Duck Silverwood	Duck South	Duck North
	DK-1	DK-Trib	DK-2	DK-3	DK-4 (WCE)	DK-5 (WCE)	DK-6 (WCE)
Longfin eel	3	2	38	8	6	15	14
Shortfin eel		1	7	15	4	4	2
Koaro		1	9	1	1		
Redfin bully			1	1	4	7	2
Common bully						5	9
Banded kokopu		5		4	3	2	
Giant kokopu				2	2	4	
Inanga						5	2
Lamprey							
Common smelt							
Elver sp					6	9	9
Eel sp (unidentified)		1				7	18
White bait					8		4
Brown trout (juvenile)							
Total # Fish	**3**	**10**	**55**	**31**	**34**	**58**	**60**
Total No. taxa	**1**	**5**	**4**	**6**	**8**	**9**	**8**

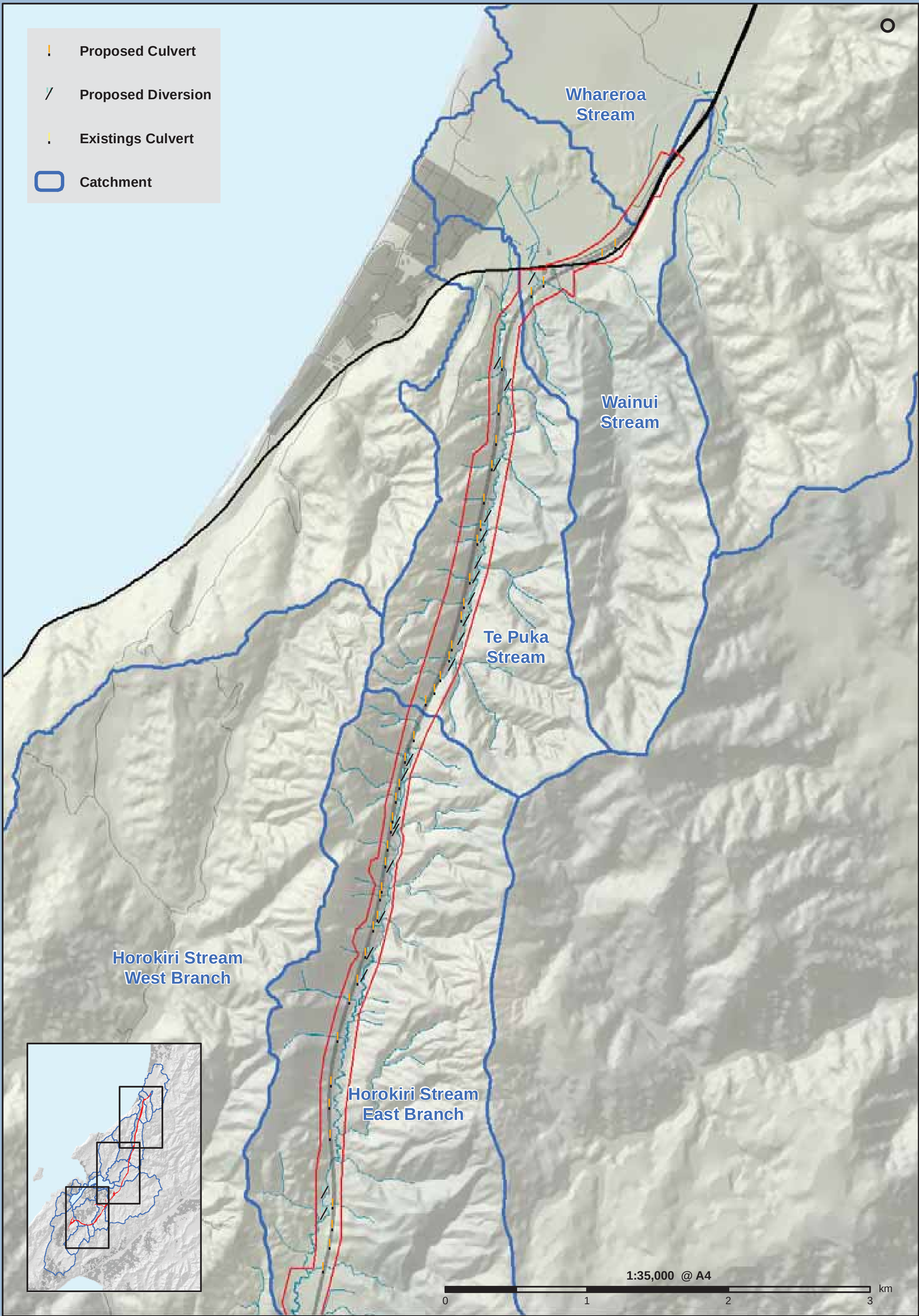
	Cannons Creek			Kenepuru Stream	
	Cannon upper	Cannon mid	Cannon lower	Kenepuru Lower	Kenepuru mid
	CC-U	CC-M	CC-L	KP - L	K - M
Longfin eel			3		
Shortfin eel	4	2	23	7	1
Koaro					
Redfin bully			9	9	11
Common bully					
Banded kokopu	12	14			
Giant kokopu		1			
Inanga			1		
Lamprey					
Common smelt					
Elver sp					
Eel sp (unidentified)					
White bait					
Brown trout (juvenile)					
Total # Fish	**16**	**17**	**36**	**16**	**12**
Total No. taxa	**2**	**3**	**4**	**2**	**2**

