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Waiwhetu Stream 2009

Broad and Fine Scale Baseline Monitoring in the Tidal Reaches

Prepared for
Greater Wellington Regional Council
June 2009

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By

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Cover Photo: Lower reach of Waiwhetu Stream.

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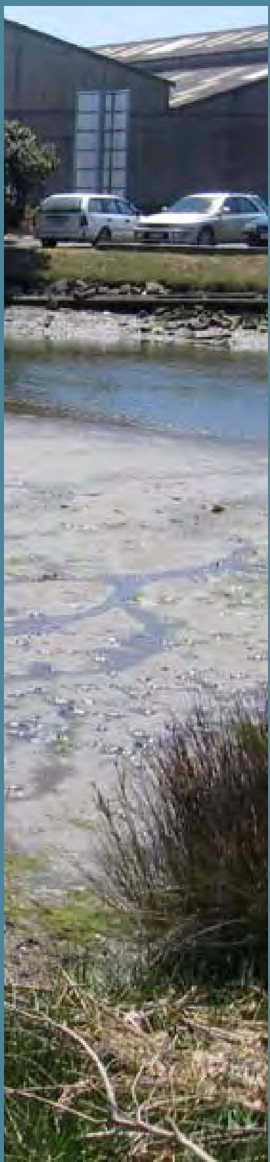
WAIWHETU STREAM - EXECUTIVE SUMMARY



This report summarises baseline sampling undertaken in Waiwhetu Stream in January 2009 before extensive flood control and contaminated sediment remediation work was commenced by Greater Wellington Regional Council (GWRC) and Hutt City Council (HCC). A second survey is programmed for January 2011 once work is complete.

Sampling methods were based on the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002), and recent extensions (Robertson and Stevens 2006, 2007, 2008, 2009), with the results providing baseline data to compare future changes. Results (summarised below) are also compared to broad and fine scale indicators of chemical and biological condition to help relate estuary condition to the key issues of eutrophication, sedimentation, toxicity, and habitat loss.

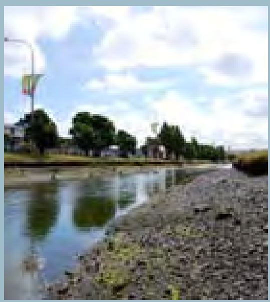
INDICATOR	2009	RESULT
SALTMARSH	FAIR	Saltmarsh habitat is scarce, as streamway margins extensively reclaimed and often steepened, straightened and reinforced to mitigate flood flows
TERRESTRIAL MARGIN	POOR	Most (80%) highly modified e.g. industrial, commercial, residential, or roading. Remaining 18% in grassland with only 2% densely vegetated
MACROALGAE	FAIR	Cover very low but widespread areas of anoxic muds and sulphide odours indicate sediment eutrophication is a significant issue
SOFT MUD	POOR	Dominant in the mid and lower intertidal area and characterised by high levels of anoxia (a lack of oxygen), and the presence of sulphides
RPD Depth	POOR	Very shallow (~1mm deep) indicating poor sediment oxygenation
Nutrients	ENRICHED	TN and TP, indicators of nutrient enrichment, elevated at both sites
Organic Content	ENRICHED	TOC, the indicator of organic enrichment, elevated at both sites
Arsenic	GOOD	All below ANZECC (2000) ISQG-Low trigger values
Cadmium	GOOD	All below ANZECC (2000) ISQG-Low trigger values
Chromium	GOOD	All below ANZECC (2000) ISQG-Low trigger values
Copper	GOOD-FAIR	3 sites between ANZECC (2000) ISQG-Low and High, 1 site below ISQG-Low
Lead	POOR	All exceeded ANZECC (2000) ISQG-High trigger values
Mercury	FAIR	All between ANZECC (2000) ISQG-Low and High trigger values
Nickel	GOOD	All below ANZECC (2000) ISQG-Low trigger values
Zinc	POOR	All exceeded ANZECC (2000) ISQG-High trigger values
PAHs	GOOD	10 PAHs detected but all below ANZECC ISQG-Low trigger values
PESTICIDES	POOR	4,4'-DDD present at Site A above ANZECC ISQG-High trigger values
Benthic Community	Community reflects species that tolerate moderate organic enrichment (i.e. omnivorous surface deposit feeding species) and which live predominantly in a relatively clean layer of oxygenated surface mud present above the underlying anoxic sediments	

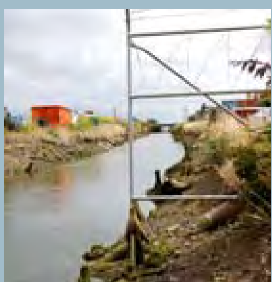
The monitoring results show the lower part of the Waiwhetu Stream to be muddy, with organically enriched sediments that contain a range of industrial contaminants. Past stream modification has been significant with the loss of most saltmarsh and the vegetated terrestrial buffer. Consequently the streamway rated poorly in terms of eutrophication, sedimentation, toxicity and habitat loss.

The proposed remediation works are expected to result in a significant improvement to the lower streamway. The baseline data presented in this report will enable changes made following streamway remediation to be assessed after the biological community has had time to re-establish.

1. INTRODUCTION

OVERVIEW





An extensive programme of flood control and contaminated sediment remediation is currently being undertaken within the lower reaches of the Waiwhetu Stream by Greater Wellington Regional Council (GWRC) and Hutt City Council (HCC). As part of this programme, Wriggle Coastal Management was contracted by GWRC to establish an ecological baseline in the transitional (seawater influenced) waters in the lower stream, against which future changes can be compared. This report presents the findings of the initial baseline sampling undertaken on 16-17 January 2009 before work in the stream began. A second survey is programmed for January 2011 after flood control and remediation works are complete.

As the lower streamway is estuarine in character, the sampling approach is based on the methods described in the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions (e.g. Robertson and Stevens 2006, 2007, 2008, 2009). It consists of two key components (summarised below) to provide a defensible but cost effective overview of the existing ecological health of the stream, recognising that extensive sampling and analysis of sediment contaminants is being undertaken as part of the wider remediation programme. This report describes the following:

1. **Broad scale habitat mapping**. This component is used to characterise the dominant surface substrate and vegetation within the study area, as well as the adjoining terrestrial margin (approximately 100m either side of the streamway) using a combination of aerial photos, ground truthing, and GIS based digital mapping. Results detail the location and area of saltmarsh, unvegetated substrates, and dominant terrestrial features.

2. **Fine scale physical, chemical and biological monitoring**. This component provides detailed information on sediment chemistry and the condition of sediment biota at both intertidal and subtidal sites within the remediation zone. Results are compared to condition ratings for key indicators of stream/estuary condition (e.g. metals, organic matter), and provide a baseline to compare future changes with. Shellfish were also sampled at the mouth of the Waiwhetu Stream to provide a baseline for the accumulation of contaminants in shellfish flesh downstream of the remediation works.

For the fine scale monitoring, three sampling sites were selected downstream of Bell Road in the lower Waiwhetu Stream (Figure 1). This 1,500m long tidally influenced area is where remediation of the most contaminated sediments will occur. Sites A and B (Figures 2 and 3), each with an intertidal and subtidal site, were located in representative unvegetated soft mud areas to identify the current sediment dwelling animals and contaminant concentrations present. Site C (Figure 1), downstream of the proposed works, was included to provide a baseline for the accumulation of contaminants in shellfish. After removal and replacement of sediments at these sites over the next two years, they will be resampled, and changes in the community and contaminant concentrations described.

This comparative design has been used because the large number of stormwater/surface water discharges entering this section of Waiwhetu Stream, coupled with the transition from fresh to estuarine waters, precluded the meaningful inclusion of upstream and downstream biological reference sites.

This report describes the methods used, and characterises the ecological condition of the selected sites prior to the remediation works commencing.

1. Introduction (continued)

In addition to providing a baseline for assessing changes over time, the monitoring approach also provides information on four of the major issues affecting most NZ estuaries (Table 1): sedimentation, eutrophication, toxins and habitat loss. Disease risk has not been included as it is reported on separately by GWRC through its freshwater state of the environment monitoring programme. In evaluating these aspects we use the relevant indicators of each issue which are detailed in Table 2. Specific condition ratings for each are presented in the Methods (Section 2) of this report, and the results are presented and discussed in relation to each of the key issues in Section 3.

Table 1. Summary of the major issues affecting most NZ estuaries.

Issue	Impact
Sedimentation	If sediment inputs are excessive, they infill quickly with muds, reducing biodiversity and human values and uses.
Eutrophication	Eutrophication is an increase in the rate of supply of organic matter to an ecosystem. If nutrient inputs are excessive, they experience macroalgal and/or phytoplankton blooms, anoxic sediments, lowered biodiversity and nuisance effects for local residents.
Disease Risk	If pathogen inputs are excessive, the disease risk from bathing, wading or eating shellfish increases to unacceptable levels.
Toxins	If potentially toxic contaminant inputs (e.g. heavy metals, pesticides) are excessive, estuary biodiversity is threatened and shellfish and fish may be unsuitable for eating.
Habitat Loss	If habitats (such as saltmarsh) are lost or damaged through drainage, reclamation, building of structures, stock grazing or vehicle access, biodiversity and estuary productivity declines.
	If the natural terrestrial margin around the estuary is modified by forest clearance or degraded through such actions as roading, stormwater outfalls, property development and weed growth, the natural character is diminished and biodiversity reduced.

Table 2. Summary of the broad and fine scale EMP indicators.

Issue	Indicator	Method
Sedimentation	Soft Mud Area	Broad scale mapping - estimates the area and change in soft mud habitat over time.
Sedimentation	Sedimentation Rate	Fine scale measurement of sediment deposition.
Eutrophication	Nuisance Macroalgal Cover	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (*Ulva*), *Gracilaria* and *Enteromorpha*) over time.
Eutrophication	Organic and Nutrient Enrichment	Chemical analysis of total nitrogen, total phosphorus, and total organic carbon in replicate samples from the upper 2cm of sediment.
Eutrophication	Redox Profile	Measurement of depth of redox potential discontinuity profile (RPD) in sediment estimates likely presence of deoxygenated, reducing conditions.
Toxins	Contamination in Bottom Sediments	Chemical analysis of indicator metals (cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment.
Sedimentation, Eutrophication, Toxins, Habitat Loss	Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna in $0.0133m^2$ replicate cores), and on the sediment surface (epifauna in $0.25m^2$ replicate quadrats).
Habitat Loss	Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
Habitat Loss	Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
Habitat Loss	Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.

1. Introduction (continued)

BACKGROUND

Waiwhetu Stream flows from the bush covered Eastern Hutt hills, through the suburban areas of Lower Hutt, to Gracefield and Seaview, where it becomes a well-flushed tidal river mouth estuary with a very short residence time. Historically the lower Waiwhetu Stream would have had small areas of tidal flats and intertidal saltmarsh (typical for most tidal river mouth estuaries), located within a much wider area of saltmarsh and low-lying wetland at the Hutt River mouth.

