Department of Conservation

Hikurangi Catchment Monitoring Programme
Contract 4553

Kessels Ecology
SURVEY, ASSESSMENT AND RESTORATION

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Executive Summary

The Hikurangi Catchment (HC) in Northland has been identified as a focus catchment within the Kaipara Harbour for the Community Investment in Water (CIW) partnership. CIW is a partnership between the Department of Conservation and Fonterra which aims to achieve a positive, demonstrable and measureable impact on water quality and biodiversity within five selected catchments around the country.

Here we present a monitoring programme which aims to fill gaps in current knowledge and provide a framework with which to measure short and long term improvements in biodiversity and habitat quality within the HC. The monitoring programme has been designed in consultation with key stakeholders. This report follows on from Part A of the project which provides an overview of the current state of monitoring in the HC and identifies information gaps. The primary focus of this project is on water quality, though other relevant information around ecological values and habitat condition was taken into account.

Key aspects of the monitoring programme are:

- Monitoring of wetland condition, extent and water levels;
- Monitoring of stream and river water quality, both to fill knowledge gaps, monitor changes over time, and monitor success of restoration projects;
- Continuous monitoring of dissolved oxygen changes in the Wairua River at several sites within the HC to measure effects of deoxygenated flood waters and summer low flows;
- Surveys of water quality in oxbow lakes;
- Measurement of sediment loads at Northland Regional Council flow monitoring sites to determine the sediment contributed by each Wairua River tributary;
- Fish surveys, including targeted surveys to measure the abundance and distribution of kakahi (freshwater mussels), mudfish and tuna (eels).

Rationale for monitoring, locations, methods and frequency of monitoring and surveys are outlined. Monitoring techniques will need to be prioritised according to available resources and technical ability in collaboration with stakeholders.

1 Introduction

The Hikurangi Catchment (HC) in Northland has been identified as a catchment of interest for the Community Investment in Water (CIW) partnership, a joint project between the Department of Conservation and Fonterra which aims to restore selected catchments around the country. As part of this initiative Kessels Ecology was contracted by the Department of Conservation to establish an environmental baseline within HC, including water quality, ecological values, and habitat condition.

Part A of the environmental baseline project provides an overview of the current state of monitoring in the HC and identifies information gaps. It was compiled by reviewing existing literature and monitoring data and is available as a separate report (Price and Dean, 2014). The primary focus of this project is on water quality, though other relevant ecological information was taken into account.

Accompanying Part A is a GIS-based database of information reviewed during the course of report writing, including spatial information such as land use patterns, protected natural areas, wetlands, streams, fauna species records, monitoring sites, and locations of water takes and discharges. The database is available for viewing in interactive PDF of Google Earth formats.

This report forms Part B of this project. This part aims to create a monitoring programme for water quality and freshwater ecological values that will be effective in detecting short and long-term effects of restoration initiatives and other environmental changes.

2 Methodology

The scope of this monitoring programme was the approximate floodplain area of the HC and its upstream catchments (Figure 1).

The environmental monitoring data reviewed in Part A were assessed according to the Community Investment in Water project objectives and outcomes. Gaps in monitoring were identified as necessary for measuring the future success of the project outcomes; these were used to guide the monitoring programme in Part B. Information gathered during Part A was used to create a monitoring programme with the aim to provide a complete baseline of freshwater ecological values and water quality for the site as well as provide information on changes related to restoration initiatives.

The monitoring programme aims to complement existing monitoring so that the value of additional monitoring is maximised. Potential reference sites will be suggested. Suggested location, timing and frequency of different monitoring approaches will be outlined. A draft plan will be presented to stakeholders, and feedback will be incorporated.

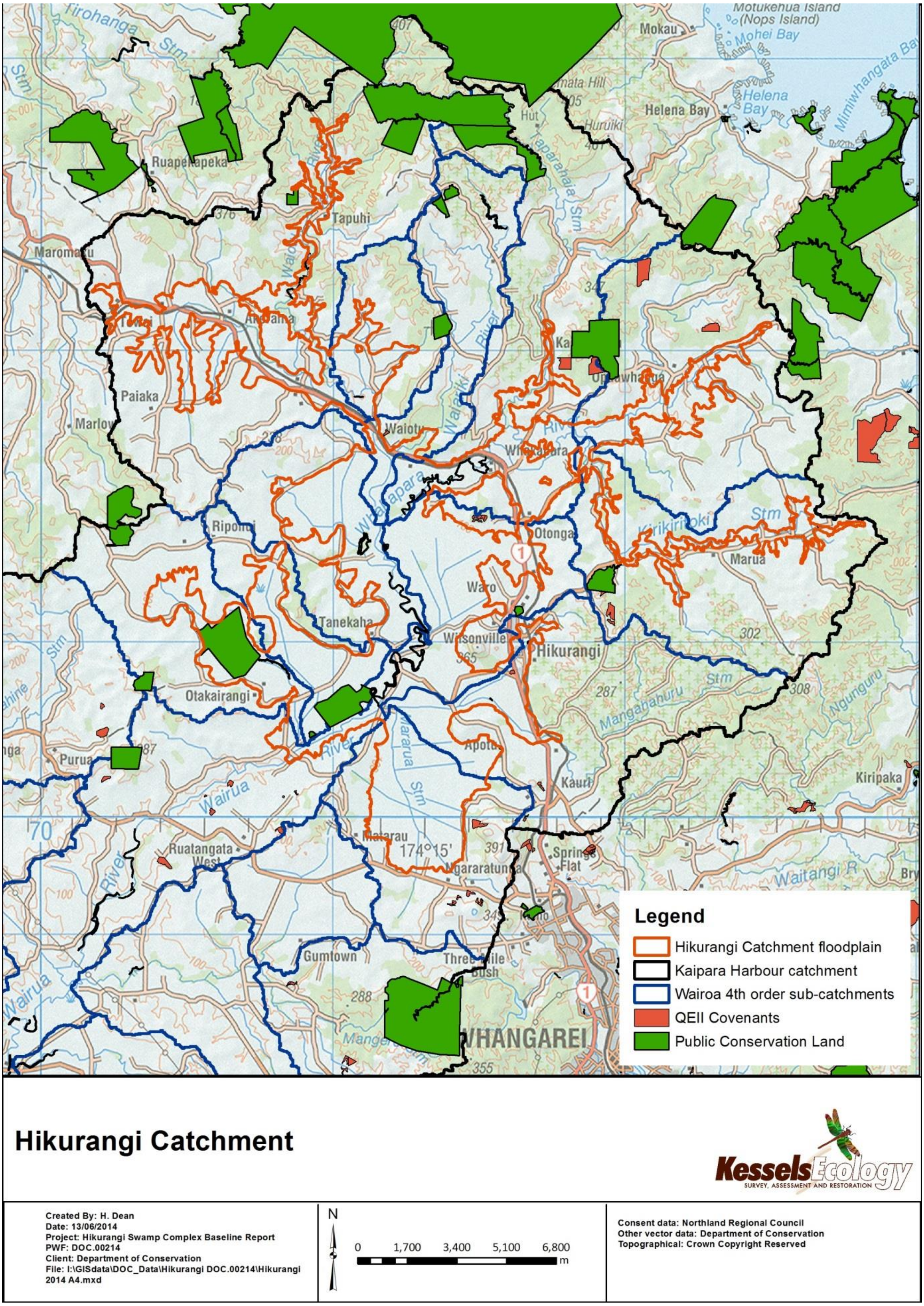

Figure 1. Hikurangi Catchment, showing public conservation land, QEII covenants, floodplain extent, and Wairoa River 4th order sub-catchments and catchment boundary.

3 Background Information

3.1 General Overview

The HC is located approximately 20 km north of Whangarei. The catchment is fed by three main tributaries: the Waiotu River, Waiariki Stream and Whakapara River, which drain a combined area of 321 km^2 and combine to form the Wairua River at the northern end of the catchment's lower-lying areas. The Wairua River flows through the low-lying area of the catchment and exits in the south-west, where its catchment area is 528 km^2. The waterways in these catchments have relatively low habitat quality for aquatic biota, and show comparatively high *E. coli*, and ammonia and turbidity levels. Aquatic macroinvertebrate community indices are consequently low at the lowland pastoral dominated sampling sites.

