Appendix 19: Kinleith Discharge

1. Introduction

The Kinleith pulp and paper mill, south of Tokoroa, is operated by Carter Holt Harvey Ltd (CHH). The mill is consented to discharge treated wastewaters into Lake Maraetai. The discharge causes a discernable change in water colour of the lake and for some distance downstream and this discolouration has been identified by river iwi and the wider community as being a cause for concern (NIWA et al., 2009).

As part of their resource consent, CHH Kinleith is required to monitor the mill's wastewater discharge into the Waikato River and report the results to Environment Waikato (EW). They are also required to investigate and report on the feasibility and costs associated with improving the quality of the discharge (Environment Waikato, 2006).

Colour is a property of the effluent and is defined as the absorption of light at a specific wavelength in a filtered effluent sample. It is commonly expressed as platinum cobalt units (PCU) either as a concentration or a mass load (kg/d).

The colour of pulp and paper mill effluents originate in the wood handling, chemical pulping and bleaching, and papermaking processes and is due to tannin and lignin compounds in the wood. The majority of colour is produced in the chemical pulping and bleaching stages where the lignin in the wood is separated from the cellulose fibre. In the kraft pulping process, under alkaline conditions at high temperature and pressure, the lignin is solubilised and removed from the wood chips. These dissolved solids form highly coloured spent liquor called black liquor. This black liquor is washed from the pulp in subsequent washing stages and is collected and returned to the recovery cycle. The majority of the black liquor is typically recovered and reused in the process and does not enter the effluent system, although a small quantity is lost routinely. In addition, intermittent discharges and spills can occur.

Some residual black liquor remains with the pulp entering the bleach plant along with residual lignin inside the fibres that has not been removed in pulping. In the bleach plant the pulp is treated in a series of stages, called a bleach sequence. The dominant colour discharged from the bleach plant is the caustic extraction stage. Because of the chloride content of the caustic extraction and its corrosive nature this stream is generally not recovered.

Table 1 summarises the trends in the quality of the discharge from the Kinleith Mill from 2001 to 2008 and planned future improvements for discharge quality.

CHH state that a 50 percent reduction in colour discharged from Kinleith was achieved in the late 1990s prior to the granting of their current consent. Much of the improvement was achieved by the introduction of oxygen delignification and improved post-oxygen washing.

Table 1: Summary of Kinleith wastewater discharge characteristics from 2001–2008, based on CHH (2009).

Parameter	Monitoring Results	Consent Conditions	Consent compliance	Improvements During 2001-2008	Planned Improvements
Flow (m^3/day)	Mean - 87,600 Max - 151,000	Mean - None Max - 165,000	Consent conditions have never been exceeded. Very slight downward trend in discharge over the period.	A 20% reduction in discharge flow has been achieved when compared to production of the plant. A 50% reduction in discharge flow volume (not linked to production) has been achieved since 1990. These improvements have been achieved through reclaiming various process waters and other process improvements. This has increased the hydraulic retention time of the treatment and led to improvements in the levels of BOD, TSS and nutrients discharged.	Investigating future projects which would further decrease wastewater volumes by approx 5million L/day (involve reuse of water). The more feasible gains have already been achieved.
Biological Oxygen Demand (BOD) (tonnes/day)	Mean - 2.8 Max - 12.1	Mean - 2.5 Max - 6.0	The mean BOD reading exceeds the consent limit. Significant improvements have been made to BOD discharge over the period and BOD has reduced accordingly. Latest rolling mean shows consent compliance.	Addition of phosphorus and oxygen to the treatment process has addressed the nutrient imbalance and improved removal of BOD. CHH identified BOD as one area where significant improvements could be made easily. Process changes are aimed at directing flows with high organic loads to the recovery circuit. CHH has undertaken a number of process changes and improvements to the treatment process to improve BOD removal.	Future projects will focus on improving mill discharge to the treatment process.
Total Suspended Solids (TSS) (tonnes/day)	Mean - 5.9 Max - 16.6	Mean - 7.0 Max - 14.0	The mean consent limit has not been exceeded since 2004. The extreme limit has been exceeded 4 times, but not since 2003 and the consent conditions have never actually been violated.	Addition of phosphorus and oxygen to the treatment process has addressed the nutrient imbalance and improved removal of TSS. Process changes and improvements have been made to improve TSS removal.	Ongoing improvements to hydraulic retention time and monitoring are expected to yield some improvements.

Table 1 (cont):

Parameter	Monitoring Results	Consent Conditions	Consent compliance	Improvements During 2001-2008	Planned Improvements
Colour (tonnes/day)	Mean - 35 Max - 75	Mean - 75 Max - 140	Consent conditions have never been exceeded. No significant improvement has been made in the period, however CHH state that they have managed to reduce colour significantly prior to 2001.	No improvement has been made in the monitoring period, but between 1996 and 2001 an approx 50% reduction of colour load was achieved (while mill output increased significantly). Projects undertaken to reduce colour load relate to the mill processes and include pulp washing improvements, black liquor improvements and improvements to bleaching.	CHH is keeping abreast of emerging technologies to reduce colour loads. It is also expected that improvements could be achieved through reducing black liquor discharge to the treatment process.
Total Nitrogen (TN) (kg/day)	Mean - 431 Max - 728	Mean - 600 Max - 750	Consent conditions have never been exceeded. There has been a downward trend in TN discharged over the period.	No significant improvements to total nitrogen have been achieved, due to the need to maintain a nutrient balance in the treatment process.	Ongoing improvements to hydraulic retention time and monitoring are expected to yield some improvements.
Total Phosphorus (TP) (kg/day)	Mean - 52 Max - 97	Mean - 62 Max - 75	The mean consent limit has never been exceeded. The extreme limit has been exceeded three times, most recently in 2005. There has been a steady increase in the discharge of TP since 2004.	The amount of phosphorus has increased. This is due to the addition of phosphorus to the treatment process that has brought about improvements in the removal of BOD and TSS.	Ongoing improvements to hydraulic retention time and monitoring are expected to yield some improvements.

The composition and concentration of colour in the effluent stream of a pulp and paper mill is affected by differences in raw materials, wood type, process water characteristics, process lines, and operating regimes. The colour of effluent produced by a particular mill will be specific to their production line or processing technology, or an interaction of several processes. The exact nature of the discharge and cause of the colour is therefore likely to be unique to a particular mill and one treatment process is unlikely to provide a solution for all mill discharges.

Recently the CHH and Norkse Skog Tasman mills[1] at Kawerau renewed their wastewater discharge consents. As part of that process extensive reviews of colour removal technologies, costs and feasibility were undertaken. The capital and operating costs were calculated as was the likely colour reduction that would be achieved.

In assessing the probable cost to reduce Kinleith's colour load to the river reference has been made to reports and evidence presented in the Environment Court relating to the appeal against the CHH and Norske Skog Tasman mill discharges. Key references included Beca AMEC (2008), Beca AMEC (2009), and Johnson (2009 and 2010).

The Kinleith mill will have differences in the process configuration, the raw material inputs and the nature of the colour and the volume of wastewater compared to the Tasman mills (e.g., see Table 2 comparing flow and colour). However the costs generated for Tasman may be used to give an approximate order of magnitude of costs to treat Kinleith's colour (assuming similarities in production and mill age). More accurate cost estimates for the Kinleith plant would require a highly detailed study, undertaken in collaboration with CHH.

Table 2: Comparison of Kinleith and Tasman discharges.

Item	Tasman	Kinleith
Flow (million L/day)	Typical 127 – 137	Mean 87.6 Max 151
Colour (t/day)	Typical 20 – 27	Mean 35 Max 75

[1] Norske Skog operate the paper mill while Carter Holt Harvey operate the pulp mill.

Effluent colour reduction technologies that are not currently used by Tasman were investigated and then ranked to identify the best viable technologies for implementation. The top-five technologies are summarised in the Table 3. CHH provided commentary as to which treatment technologies identified for Tasman may or may not be applicable to Kinleith. Capital cost estimates are indicative only.

Table 3: Tasman colour reduction options and suitability for adoption at Kinleith.