Over the past 60 years the stream has received an extensive range of contaminant inputs from sewage overflows, stormwater and, in particular, industrial discharges. This has left a legacy of heavy metals and other chemical pollutants in the sediments of the streambed, particularly near Gracefield and Seaview (e.g. Sheppard 2001, Sheppard and Goff 2001, 2002, Tremblay et al. 2005). The stream corridor itself has also been extensively modified by flood protection works, reclamation, and removal of the natural vegetated margin. Particularly in the lower reaches, public access to the stream is restricted by fencing of industrial sites. Because of extensive hard surfacing and channelling, the area responds quickly in terms of flow and is subject to flooding.

As a direct consequence of impacts from reclamation, loss of vegetated margins, increased muddiness, litter, sediment contamination, and disease risk, the stream is in a poor condition. Despite this, it remains valued for activities such as walking, jogging, dog exercising, and whitebaiting/fishing (near the mouth) and the proposed restoration initiatives have a high potential to improve its quality.

Figure 1. Location of monitoring sites in Waiwhetu Stream (sampled 16 January 2009).

Site	NZMG East	NZMG North
A	2669597	5995107
B	2670150	5994940
C	2669354	5994851

1. Introduction (continued)

Figure 2. Location of Waiwhetu Stream monitoring site A (downstream of the Seaview Road bridge).

Site	NZMG East	NZMG North
WwhA1 01	2669597	5995107
WwhA1 02	2669601	5995108
WwhA1 03	2669604	5995108
WwhA2 01	2669597	5995101
WwhA2 02	2669601	5995103
WwhA2 03	2669604	5995104

Figure 3. Location of Waiwhetu Stream monitoring site B (downstream of the Bell Road bridge).

Site	NZMG East	NZMG North
WwhB1 01	2670148	5994941
WwhB1 02	2670150	5994943
WwhB1 03	2670152	5994944
WwhB2 01	2670150	2994938
WwhB2 02	2670152	5994940
WwhB2 03	2670154	5994942

2. METHODS

BROAD SCALE HABITAT MAPPING

Unvegetated
1-5%
5-10 %
10-20 %
20-50 %
50-80 %
80-100 %

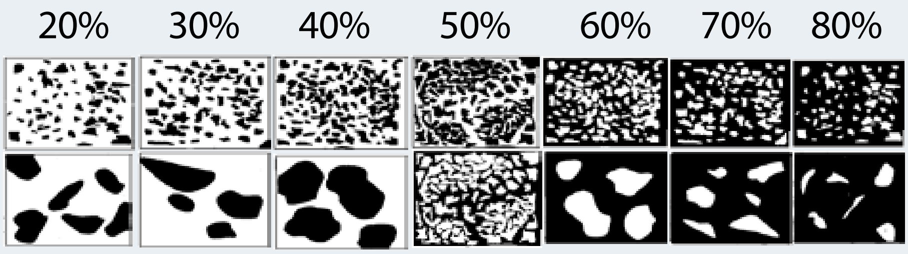
Broad-scale mapping is a method for describing habitat types based on the dominant surface features present (e.g. substrate: mud, sand, cobble, rock; or vegetation: macrophyte, macroalgae, rushland, etc). It follows the EMP approach originally described for use in NZ estuaries by Robertson et al. (2002) with a combination of aerial photography, detailed ground-truthing, and GIS-based digital mapping used to record the primary habitat features present. Very simply, the method involves three key steps:

- Obtaining laminated aerial photos for recording dominant habitat features.
- Carrying out field identification and mapping (i.e. ground-truthing).
- Digitising the field data into GIS layers (ArcMap 9.2).

For the 2009 study, GWRC supplied rectified ~10cm/pixel resolution colour aerial photos. Photos covering the lower streamway/estuary at a scale of 1:2,500 were laminated, and two scientists ground-truthed the spatial extent of dominant habitat and substrate types by walking the area, and recording features directly on the laminated aerial photos in January 2009.

When present, macroalgae and macrophyte percentage cover is classified using a seven category visual rating scale (see examples below and left) to describe macroalgae and macrophyte density and distribution.

Visual rating scale for percentage cover estimates



Sampling positions and photographs were georeferenced and the information collected was used to produce GIS-based habitat maps showing the following:

- Dominant substrate.
- Dominant saltmarsh vegetation.
- 200m wide terrestrial margin vegetation/landuse.

Appendix 1 lists the class definitions used to classify substrate and vegetation.

Digital mapping results were entered by digitising features directly off aerial photos in the GIS using a Wacom Intuos3 electronic drawing tablet within ArcMap 9.2. The spatial location, size, and type of broad scale habitat features in the estuary are provided as ArcMap 9.2 GIS shapefiles on a separate CD. Georeferenced digital field photos (GPS-Photolink) are also supplied as a GIS layer. The broad scale results are summarised in the current report in Section 3, with the supporting GIS files providing much more detail in a data set designed for easy interrogation to address specific monitoring and management questions.

2. Methods (continued)

FINE SCALE MONITORING

Fine scale monitoring was based on the methods described in the EMP (Robertson et al. 2002) and provides detailed information on indicators of chemical and biological condition of the dominant habitat type present. For the current study two representative sampling sites were selected from unvegetated intertidal soft mud at low-mid water, and from two adjacent subtidal sites at the edge of the stream channel (Figures 1, 2 and 3). Samples were collected and analysed for:

- Oxygenation (Redox Potential Discontinuity - RPD depth).
- Organic Matter: (Total organic carbon - TOC).
- Nutrients: Total nitrogen (TN), Total phosphorus (TP).
- Heavy metals: Total recoverable Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg), Nickel (Ni) and Zinc (Zn).
- Semi volatile organic compounds (SVOCs), including organochlorine pesticides (OCPs), and polycyclic aromatic hydrocarbons (PAHs).
- Macroinvertebrate abundance and diversity (infauna and epifauna).

At sites A and B the following sampling was undertaken:

Physical and chemical analyses:

- Three randomly positioned sediment cores were collected to a depth of at least 100mm and photographed. Colour and texture were described and average RPD depth recorded.
- A composite sample of the top 20mm of sediment (each approx. 250gms) was collected adjacent to the three sediment cores.
- All samples were kept in a chillybin in the field or stored as appropriate.
- Chilled samples were sent to R.J. Hill Laboratories for analysis (details in Appendix 2). To allow direct comparison with ANZECC guidelines, metal and nutrient analyses were based on whole sample fractions, while PAH results were normalised to 1% carbon.
- Samples were tracked using standard Chain of Custody (COC) forms and results checked and transferred electronically to avoid transcription errors.
- Photographs were taken to record the general site appearance.

Epifauna (surface-dwelling animals):

- Epifauna were assessed from three random 0.25m^2 quadrats at each site. All animals visible on the sediment surface were identified and counted, and any microalgal mat development noted. The species, abundance and related descriptive information were recorded on waterproof field sheets containing a checklist of expected species. Photographs of quadrats were taken and archived for future reference.

Infauna (animals within sediments):

- Three randomly placed sediment cores were taken from each site using a 130mm diameter (area = 0.0133m^2) PVC tube.
- The core tube was manually driven 150mm into the sediments, removed with the core intact and inverted into a labelled plastic bag.
- Once all replicates had been collected at a site, each core was washed through a 0.5mm nylon mesh bag, with the infauna retained and preserved in 90% isopropyl alcohol.
- Samples were then sent to a commercial laboratory (Gary Stephenson, Coastal Marine Ecology Consultants) for sieving, counting and identification.

Shellfish flesh:

At Site C, beneath the Port Road bridge:

- Approximately 20 blue mussels (*Mytilus galloprovincialis*) were collected from the intertidal zone, wrapped in aluminium foil and sealed in a plastic bag. The sample was sent chilled to R.J. Hill Laboratories for shucking and analysis for metals, PAHs and OCPs (details in Appendix 2).

2. Methods (continued)

CONDITION RATINGS

A series of interim broad and fine scale estuary "condition ratings" (presented below) have been proposed for estuaries in the Wellington region (based on the ratings developed for New Zealand estuaries - Robertson & Stevens 2006, 2007, 2008, 2009). The condition ratings have been developed through a review of monitoring data, use of existing guideline criteria, and expert opinion. They are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management responses. The condition ratings include an "early warning trigger" of any rapid or unexpected change, and each rating has a recommended monitoring frequency and management response. In most cases the management recommendation is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP). Only condition ratings appropriate for use in the lower reaches of the Waiwhetu Stream have been applied. In particular, the macrofauna biotic index, used in other estuaries in the Wellington region (e.g. Robertson and Stevens 2009), has not been used as the physical stressors in the lower Waiwhetu (e.g. high freshwater dilution and varying salinity) favour a community of tolerant species with generally low diversity. Consequently the index does not provide a reliable rating of ecological condition.

Saltmarsh Percent Cover

A variety of saltmarsh species (commonly dominated by rushland but including scrub, sedge, tussock, grass, reed, and herb fields) grow in the upper margins of most NZ estuaries where vegetation stabilises fine sediment transported by tidal flows. Saltmarshes have high biodiversity, are amongst the most productive habitats on earth and have strong aesthetic appeal. Where saltmarsh cover is limited, these values are decreased.

SALTMARSH PERCENT COVER CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	>20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
High	10%-20% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Moderate	5%-10% of estuary area is saltmarsh	Monitor at 5 year intervals after baseline established
Low	2%-5% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Very Low	<2% of estuary area is saltmarsh	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<5% of estuary area is saltmarsh	Initiate ERP (Evaluation and Response Plan)

Macroalgae Index

Certain types of macroalgae can grow to nuisance levels in nutrient-enriched estuaries causing sediment deterioration, oxygen depletion, bad odours and adverse impacts to biota. A continuous index (the macroalgae coefficient - MC) has been developed to rate macroalgal condition based on the percentage cover of macroalgae in defined categories using the following equation: ***MC=((0 x %macroalgal cover <1%)+(0.5 x %cover 1-5%)+(1 x %cover 5-10%)+(3 x %cover 10-20%)+(4.5 x %cover 20-50%)+(6 x %cover 50-80%)+(7.5 x %cover >80%))/100.*** Overriding the MC is the presence of either nuisance conditions within the estuary, or where >5% of the intertidal area has macroalgal cover >50%. In these situations the estuary has a minimum rating of FAIR, should be monitored annually, and an Evaluation & Response Plan initiated.