Six kilometres downstream of the HC study area, the Wairua River reaches the Mangere Rapids. A further 16 km downstream the river reaches the Wairua (Omiru) Falls, where it is partially diverted through the Wairua Power Station. The confluence with the Mangakahia River is downstream of the dam, at which point the Wairoa River is formed, which flows to the Kaipara Harbour.

For convenience, in this report we refer to the low-lying, flatter areas of the HC as the "HC floodplain". This area approximates the historical extent of the Hikurangi Swamp. The sloping, upper catchment of the floodplain bordering the low-lying areas is referred to as the "upper HC" or "upper catchment".

The area of remaining (extant) wetland habitat within the HC floodplain is approximately 650 ha. The two largest and most significant wetlands are the Wairua River and Otakairangi Government Purpose Wildlife Management Reserves (hereafter Wildlife Management Reserves). The Wairua River Wildlife Management Reserve measures 178.4 ha and represents a large area of the remaining intact area of the HC. The Otakairangi Wildlife Management Reserve is the largest area of undrained fen in the Hikurangi Plains, measuring 250 ha.

Fish diversity is limited in the upper Wairua River and its catchment by the Wairua Falls and Wairua Power Station, which present a barrier to most migratory species (Chisnall and Boothroyd, 2000); however, the threatened species black mudfish *Neochanna diversus* and longfin eel *Anguilla dieffenbachii* are present in the Wairua catchment.

3.2 Cultural Values

The HC is of great cultural importance to local hapū, in particular the traditional fishery for tuna (eels). Tuna are a taonga species, and many whānau, marae and hapū residing in the catchment of the Wairua River harvest tuna regularly (Williams et al., 2013). Tuna are used to supply hui, tangiand general consumption by whānau (Williams et al., 2013).

The hapū Ngāti Hau, Ngāti Kahu o Torongaere and Te Parawhau (collectively referred to as Nga Hapū o te Reponui) have status as mana whenua or kaitiaki of the area of the Hikurangi Swamp Scheme (Chetham and Shortland, 2009).

Ngā Kaitiaki O Ngā Wai Māori (caretakers of freshwater rivers and tributaries) is a group comprising representatives from Te Parawhau, Te Kahu o Torongare, Te Uri-ro-roi, Ngāti Hau and Te Ore Wai, that has developed a five year strategic plan for waterways within the area from the headwaters in Te Ruapekapeka, Tapuhi and Puhipuhi to the Wairua/Mangakāhia confluence (Ngā Kaitiaki O Ngā Wai Māori, 2012).

3.3 Management Issues

Current management issues for the HC include natural and man-made barriers to fish passage, water abstractions and discharges, deoxygenation of water during flooding, pest fish, and management of stock access to riparian margins. Many waterways in the HC floodplain are managed by Whangarei District Council as part of a flood protection scheme called the Hikurangi Swamp Scheme. The Scheme's stopbanks present a barrier to fish passage, and the Scheme also affects habitat quality near the pump stations; water may be impounded for several days, becoming deoxygenated and potentially causing fish and invertebrate mortality.

3.4 Current Monitoring

Current regular monitoring within the HC and downstream includes measurement of water quality, river levels, rainfall, aquatic macroinvertebrates, habitat quality and periphyton in the larger rivers and two drain sites. Mudfish are also surveyed annually in the Wairua River Wildlife Management Reserve. Regular monitoring programmes for fish and wetlands are currently under development at the Northland Regional Council. The Department of Conservation's new monitoring and reporting system (Tier One), which measures ecological integrity or ecological health, will include wetland monitoring in the near future. The two main wetland reserves within HC, Wairua River Wildlife Management Reserve and the Otakairangi Wildlife Management Reserve, are included in a Tier One pilot in 2014, and decisions will be made in the future on sites that will be monitored over time.

For a detailed review of the HC and associated monitoring, please refer to the report for Part A of this project (Price and Dean, 2014).

4 Conclusions and Recommendations from Part A

The environmental monitoring data outlined in this report were assessed according to the Community Investment in Water objectives and outcomes (Appendix I); specifically those that relate to biodiversity and water quality improvement (Objectives 1-3) and fostering a close working partnership with iwi (Objective 5). The following gaps in monitoring were identified as necessary for measuring the future success of the project outcomes (summarised in Table 1):

- Water quality, habitat and aquatic invertebrates are monitored in major rivers in the project area as well as two farm drain sites. Water quality is also measured at several sites in the Mangahahuru River and its tributary, the Mangawhero Stream, as part of resource consent requirements. To measure the success of Community Investment in Water outcomes it is likely that this kind of monitoring will need to be extended to cover smaller input tributaries encompassing areas where restoration is taking place, as well as control areas. Locations and methods will be suggested in Part B of this project and as restoration priorities are finalised.

- Minimising sediment deposition is listed explicitly as an outcome for supporting aquatic values (Outcome 1.2). Monitoring of in-stream sediment cover at key sites (e.g. in accordance with Clapcott et al. [2011] or the Quorer method[1]) is recommended a possible way of measuring this outcome. In addition, monitoring of suspended sediment levels at NRC flow monitoring sites is recommended as this information could be used to identify on a broad scale which catchments are contributing the most sediment to the HC.

- Spot water quality measurements by Williams et al. (2013) carried out during an eel survey showed that dissolved oxygen concentrations were severely depleted at the Tanekaha oxbow sites and at the Mountain oxbow, and were also low at the Hikurangi Repo oxbow. Other than the information in this study, the water quality and oxygen concentrations in the oxbows are not well understood. Continuous dissolved oxygen and temperature monitoring over several weeks during dry and rainy periods would aid our understanding of habitat conditions in the oxbows.

- The extent and effects of large-scale flooding events on river and oxbow water quality are also not well understood. Deoxygenation of flood waters prior to re-entering the Wairua River may have adverse effects on river habitat quality, but monitoring of dissolved oxygen during these events is required to measure this.

[1] http://www.niwa.co.nz/our-science/freshwater/tools/quorer

- Wetland extent and ecological health is not currently monitored on a regular basis. Regular wetland monitoring using nationally recognised methodology is recommended at key sites (e.g. in accordance with Clarkson et al., 2004), especially the Otakairangi Wildlife Management Reserve and Wairua River Wildlife Management Reserve. Characterisation of hydrological patterns including changes in water levels over time would also aid in our understanding of these systems. Ecological information for Otakairangi Wildlife Management Reserve in particular is very limited; robust baseline ecological information is required.
- The distributions of black mudfish and other threatened species such as koura/kēwai (freshwater crayfish) and kākahi (freshwater mussels) in the study area are not well known; determining the distributions of these species would aid in the identification of key ecological monitoring sites and target areas for restoration.
- Black mudfish, kēwai, kākahi and tuna are potential indicator species for both cultural and ecological values and monitoring at repeated sites over time is recommended to provide a measure of the project outcomes.
- Key ecological sites for monitoring, including streams, wetlands and other water bodies such as oxbows, should be selected following further analysis and stakeholder consultation in Part B of this project.

Note that some monitoring programmes will fulfil more than one project outcome.

Table 1. Summary of Community Investment in Water outcomes which require additional monitoring.