Treatment	Description and Comment	Expected Colour Reduction (t/d)	% of Tasman Colour Load[1]	Estimated Capital Cost $Million	Suitability for Kinleith[2]
Spill collection	Reducing spills by monitoring, prevention and recycle within the liquor system is proven technology widely implemented in all major jurisdictions as well as an integral part of all new kraft pulp mill designs. Tasman monitors spills and recovers evaporator washings, but does not have a spill recovery system in place for all areas.	1–2	4–9%	0.5–1.5	Spill control systems at Kinleith are already advanced and do not provide significant scope for enhancement.
Improved brownstock washing	Good brown stock washing is a fundamental requirement in any fibreline. Washing should remove most of the organics from the pulp in the fibreline so that they can be sent to the chemical recovery cycle. Any improvement that can be made in washing efficiency will reduce the organic loading in the effluent stream. This option has high capital costs and has implications for the quality of specialty pulps.	0.3–1.6	1–7%	4–7	The opportunities for improved washing are less at Kinleith than at Tasman, because the washing efficiency of the Kinleith washers is already high and because the plant configuration does not give a ready upgrade path.
EOP filtrate recycle	Filtrate from the caustic extraction stage (termed EOP filtrate) of the bleach plant is the largest contributor to effluent colour. The recycling of this filtrate is a proven technology although it has limited acceptance by the pulp and paper industry, but can be limited by evaporator capacity. Tasman does not currently have the evaporator capacity to recycle more than a small portion of the EOP filtrate.	0.9–1.4	4–6%	5–8	Filtrate recycling faces the same barriers at Kinleith as at Tasman.

Table 3 (cont):

Treatment	Description and Comment	Expected Colour Reduction (t/d)	% of Tasman Colour Load[1]	Estimated Capital Cost $Million	Suitability for Kinleith[2]
Advanced oxidation processes	Recent research has focused on use of advanced oxidation processes to treat various mill effluents. Although there are several processes in an experimental stage, the current viable oxidation processes use hydrogen peroxide, ozone or chlorine. Hydrogen peroxide treatment requires minimal capital investment but has been shown in some cases to exhibit a colour reversion in subsequent ASB treatment. The ozone treatment involves large capital investment and a large operating cost. Both peroxide and ozone have large chemical operating costs. Reducing effluent colour with chlorine has shown to be very effective, but chloroform generation can occur under certain conditions. The downside of this option is the increased generation of other contaminants.	0.7–1.6	3–7%	0.3–4	The options for advanced oxidative treatment at Kinleith are similar to those at Kawerau.
End-of-pipe treatment	A broad category that includes tertiary clarification activated sludge treatment (AST), membrane filtration and chemically enhanced primary clarification. Each is a proven technology with the exception of membrane filtration. The use of membranes for effluent treatment is still under development. Chemically enhanced primary clarification is not favoured because it is expensive to operate and sludge characteristics make it very difficult to handle. Activated sludge plants have high operating costs due to the aeration demand and the costs associated with sludge dewatering and disposal. The chemicals in the sludge make disposal particularly problematic. This option has very high capital and operating costs.	7–12	30–50%	25–50	The end-of-pipe options for Kinleith are similar to those at Kawerau.

[1] Based on 23.5 t/d which is the midpoint of the typical Tasman colour range of 20–27 t/d.

[2] Comment provided by CHH Kinleith mill.

No viable colour reduction technologies were identified for the Norske Skog Tasman Mill. Of the options considered for CHH Tasman, spill recovery and brownstock washing measures were the most reasonable methods of reducing the mill effluent discharge colour, however neither of these are considered to be suitable options for Kinleith. The Kinleith mill already has spill recovery systems and the brownstock washing already has a high washing efficiency. Also, the Kinleith mill has limited evaporator capacity so that implementation of any treatment process which increases evaporator loading will require either significant capital investment to increase capacity or will impact on total plant throughput.

2. Goals

The colour change in the Waikato River produced by the mill discharge at Kinleith is regarded by river iwi and the wider community as being an issue which needs to be addressed. While the goal can be simply stated as wanting to reduce the colour load to the mill discharge, the challenge is to ensure that the mill remains economically viable.

3. Actions

Only three treatment options emerge as being suitable for adoption at Kinleith (see Table 3). Although based on options for Tasman, it has been assumed that implementation of any one of these processes could produce the same order of magnitude in colour reduction at Kinleith and would have similar capital and operational costs. Implementation of a combination of processes would not necessarily have an additive effect on colour reduction but some further reduction is likely.

The three actions, their potential costs (capital and operational), and the possible benefit in terms of colour reduction are summarised in Table 4.

Table 4: Colour reduction and indicative costs for the three Kinleith options.

Action	Scenario	% Colour Reduction	Capital Cost ($ million)	Annual Operating Cost ($100,000)
A	End-of-pipe activated sludge treatment	30–50%	25–50	20–50
B	Advanced oxidation processes - Chlorine, peroxide or ozone	3–7%	0.3–4.0	2–40[1]
C	EOP filtrate recycle (partial recycle of bleach plant effluent)	4–6%	5–8	5–7

[1] Chlorine has a relatively low to neutral supply cost. Peroxide has a high chemical supply cost and ozone has an extremely high chemical supply cost.

4. Outcomes

Action A involving end-of-pipe treatment could possibly achieve up to 50 percent colour reduction. However it would require significant capital expenditure and has a high associated operating cost. Implementation of any these three options would result in some reduction of colour load to the Waikato River, with increase in water clarity and light transmissivity in the vicinity of the discharge. Environment benefits would however have to be considered against the higher costs of production to cover the associated capital investment and operating costs (associated with process chemicals, energy, labour). There would also be flow-on regional social and economic effects as a consequence of lower nett revenues if these higher costs cannot be recovered from mill product sales.

5. Risks and probability of success

To achieve even a modest colour load reduction at the Kinleith mill would require significant capital investment and depending on the process may also have significant ongoing operating costs. For significant colour load reductions, end of pipe activated sludge treatment is required, which requires large capital expenditure and has high on-going operating costs. Advanced oxidation with chlorine has the lowest capital and operating cost but only achieves a modest colour reduction. It also has the potential disadvantage of forming chloroform. Bleach plant EOP filtrate recycling only achieves a modest colour reduction for a relatively high capital cost. This cost could be even higher if evaporator capacity has to be increased.

Implementing large capital works for effluent treatment may impact on the commercial viability of the mill. The mill produces commodity products that are subject to global supply and demand forces. This dictates the returns the mill receives. Although the Kinleith mill is the largest of its type in New Zealand it is relatively small by modern international standards and so it is important that any investment decision is economically sound.

6. References

CHH (2009). Kinleith pulp and paper mill wastewater discharge monitoring report – Conditions 22B and 23, Resource Consent 961348, January 2009.

Beca AMEC (2008). Literature review of colour reduction technologies for kraft pulp mill effluent. Prepared for Norske Skog Tasman & Carter Holt Harvey Tasman by Beca AMEC Ltd, September 2008.

Beca AMEC (2009). Colour reduction technology report. Prepared for Norske Skog Tasman & Carter Holt Harvey Tasman by Beca AMEC Ltd, June 2009.

Environment Waikato (2006). Review of science relating to discharges from the Kinleith pulp and paper mill. Environment Waikato Technical Report 2005/58.

Johnson, A.P. (2009). Statement of evidence of Anthony Peter Johnson (Beca AMEC Ltd). Presented to the Environment Court, 3 August 2009.

Johnson, A.P. (2010). Statement of evidence of Anthony Peter Johnson (Beca AMEC Ltd). Presented to the Environment Court, 5 March 2010.