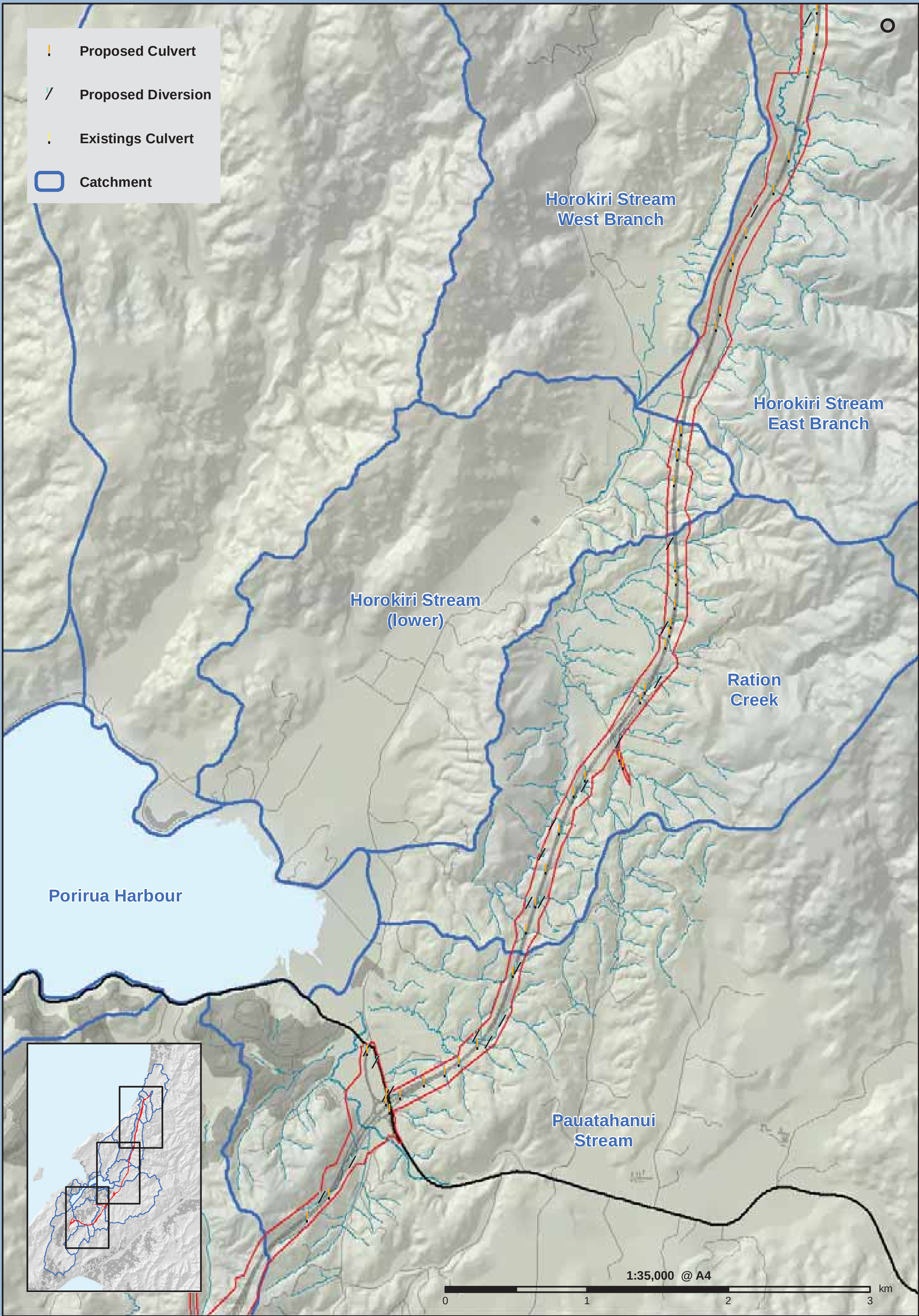
Appendix 9.G Fish Passage Requirements at Crossings

Catchment	Culvert ID	Chainage	Fish passage	Area (catchment)
1	Wainui_01		Y	96,258
1	Wainui_02		Y	175,136
1	Wainui_03		Y	2,643,496
1	Wainui_04		Y	212,036
2	TePuka_01		Y	3,144,647
2	TePuka_02		N	85,934
2	TePuka_03		N	85,085
2	TePuka_04		N	31,120
2	TePuka_05		N	98,305
2	TePuka_06		N	20,324
2	TePuka_07		N	49,881
2	TePuka_08		N	76,128
2	TePuka_09		N	81,299
2	TePuka_10		Y	151,535
2	TePuka_11		N	39,874
2	TePuka_12		N	71,972
2	TePuka_13		N	66,241
2	TePuka_14		N	34,951
2	TePuka_15		N	16,347
3	Horokiri_01		N	4,480,966
3	Horokiri_02		N	92,313
3	Horokiri_03		N	99,529
3	Horokiri_04		Y	118,656
3	Horokiri_05		N	38,960
3	Horokiri_06A		N	17,002
3	Horokiri_06B		N	10,412
3	Horokiri_07		Y	168,211
3	Horokiri_08		N	11,494
3	Horokiri_09		N	50,472
3	Horokiri_10		N	30,359
3	Horokiri_11		N	39,234
3	Horokiri_12		N	57,758
3	Horokiri_13		N	53,266
3	Horokiri_14		N	34,974
3	Horokiri_15		Marginal	151,048
3	Horokiri_16		Marginal	151,183
3	Horokiri_17		N	73,424
3	Horokiri_18		N	96,647
3	Horokiri_19		N	91,121
3	Horokiri_20		N	40,603
3	Horokiri_21		Y	545,474
3	Horokiri_21A			113,711
3	Horokiri_22			63,648
3	Horokiri_23			33,432
3	Horokiri_24		Y	1,056,013
3	Horokiri_25		Y	11,276,325
3	Horokiri_26			29,945
3	Horokiri_27			31,338
3	Horokiri_28			50,754
3	Horokiri_29			25,858
3	Horokiri_30			6,868
3	Horokiri_31			12,901
3	Horokiri_32			12,572

3	Horokiri_33			40,658
3	Horokiri_34			17,689
3	Horokiri_35			47,437
3	Horokiri_36			58,375
3	Horokiri_37			42,668
3	Horokiri_38			26,887
4	Ration_01		Y	469,868
4	Ration_02		N	20,659
4	Ration_03		Y	124,261
4	Ration_04		N	8,717
4	Ration_05		N	25,466
4	Ration_06		N	12,004
4	Ration_07		Y	1,493,690
4	Ration_08		Y	288,520
4	Ration_09		N	50,392
4	Ration_10		Y	1,078,770
4	Ration_11		N	83,689
4	Ration_12		N	24,490
4	Ration_13		Y	127,772
4	Ration_14		N	50,031
5	Collins_01		N	43,922
6	Pauatahanui_01		Y	284,124
6	Pauatahanui_02		Y	153,421
6	Pauatahanui_03		N	14,745
6	Pauatahanui_04		N	14,460
6	Pauatahanui_05		N	27,443
6	Pauatahanui_06		Y	110,683
6	Pauatahanui_07		Y	39,085,877
6	Pauatahanui_08		N	29,067
7	Duck_01		N	13,986
7	Duck_02		N	20,550
7	Duck_03		N	23,587
7	Duck_04		N	10,460
7	Duck_05		N	22,801
7	Duck_06		N	29,311
7	Duck_07		Y	393,191
7	Duck_08		N	128,216
7	Duck_09		Y	179,127
7	Duck_10		N	89,193
7	Duck_11		Y	1,829,355
7	Duck_12		Y	844,740
7	Duck_13		N	17,839
7	Duck_14		Y	207,124
7	Duck_15		Y	390,698
7	Duck_16		N	6,329
7	Duck_17		N	7,454
7	Duck_18		N	5,721,062
7	Duck_19		N	15,148
7	Duck_20		N	25,795
7	Duck_21		N	14,637
7	Duck_22		N	21,305
7	Duck_23		N	94,464
7	Duck_24		N	48,893
7	Duck_25		N	33,176
7	Duck_26		N	34,492
8	Kenepuru_01		N	1,491,405
8	Kenepuru_02		N	24,464