MACROALGAE CONDITION RATING

RATING	DEFINITION (+Macroalgae Coefficient)	RECOMMENDED RESPONSE
Over-riding rating: Fair	Nuisance conditions exist, or >50% cover over >5% of estuary	Monitor yearly. Initiate Evaluation & Response Plan
Very Good	Very Low (0.0 - 0.2)	Monitor at 5 year intervals after baseline established
Good	Low (0.2 - 0.8)	Monitor at 5 year intervals after baseline established
	Low Low-Moderate (0.8 - 1.5)	Monitor at 5 year intervals after baseline established
Fair	Low-Moderate (1.5 - 2.2)	Monitor yearly. Initiate ERP
	Moderate (2.2 - 4.5)	Monitor yearly. Initiate ERP
Poor	High (4.5 - 7.0)	Monitor yearly. Initiate ERP
	Very High (>7.0)	Monitor yearly. Initiate ERP
Early Warning Trigger	Trend of increasing Macroalgae Coefficient	Initiate ERP (Evaluation and Response Plan)

2. Methods (continued)

Terrestrial Vegetated Buffer Percent Cover

The presence of a terrestrial margin dominated by a dense assemblage of scrub/shrub and forest vegetation acts as an important buffer between developed areas and the saltmarsh and estuary. This buffer protects against introduced weeds and grasses, naturally filters sediments and nutrients, and provides valuable ecological habitat.

TERRESTRIAL VEGETATED BUFFER PERCENT COVER CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very High	80%-100% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
High	50%-80% cover of terrestrial vegetated buffer	Monitor at 5 year intervals after baseline established
Fair	25%-50% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Poor	5%-25% cover of terrestrial vegetated buffer	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	<50% cover of terrestrial vegetated buffer	Initiate ERP (Evaluation and Response Plan)

Soft Mud Percent Cover

Soft mud in estuaries decreases water clarity, lowers biodiversity and affects aesthetics and access. Increases in the area of soft mud indicate where changes in catchment land use management may be needed.

SOFT MUD PERCENT COVER CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	<2% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Good	2%-5% of estuary substrate is soft mud	Monitor at 5 year intervals after baseline established
Fair	5%-15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Poor	>15% of estuary substrate is soft mud	Post baseline, monitor 5 yearly. Initiate ERP
Early Warning Trigger	>5% of estuary substrate is soft mud	Initiate ERP (Evaluation and Response Plan)

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. The RPD marks the transition between oxygenated and reduced conditions and is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. In addition, nutrient availability in estuaries is generally much greater where sediments are anoxic, with consequent exacerbation of the eutrophication process.

RPD CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate Evaluation & Response Plan
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate Evaluation & Response Plan
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Low-Mod Enrichment	1-2%	Monitor at 5 year intervals after baseline established
Enriched	2-5%	Monitor at 2 year intervals and manage source
Very Enriched	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

2. Methods (continued)

Total Phosphorus

In shallow estuaries the lower Waiwhetu, the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL PHOSPHORUS CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established
Low-Mod Enrichment	200-500mg/kg	Monitor at 5 year intervals after baseline established
Enriched	500-1000mg/kg	Monitor at 2 year intervals and manage source
Very Enriched	>1000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Nitrogen

In shallow estuaries like the lower Waiwhetu, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Low-Mod Enrichment	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Enriched	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Very Enriched	>4000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Metals

Heavy metals provide a low cost preliminary assessment of toxic contamination in sediments and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for the presence of other major contaminant classes: pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

METALS CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<0.2 x ISQG-Low	Monitor at 5 year intervals after baseline established
Good	<ISQG-Low	Monitor at 5 year intervals after baseline established
Fair	<ISQG-High but >ISQG-Low	Monitor at 2 year intervals and manage source
Poor	>ISQG-High	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

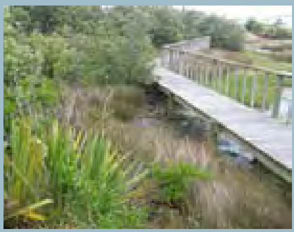
Semi Volatile Organic Compounds (SVOCs)

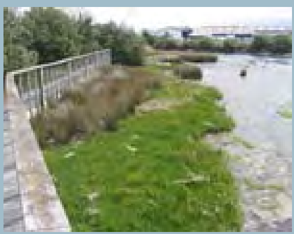
Semi-volatile organic compounds, including organochlorine pesticides (OCPs), and polycyclic aromatic hydrocarbons (PAHs) provide a more in depth assessment of toxic contamination in sediments. A broad screen of contaminants requires a range of guideline criteria to be used. Here, a condition rating is provided for PAHs as indicative of wider contamination issues which are discussed in the text where relevant.

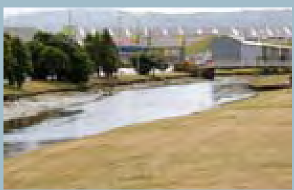
PAH CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<0.2 x ISQG-Low	Monitor at 5 year intervals after baseline established
Good	<ISQG-Low	Monitor at 5 year intervals after baseline established
Fair	<ISQG-High but >ISQG-Low	Monitor at 2 year intervals and manage source
Poor	>ISQG-High	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

3. RESULTS AND DISCUSSION

BROAD SCALE MAPPING

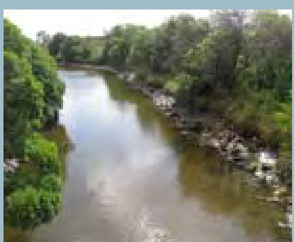






SALTMARSH CONDITION RATING

FAIR



Broad scale habitat mapping uses measures of the areas of saltmarsh, densely vegetated terrestrial margin, macroalgal cover, and soft mud to apply condition ratings to assess key estuary issues of habitat modification, eutrophication, and sedimentation. The results of the broad scale assessments are presented below, followed by the fine scale results.

SALTMARSH: Saltmarsh (vegetation able to tolerate saline conditions where terrestrial plants are unable to survive) is important as it is highly productive, naturally filters and assimilates sediment and nutrients, acts as an important buffer that protects against introduced grasses and weeds, and provides an important habitat for a variety of species including fish and birds.

While historically the lower Waiwheu Stream estuary would have been surrounded by saltmarsh, the stream is now confined within narrow banks, often steepened, straightened and reinforced to mitigate flood flows. Combined with extensive reclamation and draining of surrounding land, saltmarsh habitat is scarce. The only area where saltmarsh remains is a small remnant (0.06ha, 2.1% of the estuary - see Table 3), downstream of the Seaview Road bridge. Here, a boardwalk provides access to saltmarsh comprising rushland (searush *Juncus kraussii*, jointed wire rush *Apodasima similis*), herbfield (glasswort *Sarcocornia quinqueflora*) and reedland (the introduced invasive cord grass *Spartina anglica*). The saltmarsh is also flanked by a stand of native trees located adjacent to an urupa.

Overall, saltmarsh has a condition rating category of “fair”, the 2.1% cover putting it above just (0.1%) above the “poor” category.

In recognition of the value of saltmarsh habitat, the proposed remediation work will maintain the existing saltmarsh (removing the invasive *Spartina*), and create new saltmarsh habitat upstream near the old stables stormwater drain (Figure 4).

Table 3. Summary of dominant intertidal estuary features downstream of the Bell Road Bridge, January 2009.

Feature	Dominant saltmarsh species	Area (Ha)	Area (%)
Saltmarsh		0.06	2.1
Rushland	*Juncus kraussii* (searush)	0.01	0.4
	Apodasima similis (jointed wire rush)	0.02	0.7
Reedland	*Spartina anglica* (cord grass)	0.01	0.2
Herbfield	*Sarcocornia quinqueflora* (glasswort)	0.02	0.8
Intertidal flats		1.14	40.2
Water		1.64	57.7
TOTAL		**2.84**	**100**

TERRESTRIAL MARGIN VEGETATION: Like saltmarsh, a densely vegetated terrestrial margin naturally filters and assimilates sediment and nutrients, acts as an important buffer that protects against introduced grasses and weeds, is an important habitat for a variety of species, provides shade helping to moderate stream temperature fluctuations, and improves estuary biodiversity. Figure 4 and Table 4 summarise the dominant features present in a 100m buffer strip around the lower estuary. The majority of the buffer (80%) had little vegetation and was highly modified for industrial, commercial, residential, or roading purposes.

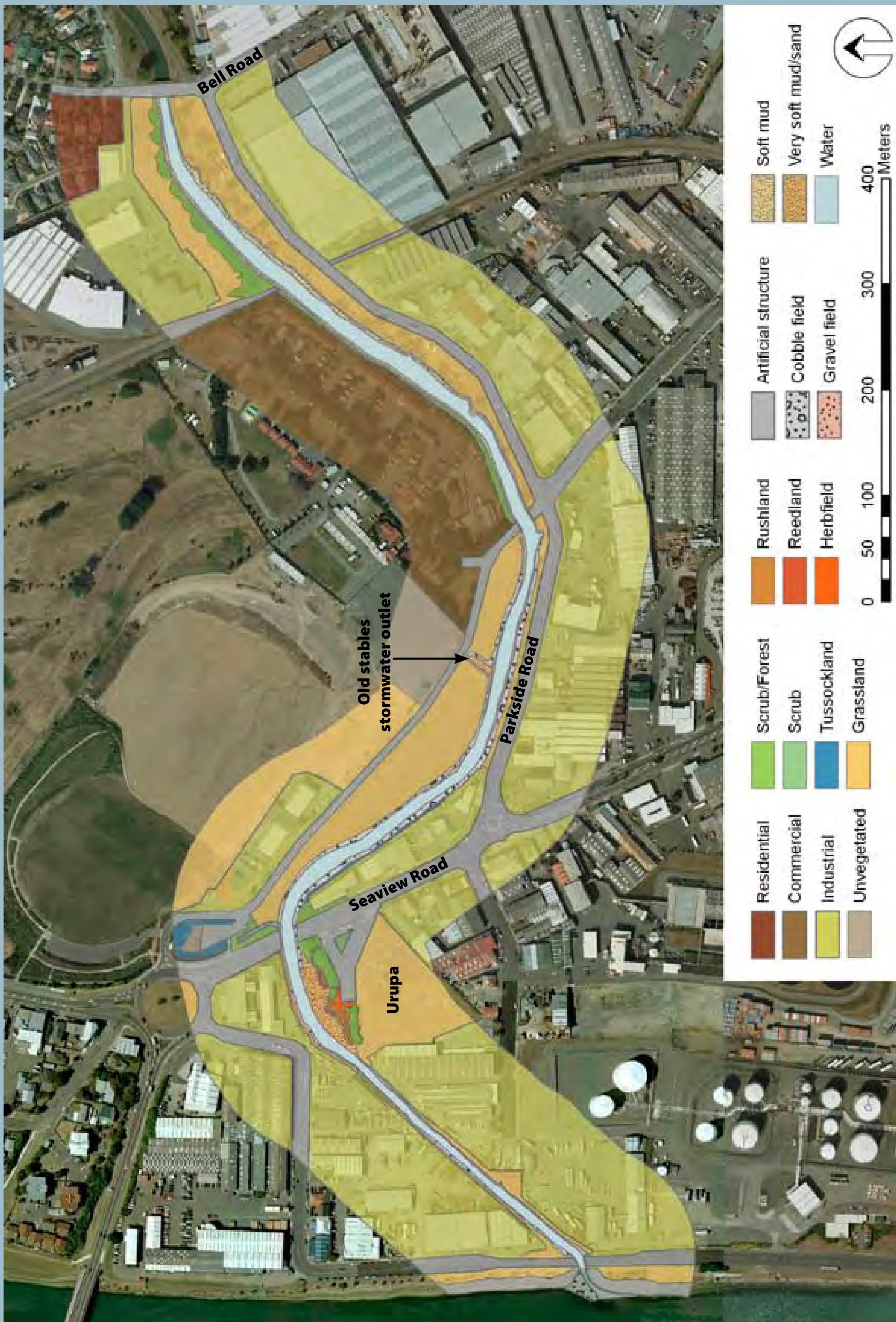
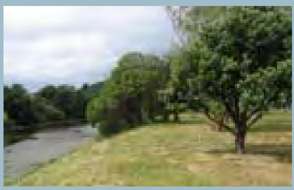
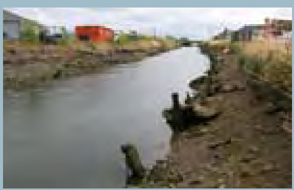


Figure 4. Broad scale features of the lower Waiwhetu Stream.