Appendix 20: Cyanotoxin Treatment

1. Introduction and methods

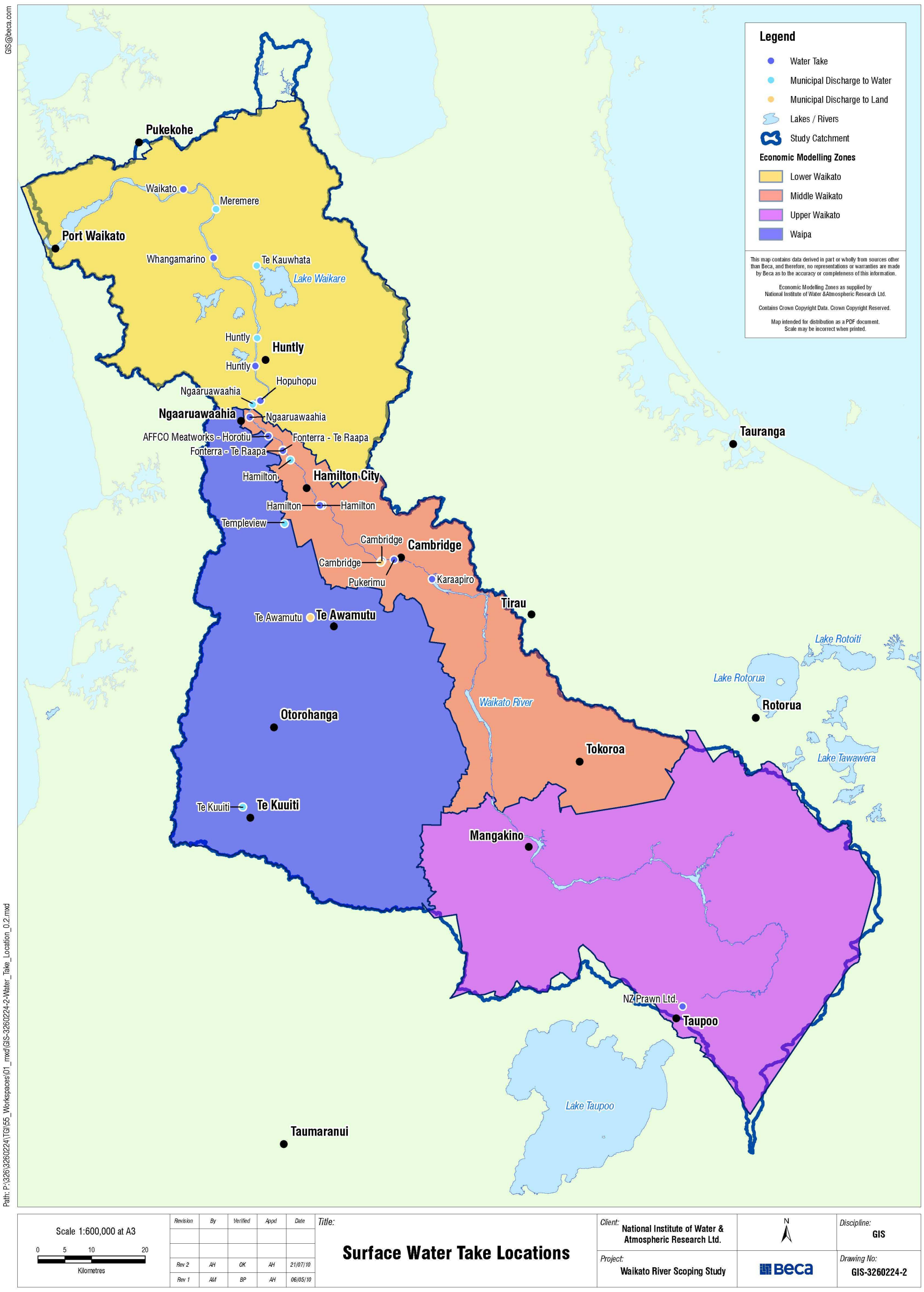
Some reaches of the Waikato River downstream of Lake Karaapiro are susceptible to blue-green algal blooms. If the nutrient load (nitrogen and phosphorus) to the river continues to rise, it is likely that these blooms will occur more frequently. The blooms pose a risk to public (human and animal health) as the chemicals (cyanotoxins) released into the water when the cyanobacteria (blue-green algae) die are toxic. If nothing is done to improve the nutrient loading of the Waikato River, community water treatment plants (WTPs) may need to upgrade their treatment processes to deal with the increased frequency and intensity of algal blooms.

This Study has considered the possibility of cyanotoxin treatment at any location where water is taken from the Waikato River (or an inline lake) and the water is used for drinking or food processing purposes. There is no historic evidence of algal blooms occurring in the Waipa River - therefore this Study has not considered water takes from this river. Water extracted from tributaries for drinking water has also not been evaluated.

WTPs and other businesses that draw water from the Waikato River have been identified from the Register of Community Drinking Water Supplies and the Resource Consents for the Waikato area. A total of 14 water takes from the Waikato River have been identified. Two of these water takes, Wairakei Resort and NZ Prawns Ltd, are located just downstream of Huka Falls. Blue-green algae levels very occasionally exceed 'trigger' levels in Lake Taupoo but this is thought to occur as a result of wind concentration. The risk to these water intakes is considered small and, as such, they have been excluded from the cost estimate.

Of the remaining 12 water takes, 10 are for community drinking water supplies and two, Fonterra Te Raapa and the AFFCO Meatworks, are industrial. Both are primary processing industries and the water may be used in the production of food. Although both these operations have treatment systems, neither have processes suitable for the removal of cyanotoxins.

Figure 1: Locations of water takes from the Waikato River which are used for drinking water supply or food processing.



2. Goals

The purpose of this paper is to generate an estimated cost for the increased level of treatment that may be required at community and industrial WTPs at risk from more frequent and severe algal blooms in the Waikato River should nutrient levels in the river continue to rise.

3. Actions

Algal blooms have a number of effects on drinking water. The cyanotoxins released by the algae are toxic to human and animal life, and also impart an unpalatable taste and odour to the water. Treatment for algal blooms should include processes to remove the entire cells, and treat the water for removal of cyanotoxins, taste and odour.

Under the Drinking Water Standards for New Zealand 2005 (revised 2008) (DWSNZ), water suppliers do not currently need to provide treatment to remove cyanobacteria but they do need to comply with the Chemical MAV (Maximum Acceptable Value) limits for cyanobacteria.

Regardless of whether a water source is able to treat for cyanotoxins or not, in areas where source water has previously experienced algal blooms the water supplier must implement a monitoring programme for cyanotoxins and develop a management protocol that specifies the actions to be taken should cyanotoxin levels reach a potentially hazardous level. The protocol will be site specific and will outline what steps are to be taken to provide safe drinking water in the event of an algal bloom. It will take into consideration factors such as whether the water supply is the sole supply for the community, the size of the community and whether alternative source water can be used. For some supplies it may be possible to stand down the WTP until the bloom is over. For others, installation of either a temporary or permanent treatment process may be the only solution.

If the cyanotoxin levels exceed 50 percent of the maximum acceptable value (MAV), more frequent monitoring must be implemented and the Drinking Water Assessor (DWA) informed. If the MAV is exceeded, the DWA and consumers must be informed. An alternative source of water must be used until levels drop below 50 percent of the MAV.

In conjunction with monitoring cyanotoxin levels, cyanobacterial cell counts may also be routinely monitored by authorities with water takes in water bodies at risk from blue-green algae blooms. The following table outlines some of the cyanobacterial cell count trigger levels, and the recommended actions (by the Ministry of Health) to be taken by local authorities in the event the trigger level is exceeded.

Table 1: Guideline values for a drinking water source and recommended actions (Kouzminov et al., 2007).

Guideline Value	Threshold Level	Actions by Local Authorities
Vigilance Level	2,000 cells/mL, or 0.2 mm3/L biovolume, or 10 µg/L chlorophyll a.	Continue regular monitoring of raw and treated water to ensure adequate system performance and consider analysis (bioassay test) of the treated water to confirm the absence of toxins.
Alert Level 1	20,000 cells/mL, or 2 mm3/L biovolume, or 10 µg/L chlorophyll a.	Prepare to implement water supply contingency plan, use an alternative source of water, or use water treatment processes capable of removing cells or toxin, or provide drinking water by tanker or bottles.
Alert Level 2	50,000 cells/mL, or 5 mm3/L bio-volume, or 25 µg/L chlorophyll or toxin concentrations exceeds MAV.	Monitoring frequency should be increased to at least twice weekly (preferably daily), the water body should be closed temporarily and a contingency plant should be activated, including advanced treatment process.

It is important to note that cyanobacterial cell counts in excess of vigilance or alert levels do not necessarily mean that cyanotoxin levels will also exceed MAV values. Routine monitoring of cell counts is not part of DWSNZ, but is a best practice measure that provides an early warning of bloom conditions.

This Study’s review found that the two largest water supplies extracting from the Waikato River have some degree of permanently installed treatment for cyanotoxins.

Three upgrade options have been reviewed.

Option 1 assumes that the river nutrient levels stay the same or decrease from the current situation. Option 2 would apply if algal bloom frequency showed a moderate increase i.e., an event every 1–3 years. Option 3 would apply if the algal bloom frequency increased to say an annual basis.

Table 2: Options for the treatment of algal blooms (cyanotoxins).