Outcome	Suggested monitoring	Key partners
1.1 Maintained or re-established water regime (water levels, duration and seasonality), which enhances aquatic values	Monitoring of water levels in key ecological sites (e.g. oxbows, wetlands), and hydrological analysis of key wetland sites (inflows, outflows).	NRC, specialist hydrologists, landowners at survey sites
1.2 Rates of sediment deposition are minimised	Monitoring of in-stream sediment cover (e.g. in accordance with Clapcott et al. 2011 or Quorer method[1]) or turbidity/clarity in key tributaries	NRC, landowners at survey sites
1.3 Maintained or enhanced water quality and trophic state and a shift from low nutrient to high nutrient adapted species reversed	Monitoring of water quality parameters in key tributaries to complement monitoring of larger rivers carried out by NRC (e.g. temperature, nitrogen, phosphorus, turbidity, clarity, pH, *E. coli*, conductivity, dissolved oxygen over a 24 hour cycle)	NRC, landowners at survey sites
2.1 Condition of indigenous habitat Is maintained or restored	Surveys of key threatened species (e.g. longfin eel, black mudfish, koura/kēwai, and kākahi) to determine abundance and distribution and changes over time	DOC, NRC, NIWA, Nga Kaitiaki O Nga Wai Māori, landowners at survey sites
2.2 Current extent of wetland habitat is maintained or restored	Monitoring of wetland extent and health according to standardised methods such as Clarkson et al. (2004), including threatened plant presence and extent	DOC, NRC, landowners at survey sites
3.1 Maintained or enhanced diversity and abundance of the representative range of indigenous species and guilds	Survey of fish, aquatic plants and invertebrates in key tributaries	DOC, NRC, NIWA, Nga Kaitiaki O Nga Wai Māori, landowners at survey sites
3.2 Maintained or improved abundance and distribution of target threatened species	Surveys of key threatened or At Risk species (e.g. longfin eel, black mudfish, koura/kēwai, and kākahi) to determine abundance and distribution and changes over time	DOC, NRC, NIWA, Northtec, Nga Kaitiaki O Nga Wai Māori, landowners at survey sites
5.2 Cultural values recognized and protected	Monitoring of distribution, abundance and populations parameters of tuna	NIWA, Nga Kaitiaki O Nga Wai Māori, landowners at survey sites

Recommendations for further work include:

- Determining the length of unfenced streams in the catchment may be a useful next step for planning restoration priorities.

- Though not specifically mentioned in the project outcomes, the extent of aquatic and riparian margin weeds should also be noted during future biodiversity surveys, as control may be necessary.
- Monitoring programmes for wetlands and fish should be developed in conjunction with NRC who are currently developing monitoring programmes in these areas.
- Movement of tuna is currently restricted by the Hikurangi Swamp Scheme and the Wairua Power Station. Monitoring of tuna will need to take into account the effects of these barriers and associated mitigation measures such as elver transfer operations and improvements to pumping stations. It may be possible to implement a tuna monitoring programme that will measure outcomes of both the Community Investment in Water project and mitigation measures associated with the Hikurangi Swamp Scheme and Wairua Power Station.

5 Monitoring Programme

An overview of recommended monitoring actions is presented in Table 2, and the rationale and methods for each type of monitoring are outlined in the following text.

5.1 Wetlands

5.1.1 Rationale

Freshwater wetlands are one of Northland's rarest habitat types. The original extent of wetlands within Northland has greatly diminished, and only about 5.5% of Northland's original freshwater wetlands remain today (excludes lakes, rivers and streams); from a national perspective the total figure is approximately 10% (Ausseil et al. 2008).

Wetlands were once the dominant land cover in the floodplain areas of the HC and the two largest wetland remnants, the Wairua River and Otakairangi Wildlife Management Reserves, are home to several threatened and at risk plant and animal species. The extent or health of wetlands in the HC is currently not regularly monitored.

Wetland monitoring would aid in assessing progress of the following project outcomes:

- 1.1 Maintained or re-established water regime (water levels, duration and seasonality), which enhances aquatic values;
- 2.1 Condition of indigenous habitat Is maintained or restored; and
- 2.2 Current extent of wetland habitat is maintained or restored.

5.1.2 Monitoring

5.1.2.1 Monitoring carried out by ecologists

Regular wetland monitoring using nationally recognised methodology (Clarkson et al., 2004) is recommended for all wetlands within the floodplain of the HC.

The Otakairangi Wildlife Management Reserve and Wairua River Wildlife Management Reserve are the highest ranked and largest within the HC and should be prioritised for monitoring. Ecological information for Otakairangi Wildlife Management Reserve in particular is very limited; robust baseline ecological information is required. A baseline of information on these two wetlands will be gained by the Department of Conservation's new monitoring and reporting system (Tier One), which measures ecological integrity or ecological health. This programme will include wetland monitoring in 2014. The Wairua River Wildlife Management Reserve and the Otakairangi Wildlife Management Reserve are included in a Tier One pilot in 2014, and decisions will be made in the future on sites that will be monitored over time. For the Community Investment in Water project it is important that this monitoring continues on a regular basis (i.e. at least once every 2-3 years), whether as part of Tier One monitoring or independently.

Characterisation of hydrological patterns including changes in water levels over time is also recommended as it would also aid in our understanding of these systems and how they are changing over time. Water levels should be monitored seasonally at several points around the wetlands using staff gauges, dipwells, piezometers or water level recorders as appropriate (Clarkson et al., 2004). Continuous monitoring via water level recorders would provide the most detailed information (but also present a significant cost). In the Wairua River Wildlife Management Reserve, water levels should be measured in each management unit and at key oxbow sites, inflows and outflows. In the Otakairangi Wildlife Management Reserve, water levels should be monitored at several points within the wetland as well as the outflow and inflow.

Wetland monitoring is also recommended at all the wetland sites identified in FENZ within the HC as little information on these wetlands exists currently. This brings the total number of wetlands to be monitored to 12.

5.1.2.2 Monitoring carried out by citizen scientists

In addition to wetland monitoring suggested above, smaller wetlands situated on private land could be monitored by trained volunteers or “citizen scientists”. This monitoring will supplement monitoring carried out by professional scientists.

It is recommended that sites are selected on the basis of volunteer availability and landowner willingness to participate. This data requires a long-term sustained commitment to monitoring and careful recording of observed data, so the cooperation of motivated volunteers and landowners is key. Monitoring of 3-4 wetlands (ideally representing a range of different wetland types and conditions) would provide a foundation dataset to measure changes over time and increase community engagement.

Monitoring should be carried out according to the WETMAK (Wetlands Monitoring and Assessment Kit) published by Landcare Research[2]. This system contains several easy-to-follow modules with instructions and fieldsheets for monitoring wetland condition using a “Warrant of Fitness (WOF)” check, vegetation, weeds, and animal pests. The wetland WOF requires minimal equipment and intermediate-level knowledge and is a good starting point for monitoring.

Special attention should be paid to monitoring of boundary fences as stock incursion into wetlands can be a significant cause of damage.

2 http://www.landcare.org.nz/wetmak

Table 2. Overview of recommended monitoring for the Hikurangi Catchment and catchment.

Type of monitoring	Sites	Parameters	Frequency
Wetland condition	Priority: Wairua River and Otakairangi Wildlife Management Reserves If possible: 10 additional wetlands in HC floodplain identified in FENZ	Wetland condition, extent, water levels	To be determined; on project startup and thereafter every 2-3 years
Stream and river water quality- knowledge gaps	Priority: 8 stream sites within HC floodplain. If possible: 5 sites within upper Hikurangi catchment; plus 2 control sites in upper catchment (see Table 4, Figure 2)	Water quality spot measurements, water quality analysis, sediments, macrophyte/periphyton cover, invertebrates, aquatic habitat, fish at sites within HC, search for kakahi	Every 5 years to obtain overall picture of water quality in HC and catchment
Stream and river water quality- restoration	To be determined based on restoration locations and methods.	Top priority: Yearly temperature logging, sediments, macrophyte/periphyton cover, invertebrates, aquatic habitat If possible: Seasonal water quality analysis	Full suite yearly, water quality seasonally
Dissolved oxygen in Wairua River	6 sites in Wairua River (see Table 5, Figure 3)	Continuous logging of dissolved oxygen over at least 2 weeks	Twice yearly during summer low flow period and winter flooding
Water quality in oxbow lakes	5 key oxbows (see Table 6, Figure 4)	Temperature, nitrogen, phosphorus, turbidity, clarity, pH, *E. coli*, conductivity, continuous logging of dissolved oxygen over several days	Every 5 years
River sediment loads	NRC monitoring sites: Mangahahuru at Apotu Rd, Waiotu River at SH1, Whakapara River at Cableway	Turbidity and suspended solids	Continuous logging of turbidity; samples to be taken at different flows to establish correlation between turbidity and suspended solids
Fauna surveys	Mudfish: wetlands within HC floodplain identified in FENZ Kakahi: stream and river monitoring sites Tuna: 7 key sites from Williams et al. (2013) study	Abundance Abundance Abundance, length	Every 2-3 years concurrent with wetland sampling Every 5 years Every 5 years

5.2 Stream and River Water Quality

5.2.1 Rationale

Water quality and aquatic invertebrates are currently monitored in major rivers in the project area as well as two farm drain sites. Water quality is measured at these sites as well as several sites in the Mangahahuru River and its tributary, the Mangawhero Stream. However, the state of smaller streams and drains in the project area has not yet been assessed.