8	Kenepuru_03		N	28,988
8	Kenepuru_04		N	32,649
8	Kenepuru_05		N	61,946
8	Kenepuru_06		N	7,771
8	Kenepuru_07		N	88,854
8	Kenepuru_08		N	18,294
8	Kenepuru_09		Y	155,828
8	Kenepuru_10		N	36,586
9	Porirua_01		Y	386,455
9	Porirua_02		N	15,149
9	Porirua_03		N	49,230
9	Porirua_04		N	98,047
9	Porirua_05		N	237,875
9	Porirua_06		N	134,343
9	Porirua_07		Y	831,217


Proposed Culvert
Proposed Diversion
Existings Culvert
Catchment
Whareroa Stream
Wainui Stream
Te Puka Stream
Horokiri Stream West Branch
Horokiri Stream East Branch
1:35,000 @ A4
0
1
2
3
km

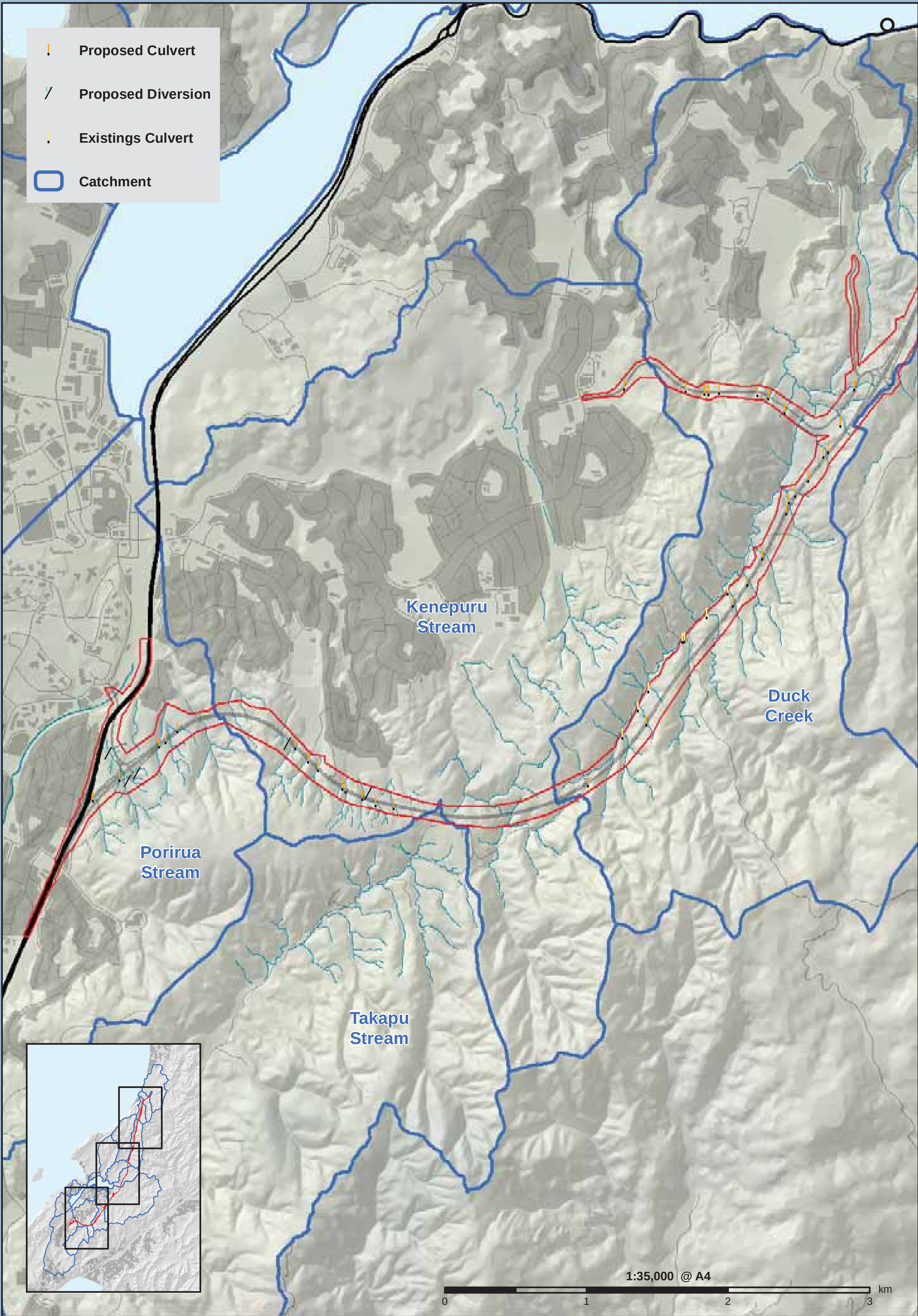


Boffa Miskell

NZ TRANSPORT AGENCY
WAKA KOTAHI

TRANSMISSION GULLY

CULVERTS & DIVERSIONS



Proposed Culvert
Proposed Diversion
Existings Culvert
Catchment
Kenepuru Stream
Duck Creek
Porirua Stream
Takapu Stream
1:35,000 @ A4
0
1
2
3
km

Appendix 9.H Macroinvertebrate Data

SEV - MCI Invert List									
	Te Puka upper			Te Puka mid			Te Puka lower		
SEV Version 8.2	TP-U (a)	TP-U (b)	TP-U (c)	TP-M (a)	TP-M (b)	TP-M (c)	TP-L (a)	TP-U (b)	TP-L (c)
Ephemeroptera									
Acanthophlebia	r	r	c			r	c	c	c
Amelotopsis	r	r	r				r	r	r
Austroclima						r			
Coloburiscus				c	c	c	c	c	c
Deleatidium	c	c	c	va	va	va	va	a	va
Ichthybotus									r
Mauiulus									
Neozephlebia							r	c	r
Nesameletus	c	r		c	r	r	r		
Zephlebia sp		c	r	r			r		
Trichoptera									
Aoteapsyche	a			a	a	a	c	a	c
Beraeoptera					r	r			
Costachorema				r					
Cryptobiosella									
Helicopsyche		c			c	c	r	r	r
Hydrobiosella	c	r	c	r	a	c	c	a	a
Hydrobiosis sp.		r		r	c	r	c	r	r
Oeconesidae									
Olinga	r	r	r	va	a	va	va	a	a
Orthopsyche		a	c	a			a	c	r
Plectrocnemia	r		r	r		r	c		
Polyplectropus									
Psilochorema		r		r	c	c	c	c	c
Pycnocentria			r		r	c			
Pycnocentrodes				va	va	a	a	a	a
Zelolessica									
Plecoptera									
Acroperla									r
Austroperla	c	r							
Spaniocerca		c	c					r	
Stenoperla	a	a	c	a	a	a	a	a	a
Zelandobius	c	c	c	r		r			
Zelandoperla	a	c	c	r	c	r	c		r
Hemiptera									
Coleoptera									
Elmidae	c			a	va	va	a	a	a
Ptilodactylidae	r		c		r				
Odonata									
Antipodochlora									
Neuroptera									
Diptera									
Aphrophila							r		r
Austrosimulium									
Eriopterini	c	c	c	c	a	a	a	a	c