Upgrading Option	Upgade Required	Description
Option 1	No new treatment.	Blooms are managed under the existing Public Health Risk Management Plan and there is no additional cost.
Option 2	For plants with existing conventional filters, convert to Biological Activated Carbon (BAC). Where no existing filters install new BAC filters.	The filters remove algae cells while the biological media is able to adsorb toxins, taste and odour. The bacteria are grown on granulated activated carbon (GAC) media and will take some time to adjust to bloom conditions. Conversion of existing filters includes: • Replacement of sand media with GAC. • Combined air/water scour for backwash. • Non-chlorinated backwash, including new tanks. • Modifications to filters to increase bed depth. • Automation of backwash procedure.
Option 3	Option 2 plus: • Powdered activated carbon (PAC) dosing for small plants. • Ozone or UV-peroxide oxidation for large plants.	For the case where blooming is very frequent and additional treatment is required. Large plants are those with population greater than 10,000. PAC is able to adsorb the toxins. Ozone and UV-peroxide oxidation work by degrading the chemical structure of the toxins.

Suppliers were approached for costs for both Option 2 and Option 3. Due to the increased complexity of the treatment process for Option 3 this Study has not been able to provide a reasonable cost estimate, however they are anticipated to be significantly more than Option 2. The economic modelling scenarios are therefore based on the treatment plants upgrading to Option 2. The following three options have been selected for modelling:

Option 1: No changes to installed treatment.

Option 2: Supplies greater than 10 MLD install Option 2 level of treatment permanently.

Option 3: All suppliers install Option 2 treatment.

Three of the WTPs already had BAC treatment in place (Waikato, Waiora Tce, Hamilton and Whangamarino). Hence these WTPs were excluded from possibly requiring upgrades under Option 2.

The following table summarises the water takes identified as being at risk of being affected by algal blooms.

Table 3: Water takes considered at risk of algal blooms.

Water Take	Design Flow (ML/day)	Population [1]	Upgrading Options	
			Option 2	Option 3
Waikato (serves Auckland city)	75	956,800	Nothing required	Add ozone/UV-oxidation
Mercer Country Stop	0.06	200	Add BAC filter	Add PAC dosing
Alpha St. Cambridge	16.8	13,400	Replace filter with BAC	Add ozone/UV-oxidation
Karaapiro	20.5	13,500	Convert to BAC filter	Add ozone/UV-oxidation
Parallel Rd, Pukerimu	7.8	3,700	Convert to BAC filter	Add PAC dosing
Waiora Tce, Hamilton	94	132,200	Nothing required	Add ozone/UV-oxidation
Ngaaruawaahia	7	5,700	Convert to BAC filter	Add PAC dosing
Hopu Hopu	0.8	660	Convert to BAC filter	Add PAC dosing
Huntly	7	7,410	Convert to BAC filter	Add PAC dosing
Whangamarino	3.1	1,700	Nothing required	Add ozone/UV-oxidation
Fonterra Te Raapa	28	NA - Industrial	Convert to BAC filter	Add ozone/UV-oxidation
AFFCO Meatworks	29	NA - Industrial	Convert to BAC filter	Add ozone/UV-oxidation

4. Desired outcome

The risk of illness caused by accidental consumption of cyanobacteria from drinking water is reduced.

5. Risks and probability of success

The biological media in BAC filters takes some time to adjust to algal bloom conditions. There is, therefore, a lapse in time before the bloom starts and treatment begins. Process such as PAC, ozone and UV-oxidation are effective as soon as they are started.

If nothing is done to prevent the increased nutrient levels in the river, the frequency and intensity of algal blooms will continue to increase. This will mean that the

[1] Source: Water Information New Zealand, as extracted from the National WINZ database on 3 May 2010 and rounded to the nearest 100.

treatment process may not be adequate in the future, or under unanticipated bloom conditions.

At present, the cyanobacterial monitoring data collected by the various local authorities in the Waikato region is collected and collated by Environment Waikato. This information is publicly available. This is an important source of information and could be used as a tool for identifying and tracking the development and extent of algal blooms conditions.

6. Costs and timelines

The following table summarises the upgrade costs necessary to install treatment for cyanotoxins under Option 2. Costs for Option 3 have not been determined at this time. They are anticipated to be significantly more than Option 2.

The upgrade works would be implemented by the water suppliers and the costs ultimately passed on to the communities in the form of increased property or water rates.

It will take 3 to 6 months to design and tender the WTP upgrade. A further 6 months to 2 years should be allowed for procurement, construction and commissioning. This may seem like a long timeframe, but for some WTPs the construction and commissioning may need to be staged or sequenced in such a way to ensure that there is a sufficient quantity and quality of water supplied at all times.

Projects would be implemented on a case by case basis and potentially could have programme overlaps.

Table 4: Cost estimates for cyanotoxin treatment – Option 2.

Water Take	River Reach	Capital Cost $	Annual Operating Cost $	Preliminary & General (12%) $	Consenting and Investigations (10%) $	Design and supervision (10%) $	Contingency (30%) $	Capital Cost Total $
Waikato	Lower	-	-	-	-	-	-	-
Mercer Country Stop	Lower	19,000	10,500	2,280	2,128	2,341	7,725	30,000
Hopuhopu	Lower	201,000	600	24,120	22,512	24,763	81,719	350,000
Huntly	Lower	470,000	5,600	56,400	52,640	57,904	191,083	830,000
Whangamarino	Lower	-	-	-	-	-	-	-
Alpha St. Cambridge	Middle	1,774,000	34,300	212,880	198,688	218,557	721,237	3,130,000
Karapiro	Middle	982,000	16,500	117,840	109,984	120,982	399,242	1,730,000
Parallel Rd, Pukerimu	Middle	498,000	6,300	59,760	55,776	61,354	202,467	880,000
Waiora Tce, Hamilton	Middle	-	-	-	-	-	-	-
Ngaaruawaahia	Middle	470,000	5,600	56,400	52,640	57,904	191,083	830,000
Fonterra Te Raapa	Middle	1,127,000	22,600	135,240	126,224	138,846	458,193	1,990,000
AFFCO Meatworks	Middle	1,145,000	23,400	137,400	128,240	141,064	465,511	2,020,000
Total		**$6,686,000**	**$125,400**	**$800,000**	**$750,000**	**$820,000**	**$2,720,000**	**$11,790,000**

7. Abatement costs

Based on the engineering data, total and unit discounted cost per person for the nine water takes considered at risk of algal blooms have been calculated. Total costs are made of capital and operational costs. Capital costs are assumed to occur in year 2, whereas operational costs are spread over 30 years. Costs have been discounted at 8 percent. Net present values are summarised in the table below.

Table 5: Net present values of total and unit costs.

	Total costs ($millions)	Population Served	Cost per person ($thousands)
Alpha St. Cambridge	3.07	13,368	0.23
AFFCO Meatworks	2.00		-
Fonterra Te Raapa	1.96		-
Karaapiro	1.67	13,500	0.12
Parallel Rd, Pukerimu	0.83	3,746	0.22
Huntly	0.77	7,410	0.10
Ngaaruawaahia	0.77	5,695	0.14
Hopuhopu	0.31	660	0.46
Mercer Country Stop	0.14	200	0.72

Both AFFCO Meatworks and Fonterra Te Raapa are industrial sites and therefore do not serve a population as such – no unit costs per person have been established. The graph below gives a representation of total and unit cost for the nine sites.