Monitoring of stream and river quality will require a two-tiered approach: (1) surveys to fill current knowledge gaps in ecological health and guide future restoration; and (2) regular monitoring to characterise the effects of future restoration projects.

The key objective of restoration monitoring will be to measure success of the following project outcomes:

- 1.2 Rates of sediment deposition are minimised;
- 1.3 Maintained or enhanced water quality and trophic state and a shift from low nutrient to high nutrient adapted species reversed; and
- 2.1 Condition of indigenous habitat is maintained or restored.

The key objective of surveys to fill current knowledge gaps in ecological health and guide restoration will be to provide a baseline of information for monitoring the success of the same outcomes listed above.

Riparian planting is the most common stream restoration technique, but several different types of restoration are possible. For example, silt traps or constructed wetlands can reduce delivery of sediments, contaminants and nutrients to downstream areas (see Tanner and Kloosterman 1997 for an overview). There are also several approaches that can be used to reduce nutrient concentrations in streams, such as dosing of flocculants such as alum or altered farm management practises (McDowell 2010). Habitat in streams can be improved by addition of large woody debris (Hicks and Reeves 1994). A detailed review of potential restoration actions is beyond the scope of this report, but will be included in a later stage of the CIW project.

Here, we have focussed on riparian planting as an example of stream restoration, but these techniques could also be used to monitor other restoration types with slight alterations. The parameters measured will depend on the goals of the restoration project. For example, continuous monitoring of temperature may not be necessary for restoration actions aimed at reducing nutrients or improving habitat.

5.2.2 Monitoring of Restoration Projects

To measure the success of changed land management practises or restoration initiatives, regular monitoring of upstream and within restored areas as well as reference sites will be necessary. This should be carried out according to a BACI design (Before – After – Control – Impact). This means that monitoring should occur before and after any restoration, and sites should include a control site (i.e. upstream of the restoration and a reference site) and an impact site (downstream of the restoration). For example, if a 500 m reach of a particular stream or river was restored by planting of riparian margins, the recommended three monitoring locations would be: (1) within the restored area near the downstream edge; (2) immediately upstream of the restored area; and (3) in an unrestored stream or river nearby of similar size and with similar habitat characteristics (e.g. both sites would need to have similar bottom sediment and aquatic plant communities). The first two sites are the highest priority for monitoring, but monitoring of at least some, if not all, restored sites should also include a reference site.

Note that the full suite of parameters may not need to be monitored if there is an existing monitoring programme already underway nearby, for example, for resource consent compliance purposes. However, whether this data will be applicable for assessing the effects of restoration will need to be evaluated on a case-by-case basis.

Recommended parameters for monitoring are outlined in Table 3. Yearly monitoring parameters are the top priority with monitoring.

Table 3. Recommended parameters for monitoring of stream riparian habitat restoration.

Type of monitoring	Parameters	Equipment	Frequency	Reference
Yearly				
Water quality logging	Water temperature	Submersible temperature loggers	Once per year in summer over several weeks	
Sediments	Sediment cover, percentage sediment composition	Underwater viewer	Once per year in summer	Clapcott et al., 2011
Macrophyte/periphyton cover	Visual estimates of macrophyte and periphyton cover	No specialist equipment needed	Once per year in summer	Collier et al., 2006
Invertebrates	Macroinvertebrate samples to calculate MCI and other indices Presence/absence of freshwater mussels	Invertebrate net, sample jars to be sent to taxonomist, underwater viewer for mussel searches	Once per year in summer	Stark et al., 2001 (see also Stark and Maxted, 2007)
Aquatic habitat	Depth, width, bank stability, riparian vegetation	Tape measure, ruler	Once per year in summer	Collier and Kelly, 2005; Northland Regional Council, 2012
Seasonal				
Water quality spot measurements	pH, turbidity, dissolved oxygen, temperature, water clarity, time measurements taken	Water quality meter/s, clarity tube	2-4 times per year	
Water quality analysis	*E. coli*, Enterococci, ammonia, nitrate-nitrite, total nitrogen, dissolved reactive phosphorus, total phosphorus, and total suspended sediments	Sample bottles to be sent to analysis provider, chilly bin, ice	2-4 times per year	

The number of sites monitored will depend on the type of restoration undertaken. For example, if many smaller-scale stream restoration projects are undertaken, using the above scenario as a guide, monitoring of at least 5 but ideally 10 restoration sites is recommended to obtain a representative and statistically robust picture of changes that are occurring. Alternatively, if fewer projects are undertaken, it may be appropriate to monitor fewer sites. Monitoring should commence at least 1 year before restoration begins and continue for at least 5 years following completion of restoration.

Summer is the best time to monitor streams because flows are usually lower and the water is clearer, making the streams more accessible and practical to survey.

5.2.3 Methods for Monitoring of Restoration Projects

All monitoring (Table 3) should be carried out by appropriately trained personnel. The full suite of monitoring methods listed here should be carried out by an appropriately trained ecologist, and the reduced suite of monitoring parameters could be carried out by a trained volunteer if desired.

There is also a widely used ready-made monitoring kit for community groups called SHMAK[3] (Stream Health Monitoring and Assessment Kit), including all necessary methods and equipment, that could be used to carry out regular monitoring at each site or a subset of sites. Water quality samples for nutrient analysis are not included in the SHMAK system however. Challenges with this system may include maintaining consistency of data and adequate availability of volunteers, and it is therefore recommended that the monitoring is carried out by trained ecologists if possible.

[3] http://www.niwa.co.nz/our-science/freshwater/tools/shmak

5.2.3.1 Water quality

Spot measurements of water quality should be taken at the same time each day where possible, and should be taken with a recently calibrated meter. Water quality samples should be taken in accordance with the instructions of the analysing laboratory and delivered to the lab within the required time frames.

The temperature of streams is expected to fall with increased planting and shading, providing better habitat quality for stream biota. Change in macroinvertebrate communities is strongly linked to temperature changes in restoration projects (Parkyn et al., 2003) and continuous monitoring of temperature upstream of and within restoration areas could provide a useful indicator of restoration success. Stream temperature can be monitored using submersible temperature loggers, which should be installed for several weeks during summer at upstream, downstream and control sites.

5.2.3.2 Sediment cover

Sediment cover should be assessed at each site using ‘Method 2- Instream visual assessment of % sediment cover’ in ‘Sediment assessment methods- Protocols and guidelines for assessing the effects of deposited fine sediment on instream values’ (Clapcott et al., 2011). At each site, five transects are measured within a 100 m stream section. For each transect, estimates of percentage fine sediment cover (<2 mm diameter) are made at 4 randomly spaced locations across the stream using a bathyscope (underwater viewer). A total of 20 percentage cover estimates are made at each site.

5.2.3.3 Habitat

Several methods are available for assessing stream and river habitat. National protocols were developed by Harding et al. (2009) but regional authorities tend to use their own systems, such as the method used by Waikato Regional Council which includes sediment size, channel width and depth, and a range of qualitative parameters such as bank stability and riparian vegetation cover (Collier and Kelly, 2005). Northland Regional Council assesses habitat according to the methods of Pfankuch (1975), whereas Auckland Council has its own system for Auckland streams (Storey et al., 2011). Two options are available here: a method for stream habitat assessment could be chosen to align with other surveys in the Northland region; or the method used could be a nationally standardised approach such as that of Harding et al. (2009). The standardised approach would have the advantage that data could be easily compared with other studies, especially if future Community Investment in Water projects also employ this method.