Maoridiamesa				r	c	r			
Orthocladiinae						r			
Paralimnophila		r	r						
Polypedilum	c	c	c	r			c	a	a
Tabanidae				c	c	c			r
Tanypodoninae				r					r
Megaleptopera									
Archichauliodes				a	a	a	c	a	a
Lepidoptera									
Collembola									
Crustacea									
Amphipoda									
Ostracoda									
Paranephrops									
Acarina									
Arachnida									
Mollusca									
Potamopyrgus	a	c	r	a	a	a	a	a	a
Bryozoa									
Hirudinea									
Nematoda									
Nematomorpha									
Nemertea									
Oligochaeta				r	r	r		r	r
Platyhelminthes									
Polychaeta									
Rhabdocoela									
Tardigrada									
COELENTERATA									
Hydra									
Total coded abundance	127	96	62	452	480	460	372	246	293
EPT coded abundance	88	77	40	378	308	292	300	144	203
Taxonomic richness	20	23	23	25	22	26	25	22	27
No. of Insect Taxa	18	22	22	23	20	24	24	20	25
EPT	12	16	13	16	14	18	18	15	17
%EPT abundance	69	80	65	84	64	63	81	59	69
MCI	114	123	117	130	129	125	130	131	113
SQMCI	6.2	7.3	6.6	7.7	6.8	7.2	7.8	6.8	7.4
Ephemeroptera	**9**	**13**	**11**	**25**	**22**	**23**	**29**	**13**	**37**
Plecoptera	**39**	**38**	**32**	**5**	**5**	**5**	**7**	**9**	**8**
Trichoptera	**21**	**30**	**21**	**54**	**37**	**35**	**45**	**37**	**25**
Megaloptera	**0**	**0**	**0**	**4**	**4**	**4**	**1**	**8**	**7**
Coleoptera	**5**	**0**	**8**	**4**	**21**	**22**	**5**	**8**	**7**
Diptera	**9**	**15**	**24**	**3**	**6**	**6**	**7**	**17**	**10**
Mollusca	**16**	**5**	**2**	**4**	**4**	**4**	**5**	**8**	**7**
Others	**1**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**0**

SEV - MCI Invert List									
	Horokiri upper			**Horokiri mid**			**Horokiri lower**		
SEV Version 8.2	**HK-U (a)**	**HK-U (b)**	**HK-U (c)**	**HK-M (a)**	**HK-M (b)**	**HK-M (c)**	**HK-L (a)**	**HK-L (b)**	**HK-L (c)**
Ephemeroptera									
Acanthophlebia	c	c	c						
Amelotopsis	r		r		c			r	
Austroclima					r	c		c	c
Coloburiscus	a	a	a	c		r	r	r	
Deleatidium	a	a	a	va	va	a	va	a	a
Ichthybotus	r	r	r	r		r			
Mauiulus				c			c		
Neozephlebia		r	c						
Nesameletus		r	r	a	a	a	a	a	a
Zephlebia sp									
Trichoptera									
Aoteapsyche	c	r	c	a	a	a		r	r
Beraeoptera				r			c	r	c
Costachorema							r		
Cryptobiosella			r						
Helicopsyche	a	va	va			r		r	r
Hydrobiosella	c	c	a			r		r	
Hydrobiosis sp.	c	r		r	r	r			r
Oeconesidae									
Olinga	a	a	a	r	r	c	r	c	
Orthopsyche		r	r						
Plectrocnemia	r			c	r		r	r	
Polyplectropus			r						
Psilochorema		r			r				
Pycnocentria			r		r		r	r	r
Pycnocentrodes		c	a	a	a	a	a	a	a
Zelolessica								r	
Plecoptera									
Acroperla									
Austroperla	r			r					
Spaniocerca	r		r						
Stenoperla	c	c	c	r			r		
Zelandobius	c				r		a	c	c
Zelandoperla	r	c	r	c	r	r		r	r
Hemiptera									
Coleoptera									
Elmidae	a	a	a	a	a	a	a	a	a
Ptilodactylidae	r	r	r						
Odonata									
Antipodochlora									
Neuroptera									
Diptera									
Aphrophila					r		r		
Austrosimulium							c	r	
Eriopterini	c	r	c					r	r
Maoridiamesa							c		r
Orthocladiinae							a	r	c

Paralimnophila			r						
Polypedilum	r	r	c			r			
Tabanidae						r		r	r
Tanypodoninae		r							
Megaleptopera									
Archichauliodes	c	a	a	a	a	c	a	c	a
Lepidoptera									
Collembola									
Crustacea									
Amphipoda									r
Ostracoda									
Paranephrops									
Acarina									
Arachnida									
Mollusca									
Potamopyrgus	va	va	a	a	a	c	a	a	a
Bryozoa									
Hirudinea									
Nematoda									
Nematomorpha									
Nemertea									
Oligochaeta	r	r		r	r	r		r	r
Platyhelminthes									
Polychaeta									
Rhabdocoela									
Tardigrada									
COELENTERATA									
Hydra									
Total coded abundance	244	332	296	247	235	129	267	135	150
EPT coded abundance	111	187	224	186	173	96	176	85	80
Taxonomic richness	23	24	26	18	18	18	19	24	20
No. of Insect Taxa	21	22	25	16	16	16	18	22	17
EPT	16	16	19	14	13	12	12	16	11
%EPT abundance	45	56	76	75	74	74	66	63	53
MCI	130	130	133	134	134	134	126	127	116
SQMCI	5.7	6.5	7.5	7.5	7.5	7.3	7.0	6.4	6.2
Ephemeroptera	**17**	**13**	**16**	**53**	**54**	**36**	**47**	**35**	**30**
Plecoptera	**5**	**3**	**2**	**3**	**1**	**1**	**8**	**4**	**4**
Trichoptera	**23**	**40**	**57**	**19**	**19**	**37**	**11**	**24**	**19**
Megaloptera	**2**	**6**	**7**	**8**	**9**	**4**	**7**	**4**	**13**
Coleoptera	**9**	**6**	**7**	**8**	**9**	**16**	**7**	**15**	**13**
Diptera	**2**	**1**	**4**	**0**	**0**	**2**	**12**	**3**	**5**
Mollusca	**41**	**30**	**7**	**8**	**9**	**4**	**7**	**15**	**13**
Others	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**1**