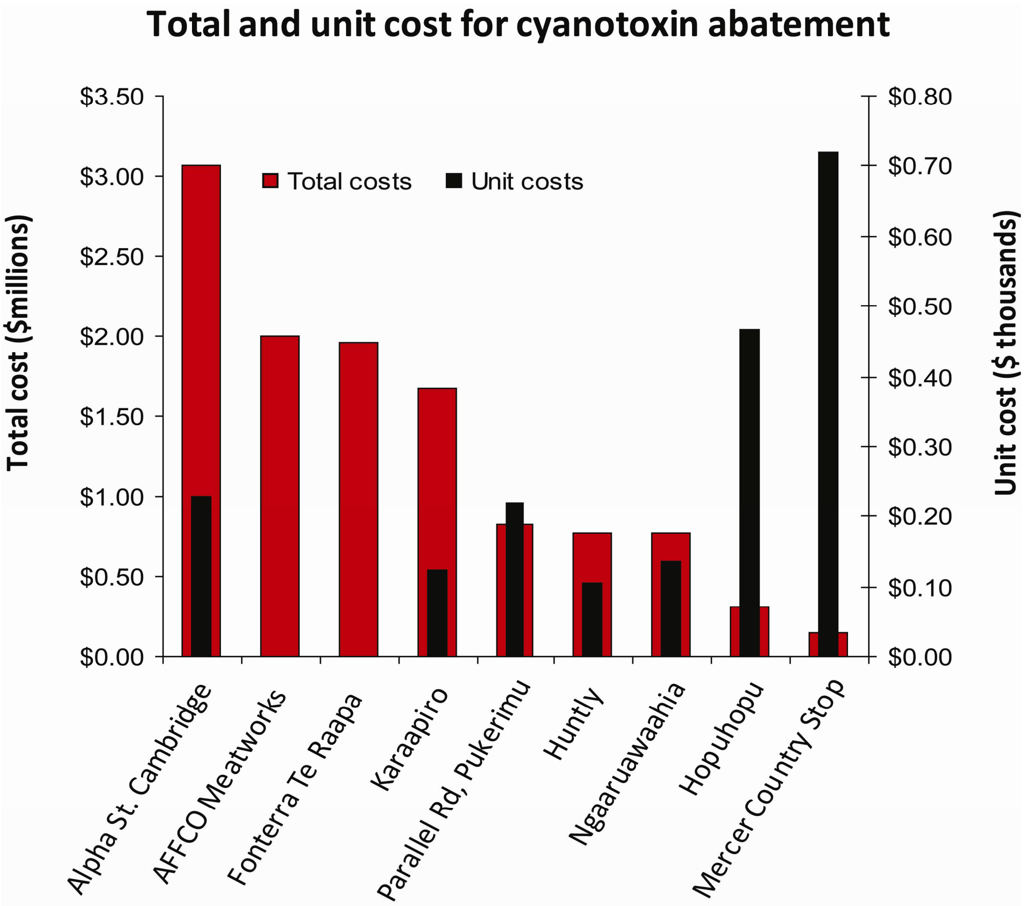


Figure 2: Cyanotoxin abatement costs.

The most expensive option is to treat cyanotoxin is at Alpha St. Cambridge where the net present value of total costs is $3.07m. Unit cost per person amount to $230 and rank as the third most expensive action. Hopuhopu and Mercer Country Stop have the lowest total discounted costs, but in contrast exhibit the highest per unit discounted costs, showing that these two options require extensive spending in a low population area, i.e., only a small number of people would benefit.

8. Glossary

WTPs	Water treatment plants
DWSNZ	Drinking Water Standards for New Zealand 2005 (revised 2008)
MAV	Maximum acceptable value
DWA	Drinking water assessor
BMP	Best management practice

EBMP	Enhanced best management practice
BAC	Biological activated carbon
GAC	Granulated activated carbon
PAC	Powdered activated carbon

9. References

Kouzminov, A.; Ruck, J.; Wood, S. (2007). New Zealand Risk Management Approach for Toxic Cyanobacteria in Drinking Water. *Australian and New Zealand Journal of Public Health Vol. 31 No. 3.*

Appendix 21: Toxic Contaminants

1. Introduction

A range of potentially toxic chemical contaminants enter the Waikato River from natural geothermal activity, wastewater discharges, and indirect diffuse source inputs. Geothermal sources result in high concentrations of mercury, arsenic and boron. The river receives background geothermal contaminants from Lake Taupoo with additional natural inputs downstream. A major input of geothermal contaminants enters the river from the Wairaakei Geothermal Power Station. As a result of these upstream inputs geothermally-contaminated sediment has accumulated in the bottom of Lake Ohakurii. At certain times of the year conditions in the lake lead to re-release of these contaminants into the overlying water.

A major point-source discharge of pulp and paper wastewaters occurs in the mid-river section at Maraetai. Historically this had significant concentrations of both mercury and dioxin in addition to resin acids and other organic material. However, improved treatment systems have markedly reduced contaminant concentrations.

The most significant urban contaminant inputs are from Cambridge, Hamilton and Huntly, with associated industrial inputs along this lower river reach. The Waipa River drains a wide agricultural area and receives the run-off and wastewater discharges from Te Kuuiti, Otorohanga and Te Awamutu. Numerous discharges of stormwater runoff occur from agricultural and urban areas. The Hamilton City discharges are elevated in contaminants (particularly metals) particularly during storms.

Run-off results in input of DDT, and other insecticides, as a legacy of past agricultural practices. Increases in zinc inputs are occurring because of the high usage for facial eczema control. The cumulative inputs of dairy processing wastewaters may result in toxic conditions in tributary streams (largely from ammonia) but not in the Waikato River.

A number of other significant point source discharges occur to the river, including municipal wastewaters, power station cooling tower discharges and various industrial wastewater and stormwater discharges. The individual and cumulative effect of contaminants derived from these discharges has not been assessed.

The contaminants in the river are of concern for two reasons; they can reach levels at which there will be an ecological effect with toxicity affecting some organisms and plants, and there can be human health risks associated with drinking untreated river water and consuming fish and invertebrates from the river.

2. Ohakurii sediment toxicity

Geothermally-derived arsenic (As) and mercury (Hg) accumulate in the sediments of Lake Ohakurii. It is estimated that more than 380 tonnes of arsenic and 0.5 tonne of Hg may have accumulated in the lake sediments since its formation in 1961 (N. Kim, Environment Waikato, pers. comm.). Ohakurii has the highest sediment concentrations of any of the Waikato River lakes, with arsenic and mercury concentrations exceeding sediment quality guidelines for ecological protection (Rumbsy and Coombes, 2008; ANZECC, 2000). (Other downstream lakes also have elevated concentrations which exceed sediment quality guidelines.)

A preliminary toxic risk assessment for these sediments could be made by comparing the sediment concentrations with the sediment quality guideline value (ANZECC, 2000). Exceedance would trigger the need for further investigation. In Lake Ohakurii, the average exceedance is about eight times the guideline value (with a maximum exceedance of 31 times). Sediment pore-water concentrations of the most toxic form of arsenic (AsIII) are known to be elevated and released to the overlying water when dissolved oxygen conditions in the lake drop (Aggett and Kriegman, 1988). This can potentially result in toxic conditions for both sediment-dwelling organisms and those living in the lake waters. Similarly, mercury concentrations will be elevated in pore waters and release to the overlying waters. These elevated in situ concentrations of geothermal contaminants pose a significant toxic hazard to key native species inhabiting sediments (particularly kooura and kaaeo/kaakahi), and the overlying waters.

Previous studies have shown marked accumulation of geothermal contaminants in Waikato River kaaeo/kaakahi (Hickey et al., 1995). The highest flesh and shell concentrations were in the upper Waikato River associated with geothermal inputs. The sensitivity of the larval glochidial life-stage or juvenile mussels to geothermal contaminants has not been determined. However, the field observations have shown marked declines in kaaeo/kaakahi at river sites downstream of upper Ohakurii (Roper and Hickey, 1994).

On the basis of the above summary, it is apparent that there is a major information gap around the toxicity of arsenic (and to a lesser extent mercury) in the Upper Waikato River. This gap could be most addressed by undertaking sediment toxicity tests, including multi-species sediment toxicity tests (e.g., with amphipods, fingernail clams, oligochaetes and juvenile kooura) and short- and long-term water toxicity tests with arsenic (e.g., with cladocerans, amphipods, iinanga and bullies). Additional information on chemical contamination, sediment physical characteristic and benthic community structure would be required to properly interpret test findings. Some studies on benthic macroinvertebrates have shown that animals in Lake Ohakurii appear to be affected by both chemical contaminants and the nature of the sediment (i.e., organic/muddy enrichment) (Hickey and Martin, 1996). Further investigations would be needed to provide a comprehensive assessment of the level of toxicological impacts, together with a characterisation of the sensitivity of a range of key species to arsenic exposure.

Such a study would cost (including report documentation and communication of study objectives and findings) about $220,000.

3. Health risks

Elevated concentrations of arsenic (As) in the river mean that untreated river water exceeds the water quality guidelines for drinking water at all river sites downstream of Aratiatia. However, arsenic is substantially removed by most conventional drinking water treatment systems (e.g., 90 percent reduction of arsenic is achieved after treatment of Hamilton drinking water; N. Kim, Environment Waikato, pers. comm.).

The risk from consuming food collected from the river is only poorly understood for a few contaminants and food species. Mercury is of particular concern because it can biomagnify through the food-chain. This can result in concentrations that could adversely affecting people eating kai from the river. Surveys of trout in 1998 found that mercury concentrations exceeded health regulations in only 11 of the 285 fish sampled, however, comparison with accepted daily intake values indicated that some sites "could conceivably pose some threat to human health" (Mills, 1995). Arsenic levels in fish were low and below health regulation limits at all sites. Previous studies have shown marked accumulation of geothermal contaminants in Waikato River kaaeo/kaakahi (Hickey et al., 1995). The highest flesh and shell concentrations were in the Upper Waikato River associated with geothermal inputs.