5.2.3.4 Aquatic plants

Periphyton and macrophytes should be assessed following Waikato Regional Council guidelines (Collier et al., 2006); these guidelines allow rapid assessment of aquatic plant life and require no specialised equipment or analysis. At each site, five transects are laid out at 20 m intervals. At each transect, the percentage cover of submerged, surface-reaching and emergent macrophytes is assessed, and periphyton is visually assessed by manually scraping five substrates and determining the type present. Periphyton abundance, distribution and type are determined using the following criteria:

- Thin mat or film (less than 0.5 mm thick) - Any colour.
- Medium mat (0.5 to 3 mm thick) - Green, light brown or black/dark brown.
- Thick mat (more than 3 mm thick) - Green, light brown or black/dark brown.
- Short filaments (less than about 2 cm long) - Green, brown/reddish.
- Long filaments (more than about 2 cm long) - Green, brown/reddish.

The percentage cover of each periphyton type and macrophyte species at each transect are estimated and then averaged for each site.

5.2.3.5 Aquatic macroinvertebrates

Aquatic macroinvertebrates should be collected from each site according to the methods of Stark et al. (2001), with four samples collected from run or riffle habitat within each site to ensure adequate sampling representation. Samples should be collected using a standard kick net (mesh size 500 µm) in accordance with procedures and methods detailed in Stark et al. (2001). Semi-quantitative methods for either soft or hard-bottomed substrates should be used, depending on the stream habitat. Samples should be preserved in 70% isopropyl alcohol or ethanol and processed using relevant protocols by a qualified invertebrate taxonomist.

The following indices can then be calculated and compared among sites:

- Number of taxa- the number of invertebrate taxa present in each sample. Sites with more taxa are considered likely to be of higher environmental quality than sites with fewer taxa.
- Number of individuals- the number of macroinvertebrates in the sample. The number of individuals can indicate toxic pollution (if numbers are very low) or severe nutrient enrichment (if numbers of tolerant taxa are very high).
- EPT value (excluding Hydroptilidae)- the number of taxa of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) in the sample. These taxa are highly sensitive to environmental perturbations, and samples with higher numbers of these taxa indicate high environmental quality. The percentage of EPT taxa and the percentage of EPT individuals were also calculated. The family Hydroptilidae is not included in these indices because this taxon is able to survive in more degraded environments than other EPT taxa.
- MCI and QMCI- the Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) indicate organic enrichment. The indices are calculated by giving each taxon a score from 1 to 10, with 1 indicating highly tolerant taxa and 10 indicating highly sensitive taxa. The MCI uses presence/absence data, and the QMCI uses abundance of each taxon. Higher MCI and QMCI scores indicate better habitat and water quality.

5.2.3.6 Fish

Fish have not been included in this part of the monitoring programme, as fish populations are less likely to show measureable differences due to stream riparian habitat restoration at a small scale and over short time frames. However, monitoring of fish populations may be useful for measuring the success of other types of restoration, such as wetland habitat creation, specific eel habitat creation, fish passage improvement or pest fish removal. In this case, monitoring should be carried out by appropriately trained personnel according to national protocols outlined in Joy et al. (2013). Potential methods include spotlighting, nets and traps, and backpack electrofishing, but the method will depend on site characteristics such as depth, flow and water clarity. As with other restoration monitoring, a BACI design is recommended: surveys should be carried out before and after restoration takes place and should include a control site as well as the restored site.

5.2.4 Stream Surveys to Address Knowledge Gaps

Suggested survey streams (Figure 2, Table 4) have been compiled by assessing existing fauna records and assessing spatial gaps in monitoring records. Sites within the HC floodplain (shown in red in Figure 2) should be prioritised as little or no information exists on these streams.

Stream surveys to address knowledge gaps should use the same methods outlined in Section 5.2.3. Continuous temperature logging is less of a priority for these surveys and could be left out if necessary.

Fish should be surveyed according to national protocols (Joy et al. 2013). Potential methods include nets and traps, spotlighting and backpack electrofishing, depending on water depth, flow velocity, and visibility, and should be decided upon following a site visit. Fish surveys in the HC floodplain area are considered to be a higher priority than the sites in the upper catchment, as the floodplain sites have less existing fish data. If possible, fish surveys in the upper catchment sites would also be useful to assess whether populations have changed since last surveyed in 1999.

These stream surveys should be carried out at least once and ideally repeated at least every 5 years to obtain a broad picture of the state of freshwater ecosystem health in the HC and catchment.

Figure 2. Recommended stream monitoring sites within the Hikurangi Catchment (HC). Red pins = sites within the HC floodplain, purple pins = sites in the upper catchment, and blue pins = potential control sites. Border of the HC floodplain shown in green.

Table 4. Recommended stream monitoring sites within the Hikurangi Catchment. Locations have been chosen to give adequate coverage of contributing sub-catchments. Locations are approximate; actual sites sampled will depend on site access. Sites with * are in catchments with a greater proportion of dairy farming area (unpublished data).

Site	NZTM Northing	NZTM Easting	Survey methods	Site notes
Sites within HC floodplain				
Mararua Stream*	6056224	1711953	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Flows into Wairua River in southeastern side of HC. Contains high protection priority area
Riponui Stream*	6060280	1708175	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	In catchment of Wairua River Wildlife Management Reserve. High protection priority
Waiariki River Downstream	6066543	1712177	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Flows into Whakapara River downstream of NRC monitoring site
Rowlands Stream	6058591	1706244	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	High protection priority
Forsythe Stream*	6063923	1710417	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	
Luptons Point Drain	6060395	1713482	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Flows into Wairua River in eastern side of HC
Otakairangi Stream- Wetland Outflow*	6059363	1707552	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	
Otakairangi Stream- Wetland Inflow*	6060740	1705579	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Fish last surveyed in 1999.
Sites in upper HC catchment				
Waiotu River at Tapuhi	6074637	1709568	Spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Fish last surveyed in 1999.
Ngaruawahine Stream*	6072258	1705796	Spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Fish surveyed by Williams et al. (2013)
Kaimamaku Stream	6071395	1717069	Spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Fish last surveyed in 1999.
Mataroa River*	6069908	1723370	Spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Fish last surveyed in 1999.
Te Waiongatahuna Stream (trib of Kirikiritoki Stream)	6062867	1719735	Spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Fish surveyed by Williams et al. (2013)
Sites in HC catchment- control sites with native forest catchment				
Waiariki River headwater	6057877	1722134	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Potential control site- native forest upstream
Mangahahuru Stream headwater	6074588	1715226	Fish, spot water quality, sediment cover, habitat, aquatic plants, macroinvertebrates, search for kakahi	Potential control site- native forest upstream

5.2.5 Bacterial Source Tracking

Current monitoring of *E. coli* in streams and rivers is unable to determine the actual cause of the bacteria, whether from wild animals, human wastewater, or agricultural sources. The source of *E.*

coli in surface waters can be ascertained by bacterial source tracking. This is a DNA-based technique that is able to distinguish strains of *E. coli* from the guts of different animals including universal, ruminant, human, dog, seagull, and wildfowl. This technique could help identify priorities for restoration options. Recommended starting points for monitoring are the NRC monitoring sites: Mangaharuru Stream at county weir and Apotu Road bridge, the Waiotu River at the SH 1 Bridge, and the Whakapara River at the Cableway. At a later stage in the project it may be useful to sample drain inputs into the Wairua River to further narrow down sources of bacteria.

5.2.6 Ecosystem Respiration and Metabolism

A good way to measure the ecological response of these larger river sites is through measuring ecosystem respiration and metabolism using the methods proposed by Young et al. (2008).