3. Results and Discussion (continued)

BROAD SCALE MAPPING (CONT.)





TERRESTRIAL MARGIN CONDITION RATING

POOR

Of the remaining 20% of the terrestrial margin, ~18% was open grassland. Much of this was amenity area, with plantings of native and exotic shrubs and trees. Grassland adjacent to industrial sites tended to be un-maintained and dominated by introduced weeds and rubbish. Just 2% of the terrestrial margin was densely vegetated (mostly along the stream banks downstream of the Bell Road bridge). Overall the terrestrial margin had a condition rating of "poor" which reflects the area's industrial nature.

At present, HCC maintain the public amenity spaces directly adjacent to the streamway, and actively undertake weed control. There remains a great opportunity to further improve the value of the terrestrial margin adjacent to many of the industrial sites as the streamway is cleaned up by removing weeds and planting the stream margins appropriately. This has been incorporated into the proposed remediation plans.

Table 4. Summary of dominant terrestrial margin features, January 2009.

Dominant Feature	Comment	Area (ha)	%
Scrub/Forest	Mostly plantings of pohutukawa, ngaio, willow, taupata, karo, and flax. Saltmarsh ribbonwood, five finger and manuka also present adjacent to the saltmarsh by Seaview Road bridge.	0.5	1.8
Tussockland	Predominantly flax, often mixed with introduced weeds.	0.1	0.4
Grassland	Mainly grass amenity areas and small overgrown areas of tall fescue with introduced weeds. Scrub and forest trees present as above.	5.5	18.4
Artificial Structures		4.7	15.7
	Railway Road Rock field (man made) Boulder field (man made) Cobble field Unvegetated	0.15 3.64 0.03 0.28 0.04 0.6	0.5 12.0 0.1 0.9 0.1 2.0
Residential		0.5	1.6
Commercial		3.5	11.6
Industrial		15.3	50.7
TOTAL		**30.1**	**100**

MACROALGAL COVER CONDITION RATING

FAIR

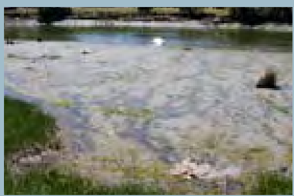
MACROALGAL MAPPING: Macroalgal blooms are a symptom of estuary eutrophication. These can deprive seagrass areas of light causing their eventual decline, while decaying macroalgae can accumulate subtidally and on shorelines causing oxygen depletion and nuisance odours. The results showed that macroalgae was not widespread at the time of sampling (growths are likely to be regularly washed out of the stream), with only a few small patches of the green alga *Enteromorpha* present along the upper tidal edges of the main channel between the Bell Road and Seaview Road bridges (0.02ha with >80% cover).

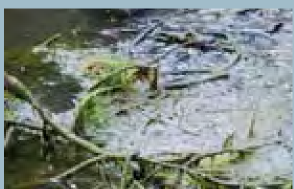
The Macroalgae Coefficient (MC) was "moderate" (0.1), a condition rating of "very good". However, there were widespread areas of nuisance conditions of anoxic muds and sulphide odours. Under such conditions, sediment P and N become much more available, further contributing to nuisance algal growth and making a return to oxygenated sediment conditions difficult to achieve. Because of the nuisance conditions present, macroalgae has been given a condition rating of "fair".

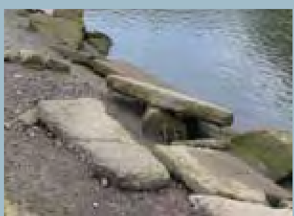
No seagrass was present in Waiwhetu Stream.

3. Results and Discussion (continued)

BROAD SCALE MAPPING (CONT.)







SOFT MUD CONDITION RATING
POOR

SUBSTRATE MAPPING: Increases in fine sediment, a common problem resulting from soil erosion from catchment development, can cause impacts such as increased muddiness and turbidity, shallowing, increased nutrients, changes in saltmarsh and seagrass habitats, less oxygen, increased organic matter degradation by anoxic processes (e.g. sulphide production) and alterations to fish and invertebrate communities. Also, because contaminants are most commonly associated with finer sediment particles, extensive areas of fine soft muds provide a sink which concentrate catchment contaminants.

Overall, muds were a key characteristic across most of the intertidal area of the lower Waiwhetu Stream, and were characterised by high levels of anoxia (a lack of oxygen), and the presence of sulphides. Although cobble (33%) and gravel (9%) were visually dominant surface features towards the high tide line (Table 5, Figure 4), these overlay deposits of a very thick, black sulphide-rich ooze of mud - a key target in the proposed sediment remediation. Soft mud was the dominant surface feature in the mid and lower intertidal zone (30%), becoming very soft (15%), and deep, near low tide and throughout much of the subtidal stream channel. The remaining intertidal area comprised rock and boulder flood protection (0.09ha, 8%), particularly in the lower streamway, and saltmarsh (0.06ha, 2%) (Table 5, Figure 4).

The percentage of intertidal soft and very soft mud (45% - Table 5) fits a condition rating of "poor".

Despite the high mud content of the sediments, the water in the stream was clear and numerous fish were observed while undertaking the sampling.

Table 5. Summary of dominant intertidal features, January 2009.

Dominant Feature	Area (ha)	%	Comments
Rushland	0.03	2.7	Upper intertidal opposite the urupa.
Reedland	0.01	0.6	Lowest edge of upper intertidal opposite the urupa.
Herbfield	0.12	1.9	High intertidal opposite the urupa.
Rock field (man made)	0.01	1.2	Mostly along the lower estuary terrestrial margin.
Boulder field (man made)	0.08	6.7	Mostly along the lower estuary terrestrial margin.
Cobble field	0.39	32.6	Mostly along the upper intertidal area.
Gravel field	0.11	9.4	Dominant across most of the intertidal delta.
Soft mud	0.36	30.4	Predominantly in the middle intertidal reaches.
Very soft mud	0.17	14.5	Narrow band in the lower intertidal area.
TOTAL	**1.28**	**100**	

FINE SCALE MONITORING

Fine scale chemical and biological results from sediment sampling are summarised below in Tables 6-8, and described in detail in the following section. Appendix 3 presents all the results in full.

Table 6. Physical and chemical results for Waiwhetu Stream, 16 January 2009.

Site	RPD	TOC	TN	TP	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Waiwhetu	cm	%	mg/kg (dry weight)									
A-01 Subtidal	0.1	3.8	2,100	460	10	1.2	42	49	0.56	18	490	660
A-02 Intertidal	0.1	4.2	2,600	650	10	1.2	32	65	0.27	15	440	860
B-01 Subtidal	0.1	4.7	3,300	550	11	1.2	34	74	0.34	16	1,200	850
B-02 Intertidal	0.1	4.8	3,100	730	11	1.3	34	76	0.44	16	1,900	920

Note: results are for a single composite sample for each site.

Table 7. Semi volatile organic compounds (SVOCs) in Waiwhetu Stream, 16 January 2009 (only detected compounds are presented, all mg/kg d.w.).

SVOCs	Sample site Wwh	A-01	A-02	B-01	B-02
Organochlorine Pesticides	4,4'-DDD	0.36	0.45	< 0.28	< 0.27
Plasticisers	Bis(2-ethylhexyl)phthalate	1.7	9.6	7.9	13
	Butylbenzylphthalate	< 0.33	0.51	0.75	1.8
Polycyclic Aromatic Hydrocarbons PAHs)	Benzo[b]fluoranthene	0.31	0.73	0.51	0.67
	Benzo[g,h,i]perylene	0.18	0.55	0.34	0.46
	Benzo[k]fluoranthene	< 0.17	0.3	< 0.28	< 0.27
	Indeno(1,2,3-c,d)pyrene	< 0.17	0.33	< 0.28	< 0.27
Low molecular weight PAHs	Phenanthrene	0.29	0.43	0.22	0.23
High molecular weight PAHs	Fluoranthene	0.82	1.1	0.62	0.72
	Pyrene	0.66	1.1	0.68	0.76
	Benzo[a]anthracene	0.26	0.47	0.21	0.3
	Chrysene	0.26	0.47	0.28	0.29
	Benzo[a]pyrene (BAP)	0.24	0.56	0.35	0.34
Total Petroleum Hydrocarbons	C15 – C36	290	410	420	290
	Total hydrocarbons (C7 – C36)	300	430	420	310

Note: results are for a single composite sample for each site. Appendix 2 lists all the analyses undertaken, the vast majority for which no detectable results were obtained.

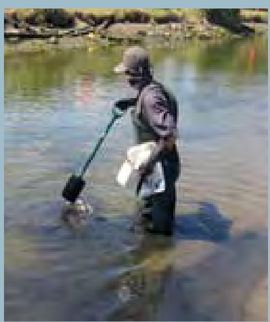


Table 8. Macrofauna results (means) for Waiwhetu Stream, 16 January 2009.

Site	Reps	Infauna		Epifauna	
Waiwhetu		Abundance/m^{-2}	No. Species/core	Abundance/quadrat	No. Species/quadrat
A-01 Subtidal	3	51,729	8	Not assessed	Not assessed
A-02 Intertidal	3	9,474	7	>200*	2*
B-01 Subtidal	3	22,030	11	Not assessed	Not assessed
B-02 Intertidal	3	32,782	6	>200*	2*

*=Predominantly juvenile estuarine snails (*Potamopyrgus*) buried in soft surface mud. Therefore not possible to accurately count or determine the different species (*P. estuarinus* or *P. antipodarum*) in the field.