Since 1996–97 an estimated 4,200 elvers (juvenile tuna) have been transferred to Lake Ohakurii (Boubée, NIWA, pers. comm.). The introduction of tuna to Lake Ohakurii poses a significant risk for accumulation of high mercury concentrations from the contaminated sediments. This in term poses a risk to people who eat large quantities of tuna from the lake. No information is available on the contaminant concentrations in Ohakurii tuna.

Some species of aquatic plants are 'hyper-accumulators' of water and sediment-derived arsenic. Watercress is among the species which strongly accumulates arsenic (Robinson et al., 2006). A health assessment of watercress from Lake Ohakurii has indicated that regular consumption of 16 g of fresh watercress a week from Lake Ohakurii would be sufficient to exceed the tolerable daily intake (Robinson et al., 2006). While watercress occurs in some locations in the upper Waikato River main stem, its distribution is limited in extent and collection would largely occur from the less contaminated tributary streams. Health risk is therefore probably minimised by the low availability and suitability of river sites for regular collection. Watercress is an accumulator of a number of other metal contaminants (especially copper).

Previous fish and mussel monitoring studies have measured DDT, PCB, dioxin and other pulp and paper related contaminants at low tissue concentrations (Hickey et al., 1997; Burggraaf, 1996). While the use or discharge of many of these contaminants would be far less now than it has been in the past, some legacy areas of sediment contamination may still contain these persistent chemicals. DDT and PCBs have had multiple potential sources throughout the river. The dioxins have historically been associated with the pulp and paper mill discharge to Lake Whakamaru.

Different species of fish are harvested for consumption from the Lower Waikato River. The major harvested fisheries would be for mullet and whitebait. The whitebait would generally be considered of low risk to human health as their short time in the river does not provide sufficient time for chemical contaminant accumulation. There is no contaminant information available for mullet.

Kooura occur throughout the river system but currently there is no information is available on their distribution or abundance, nor on contaminant concentrations in their tissue.

To assess the health risk associated with a ‘food basket’ of the most commonly eaten species it is necessary to have robust data on the concentrations of contaminants in a range of species. From the above, contaminants of most interest are heavy metals (especially copper, arsenic and mercury), methyl mercury, PCB, DDT and dioxin. Species of most relevance are tuna, mullet, kaaeo/kaakahi, trout, whitebait and kooura. Information to help understand factors controlling contaminant uptake into these food species is also needed (e.g., animal size, age and condition, lipid content, and stable isotope analysis to understand food-chain routes).

A health risk assessment for food consumption would also need to be undertaken for different risk categories (e.g., river iwi, the general population, women of child-bearing age, and children) and for realistic levels of consumption which reflect actual amounts consumed (e.g., moderate and high consumers). Such analysis would help to show if there are health risks associated with ‘normal’ consumption levels or if guidance needs to be provided to limit consumption.

If significantly elevated concentrations of multiple chemical contaminants were found to occur, a cumulative health risk approach could be used to assess the risk for all of the contaminants present (Barnes and Dourson, 1988). Such a study would cost in the vicinity of $290,000.

4. Restoration

There are legitimate concerns for arsenic and mercury contamination occurring in the water and kai of the Waikato River, although there are many unknowns and further study is needed before specific restoration actions can be confirmed. There are also initiatives underway that will address some of the existing problems. For example geothermal contaminant inputs from the Wairakei Geothermal Power Station discharge will be managed through their resource consents. Similarly, although untreated river water is high in arsenic this can be substantially removed by most conventional large-scale drinking water treatment systems. The most likely restoration action that could be undertaken would involve capping or fixing arsenic and mercury in the sediments of Lake Ohakurii. This would have the benefit of limiting arsenic and mercury release from the lake sediments into the overlying water. While this action is not being recommended at this time it has been costed for future reference.

There is considerable uncertainty regarding other contaminants in the river and it is presently impossible to assess if or when a problem might arise. This is clearly a significant information gap, but of major interest to river iwi.

There are other discharges to the river that may have an ecological impact. These include stormwater discharges and dairy wastewater discharges to streams. While it is recognised that these effects may be occurring, they are of limited extent and are of low priority in the scheme of restoration actions.

Abatement costs have been developed for three options for restoration in Lake Ohakurii: Core cost, Anticipated Treatment and Whole-lake Treatment (see Table 1).

Figure 1 shows total abatement costs of reducing arsenic and mercury, and improving sediment ecology for each of three actions: Core cost, Anticipated Treatment and Whole-lake Treatment. Abatement potentials differ amongst actions, e.g., The Whole-lake treatment action is most costly for improving sediment ecology, but at the same time generates maximum benefits for sediment ecology (e.g., 100 percent). If the objective is to reduce both mercury and arsenic, and improve sediment ecology at the same time, then the Whole-lake action has to be implemented. Improving sediment ecology is positively correlated to costs; the higher the improvement the higher the cost. The most cost-effective way to reduce arsenic is by implementing the Core cost action, at a total cost of $1,505,000. Mercury can only be reduced by implementing the Whole-lake Treatment action.

Table 1: Benefits and costs of action components for reducing toxic contaminants.

Components	Description	Details	Benefit	Cost	Options		
					1	2	3
1	Laboratory testing of Ohakurii sediments and calibration of dosage.	Validation of various product options ranging from alum (binding only phosphorus and As) to Aqua-P (binding P, As, and Hg).	Capping dose and product selection established. Proof of As (and Hg) binding efficiency.	$110,000			
2	Field efficacy trial in Whirinaki arm.	Field trial of Aqua-P applied to 74 ha of arm at 200g/m^2 (148 tonnes). Application cost estimate at 30% product cost. Monitoring allowance for As and P in and out of arm ($50k). Contingency of $75k for higher dosing rate if required.	Field efficacy established for arm of lake known to deoxygenate. Can be used to validate suitability of application method.	$585,000			
3	Alum lake dose for As removal	Base alum dose calculation (480 tonnes). Contingency of 50% for possible higher dose requirement.	Peak As (and phosphorus) removed from export to downstream lakes and water supplies.	$660,000			
4	Aqua-P lake dose for As removal	Base Aqua-P dose calculation (960 tonnes). Contingency of 50% for possible higher dose requirement.	Peak As (and phosphorus and mercury) removed from export to downstream lakes and water supplies.	$4,110,000			
5	Whole lake treatment for As and Hg removal	Base Aqua-P dose calculation (1600 tonnes). Contingency of 50% for possible higher dose requirement.	Peak As (and phosphorus and mercury) removed from export to downstream lakes and water supplies.	$6,900,000			

Table 1: (cont.)

Components	Description	Details	Benefit	Cost	Options		
					1	2	3
6	Lake monitoring programme, public presentations and reports.	Lake biota and chemical monitoring associated with treatments. Report documentation and presentations.	Monitoring to show no adverse effects of treatments. Full documentation of remediation process. Long-term monitoring will show whole-lake benefits.	$150,000			
			1 Core cost	$1,505,000			
			2 Anticipated treatment	$4,955,000			
			3 Whole-lake treatment	$7,745,000			