SEV - MCI Invert List						
	Battle Hill main			Battle Hill trib		
SEV Version 8.2	BH-M (a)	BH-M (b)	BH-M (c)	BH-T (a)	BH-T (b)	BH-T (c)
Ephemeroptera						
Acanthophlebia				r	c	c
Amelotopsis	r		r	c	r	c
Austroclima	c	c		r	c	c
Coloburiscus	a	a	a	a	va	a
Deleatidium	a	va	a	a	c	a
Ichthybotus					r	
Mauiulus	a		c			
Neozephlebia	c				r	
Nesameletus	a	a	a			c
Zephlebia sp					c	
Trichoptera						
Aoteapsyche	a	c	c			
Beraeoptera						
Costachorema						
Cryptobiosella						
Helicopsyche				r	r	c
Hydrobiosella	r	r	r	a	a	c
Hydrobiosis sp.	r	r	r		r	r
Oeconesidae						
Olinga	va	va	a		r	
Orthopsyche				r	c	r
Plectrocnemia						
Polyplectropus						
Psilochorema	c	c	r	r	c	r
Pycnocentria	c	c	c			
Pycnocentrodes	a	a	va			
Zelolessica						
Plecoptera						
Acroperla		r		c	c	c
Austroperla						
Spaniocerca				c	c	c
Stenoperla				r	r	
Zelandobius	a	r	r			
Zelandoperla				r		r
Hemiptera						
Coleoptera						
Elmidae	a	a	a		r	
Ptilodactylidae		r		r	c	r
Odonata						
Antipodochlora					r	
Neuroptera						
Diptera						
Aphrophila					r	
Austrosimulium	r	c				
Eriopterini	r	r		c	c	r
Maoridiamesa	r		r			
Orthocladiinae		r				
Paralimnophila					r	

Polypedilum				c	c	c
Tabanidae	r		r			
Tanypodoninae		r				
Megaleptopera						
Archichauliodes	a	a	a	a	a	c
Lepidoptera						
Collembola						
Crustacea						
Amphipoda	r					
Ostracoda	r					
Paranephrops				r		
Acarina						
Arachnida						
Mollusca						
Potamopyrgus	c	a	va		r	
Bryozoa						
Hirudinea						
Nematoda						
Nematomorpha						
Nemertea						
Oligochaeta	c	c	c			
Platyhelminthes						
Polychaeta						
Rhabdocoela						
Tardigrada						
COELENTERATA						
Hydra						
Total coded abundance	319	358	347	113	202	91
EPT coded abundance	263	284	200	81	162	79
Taxonomic richness	25	22	19	18	26	18
No. of Insect Taxa	21	20	17	17	25	18
EPT	15	13	13	13	17	14
%EPT abundance	82	79	58	72	80	87
MCI	119	125	133	127	123	130
SQMCI	7.7	7.8	6.0	6.7	6.8	7.2
Ephemeroptera	**29**	**41**	**19**	**41**	**58**	**60**
Plecoptera	**6**	**1**	**0**	**11**	**5**	**12**
Trichoptera	**48**	**38**	**38**	**20**	**16**	**14**
Megaloptera	**6**	**6**	**6**	**18**	**10**	**5**
Coleoptera	**6**	**6**	**6**	**1**	**3**	**1**
Diptera	**1**	**2**	**1**	**9**	**6**	**7**
Mollusca	**2**	**6**	**29**	**0**	**0**	**0**
Others	**2**	**1**	**1**	**1**	**0**	**0**

SEV - MCI Invert List										
	Duck upper			Duck mid			Duck lower			
SEV Version 8.2	DK-U (a)	DK-U (b)	DK-U (c)	DK-M (a)	DK-M (b)	DK-M (c)	DK-L (a)	DK-L (b)	DK-L (c)	COUNT ALL (max 33)
Ephemeroptera										1
Acanthophlebia		r	r							10
Amelotopsis										11
Austroclima	c	a	a	c	c	c	r		r	19
Coloburiscus	a	c	a	c	c	c	c		r	23
Deleatidium	va	a	c	va	a	a	va	va	a	26
Ichthybotus										8
Mauiulus		c				r		c		9
Neozephlebia		c	r							8
Nesameletus				r		r		c	r	18
Zephlebia sp		c	c		r	r				7
Trichoptera										1
Aoteapsyche	a	c	c	c	r	r	a	r	a	22
Beraeoptera				r	r			r		9
Costachorema										3
Cryptobiosella										3
Helicopsyche	a	a	a	r	c	r	r	r	r	20
Hydrobiosella	a	r	a	c	c	a	r		r	21
Hydrobiosis sp.	r	r	r	r	r	r	c	c	c	22
Oeconesidae		r								3
Olinga	a	a	a	va	a	a	va	c	a	23
Orthopsyche										7
Plectrocnemia					r					8
Polyplectropus								r		4
Psilochorema	r		r	c	r	r	c	c	r	18
Pycnocentria	r	c	c	c	c	r	c	r	c	19
Pycnocentrodes	c		c	va	a	a	a	a	va	21
Zelolessica										3
Plecoptera										1
Acroperla	r								r	8
Austroperla										4
Spaniocerca	r									8
Stenoperla	c	c	c	c	c	c				15
Zelandobius	c		r	r	r	r		r		16
Zelandoperla	r			r		r				15
Hemiptera										1
Coleoptera										1
Elmidae	a	a	va	va	va	va	va	va	va	24
Ptilodactylidae				r	r	r	r			13
Odonata										1
Antipodochlora										3
Neuroptera										1
Diptera										1
Aphrophila				r					r	7
Austrosimulium				r			r			8
Eriopterini	r	r	r	r	r	c	r	c		20
Maoridiamesa	r					r	r			9
Orthocladiinae	r	c	r	r		r				11
Paralimnophila		r					r	r		7