5.3 Dissolved Oxygen in the Wairua River

5.3.1 Rationale

The Wairua River receives inputs of oxygen-depleted and nutrient-enriched water from the Hikurangi Swamp Scheme following flood events. Water becomes deoxygenated during floods when it remains in flooded pastures and oxbows for extended amounts of time. This is due to microbial breakdown of plant material and other degradable material such as animal waste. If the water remains stagnant, oxygen from the air is unable to penetrate into the deeper areas of water.

The extent and effects of large-scale flooding events on river and oxbow water quality are not well understood. Deoxygenation of flood waters prior to re-entering the Wairua River may have adverse effects on river habitat quality, but monitoring of dissolved oxygen during these events is required to measure this.

Dissolved oxygen fluctuates in rivers, stream and lakes over a 24-hour cycle due to photosynthesis and respiration by plants and algae. Spot measurements may therefore miss the lowest concentrations and often do not give a complete picture of how severe oxygen depletion is, therefore underestimating effects on aquatic biota.

The key objective of restoration monitoring will be to measure success of the following project outcomes:

- 1.3 Maintained or enhanced water quality and trophic state and a shift from low nutrient to high nutrient adapted species reversed;
- 2.1 Condition of indigenous habitat is maintained or restored; and
- 5.2 Cultural values recognized and protected.

5.3.2 Methods

Oxygen levels in the Wairua River and selected oxbows should be measured by continuous logging (i.e. logging (i.e. every 5-15 minutes) using submersible data loggers. Several loggers should be deployed at deployed at once at several sites for an accurate comparison. Ideally, dissolved oxygen should be logged logged before, during, and after a flooding event, though it may be difficult to predict when such events will events will take place. Securing the loggers to an anchor point may prove difficult in flood conditions; conditions; monitoring points should be chosen to ensure that a secure anchor point is available. Suggested Suggested sites for monitoring are based on obtaining a complete picture of the effects of low dissolved dissolved oxygen inputs within the HC and are spaced upstream, downstream and within the area of of pumping stations (Figure 3,

Table 5

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Table 5. Recommended dissolved oxygen logging sites in the Wairua River.

Site	NZTM Northing	NZTM Easting	Notes
Upstream site	6064597	1711501	Upstream of all pumping stations
Site 1	6062887	1711673	Downstream of Te Mata pumping station
Site 2	6060477	1713133	Upstream of Tanekaha, Mountain and Otonga pumping stations
Site 3	6059552	1712069	Downstream of Tanekaha, Mountain and Otonga pumping stations
Site 4	6057516	1711400	Downstream of Ngararatunua pumping station
Site 5	6056197	1708680	Downstream of all pumping stations

Figure 3. Recommended dissolved oxygen logging sites in the Wairua River, showing locations of pump stations. Border of the Hikurangi Catchment floodplain shown in green.

5.4 Water Quality in Oxbow Lakes

5.4.1 Rationale

Spot water quality measurements by Williams et al. (2013) showed that dissolved oxygen concentrations were severely depleted at the Tanekaha oxbow sites and at the Mountain oxbow, and were also low at the Hikurangi Repo oxbow. Other than the information in the Williams study, the water quality and oxygen concentrations in the oxbows have not been measured and are not well understood.

Continuous dissolved oxygen and temperature monitoring over several weeks during dry and rainy periods would aid our understanding of habitat conditions in the oxbows. Monitoring is necessary in both summer and winter, because (1) dry periods during summer typically show the lowest dissolved oxygen due to lower flows and higher temperatures; and (2) in winter, flooding is more likely, which can result in stagnant water remaining in the oxbows for several days and becoming deoxygenated.

The key objective of oxbow monitoring will be to measure success of the following project outcomes:

- 1.3 Maintained or enhanced water quality and trophic state and a shift from low nutrient to high nutrient adapted species reversed;
- 2.1 Condition of indigenous habitat is maintained or restored; and
- 5.2 Cultural values recognized and protected.

5.4.2 Monitoring

Monitoring of water quality and habitat parameters in key oxbows is recommended to complement monitoring of larger rivers carried out by NRC. Parameters should include temperature, nitrogen, phosphorus, turbidity, clarity, pH, *E. coli*, conductivity, aquatic plant cover, and dissolved oxygen logging as described in 5.2.3. Only one site per oxbow is needed.

Suggested sites are those oxbows where high densities of eels were caught in the survey by Williams et al. (2013). These include (in order of highest eel catch to lowest): Mountain Oxbow, Hikurangi Repo Oxbow, Tanekaha Borrow Cut 2, and Tanekaha Oxbow (Table 6, Figure 4). For this monitoring, one of the oxbow lakes within the Wairua River Wildlife Management Reserve should also be surveyed as a control oxbow within largely natural surrounds (though it is recognised that most of the catchment is pasture). Dissolved oxygen should be monitored continuously for at least a period of two weeks per sampling round, as described in Section 5.3.2.

Oxbow surveys should be carried out at least once and ideally repeated at least every 5 years to obtain a broad picture of the state of freshwater ecosystem health in the HC and catchment.

Table 6. Recommended oxbow lake monitoring sites in the Hikurangi Catchment.

Site	NZTM Northing	NZTM Easting
Mountain Oxbow	6059757	1713011
Hikurangi Repo Oxbow	6058397	1711347
Tanekaha Borrow Cut 2	6060138	1713195
Tanekaha Oxbow	6060401	1712977
Wairua River Wildlife Management Reserve Oxbow	6057915	1710975

Figure 4. Recommended oxbow lake monitoring sites in the Hikurangi Catchment.

5.5 River Sediment Loads

5.5.1 Rationale

Minimising sediment deposition is listed explicitly as an outcome for supporting aquatic values (Outcome 1.2). Monitoring of suspended sediment levels at NRC flow monitoring sites is recommended as this information could be used to identify on a broad scale which catchments are contributing the most sediment to the HC.

Monitoring of sediment cover is also recommended as part of stream and river monitoring; this is outlined in Section 5.2.3.1.

5.5.2 Methods

Estimating sediment loads in rivers requires information on flow rates and sediment concentrations in the water. Flow rates are already measured continuously by NRC in the Mangaharuru Stream at 50 m above the county weir and the Apotu Road bridge, the Waiotu River at the SH 1 Bridge recorder site, and the Whakapara River at the Cableway recorder site.

To obtain a reliable estimate of suspended sediment load, continuous turbidity measurements can be taken using a turbidity sensor. Sensor measurements then need to be calibrated to the sediment concentrations in that particular river by comparing to measurements of suspended sediments from water samples. Water samples for measurement of suspended sediment concentration need to be taken from a representative number of points across a river and must be depth integrated, as suspended sediment concentrations vary with river width and depth (Hicks et al., 2004).

5.6 Fauna Surveys

5.6.1 Rationale

The distributions of black mudfish and other threatened species such as koura/kēwai (freshwater crayfish; *Paranephrops planifrons*) and kākahi (freshwater mussels) in the study area are not well known; determining the distributions of these species would aid in the identification of key ecological monitoring sites and target areas for restoration.

Black mudfish are classified as At Risk-Relictual (Allibone et al., 2010), and are restricted to wetland habitats. Two species of kakahi (freshwater mussels) are present in New Zealand: *Echyridella menziesii* (Declining) and *Cucumerunio websteri* (Data Deficient; Hitchmough et al., 2007). As environmental indicators, they provide useful information about water quality and connectivity with other areas.

The longfin eel/tuna is classified as At Risk-Gradual Decline (Allibone et al., 2010), and is also a taonga species for local iwi (Williams et al., 2013). Movement of tuna is currently restricted by the Hikurangi Swamp Scheme and the Wairua Power Station, and habitat of tuna in the Wairua River is under threat from deoxygenation of flood waters. Repeating the survey of Williams et al. (2013) at sites within the Hikurangi Catchment as well as the Wairua Canal is necessary to measure growth rates of tuna, track movement of previously tagged fish, and monitor changes in distribution and abundance.