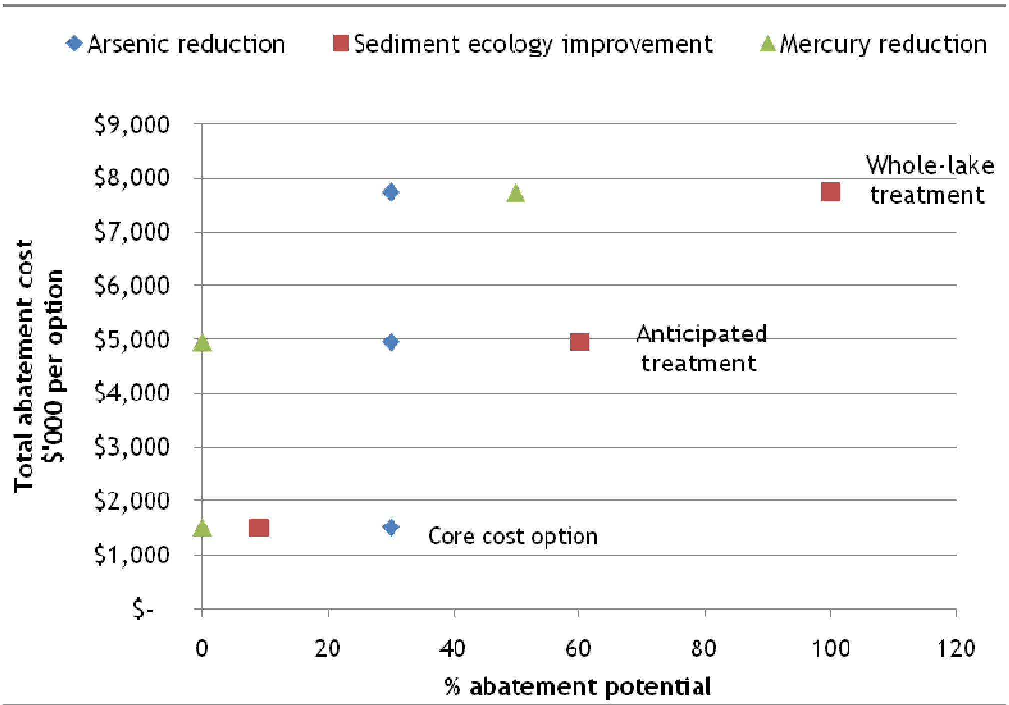


Figure 1: Abatement costs for three toxic contaminants reduction actions.

Each action has co-benefits, for example if the objective is to reduce arsenic, the core Cost option is most cost-effective and also has the additional benefits of improving sediment ecology (although at a higher cost than the other two options). Abatement potentials differ for each action. Therefore it is useful to construct another graph analysing unit costs (see other graph), which shows that the Whole-lake option is most the most cost-effective way to improve sediment ecology. Figure 2 shows the unit abatement cost per unit of reduction in arsenic and mercury, and per unit of improvement for sediment ecology for each action.

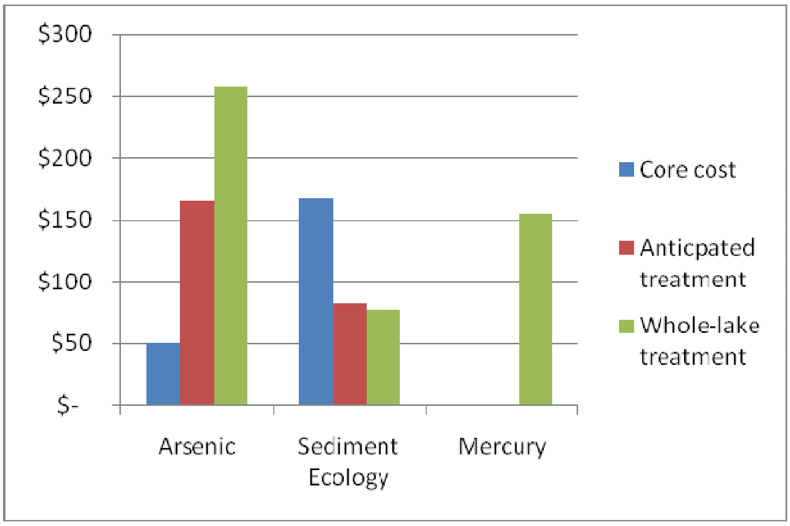


Figure 2: Unit costs for reducing toxic contaminants for all three actions.

The core cost option is the most cost effective at reducing arsenic, whereas the Whole-lake action is most cost-effective at improving sediment ecology and also has the added benefit of reducing mercury. The costs of reducing mercury for the first two actions are effectively zero as they do not have the ability to reduce mercury.

5. Information gaps

This review has highlighted many information gaps which need to be addressed before restoration recommendations can be developed further. Specific studies that are recommended include:

1. Monitor arsenic and mercury levels in tuna, kooura, and kaakahi throughout river to assess contaminant levels and monitor arsenic levels in water and watercress.
2. Undertake a full Health Risk Assessment (HRA) for mercury including food chain accumulation and species/amount consumed to gauge the seriousness of the problem and identify priorities and where effort needs to be focused.
3. Investigate arsenic mobilization mechanisms in Lake Ohakurii may to determine how big an issue it would be if the “worst case” scenario occurred of lake deoxygenation.
4. Investigate sediment arsenic toxicity to establish how big an issue it is and

determine the sensitivity of key native species (including juvenile kooura and kaaeo/kaakahi).

5. Undertake trials on sediment capping in Lake Ohakurii and assess its effectiveness at immobilisation of arsenic and mercury.
6. Investigate DDT, PCB, arsenic, zinc and copper levels in potential food organisms.
7. Undertake monitoring (at 5-yearly intervals) for emerging contaminants which may affect the river.
8. Monitor seasonal anoxia (oxygen depletion) in the hydro-lakes, especially Lake Ohakurii. (This is a fundamental measure of both the input of organic run-off, internal lake productivity and the potential of generation of sediment-associated arsenic.)

6. References

Aggett, J.; Kriegman, M.R. (1988). The extent of formation of arsenic (III) in sediment interstitial waters and its release to hypolimnetic waters in Lake Ohakuri. *Water Research 22*: 407–411.

ANZECC (2000). Australian and New Zealand guidelines for fresh and marine water quality. Canberra, Australia, National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Barnes, D.G.; Dourson, M. (1988). Reference dose (RfD): Description and use in health risk assessments. *Regulatory Toxicology and Pharmacology 8*: 471–486.

Burggraaf, S.; Langdon, A.G.; Wilkins, A.L.; Roper, D.S. (1996). Accumulation and depuration of resin acids and fichtelite by the freshwater mussel Hyridella menziesi. *Environmental Toxicology and Chemistry 15*: 369–375.

Depree, C.; Franklin, P.; Hickey, C.; Hudson, N.; Martin, M.; van Houte-Howes, K.; Wells, R. (2008). Monitoring of Lakes Maraetai and Waipapa in compliance with Environment Waikato Resource Consent 961348 No. CHH08201, HAM2008-206. NIWA client report for Carter Holt Harvey Limited, pp. 231.

FSANZ (2004). Mercury in Fish - Further Information. Food Standards Australia New Zealand. 2008.

Hickey, C.W.; Buckland, S.J.; Hannah, D.J.; Roper, D.S.; Stüben, K. (1997). Polychlorinated biphenyls and organochlorine pesticides in the freshwater mussel Hyridella menziesi from the Waikato River, New Zealand. *Bulletin of Environmental Contamination and Toxicology 59*: 106–112.

Hickey, C.W.; Martin, M.L. (1996). Lake Ohakuri monitoring: 1994/96. No. EVW60204. Prepared for Environment Waikato, pp. 54.

Hickey, C.W.; Roper, D.S.; Buckland, S. (1995). Metal concentrations of resident and transplanted freshwater mussels Hyridella menziesi (Unionacea: Hyriidae) and sediments in the Waikato River, New Zealand. *The Science of the Total Environment 175*: 163–177.

Mills, G.N. (1995). Mercury and arsenic in Waikato River fish. No. SCJ129/06. Environment Waikato, Hamilton. 47 p.

Robinson, B.; Kim, N.; Marchetti, M.; Moni, C.; Schroeter, L.; van den Dijssel, C.; Milne, G.; Clothier, B. (2006). Arsenic hyperaccumulation by aquatic macrophytes in the Taupo Volcanic Zone, New Zealand. *Environmental and Experimental Botany 58*: 206–215.

Roper, D.S.; Hickey, C.W. (1994). Population structure, shell morphology, age and condition of the freshwater mussel Hyridella menziesi (Unionacea: Hyriidae) from seven lake and river sites in the Waikato River system. *Hydrobiologia 284*: 205–217.

Rumsby, A.; Coombes, L. (2008). Investigation of Lake Ohakuri. Report prepared for Environment Waikato by Pattle Delemore Partners Ltd.

Appendix 22: Landfills

1. Overview

Contamination of waterways from landfills is an issue in the Waikato River catchment. Concerns raised during consultation for this Study ranged from municipal and industrial landfills through to small farm dumps used to dispose of farm animals. In the past there have been environmental issues linked to old landfills, controversy around siting new landfills and inappropriate dumping of highly toxic chemicals (such as organochlorine agricultural chemicals) in the Waikato River catchment.