RPD DEPTH CONDITION RATING

POOR

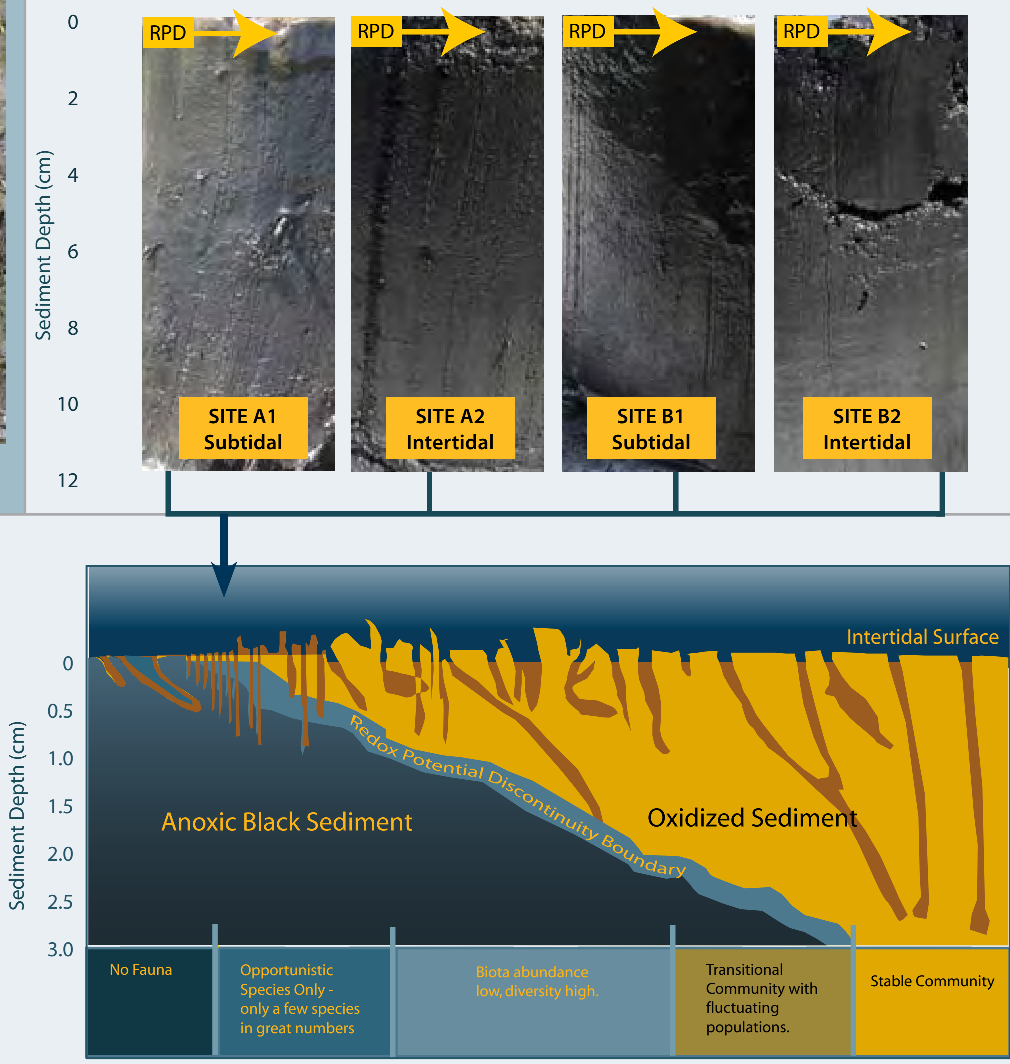
REDOX POTENTIAL DISCONTINUITY (RPD) DEPTH

RPD depth is a key indicator in that it provides a measure of whether nutrient enrichment exceeds the trigger leading to nuisance anoxic conditions in surface sediments. Anoxic sediments cause problems in that they contain toxic sulphides that support very little aquatic life. In addition, as the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large) suddenly becomes available to fuel algal blooms and worsen sediment conditions. In the lower Waiwhetu Stream the RPD depth was very shallow with only a thin 1-2mm layer of oxygenated sediment present on the surface, and beneath this there was virtually no oxygenation of sediments evident. Key observations were:

- RPD values were <1cm, a condition rating of "poor".
- The sediments at each of the four sites were dominated by very soft black muds.
- Sediments were rich in sulphide with a strong odour.
- Very few infauna feeding voids and burrows were evident below the RPD.

Figure 5 shows the sediment profiles and the very shallow RPD depths for each of the four Waiwhetu Stream sampling sites.

Figure 5. Sediment profiles and RPD depths at the four sampling sites.



This lower part of Figure 5 indicates the likely benthic community (adapted from Pearson and Rosenberg 1978) that is supported at each site based on the measured RPD depth.

The Waiwhetu Stream results indicated that the benthic invertebrate community was likely to be opportunistic and limited to relatively few species, present mainly on the surface of the sediments where they are flushed by relatively clean flows of tidal and stream water.

3. Results and Discussion (continued)

Figure 6. Total organic carbon in the lower Waiwhetu Stream, 16 January 2009.

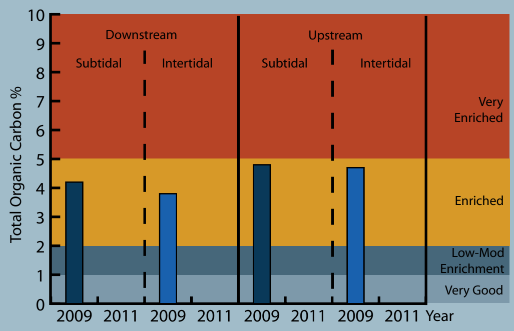


Figure 7. Total phosphorus in the lower Waiwhetu Stream, 16 January 2009.

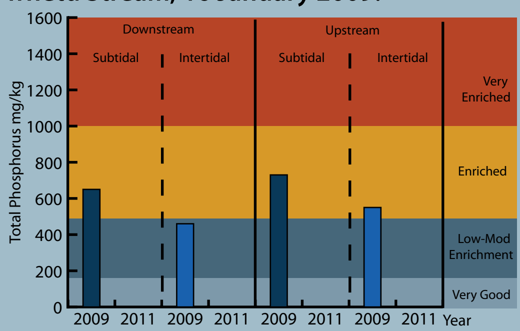
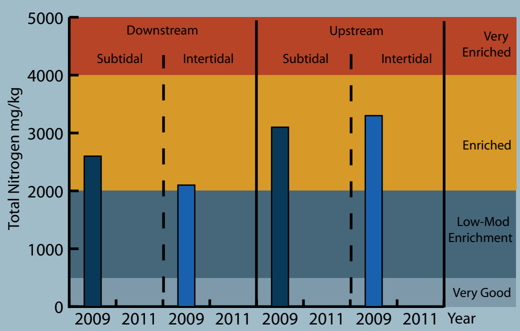


Figure 8. Total nitrogen in the lower Waiwhetu Stream, 16 January 2009.



CONDITION RATINGS	TOC	TP	TN
	ENRICHED	ENRICHED	ENRICHED

ORGANIC MATTER (TOTAL ORGANIC CARBON - TOC):
Fluctuations in organic input are considered to be one of the principal causes of faunal change in estuarine and near-shore benthic environments. Increased organic enrichment results in changes in physical and biological parameters, which in turn have effects on the sedimentary and biological structure of an area. The number of suspension-feeders (e.g. bivalves and certain polychaetes) declines and deposit-feeders (e.g. opportunistic polychaetes) increase as organic input to the sediment increases (Pearson and Rosenburg 1978).

The indicator of organic enrichment (TOC) at all four sites (Figure 6) was relatively high (range 3.8%-4.7%), and in the "enriched" condition rating. This is likely to reflect the deposition of organic matter (mostly plant material) from both estuary and stream sources and, to a lesser extent, inputs from the growth of benthic microalgae on the surface of the sediments.

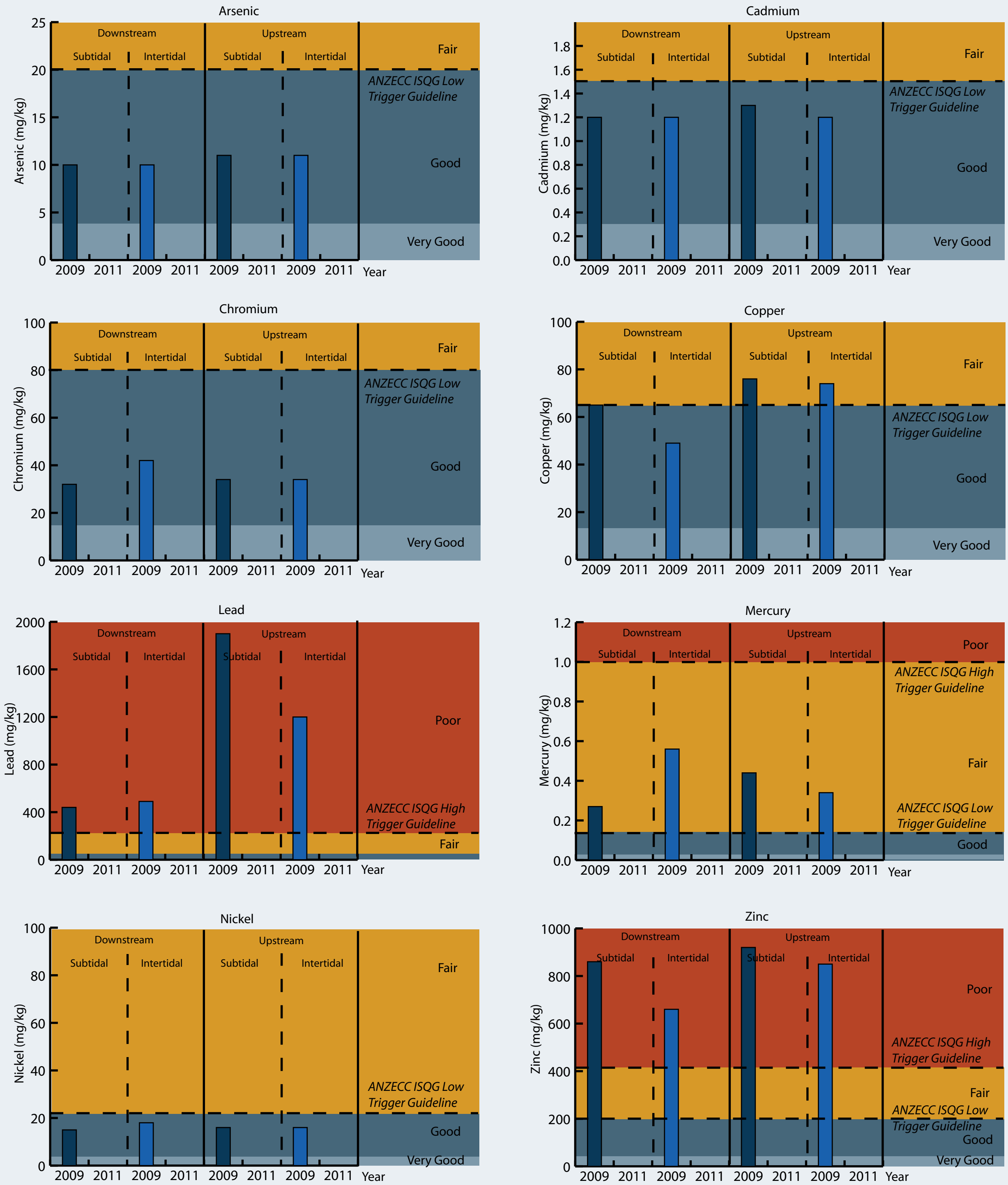
TOTAL PHOSPHORUS:
Total phosphorus (a key nutrient in the eutrophication process) was present in the "enriched" category (Figure 7) at both the subtidal sites, and the upstream intertidal site (range 550-730mg/kg). It was at the top of the "low to moderate enrichment" category at the downstream intertidal site (460mg/kg).