The key objective of fauna monitoring will be to measure success of the following project outcomes:

- 1.3 Maintained or enhanced water quality and trophic state and a shift from low nutrient to high nutrient adapted species reversed;
- 2.1 Condition of indigenous habitat is maintained or restored;
- 3.1 Maintained or enhanced diversity and abundance of the representative range of indigenous species and guilds;
- 3.2 Maintained or improved abundance and distribution of target threatened species; and
- 5.2 Cultural values recognized and protected.

5.6.2 Methods

Kākahi should be searched for during stream and river surveys to determine their distribution and abundance. Recommended sites for this monitoring are outlined in Section 5.2.4. Kākahi surveys should be carried out in April- May if possible and should focus on visually searching the banks of streams and rivers using an underwater viewer (Hamer et al., 2013). The stream length and width searched should be recorded as well as the number and species of any mussels found. Sites for kakahi monitoring should be those surveyed as part of the stream and river surveys to address knowledge gaps (see Section 5.2.4).

To determine the distribution and abundance of mudfish within the HC, mudfish surveys should be carried out in wetlands. Surveys should follow the methods set out in Ling et al. (2009); these involve setting multiple specialised Gee's minnow traps at each site overnight. Wetlands surveyed should include all wetlands with the HC but should prioritise the Otakairangi Wildlife Management Reserve, Jordan Valley Rd wetland remnants, and other wetlands near the Wairua River if all sites cannot be surveyed. The Wairua River Wildlife Management Reserve is currently being surveyed by NorthTec. Surveys of mudfish should not be carried out during the summer months when mudfish are likely to be dormant.

Kēwai are typically caught during fish surveys using electrofishing and spotlighting techniques, such as those recommended for within the HC area (see Section 5.2.4), therefore no extra surveys for monitoring of kēwai will be necessary to monitor their distribution or abundance.

Specific surveys for tuna are necessary to measure growth rates of tuna, track movement of previously previously tagged fish, and monitor changes in distribution and abundance. Ideally, all study sites listed in listed in Willams et al. (2013) should be re-visited. If repetition of the whole survey is not feasible, survey survey sites could be prioritised, with those sites showing the highest tuna populations surveyed (

Table 7). The Wairua Canal should be surveyed during dewatering for maintenance if feasible, as this will improve the likelihood of catching tuna.

Any tuna caught during fish surveys should be checked for Passive Integrated Transponder (PIT) tags using an appropriate PIT tag reader. These are small internal tags carrying a unique ID code installed during previous surveys. Lengths and weights of all tuna caught should be recorded.

Table 7. Recommended minimum tuna monitoring sites in the Hikurangi Catchment.

Site	NZTM Northing	NZTM Easting
Wairua Canal	6043875	1698044
Mountain Oxbow	6059757	1713011
Hikurangi Repo Oxbow	6058397	1711347
Tanekaha Borrow Cut 2	6060138	1713195
Tanekaha Oxbow	6060401	1712977
Wairua River Wildlife Management Reserve Oxbow	6057915	1710975
Ngaruawahine Stream	6072258	1705796

5.7 Monitoring Review

The results and suitability of the monitoring programme for achieving the project objectives should be assessed once the project is underway; a suggested timeframe for review is 5 years after the beginning of monitoring. The review should be carried out by an independent and appropriately qualified person and should assess whether each part of the monitoring programme is producing useful information and which, if any, aspects should be modified, removed from, or added to the programme.

6 References and Bibliography

ANZECC (Australian and New Zealand Environment and Conservation Council). 2000. Australian and New Zealand guidelines for fresh and marine water quality. Volume 1 - The Guidelines. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Ausseil, A.-G., Gerbeaux, P., Chadderton, W.L., Stephens, T., Brown, D., Leathwick, J. 2008. Wetland ecosystems of national importance for biodiversity: Criteria, methods and candidate list of nationally important inland wetlands. Landcare Research Contract report LC0708/158.

Biggs, B. J. F. 2000. New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams. Ministry for the Environment, Christchurch.

Clapcott, J.E., Young, R.G., Harding, J.S., Matthaei, C.D., Quinn, J.M. and Death, R.G. 2011. Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Cawthron Institute, Nelson.

Clarkson, B. R., Sorrell, B. K., Reeves, P. N., Champion, P. D., Partridge, T. R., Clarkson, B. D. 2004. Handbook for monitoring wetland condition: Coordinated Monitoring for Sustainable Management of New Zealand Wetlands. Ministry for the Environment, Wellington.

Collier, K. J., and J. Kelly. 2005. Regional Guidelines for Ecological Assessments of Freshwater Environments: Macroinvertebrate Sampling in Wadeable Streams. Environment Waikato Technical Report TR2005/02.

Collier, K. J., J. Kelly, and P. Champion. 2006. Regional Guidelines for Ecological Assessments of Freshwater Environments: Aquatic Plant Cover in Wadeable Streams. Environment Waikato Technical Report 2006/47.

Department of Conservation. 2001. Natural Areas of Whangarei District- Reconnaissance Survey Report for the Protected Natural Areas Programme. Department of Conservation, Whangarei.

Department of Conservation. 2010. Freshwater Ecosystems of New Zealand (FENZ) geodatabase. Department of Conservation.

Denyer, K. and Peters, M. 2014. WETMAK: A wetland monitoring and assessment kit for community groups. NZ Landcare Trust, Hamilton.

Gray, T. 2012. State of the Environment Monitoring of Periphyton at Northland's River Water Quality Monitoring Network sites 2007 – 2012. Prepared by TEC services for Northland Regional Council.

Hamer, M., Collier, K. C., Iles, J. 2013. Freshwater Mussels in the Raglan Harbour Catchment. Presentation given at the New Zealand Freshwater Sciences Society Conference, Hamilton, 2013.

Harding, J., Clapcott, J., Quinn, J., Hayes, J., Joy, M., Storey, R., Greig, H., Hay, J., James, T., Beech, M., Ozane, R., Meredith, A., Boothroyd, I. 2009. Stream Habitat Assessment Protocols for Wadeable Rivers and Streams of New Zealand. University of Canterbury, Christchurch.

Hicks, M., Quinn, J., Trustrum, N. 2004. Stream sediment load and organic matter. Chapter 12 in: Freshwaters of New Zealand. Edited by Harding, J. S., Mosley, M. P., Pearson, C. P., Sorrell, B. K. New Zealand Hydrological Society Inc. and New Zealand Limnological Society Inc. Christchurch.

Hicks, B. J., and Reeves, G. H. 1994. Restoration of stream habitat for fish using in-stream structures. Pages 67-91 in Collier, K.J. (Ed), 1994. Restoration of Aquatic Habitats. Selected papers from the second day of the New Zealand Limnological Society 1993 Annual Conference. Department of Conservation.

Hitchmough, R., Bull, L., Cromarty, P. (comps) 2007. New Zealand Threat Classification System lists—2005. Department of Conservation, Wellington.

Joy, M., David, B., and Lake, M. 2013. Field Guide: New Zealand Freshwater Fish Sampling Protocols. Part 1: Wadeable Rivers and Streams. Massey University, Palmerston North.

Leathwick, J. R., West, D., Gerbeaux, P., Kelly, D., Robertson, H., Brown, D., Chadderton, W. L., Ausseil, A.-G. 2010. Freshwater Ecosystems of New Zealand: User Guide. Department of Conservation.

Ling, N., O'Brien, L.K., Miller, R., Lake, M. 2009. Methodology to survey and monitor New Zealand mudfish species. CBER Contract Report 104. Department of Conservation and University of Waikato, Hamilton.

McDowell, R. W. 2010. The efficacy of strategies to mitigate the loss of phosphorus from pastoral land use in the catchment of Lake Rotorua. Report for Environment Bay of Plenty. Agresearch.

MfE (Ministry for the Environment). 2003. Microbiological Water Quality Guidelines. Ministry for the Environment.

MfE (Ministry for the Environment). 1994. Water Quality guidelines No. 2 – Guidelines for the Management of Water Colour and Clarity. Ministry for the Environment.

Northland Regional Council. 2012. Northland Rivers Habitat Assessment 2011-2012. Northland Regional Council, Whangarei.