Polypedilum										9
Tabanidae										7
Tanypodoninae	c	c	r		r			r	c	10
Megaleptopera										1
Archichauliodes	a	c	c	a	c	c	a	c	c	26
Lepidoptera										1
Collembola										1
Crustacea										1
Amphipoda	r	va	va		a	c		r		10
Ostracoda				r	r	r	c	r	r	9
Paranephrops			r							4
Acarina										1
Arachnida										1
Mollusca										1
Potamopyrgus	r	c	c	a	a	c	a	a	a	24
Bryozoa										1
Hirudinea										1
Nematoda										1
Nematomorpha										1
Nemertea										1
Oligochaeta	r	c	c	c	a	c	a	va	va	1
Platyhelminthes										1
Polychaeta										1
Rhabdocoela										1
Tardigrada										1
COELENTERATA										1
Hydra										1
Total coded abundance	277	265	353	492	266	234	433	385	409	26
EPT coded abundance	226	118	134	341	97	105	263	151	177	26
Taxonomic richness	25	24	25	26	25	27	21	22	20	26
No. of Insect Taxa	22	21	21	23	21	23	18	18	17	26
EPT	16	15	16	16	16	17	11	13	13	26
%EPT abundance	82	45	38	69	36	45	61	39	43	26
MCI	120	120	122	124	127	128	129	120	119	26
SQMCI	7.8	4.6	4.7	7.2	5.5	6.1	7.1	5.7	5.6	26
Ephemeroptera	45	23	14	23	12	14	24	29	6	26
Plecoptera	5	2	2	1	2	3	0	0	0	26
Trichoptera	32	20	22	45	23	28	36	10	37	26
Megaloptera	7	2	1	4	2	2	5	1	1	26
Coleoptera	7	8	28	21	38	43	23	26	24	26
Diptera	3	5	1	1	1	3	1	2	1	26
Mollusca	0	2	1	4	8	2	5	5	5	26
Others	1	40	30	1	15	5	6	26	25	26

Appendix 9.I Macroinvertebrate community similarity tests

Habitat/site	% similarity	Excluding reference sites
Duck Nth	76.19%	84.21%
Pauatahanui lower	90.48%	100.00%
Battle main	100.00%	100.00%
Duck Silwood	95.24%	100.00%
Duck Sth	95.24%	100.00%
Cannons lower	95.24%	100.00%
Horo West-low	95.24%	100.00%
Horo East -lower	95.24%	100.00%
Horokiri lower	100.00%	100.00%
Duck lower	100.00%	100.00%
Duck upper	100.00%	100.00%
Te Puka mid	100.00%	100.00%
Horokiri mid	100.00%	100.00%
Cannons mid	95.24%	100.00%
Cannons upper	95.24%	100.00%
Te Puka lower	100.00%	100.00%
Duck mid	100.00%	100.00%
Te Puka upper	100.00%	100.00%
Horokiri upper	100.00%	100.00%
Belmont ref	90.48%	
Battle trib	57.14%	

Appendix 9.J SEV SCORES

DUCK CREEK

					Test sites					Reference sites			
Function category	Report Section*	Function	Worksheet #	Variable (code)	DKLU SEVi	DKM SEVi	DKL SEVi	DKLS SEVi	DKN SEVi	BH Trib	Hawkin's lower	Copy of BH Ttrib	Mean for Ref Sites
			1	Vbed	1.00	0.70	1.00	0.94	0.91	1.00	1.00	1.00	1.00
			2	Verosn	0.70	0.70	0.70	1.00	0.20	0.20	1.00	0.20	0.47
			30	Vimper	1.00	1.00	1.00	0.70	0.30	1.00	1.00	1.00	1.00
Hydraulic	5.1	NFR		=	0.85	0.70	0.85	0.68	0.17	0.60	1.00	0.60	0.73
			14	Vfpwidth	1.00	0.40	0.70	1.00	1.00	0.70	1.00	0.70	0.80
			3	Vfreq	0.80	0.80	0.80	0.40	0.80	0.80	0.80	0.80	0.80
Hydraulic	5.2	CFP		=	0.90	0.60	0.75	0.70	0.90	0.75	0.90	0.75	0.80
			4	Vbarr	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			31	Vcatch	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Hydraulic	5.3	CSM		=	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			1	Vhypo	0.75	0.75	1.00	0.50	0.28	1.00	0.50	1.00	0.83
Hydraulic	5.4	CGW		=	0.75	0.75	1.00	0.50	0.28	1.00	0.50	1.00	0.83
				Hydraulic function mean score	0.88	0.76	0.90	0.72	0.59	0.84	0.85	0.84	0.84
			18	Vshade	0.16	0.01	0.00	0.42	0.08	0.96	0.90	0.96	0.94
			15	Vdepth	0.50	0.60	0.60	0.70	0.70	0.50	0.70	0.50	0.57
			22	Vveloc	0.70	0.60	0.70	0.60	0.70	0.70	0.80	0.70	0.73
			21	Vlength	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
biogeochemical	5.5	WTC		=	0.35	0.27	0.28	0.49	0.34	0.75	0.77	0.75	0.75
			5	Vdod	1.13	1.00	1.00	0.96	0.65	1.00	1.00	1.00	1.00
biogeochemical	5.6	DOM		=	1.13	1.00	1.00	0.96	0.65	1.00	1.00	1.00	1.00
			19	Vcanop	0.07	0.00	0.00	0.44	0.06	1.00	0.80	1.00	0.93
			20	Vdecid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
biogeochemical	5.7	OMI		=	0.07	0.00	0.00	0.44	0.06	1.00	0.80	1.00	0.93
			23	Vtrans	0.70	0.70	0.70	1.00	1.00	0.70	1.00	0.70	0.80
			24	Vretain	1.00	1.00	1.00	0.75	0.67	1.00	0.67	1.00	0.89
biogeochemical	5.8	IPR		=	0.70	0.70	0.70	0.75	0.67	0.70	0.67	0.70	0.69
			16	Vsurf	0.64	0.63	0.61	1.00	1.00	0.80	1.00	0.80	0.86
biogeochemical	5.9	DOP		=	0.64	0.63	0.61	1.00	1.00	0.80	1.00	0.80	0.86
			14	Vfpwidth	1.00	0.40	0.70	1.00	1.00	0.70	1.00	0.70	0.80
			6	Vrough	0.10	0.10	0.10	0.70	0.70	0.40	0.40	0.40	0.40
			3	Vfreq	0.80	0.80	0.80	0.40	0.80	0.80	0.80	0.80	0.80