TOTAL NITROGEN:
Like phosphorus, total nitrogen (the other key nutrient in the eutrophication process) was quite high (Figure 8). All four sites were in the "enriched" category (range 2100-3300mg/kg). Both the TN and TP results indicate that there is a plentiful supply of nutrients in the stream sediments to support the growth of micro- and macro-algae.

METALS:
If potentially toxic contaminant inputs (e.g. heavy metals) are excessive, estuary biodiversity is threatened and shellfish and fish may be unsuitable for eating. Heavy metals (total recoverable Cd, Cr, Cu, Hg, Ni, Pb, Zn) and the metalloid arsenic (total recoverable As) were used as indicators of sediment toxicants. Results, summarised in Table 6 and Figure 9, showed that sediment concentrations of lead and zinc exceeded ANZECC (2000) ISQG-High trigger values, therefore had a condition rating of "poor". In addition, mercury concentrations were above ANZECC (2000) ISQG-Low trigger values, but below ISQG-High values - a condition rating of "fair". Arsenic, cadmium, chromium, and nickel were all below ANZECC (2000) ISQG-Low trigger values, placing them in the "good" condition rating. Copper exceeded the ISQG-Low trigger values at three of the four sites, but was below ISQG-High trigger values, therefore had a condition rating of "good to fair".

3. Results and Discussion (continued)

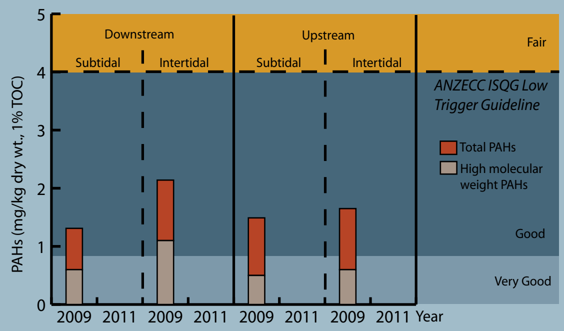
Figure 9. Total recoverable metal concentrations in the lower Waiwhetu Stream, 16 January 2009.



CONDITION RATINGS	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Zinc
	GOOD	GOOD	GOOD	GOOD-FAIR	POOR	FAIR	GOOD	POOR

3. Results and Discussion (continued)

Figure 10. PAHs (normalised to 1%TOC) in the lower Waiwhetu Stream, 16 January 2009.



CONDITION RATING
PAHs
GOOD

SEMI-VOLATILE ORGANIC COMPOUNDS (SVOC'S)

SVOCs were also analysed to screen for the presence of key pollutants including polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCPs), total petroleum hydrocarbons (TPHs) and a range of industrial chemicals.

The SVOC results (Table 7, Appendix 3) identified relatively few compounds present in the sediments above trace detection limits. Of the 14 compounds detected, 10 were PAHs, and all were present below ANZECC ISQG-Low trigger values (Figure 10, Appendix 3).

The OCP 4,4'-DDD was present at both Site A (downstream) locations, and was present above ANZECC ISQG-High trigger values. TPHs were also detected, and were visible as a surface sheen while sampling.

Two industrial plasticisers (products used to makes plastics softer) were also present - bis(2-ethylhexyl)phthalate (also known as DEHP) and butylbenzylphthalate.

PAHs are a group of chemical compounds produced by the incomplete combustion of organic material. The most common sources in urban streams are vehicle emissions, roading materials (e.g. tar), and domestic wood and coal fires. Many PAH's are chronically and/or acutely toxic to a range of aquatic organisms, and pose a health risk if present in high concentrations (they are known carcinogens).

OCPs are persistent chemicals that were used extensively in NZ before the 1980s. While now phased out with most banned from use, because they are slow to breakdown, they are still commonly found in agricultural catchments and industrial areas. They are generally of high toxicity to aquatic species, and are a concern because of their capacity to accumulate and bio-magnify up the food chain.

TPHs are a large family of several hundred chemical compounds that originally come from crude oil based products (for example, petrol, kerosene, fuel oil, mineral oil, and asphalt). TPHs have variable longevity and toxicity depending on what compounds are present. Certain TPH fractions will float in water and form thin surface films. Other heavier fractions will accumulate in the sediment at the bottom of the water, which may affect bottom-feeding fish and organisms.

The plasticisers are commonly used in manufacturing polyvinyl chloride (PVC) products like toys, vinyl upholstery, traffic cones, conveyor belts, shower curtains, adhesives and coatings, and in vinyl foams used as floor tiles. They are considered ecotoxic in the aquatic environment and are a potential endocrine disruptor in humans.

BENTHIC INVERTEBRATE COMMUNITY: The invertebrate community living in and on the sediments at the four sites sampled was surprisingly diverse. The community was dominated in terms of abundance by gastropods (both freshwater and estuarine species of the small black snail *Potamopyrgus* - range 62%-88% of all animals), followed by polychaetes and oligochaetes, and occasional amphipods, crabs, flies and shellfish (Table 9, Figure 11, Appendix 3).

The relatively high diversity present is most readily explained by the majority of the animals being sensitive juveniles or small immatures. This suggests they are mainly recent recruits, bred elsewhere, being washed into the area in low numbers, but not able to survive to adulthood. The main exception was the polychaete *Capitella* (a sulphide tolerant sub-surface deposit feeder), most of which were adult females containing eggs.

Overall the community present reflected species that tolerate moderate organic enrichment (i.e. omnivorous surface deposit feeding species) and which live predominantly in a relatively clean layer of oxygenated surface mud that was present above the underlying anoxic sediments. For example, the gastropod *Potamopyrgus* is intolerant of anoxic surface muds, but its presence in very high numbers indicates suitable surface conditions. The general absence of benthic invertebrates deeper in the sediments, and the few adults present, indicates that the underlying physical conditions are relatively harsh. This reflects both the physical extremes of being in the upper reaches of the estuary, as well as the enriched and toxic conditions present.

Compared with the intertidal mudflats in other NZ estuaries that drain developed catchments, community diversity was within a similar range (Figure 12). However, the abundance of most species was low (with the exception of *Potamopyrgus*), with generally only one or two individuals from each species being recorded (Table 9). It is expected that the community will become more diverse, and abundance will increase, following removal of contaminated stream sediments and management of catchment inputs.

Figure 11. Mean abundance of macrofauna groups per core (area = 0.0133m²).

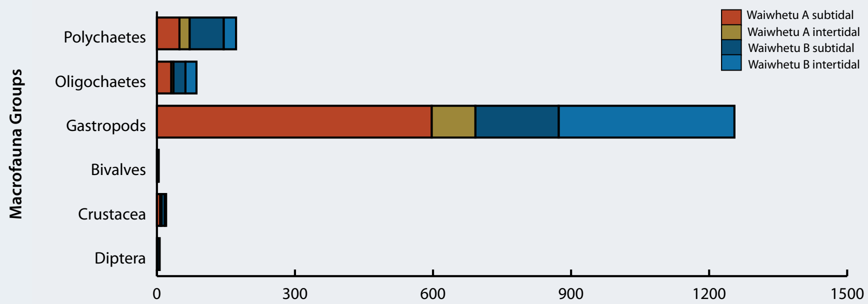


Figure 12. Mean number of infauna species, Waiwhetu Stream compared with other NZ estuaries (source: Robertson et al. 2002, Robertson and Stevens 2006).

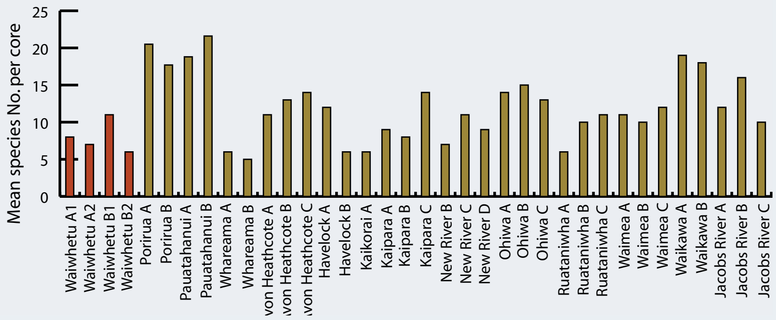


Table 9. Mean abundance of infauna species from Waiwhetu Stream (three cores per site).

Species	WwhA1	Species	WwhA2	Species	WwhB1	Species	WwhB2
Potamopyrgus antipodarum	384	*Potamopyrgus antipodarum*	57	*Potamopyrgus antipodarum*	127	*Potamopyrgus antipodarum*	268
Potamopyrgus estuarinus	213	*Potamopyrgus estuarinus*	38	*Potamopyrgus estuarinus*	54	*Potamopyrgus estuarinus*	114
Capitella sp.#1	46	*Capitella* sp.#1	18	*Capitella* sp.#1	29	Oligochaeta sp.#1	24
Oligochaeta sp.#1	31	Oligochaeta sp.#1	5	Oligochaeta sp.#1	26	*Capitella* sp.#1	19
Paphies australis	3	Amphipoda sp.#1	2	*Ceratonereis* sp.#1	22	*Ceratonereis* sp.#1	8
Halicarcinus whitei	3	*Ceratonereis* sp.#1	2	*Boccardiella magniovata*	20	Amphipoda sp.#1	1
Ceratonereis sp.#1	2	*Nicon aestuariensis*	2	Diptera sp.#1	4	*Helice crassa*	1
Amphipoda sp.#1	2	*Macrophthalmus hirtipes*	1	Amphipoda sp.#1	4	*Macrophthalmus hirtipes*	1
Diptera sp.#1	1	*Paphies australis*	1	*Microspio maori*	2		
Helice crassa	1			Diptera sp.#2	1		
Macrophthalmus hirtipes	1			Amphipoda sp.#2	1		
Microspio maori	1			*Helice crassa*	1		
				Macrophthalmus hirtipes	1		
				Perinereis vallata	1		

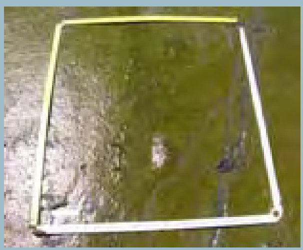


Table 10. Chemical concentrations in shellfish flesh, Waiwhetu Stream, 16 January 2009.