Northland Regional Council. In preparation. Northland river water quality and ecology: State and trends 2007-2011. Northland Regional Council, Whangarei.

Pfankuch, D.J. 1975. Stream Reach Inventory and Channel Stability Evaluation. U.S.D.A Forest Service, Region 1, Missoula, Montana.

Price, J., and Dean, H. 2014. Baseline Report: Hikurangi Catchment. Report prepared for the Department of Conservation. Kessels Ecology, Hamilton.

Stark, J. D., I. K. G. Boothroyd, J. S. Harding, J. R. Maxted, and M. R. Scarsbrook. 2001. Protocols for sampling macroinvertebrates in wadeable streams. Ministry for the Environment.

Stark, J. D., and J. R. Maxted. 2007. A user guide for the Macroinvertebrate Community Index. Cawthron Report No.1166, Report prepared by the Cawthron Institute for the Ministry for the Environment.

Storey, R.G., Neale, M.W., Rowe, D.K., Collier, K.J., Hatton, C., Joy, M.K., Maxted, J. R., Moore, S., Parkyn, S.M., Phillips, N. and Quinn, J.M. 2011. Stream Ecological Valuation (SEV): a method for assessing the ecological function of Auckland streams. Auckland Council Technical Report 2011/009.

Tanner, C. C. and Kloosterman, V.C. 1997. Guidelines for constructed wetland treatment of farm dairy wastewaters in New Zealand. NIWA Science and Technology Series No. 48. NIWA, Christchurch.

Whangarei District Council. 2011. Hikurangi Swamp Floodway Riparian and Ox-Bow/Cut Off Channel Management Plan. Whangarei District Council, Whangarei.

Whangarei District Council. 2012. Hikurangi Swamp Scheme Fishery Management Plan. Whangarei District Council, Whangarei.

Whangarei District Council. 2012. Hikurangi Swamp Scheme Management Plan. Whangarei District Council, Whangarei.

Wilcock B., Young R., Gibbs M. and McBride G. 2011. Continuous measurement and interpretation of dissolved oxygen data in rivers. Report prepared for Horizons District Council by the National Institute of Water and Atmospheric Research (NIWA).

Williams, E., Boubée, J., Halliday, A. and Tuhiwai, G. 2013. Tuna Populations in the Wairua and Mangakāhia Rivers. Prepared for Ngā Kaitiaki o Ngā Wai Māori, Northland Regional Council, Northpower & Ministry of Primary Industries. NIWA Report HAM 2013-109. NIWA, Wellington.

Young, R. G., Matthaei, C.D. & Townsend, C. R. 2008. Organic matter breakdown and ecosystem metabolism: function indicators for assessing river ecosystem health. Journal of the North American Benthological Society 27 (3): 605-325.

7 Abbreviations

ED: Ecological District

EPT or **Ephemeroptera, Plecoptera and Trichoptera:** Refers to scientific names for Mayflies, Stoneflies and Caddisflies, three orders of stream macroinvertebrates that are considered to generally sensitive to poor habitat conditions.

GIS: Geographic Information System

HC: Hikurangi Catchment

IKHMG: Integrated Kaipara Harbour Management Group

MCI or **Macroinvertebrate Community Index:** An indicator of aquatic habitat quality based on the presence/absence of species which have a predefined tolerance score.

NRC: Northland Regional Council

PNA: Protected Natural Area

WDC: Whangarei District Council

8 Glossary of Terms

Benthic: The flora and fauna living in or on the bottom sediments of a sea, river or lake.

EPT or **Ephemeroptera, Plecoptera and Trichoptera:** Refers to scientific names for Mayflies, Stoneflies and Caddisflies, three orders of stream macroinvertebrates that are considered to generally sensitive to poor habitat conditions.

Littoral: The shallow area of the lake near the shore where aquatic plants are able to grow.

Macroinvertebrate: Animals without a backbone that can be seen with the naked eye.

Macrophyte: Multicellular plants larger than algae.

MALF: Mean annual low flow. Calculated as the mean of the lowest average flows measured over a 7 day period

MCI or **Macroinvertebrate Community Index:** An indicator of aquatic habitat quality based on the presence/absence of species which have a predefined tolerance score.

Mesohabitat: Used in stream ecology to describe stream sections with similar depth and velocity characteristics (eg. pools, riffles, runs).

Percent dominant taxon: The number of individual animals in the sample belonging to the most common taxon.

Periphyton: Algae growing on the surface of rocks or other surfaces.

Q_5: The one-in-five year low flow; or the low flow that has a 20% chance of occurring in flow any one year. The used is the 7 day annual low flow, the lowest average flow measured over a 7 day period. For a full explanation of how this is calculated, go to http://tinyurl.com/potuvab

QMCI or **Quantitative Macroinvertebrate Community Index:** An indicator of aquatic habitat quality based on the relative abundances of macroinvertebrate taxa that have a predefined tolerance score.

Riparian zone: The zone along the edge of lake, stream and river beds.

Stream morphology: Shape and composition of stream channels and how they change over time.

Taxon (plural **taxa):** A group of organisms judged to be similar by a taxonomist. The smallest taxonomic grouping used is typically a 'species'.

Appendix I
Community Investment in Water Project Objectives and Outcomes

Objectives	Outcomes
Achieve biodiversity and water quality improvement	
1. Maintain and enhance the water regime and water quality to support aquatic values	1.1. Maintained or re-established water regime (water levels, duration and seasonality), which enhances aquatic values
	1.2. Rates of sediment deposition are minimised
	1.3. Maintained or enhanced water quality and trophic state and a shift from low nutrient to high nutrient adapted species reversed
2. Maintain or restore indigenous ecosystem condition	2.1. Condition of indigenous habitat is maintained or restored
	2.2 Current extent of wetland habitats in the management area is maintained or increased
	2.3 Area of indigenous habitat under legal protection is increased (on public or private land)
3. Maintain and enhance indigenous species diversity and threatened species	3.1. Maintained or enhanced diversity and abundance of the representative range of indigenous species and guilds
	3.2. Maintained or improved abundance and distribution of target threatened species
Develop environmental sustainability on-farm and off-farm	
4. Integrate land and water management on and off farm to improve catchment health and support production	4.1 Project management integrates environmental, cultural, economic, social and recreational values on and off-farm
	4.2 Farmers achieve demonstrated improvements in on-farm sustainability indicators (e.g. riparian protection, biodiversity integration, nutrient balance, effluent management, water use management).
Foster a close working partnership with iwi	
5. Work with iwi, hapu & whanau to recognise and provide for the values of Matauranga Maori	5.1 Iwi, hapu, whanau partnerships developed and strengthened
	5.2 Cultural values recognised and protected
	5.3 Iwi, hapu and whanau participate in management and sustainability at the site
Achieve engagement and participation of stakeholders, landholders and community	
6. Engage with other agencies, community organisations and stakeholders	6.1 Catchment and site management actions jointly developed with agency, community organisations and stakeholders
7. Fully involve Fonterra suppliers in restoration initiatives	7.1 Site management actions jointly implemented with Fonterra suppliers

Objectives	Outcomes
8. Foster community participation in conservation and sustainability initiatives	8.1. The community, public and Fonterra employees participate in conservation and sustainability management at the site
Promote the project, conservation and sustainability values, and best practice management	
9. Promote conservation and sustainability values and outcomes from Community Investment in Water project	9.1. The community and visitors appreciate conservation and sustainability values and the outcomes at the project site
	9.2. Key stakeholders and Fonterra suppliers support the conservation and sustainability values and the outcomes at the project site
10. Share and communicate best practice methods for protecting and restoring aquatic ecosystems	10.1 Best practice methods (ecological and farming) shared with farmers, managers and community
Raise and maintain a positive public profile of Fonterra and DOC	
11. To raise and maintain a positive public, shareholder and staff profile of Fonterra and DOC through the programme	11.1 Favourable public perception of DOC and Fonterra is achieved through the programme
	11.2 Favourable farmer perception of DOC and Fonterra is achieved through the programme
	11.3 Improved employee perception of DOC/Fonterra partnership is achieved through the programme