biogeochemical	5.1	FPR		=	0.63	0.43	0.53	0.70	0.83	0.63	0.73	0.63	0.67
				Biogeochemical function mean score	0.59	0.51	0.52	0.72	0.59	0.81	0.83	0.81	0.82
			9	Vgalspwn	1.00	1.00	1.00	0.00	0.50	0.00	1.00	0.00	0.33
			10	Vgalqual	0.75	0.25	0.25	1.00	1.00	0.25	1.00	0.00	0.42
			17	Vgobspwn	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
habitat provision	5.11	FSH		=	0.88	0.63	0.63	0.50	0.75	0.50	1.00	0.50	0.67
			7	Vphyshab	0.76	0.71	0.71	0.73	0.75	0.98	1.00	0.98	0.99
			8	Vwatqual	0.20	0.06	0.05	0.30	0.09	0.98	0.95	0.98	0.97
			30	Vimper	1.00	1.00	1.00	0.70	0.30	1.00	1.00	1.00	1.00
habitat provision	5.12	HAF		=	0.68	0.62	0.62	0.62	0.47	0.98	0.99	0.98	0.99
				Habitat provision function mean score	0.78	0.62	0.62	0.56	0.61	0.74	0.99	0.74	0.83
			28	Vfish	0.47	0.73	0.87	0.60	0.53	0.80	0.73	0.80	0.78
Biodiversity	5.13	FFI		=	0.47	0.73	0.87	0.60	0.53	0.80	0.73	0.80	0.78
			25	Vmci	0.70	0.30	0.30	0.10	0.10	1.00	0.70	1.00	0.90
			26	Vept	1.00	0.95	0.85	0.80	0.65	0.95	1.00	0.95	0.97
Biodiversity	5.14	IFI		=	0.85	0.63	0.58	0.45	0.38	0.98	0.85	0.98	0.93
			29	Vvert	0.47	0.73	0.87	0.60	0.53	0.80	0.73	0.80	0.78
			27	Vinvert	0.13	0.12	0.08	0.02	0.02	1.00	1.00	1.00	1.00
Biodiversity	5.15	ABI		=	0.30	0.43	0.48	0.31	0.28	0.90	0.87	0.90	0.89
			11	Vripcond	0.30	0.10	0.10	0.30	0.30	0.70	1.00	0.70	0.80
			12	Vripconn	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
			13	Vripar	0.00	0.00	0.00	0.00	0.10	1.00	1.00	1.00	1.00
Biodiversity	5.16	RVI		=	0.43	0.37	0.37	0.43	0.47	0.90	1.00	0.90	0.93
				Biodiversity function mean score	0.51	0.54	0.57	0.45	0.41	0.89	0.86	0.89	0.88
Sum of scores (maximum value 16)					10.62	9.48	10.25	10.13	8.76	13.29	13.80	13.29	13.46
Overall mean SEV score (maximum value 1)					0.664	0.592	0.64	0.633	0.547	0.830	0.863	0.830	0.84

HOROKIRI STREAM

					Test sites					Reference sites			
Function category	Report Section*	Function	Worksheet #	Variable (code)	HKU SEVi	HKM SEVi	HKL SEVi	BHM SEVi		BH Trib	Hawkin's lower	Copy of BH Ttrib	Mean for Ref Sites
			1	Vbed	1.00	1.00	0.97	1.00		1.00	1.00	1.00	1.00
			2	Verosn	0.20	0.10	0.70	0.70		0.20	1.00	0.20	0.47
			30	Vimper	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00
Hydraulic	5.1	NFR		=	0.60	0.55	0.84	0.85		0.60	1.00	0.60	0.73
			14	Vfpwidth	0.00	1.00	0.00	0.70		0.70	1.00	0.70	0.80
			3	Vfreq	0.10	0.80	0.80	0.80		0.80	0.80	0.80	0.80
Hydraulic	5.2	CFP		=	0.05	0.90	0.40	0.75		0.75	0.90	0.75	0.80
			4	Vbarr	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00
			31	Vcatch	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00
Hydraulic	5.3	CSM		=	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00
			1	Vhypo	0.75	0.50	0.50	0.75		1.00	0.50	1.00	0.83
Hydraulic	5.4	CGW		=	0.75	0.50	0.50	0.75		1.00	0.50	1.00	0.83
				Hydraulic function mean score	0.60	0.74	0.68	0.84		0.84	0.85	0.84	0.84
			18	Vshade	0.46	0.04	0.20	0.64		0.96	0.90	0.96	0.94
			15	Vdepth	0.60	0.70	0.70	0.70		0.50	0.70	0.50	0.57
			22	Vveloc	0.60	0.60	0.70	0.70		0.70	0.80	0.70	0.73
			21	Vlength	0.40	0.40	0.40	0.40		0.40	0.40	0.40	0.40
biogeochemical	5.5	WTC		=	0.50	0.30	0.40	0.62		0.75	0.77	0.75	0.75
			5	Vdod	1.00	1.01	1.00	1.00		1.00	1.00	1.00	1.00
biogeochemical	5.6	DOM		=	1.00	1.01	1.00	1.00		1.00	1.00	1.00	1.00
			19	Vcanop	0.59	0.00	0.26	0.76		1.00	0.80	1.00	0.93
			20	Vdecid	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00
biogeochemical	5.7	OMI		=	0.59	0.00	0.26	0.76		1.00	0.80	1.00	0.93
			23	Vtrans	0.70	0.70	0.70	0.70		0.70	1.00	0.70	0.80
			24	Vretain	0.87	0.72	0.72	1.00		1.00	0.67	1.00	0.89
biogeochemical	5.8	IPR		=	0.61	0.51	0.51	0.70		0.70	0.67	0.70	0.69
			16	Vsurf	0.78	0.85	0.70	0.62		0.80	1.00	0.80	0.86
biogeochemical	5.9	DOP		=	0.78	0.85	0.70	0.62		0.80	1.00	0.80	0.86
			14	Vfpwidth	0.00	1.00	0.00	0.70		0.70	1.00	0.70	0.80
			6	Vrough	0.40	0.10	0.46	0.13		0.40	0.40	0.40	0.40
			3	Vfreq	0.10	0.80	0.80	0.80		0.80	0.80	0.80	0.80
biogeochemical	5.1	FPR		=	0.17	0.63	0.42	0.54		0.63	0.73	0.63	0.67
				Biogeochemical function mean score	0.61	0.55	0.55	0.71		0.81	0.83	0.81	0.82
			9	Vgalspwn	0.00	1.00	0.25	0.50		0.00	1.00	0.00	0.33