Shellfish Flesh (wet wgt) Chemical concentrations	Site C-01
Metals (mg/kg)	
Arsenic (As)	0.73
Cadmium (Cd)	0.056
Chromium (Cr)	<0.098
Copper (Cu)	0.60
Mercury (Hg)	0.017
Nickel (Ni)	0.13
Lead (Pb)	0.77
Zinc (Zn)	15.0
SVOCs (mg/kg)	
Organochlorine Pesticides	
Aldrin	0.0012
2,4'-DDD	0.0033
4,4'-DDD	0.0049
4,4'-DDE	0.0022
Dieldrin	0.0016
Polycyclic Aromatic Hydrocarbons	
Benzo[a]anthracene	0.00033
Benzo[b]fluoranthene + Benzo[j]fluoranthene	0.0014
Chrysene	0.00088
Pyrene	0.0015

Note: results are for a single composite sample of ~20 blue mussels.

EPIFAUNA: Surface dwelling organisms (epifauna), as well as being included in the benthic invertebrate community sampling, were also recorded using quadrats. However, because of the very soft muds present in the Waiwhetu, intertidal epifauna were very difficult to see and count, with only the gastropod *Potamopyrgus* visible. These were generally limited to a few obvious adults, although tiny bumps in the sediment indicated hundreds of small juveniles were also buried in the very soft surface muds. The combined influence of the mud layer and small size of most individuals prevented determination of which species of *Potamopyrgus* was present, or whether the snails were alive or dead. Therefore, the results (Table 8) indicate only that >200 *Potamopyrgus* spp. were present in each of the quadrats, with the infauna core results (Table 9) providing the best measure of *Potamopyrgus* density.

Another feature evident on the surface sediments was a rich growth of green benthic microalgae. Microalgae are single-celled microscopic plants (mainly diatoms and dinoflagellates) and cyanobacteria which provide a source of food for benthic and suspension feeders, help stabilise sediments, and help regulate nutrient levels in the water column by regulating nutrient exchange rates between the sediment and water. Some cyanobacteria produce toxins that can cause health risks to humans and animals, particularly dogs, but this is unlikely to be an issue in the Waiwhetu unless stream flushing is restricted.

The presence of benthic microalgae mats is usually indicative of eutrophic (highly enriched) conditions and they can grow to nuisance levels where nutrients are readily available and conditions for growth are favourable. Although there is a ready supply of nutrients in the sediment in the Waiwhetu, the very short residence time in the estuary and continual stream flushing is likely to limit extensive microalgal mat development within the streamway. However, the presence of extensive areas of organically enriched surface sediments indicates that the growth, deposition, and rotting of plant matter is contributing to poor sediment quality by reducing sediment oxygenation and, from this, is likely to be increasing the release of sediment nutrients.

While no phytoplankton blooms are known from the lower Waiwhetu, should ponding or stratification of water occur, there is a high chance of blooms occurring during warmer summer months because of the high nutrient levels present.

SHELLFISH FLESH: In addition to the sampling and results already described, shellfish (blue mussel, *Mytilus galloprovincialis*) were collected and the flesh analysed for metals, OCPs and PAHs at the mouth of Waiwhetu Stream beneath the Port Road bridge (Figure 1). The primary aim of the sampling was to provide baseline data to check if there is any increase in contaminant concentrations following the remediation works.

Table 10 shows the chemical concentrations present with the full analytical results in Appendix 3. Relatively low levels of metals, OCPs and PAHs were present.

Cadmium, lead and mercury were all below the NZFS 2002 (Australia New Zealand Food Standards Code) for trace metals in shellfish tissue. There are no New Zealand guidelines for acceptable concentrations of chromium, copper, nickel or zinc. Aldrin, DDD, DDE and dieldrin were all detected, but were below the maximum permitted residue levels of agricultural compounds (NZFSA 2008).

There are no specified safe levels for polycyclic aromatic hydrocarbons in shellfish for human consumption in New Zealand. Pathogens, the key limiting criteria for shellfish consumption, are periodically assessed separately by GWRC and were not measured as part of this project.

4. CONCLUSION

In conclusion, the monitoring results for a range of physical, chemical and biological indicators of estuary condition show the lower part of the Waiwhetu Stream to be muddy, with organically enriched sediments that contain a range of industrial contaminants.

The poorly oxygenated soft sediment, the "unbalanced" nature of the benthic invertebrate community, and the high nutrient and organic concentrations indicate it is enriched and in a eutrophic state. Elevated concentrations of some heavy metals and the presence of other metals, pesticides, and industrial chemicals highlight historical contaminant inputs, while past stream modification has resulted in the loss of most saltmarsh and most of the vegetated terrestrial buffer. Consequently the streamway rates poorly in terms of the key estuary issues of eutrophication, sedimentation, toxicity and habitat loss.

The proposed remediation works will address many of these issues and are expected to result in a significant improvement to the lower streamway. The baseline data presented in this report for a range of broad and fine scale indicators will enable changes made following remediation of the streamway to be assessed. Repeat monitoring should be undertaken following completion of the remediation work and after allowing the biological community time to re-establish. Depending on when the works are undertaken it is anticipated that the repeat survey will be undertaken in January 2011.

5. ACKNOWLEDGEMENTS

This work has been funded by Greater Wellington Regional Council. Tim Porteous and Juliet Milne (GWRC) both provided invaluable background information on the streamway and the proposed remediation. In addition Gary Stephenson (Coastal Marine Ecology Consultants) willingly shared his local knowledge of the stream, and retained his good humour during the messy process of cleaning the samples before identifying the sediment macrofauna. His comments on the macrofauna present were also greatly appreciated. Thanks also to Maz Robertson (Wriggle) for editing.

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APPENDICES

APPENDIX 1. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

Vegetation was classified using an interpretation of the Atkinson (1985) system, whereby dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria*, was coded as Amar. An indication of dominance is provided by the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass was dominant over ice plant (*Carpobrotus edulis*). The use of ( ) is not always based on percentage cover, but the subjective observation of which vegetation is the dominant or subdominant species within the patch. A measure of vegetation height can be derived from its structural class (e.g. rushland, scrub, forest).

Forest: Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm diameter at breast height (dbh). Tree ferns ≥10cm dbh are treated as trees. Commonly sub-grouped into native, exotic or mixed forest.

Treeland: Cover of trees in the canopy is 20-80%. Trees are woody plants >10cm dbh. Commonly sub-grouped into native, exotic or mixed treeland.

Scrub: Cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (c.f. FOREST). Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed scrub.

Shrubland: Cover of shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed shrubland.

Tussockland: Vegetation in which the cover of tussock in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples of the growth form occur in all species of *Cortaderia, Gahnia,* and *Phormium*, and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla,* and *Celmisia*.

Duneland: Vegetated sand dunes in which the cover of vegetation in the canopy (commonly Spinifex, Pingao or Marram grass) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.

Grassland: Vegetation in which the cover of grass (excluding tussock-grasses) in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground.

Sedgeland: Vegetation in which the cover of sedges (excluding tussock-sedges and reed-forming sedges) in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. "Sedges have edges." Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it's probably a grass or a reed, if the stem is clearly triangular, it's a sedge. Sedges include many species of *Carex, Uncinia,* and *Scirpus*.

Rushland: Vegetation in which the cover of rushes (excluding tussock-rushes) in the canopy is 20-100% and where rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in rushland are some species of *Juncus* and all species of *Leptocarpus*.

Reedland: Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata,* and *Baumea articulata*.

Cushionfield: Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield: Vegetation in which the cover of herbs in the canopy is 20-100% and where herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Lichenfield: Vegetation in which the cover of lichens in the canopy is 20-100% and where lichen cover exceeds that of any other growth form or bare ground.

Introduced weeds: Vegetation in which the cover of introduced weeds in the canopy is 20-100% and in which the weed cover exceeds that of any other growth form or bare ground.

Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope.

Cliff: A steep face of land which exceeds the area covered by any one class of plant growth-form. Cliffs are named from the dominant substrate type when unvegetated or the leading plant species when plant cover is ≥1%.

Rock field: Land in which the area of residual rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Boulder field: Land in which the area of unconsolidated boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulder fields are named from the leading plant species when plant cover is ≥1%.

Cobble field: Land in which the area of unconsolidated cobbles (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. Cobble fields are named from the leading plant species when plant cover is ≥1%.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. Gravel fields are named from the leading plant species when plant cover is ≥1%.

Mobile sand: The substrate is clearly recognised by the granular beach sand appearance and the often rippled surface layer. Mobile sand is continually being moved by strong tidal or wind-generated currents and often forms bars and beaches. When walking on the substrate you'll sink <1 cm.

Firm sand: Firm sand flats may be mud-like in appearance but are granular when rubbed between the fingers, and solid enough to support an adult's weight without sinking more than 1-2 cm. Firm sand may have a thin layer of silt on the surface making identification from a distance difficult.

Soft sand: Substrate containing greater than 99% sand. When walking on the substrate you'll sink >2 cm.

Firm mud/sand: A mixture of mud and sand, the surface appears brown, and may have a black anaerobic layer below. When walking you'll sink 0-2 cm.

Soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When you'll sink 2-5 cm.

Very soft mud/sand: A mixture of mud and sand, the surface appears brown, and many have a black anaerobic layer below. When walking you'll sink >5 cm.

Cockle bed /Mussel reef/ Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells.

Artificial structures: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates.

APPENDIX 2. SUMMARY OF ANALYTICAL METHODS

Indicator (Sediment samples)	Laboratory	Method	Detection Limit
Infauna Sorting and ID	CMES	Coastal Marine Ecology Consultants (Gary Stephenson) *	N/A
Total organic carbon	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	<3.8 g/100g dry wgt
Total recoverable arsenic	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	<10 mg/kg dry wgt
Total recoverable cadmium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.01 mg/kg dry wgt
Total recoverable chromium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable copper	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable nickel	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable lead	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.04 mg/kg dry wgt
Total recoverable mercury	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	<0.27 mg/kg dry wgt
Total recoverable zinc	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.4 mg/kg dry wgt
Total recoverable phosphorus	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total nitrogen	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	0.05 g/100g dry wgt
Semivolatile Organic Compounds	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Haloethers	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Nitrogen containing compounds	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Organochlorine Pesticides	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Polycyclic Aromatic Hydrocarbons	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Phenols	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Plasticisers	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Other Halogenated compounds	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Other SVOCs	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
SMC Compounds	R.J. Hill	Sonication extraction, GPC cleanup, GC-MS FS analysis. US EPA 3540, 3550, 3640, 8270	
Total Petroleum Hydrocarbons	R.J. Hill	Sonication extraction, Silica cleanup, GC-FID analysis. US EPA 8015B/MfE Petroleum Industry Guidelines	
Total Recoverable digestion	R.J. Hill	Nitric / hydrochloric acid digestion. US EPA 200.2.	
Dry Matter (Env)	R.J. Hill	Dried at 103°C (removes 3-5% more water than air dry)	
Library Search on SVOC samples	A Library Search is conducted of the Mass Spectra for unidentified peaks against the NIST 2005 Mass Spectral Library containing 190,825 mass spectra of 163,198 different chemical compounds. Only peaks with a greater than 70% quality match are reported, along with their semi-quantitative concentrations, to a maximum of 50 peaks matched.		

* Coastal Marine Ecology Consultants (established in 1990) specialises in coastal soft-shore and inner continental shelf soft-bottom benthic ecology. Principal Gary Stephenson (BSc Zoology) has worked as a marine biologist for more than 25 years, including 13 years with the former New Zealand Oceanographic Institute, DSIR. Coastal Marine Ecology Consultants holds an extensive reference collection of macroinvertebrates from estuaries and soft-shores throughout New Zealand. New material is compared with these to maintain consistency in identifications, and where necessary specimens are referred to taxonomists in organisations such as NIWA and Te Papa Tongarewa Museum of New Zealand for identification or cross-checking.

Indicator (Shellfish samples)	Laboratory	Method	Detection Limit
Shucking of Shellfish	R.J. Hill*	Removal of tissue from shell.	
Homogenisation of Biological samples	R.J. Hill*	Mincing, chopping, or blending of sample to form homogenous sample fraction.	
Biological Materials Digestion	R.J. Hill*	Nitric and hydrochloric acid micro digestion, 85°C for 1 hour.	
Organochlorine Pesticides in Biomatter	R.J. Hill	Sonication extraction, GPC cleanup, dual column GC-ECD analysis.	
Polycyclic Aromatic Hydrocarbons in Biomatter	R.J. Hill		
Arsenic	R.J. Hill	Biological materials digestion, ICP-MS.	0.020 mg/kg as rcvd
Cadmium	R.J. Hill	Biological materials digestion, ICP-MS.	0.00040 mg/kg as rcvd
Chromium	R.J. Hill	Biological materials digestion, ICP-MS.	0.020 mg/kg as rcvd
Copper	R.J. Hill	Biological materials digestion, ICP-MS.	0.010 mg/kg as rcvd
Lead	R.J. Hill	Biological materials digestion, ICP-MS.	0.0020 mg/kg as rcvd
Mercury	R.J. Hill	Biological materials digestion, ICP-MS.	0.0020 mg/kg as rcvd
Nickel	R.J. Hill	Biological materials digestion, ICP-MS.	0.020 mg/kg as rcvd
Zinc	R.J. Hill	Biological materials digestion, ICP-MS.	0.010 mg/kg as rcvd
	*Analysis performed at Hill Laboratories - Food & Bioanalytical Division, Waikato Innovation Park, Ruakura Lane, Hamilton.		

APPENDIX 3. 2009 DETAILED ANALYTICAL RESULTS

Physical and chemical results for Waiwhetu Stream, 16 January 2009.

Site	RPD	TOC	TN	TP	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Waiwhetu	cm	%	mg/kg (dry weight)									
A-01 Subtidal	0.1	3.8	2,100	460	10	1.2	42	49	0.56	18	490	660
A-02 Intertidal	0.1	4.2	2,600	650	10	1.2	32	65	0.27	15	440	860
B-01 Subtidal	0.1	4.7	3,300	550	11	1.2	34	74	0.34	16	1,200	850
B-02 Intertidal	0.1	4.8	3,100	730	11	1.3	34	76	0.44	16	1,900	920
ISQG-Low*	-	-	-	-	20	1.5	80	65	0.15	21	50	200
ISQG-High*	-	-	-	-	70	10	370	270	1	52	220	410

*ANZECC 2000

PAH results (mg/kg dry weight, normalised to 1% TOC) for Waiwhetu Stream, 16 January 2009.

POLYCYCLIC AROMATIC HYDROCARBONS	ISQG-Low*	ISQG-High*	A-01	A-02	B-01	B-02
Naphthalene	0.16	2.1	0.050	0.060	0.070	0.070
2-Methylnaphthalene	-	-	0.050	0.060	0.070	0.070
Acenaphthene	0.044	0.64	0.050	0.060	0.070	0.070
Acenaphthylene	0.016	0.5	0.050	0.060	0.070	0.070
Fluorene	0.019	0.54	0.050	0.060	0.070	0.070
Phenanthrene	0.24	1.5	0.069	0.113	0.046	0.049
Anthracene	0.085	1.1	0.050	0.060	0.070	0.070
TOTAL Low molecular weight (LMW) PAHs	**0.552**	**3.16**	**0.369**	**0.473**	**0.466**	**0.469**
Fluoranthene	0.6	5.1	0.195	0.289	0.129	0.153
Pyrene	0.665	2.6	0.157	0.289	0.142	0.162
Benzo[a]anthracene	0.261	1.6	0.062	0.124	0.044	0.064
Chrysene	0.384	2.8	0.062	0.124	0.058	0.062
Benzo[a]pyrene (BAP)	0.43	1.6	0.057	0.147	0.073	0.072
Dibenzo[a,h]anthracene	0.063	0.26	0.085	0.120	0.014	0.135
TOTAL High molecular weight (HMW) PAHs	**1.7**	**9.6**	**0.618**	**1.094**	**0.460**	**0.648**
Benzo[b]fluoranthene	-	-	0.074	0.192	0.106	0.143
Benzo[g,h,i]perylene	-	-	0.043	0.145	0.071	0.098
Benzo[k]fluoranthene	-	-	0.085	0.079	0.140	0.135
2-Chloronaphthalene	-	-	0.050	0.060	0.070	0.070
Indeno(1,2,3-c,d)pyrene	-	-	0.085	0.087	0.140	0.135
TOTAL PAHs	**4**	**45**	**1.32**	**2.13**	**1.45**	**1.70**

*ANZECC 2000

APPENDIX 3. 2009 DETAILED ANALYTICAL RESULTS (CONTINUED)

Metals and semi volatile organic compound results in shellfish tissue (mg/kg wet weight), Waiwhetu Stream, Site C, 16 January 2009.

Shellfish Flesh Chemical Concentrations (Site C-01)		
Metals in Biomatter	Limit*	(mg/kg)
Arsenic (As)	1.0	0.73
Cadmium (Cd)	2.0	0.056
Chromium (Cr)	-	<0.098
Copper (Cu)	-	0.60
Mercury (Hg)	0.5	0.017
Nickel (Ni)	-	0.13
Lead (Pb)	2.0	0.77
Zinc (Zn)	-	15.0
Polycyclic Aromatic Hydrocarbons in Biomatter		(mg/kg)
Acenaphthene	-	< 0.00050
Acenaphthylene	-	< 0.00050
Anthracene	-	< 0.00020
Benzo[a]anthracene	-	0.00033
Benzo[a]pyrene (BAP)	-	< 0.00020
Benzo[b]fluoranthene + Benzo[j] fluoranthene	-	0.0014
Benzo[g,h,i]perylene	-	< 0.00020
Benzo[k]fluoranthene	-	< 0.00020
Chrysene	-	0.00088
Dibenzo[a,h]anthracene	-	< 0.00020
Fluoranthene	-	< 0.00020
Fluorene	-	< 0.00020
Indeno(1,2,3-c,d)pyrene	-	< 0.00020
Naphthalene	-	< 0.0050
Phenanthrene	-	< 0.00040
Pyrene	-	0.0015

*NZFS (2002) The New Zealand (Australia New Zealand Food Standards Code) Food Standards (2002) PART 1.4 Contaminants and Residues, Standard 1.4.1 Contaminants and Natural Toxicants. Values mg/kg.

Shellfish Flesh Chemical Concentrations (Site C-01)		
Organochlorine Pesticides in Biomatter	Limit*	(mg/kg)
Aldrin	0.1	0.0012
alpha-BHC		< 0.00050
beta-BHC		< 0.00050
delta-BHC		< 0.00050
gamma-BHC (Lindane)		< 0.00050
cis-chlordane		< 0.00050
trans-chlordane		< 0.00050
2,4'-DDD		0.0033
4,4'-DDD		0.0049
2,4'-DDE		< 0.00050
4,4'-DDE		0.0022
2,4'-DDT		< 0.00050
4,4'-DDT		< 0.00050
Sum of DDT	0.5	0.01
Dieldrin	0.1	0.0016
Endosulfan I		< 0.00050
Endosulfan II		< 0.00050
Endosulfan sulfate		< 0.00050
Endrin		< 0.00050
Endrin aldehyde		< 0.00050
Endrin Ketone		< 0.00050
Heptachlor		< 0.00050
Heptachlor epoxide		< 0.00050
Hexachlorobenzene		< 0.00050
Methoxychlor		< 0.00050
Total Chlordane [(cis+trans)*100/42]		< 0.0020

*NZFSA (2008) New Zealand (Maximum Residue Limits of Agricultural Compounds) Food Standards 2008 Published by the New Zealand Food Safety Authority, PO Box 2835, Wellington. Values mg/kg -most conservative value selected.

APPENDIX 3. 2009 DETAILED ANALYTICAL RESULTS (CONTINUED)

Sediment macrofauna results for Waiwhetu Stream Site A, 16 January 2009.

GROUP	SPECIES	Wwh A1/01	Wwh A1/02	Wwh A1/03	Wwh A2/01	Wwh A2/02	Wwh A2/03
BIVALVIA	*Paphies australis*	3	3		1		
CRUSTACEA	Amphipoda sp.#1			2	3	1	1
	Halicarcinus whitei		2	3			
	Helice crassa			1			
	Macrophthalmus hirtipes			1	1		
DIPTERA	Diptera sp.#1	1					
GASTROPODA	*Potamopyrgus antipodarum*	867	78	208	72	84	16
	Potamopyrgus estuarinus	399	127	114	29	39	46
OLIGOCHAETA	Oligochaeta sp.#1	21	4	69		8	1
POLYCHAETA	*Capitella* sp.#1	14	26	98	14	40	1
	Ceratonereis sp.#1	1	2	4	1	3	1
	Microspio maori	1					
	Nicon aestuariensis				2	1	
Total number of species		**8**	**7**	**9**	**8**	**7**	**6**
Total number of specimens		**1307**	**242**	**500**	**123**	**176**	**66**

Sediment macrofauna results for Waiwhetu Stream Site B, 16 January 2009.

GROUP	SPECIES	Wwh B1/01	Wwh B1/02	Wwh B1/03	Wwh B2/01	Wwh B2/02	Wwh B2/03
CRUSTACEA	Amphipoda sp.#1	7		1		1	
	Amphipoda sp.#2		1				
	Helice crassa			1			1
	Macrophthalmus hirtipes		1			1	
DIPTERA	Diptera sp.#1	5	6	1			
	Diptera sp.#2		1	1			
GASTROPODA	*Potamopyrgus antipodarum*	196	93	93	62	99	643
	Potamopyrgus estuarinus	42	49	72	86	37	219
OLIGOCHAETA	Oligochaeta sp.#1	33	33	11	1	52	18
POLYCHAETA	*Boccardiella magniovata*	27	21	11			
	Capitella sp.#1	41	14	32	18	3	36
	Ceratonereis sp.#1	20	20	25	1	13	10
	Microspio maori	1	1	4			
	Perinereis vallata			1			
Total number of species		**9**	**11**	**12**	**5**	**7**	**6**
Total number of specimens		**372**	**240**	**253**	**168**	**206**	**927**