			10	Vgalqual	0.25	0.25	0.25	0.25		0.25	1.00	0.00	0.42
			17	Vgobspwn	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00
habitat provision	5.11	FSH		=	0.50	0.63	0.53	0.56		0.50	1.00	0.50	0.67
			7	Vphyshab	0.80	0.63	0.73	0.86		0.98	1.00	0.98	0.99
			8	Vwatqual	0.48	0.07	0.35	0.42		0.98	0.95	0.98	0.97
			30	Vimper	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00
habitat provision	5.12	HAF		=	0.77	0.58	0.70	0.78		0.98	0.99	0.98	0.99
				Habitat provision function mean score	0.64	0.60	0.62	0.67		0.74	0.99	0.74	0.83
			28	Vfish	0.63	0.60	0.67	0.67		0.80	0.73	0.80	0.78
Biodiversity	5.13	FFI		=	0.63	0.60	0.67	0.67		0.80	0.73	0.80	0.78
			25	Vmci	1.00	0.70	0.70	0.30		1.00	0.70	1.00	0.90
			26	Vept	1.00	1.00	1.00	0.80		0.95	1.00	0.95	0.97
Biodiversity	5.14	IFI		=	1.00	0.85	0.85	0.55		0.98	0.85	0.98	0.93
			29	Vvert	0.63	0.60	0.67	0.67		0.80	0.73	0.80	0.78
			27	Vinvert	0.17	0.14	0.17	0.08		1.00	1.00	1.00	1.00
Biodiversity	5.15	ABI		=	0.40	0.37	0.42	0.37		0.90	0.87	0.90	0.89
			11	Vripcond	0.10	0.10	0.60	0.10		0.70	1.00	0.70	0.80
			12	Vripconn	1.00	1.00	1.00	1.00		1.00	1.00	1.00	1.00
			13	Vripar	0.25	0.00	0.00	0.00		1.00	1.00	1.00	1.00
Biodiversity	5.16	RVI		=	0.45	0.37	0.53	0.37		0.90	1.00	0.90	0.93
				Biodiversity function mean score	0.62	0.55	0.62	0.49		0.89	0.86	0.89	0.88
Sum of scores (maximum value 16)					9.79	9.64	9.72	10.89		13.29	13.80	13.29	13.46
Overall mean SEV score (maximum value 1)					0.612	0.603	0.607	0.681		0.830	0.863	0.830	0.84

TE PUKA

					Test sites					Reference sites			
Function category	Report Section*	Function	Worksheet #	Variable (code)	TPM SEVi	TPL SEVi				BH Trib	Hawkin's lower	Copy of BH Ttrib	Mean for Ref Sites
			1	Vbed	1.00	0.80				1.00	1.00	1.00	1.00
			2	Verosn	0.20	0.20				0.20	1.00	0.20	0.47
			30	Vimper	1.00	1.00				1.00	1.00	1.00	1.00
Hydraulic	5.1	NFR		=	0.60	0.50				0.60	1.00	0.60	0.73
			14	Vfpwidth	0.70	0.00				0.70	1.00	0.70	0.80
			3	Vfreq	0.80	0.80				0.80	0.80	0.80	0.80
Hydraulic	5.2	CFP		=	0.75	0.40				0.75	0.90	0.75	0.80
			4	Vbarr	1.00	1.00				1.00	1.00	1.00	1.00
			31	Vcatch	1.00	1.00				1.00	1.00	1.00	1.00
Hydraulic	5.3	CSM		=	1.00	1.00				1.00	1.00	1.00	1.00
			1	Vhypo	1.00	0.75				1.00	0.50	1.00	0.83
Hydraulic	5.4	CGW		=	1.00	0.75				1.00	0.50	1.00	0.83
				Hydraulic function mean score	0.84	0.66				0.84	0.85	0.84	0.84
			18	Vshade	0.00	0.52				0.96	0.90	0.96	0.94
			15	Vdepth	0.70	0.60				0.50	0.70	0.50	0.57
			22	Vveloc	0.60	0.60				0.70	0.80	0.70	0.73
			21	Vlength	0.40	0.40				0.40	0.40	0.40	0.40
biogeochemical	5.5	WTC		=	0.28	0.53				0.75	0.77	0.75	0.75
			5	Vdod	1.00	1.00				1.00	1.00	1.00	1.00
biogeochemical	5.6	DOM		=	1.00	1.00				1.00	1.00	1.00	1.00
			19	Vcanop	0.00	0.72				1.00	0.80	1.00	0.93
			20	Vdecid	0.00	0.00				0.00	0.00	0.00	0.00
biogeochemical	5.7	OMI		=	0.00	0.72				1.00	0.80	1.00	0.93
			23	Vtrans	0.70	0.70				0.70	1.00	0.70	0.80
			24	Vretain	1.00	0.89				1.00	0.67	1.00	0.89
biogeochemical	5.8	IPR		=	0.70	0.62				0.70	0.67	0.70	0.69
			16	Vsurf	0.76	0.75				0.80	1.00	0.80	0.86
biogeochemical	5.9	DOP		=	0.76	0.75				0.80	1.00	0.80	0.86
			14	Vfpwidth	0.70	0.00				0.70	1.00	0.70	0.80
			6	Vrough	0.10	0.40				0.40	0.40	0.40	0.40
			3	Vfreq	0.80	0.80				0.80	0.80	0.80	0.80
biogeochemical	5.1	FPR		=	0.53	0.40				0.63	0.73	0.63	0.67
				Biogeochemical function mean score	0.55	0.67				0.81	0.83	0.81	0.82
			9	Vgalspwn	0.00	0.25				0.00	1.00	0.00	0.33

			10	Vgalqual	0.25	0.25				0.25	1.00	0.00	0.42
			17	Vgobspwn	1.00	1.00				1.00	1.00	1.00	1.00
habitat provision	5.11	FSH		=	0.50	0.53				0.50	1.00	0.50	0.67
			7	Vphyshab	0.67	0.92				0.98	1.00	0.98	0.99
			8	Vwatqual	0.10	0.51				0.98	0.95	0.98	0.97
			30	Vimper	1.00	1.00				1.00	1.00	1.00	1.00
habitat provision	5.12	HAF		=	0.61	0.84				0.98	0.99	0.98	0.99
				Habitat provision function mean score	0.56	0.68				0.74	0.99	0.74	0.83
			28	Vfish	0.67	0.67				0.80	0.73	0.80	0.78
Biodiversity	5.13	FFI		=	0.67	0.67				0.80	0.73	0.80	0.78
			25	Vmci	0.70	0.70				1.00	0.70	1.00	0.90
			26	Vept	1.00	1.00				0.95	1.00	0.95	0.97
Biodiversity	5.14	IFI		=	0.85	0.85				0.98	0.85	0.98	0.93
			29	Vvert	0.67	0.67				0.80	0.73	0.80	0.78
			27	Vinvert	0.18	0.23				1.00	1.00	1.00	1.00
Biodiversity	5.15	ABI		=	0.42	0.45				0.90	0.87	0.90	0.89
			11	Vripcond	0.10	0.30				0.70	1.00	0.70	0.80
			12	Vripconn	1.00	1.00				1.00	1.00	1.00	1.00
			13	Vripar	0.00	0.60				1.00	1.00	1.00	1.00
Biodiversity	5.16	RVI		=	0.37	0.63				0.90	1.00	0.90	0.93
				Biodiversity function mean score	0.58	0.65				0.89	0.86	0.89	0.88
Sum of scores (maximum value 16)					10.04	10.63				13.29	13.80	13.29	13.46
Overall mean SEV score (maximum value 1)					0.628	0.665				0.830	0.863	0.830	0.84