If rain or groundwater infiltrates landfills, then leachate can contain very high concentrations of dissolved organic matter, toxic ammonia and heavy metals (especially iron and zinc), which can leach to, and contaminate groundwater or surface waters. Environmental impacts very much depend on the volume flow of leachate and the flow in the receiving waters. For example, despite highly contaminated leachate, and operating conditions that would not meet modern standards, it was not possible to discern an impact of the Horotiu landfill on the adjacent Waikato River. Impacts also depend on chemical, physical and biological processes that can occur as leachate travels through soils and other geological media, just as septic tanks rely on soil attenuation processes to treat highly contaminated leachate.

In the past, there have been problems in the Waikato River catchment with old, poorly managed landfills contaminating waterways and producing dangerous landfill gases. According to Environment Waikato's website unsatisfactory disposal sites in the region have now been closed or upgraded.[1] The website states that new landfills must use modern technology and management techniques to protect the environment. All open and most closed landfills must have resource consents from Environment Waikato. These consents set management standards including discharge controls, requirements for sealing and rehabilitation of closed sites and monitoring of ground and surface water, leachate and types of waste.

The Study team assumes that all currently used municipal land fills are adequately managed and monitored to ensure no environmental damage. The Study team was unable to identify any other specific issues around landfills and their impacts in the Waikato River catchment that were not under management by Environment Waikato. Consequently there are no recommended remediation actions around landfills.

[1] http://www.ew.govt.nz/environmental-information/Solid-waste/What-happens-to-our-waste/

The Study team acknowledges that unconsented landfills can be a potential hazard to waters, but there is a mechanism for dealing with any that are identified. Landfills are acknowledged as potential contaminated sites by Environment Waikato. They are one of 52 land uses identified in the Ministry for Environment's Hazardous Activities and Industries List (HAIL) which defines industries and activities that typically use or store hazardous substances. Contaminated sites within the Waikato Region are in the process of being registered and tested for contamination.[2] Any suspected landfill sites can brought to Enviornment Waikato's attention for registration and assessment.

[2]http://www.ew.govt.nz/environmental-information/Hazardous-substances-and-contaminated-sites/Contaminated-sites/Managing-contaminated-sites/

Appendix 23: Hydro Dams

1. Introduction

The eight hydro dams along the Waikato, from Aratiatia to Karaapiro (Table 1), have drowned important cultural and geothermal sites, altered fisheries, changed the river's ecology, hydrology, sedimentology, morphology, water clarity and quality, temperature regime, and recreational uses. These changes have impacted on the relationship of iwi with the river. However the dams have also contributed significantly to the development of the Waikato and national economies, supplying about 13 percent of the electricity and providing important system flexibility to meet daily variations in energy needs. Furthermore, they contribute to flood control and support fisheries and recreational amenities, including an international rowing facility. This appendix summarises key issues related to the Waikato hydro dams and their operation, as identified at the consultation hui and in available literature.

Table 1: Waikato hydro dams and their significance amongst moderate-large (> 10 MW) stations for NZ hydro-electric generation (Young et al., 2004).

Name	First operated	Installed capacity (MW)	%mod-large dam capacity
Karaapiro	1947	90	1.76
Arapuni	1929–46	197	3.86
Waipapa	1961	51	1.00
Maraetai	1953–62	360	7.05
Whakamaru	1956	100	1.96
Atiamuri	1958	84	1.65
Ohakurii	1961	112	2.19
Aratiatia	1964	84	1.65
All Waikato	–	994	21

1.1 Sediment and channel morphology

The dams act as sediment traps, storing on average 280,000 tonnes of sediment per year (167,000 t/yr is sand and gravel that previously would have nourished the bed of the lower Waikato and 112, 000 t/yr is silt and clay that would previously have been transported along the lower Waikato as suspended load) while 37,000 tonnes per year of fine suspended load pass downstream from Karaapiro (Hicks and Hill, 2010). Lake Ohakurii makes the greatest single contribution to this sediment storage, at about 125,000 t/yr, followed by Maraetai, Karaapiro and Whakamaru, at about 40,000 t/yr each. The reservoir lifetimes before being completely in-filled with sediment have been estimated to be in the range one thousand to several thousand years (Hicks et al., 2001). The interception of the bed-material load upstream is a major cause of falling riverbed levels downstream of Karaapiro in recent decades. The reduction in suspended sediment as water passes through the hydro dams would have increased water clarity, however, increased water residence time within the reservoirs allows more time for growth of algal phytoplankton that reduce water clarity (particularly during summer).

The accumulation of sediment within the hydro dams has important implications for restoration options involving removal of the dams or opening the dam outlets to create a non-impounded flow regime. It was estimated in 2001 that it would take at least 35 years for the stored sediment to move past Ngaaruawaahia if the river reverted to a natural flow without dams scenario (McConchie, 2001) – resulting in a corresponding period of very high turbidity, particularly during floods. This would also cause bed aggradation in the lower river, flooding, and reduced drainage of the lower river land, reducing production and increasing drainage costs. Sediment scour would also release stored arsenic.

The reduction in downstream sediment transport below Karaapiro Dam also results in downcutting of the riverbed at least as far downstream as Ngaaruawaahia. Since Karaapiro dam was built in 1947, riverbed surveys have shown that the downcutting has advanced downstream as a wave. Initially, the downcutting was focused upstream from Hamilton and the bed-material scoured from there served to replace that trapped in the reservoirs upstream. However, with time a cobbly 'armour' has formed on the riverbed between Karaapiro and Cambridge, and by the 1960s the downcutting had advanced past Hamilton. Over recent decades, at Hamilton, the downcutting rate has averaged 25-35 mm/y; some sections have deepened more while others have been more stable, apparently in response to at least partial armour development. The downcutting wave now extends past Ngaaruawaahia, although downcutting there proceeds at a lesser average rate owing to restoration of the bed-material load from the sediment scoured from upstream and from fresh inputs from the Waipa River. Further downstream, river-bed downcutting has for the most part coincided with sand extraction; when this has ceased, riverbed levels have generally recovered.

This riverbed downcutting issue was reviewed at the time of the Mighty River Power Ltd (MRP) consent hearings in 2003. Potential issues due to downcutting include erosion around engineered structures, such as bridge supports, long-term erosion of streambanks along the mainstem and in tributaries as they adjust to the lower river bed levels and perched infrastructure associated with falling water levels. It was concluded (Rogen, 2001) that the downcutting had no significant effects on the structural performance of the bridges, and that any future issues relating to pile exposure could be managed with engineering solutions. Studies of riverbank erosion then (McConchie, 2001), and since (Fellows et al., 2007) have shown no clear evidence of increased bank erosion associated with hydro-power effects. However, geomorphic responses typically take decades to develop, and since the degradation is expected to continue for the foreseeable future, continued monitoring of bank stability appears to be prudent (Hicks and Hill, 2010). As water levels have fallen with the lower bed through the Hamilton area, facilities such as water intakes, drains, boat ramps, and jetties have been perched higher than their functional levels and some have required maintenance/repair.

1.2 Arsenic

The dams also store about 7-8 percent (15 t/yr) of the total input of arsenic to the river (c. 204 t/yr) (Kim, 2010). As with sediment, arsenic storage is greatest in Lake Ohakurii (c. 8t/yr, Aggett and Aspell, 1980), where the bed may have accumulated up to 380 tonnes of arsenic since the lake was formed in 1961 (Kim, 2010). Low oxygen conditions at the lakebed during summer stratification of the hydro lakes can result in arsenic release back to the water column and summer increases in arsenic have been observed at Hamilton (see Appendix 21: Toxic Contaminants).

1.3 Power supply

MRP operates the Waikato River hydro system (installed capacity 994 MW) according to resource consents granted for 35 years in May 2006. The eight dams and nine power stations (with two at Maraetai) provide 4200 GWH on average to the New Zealand electricity requirements, representing about 13 percent of the national electricity supply and up to 25 percent of daily peak supply[1], which is strategically located closer to the centres of peak electricity demand than other major hydro-electric power sources (located in the South Island). The Waikato hydro system also provides key ancillary services to the functioning of the New Zealand power supply, including frequency control, power reserves (to cover interruptions in supply elsewhere in the system), voltage support for the central and upper North Island and black start capacity.[1] This suggests that the Waikato River hydro-electric system is a keystone asset in the New Zealand economy.

1.4 Infrastructure built around the presence of dams

The hydro system has had a fundamental impact on the development of the Waikato region. Roads and towns developed as the dams and power stations were constructed, and the dams provided road access across the river. Many water supply intakes have been designed taking advantage of the hydro system and the dams play a role in moderating the effects of floods. The international rowing facilities rely on the Karaapiro dam and the control of water levels and flows that is now possible.

[1] T.J. Truesdale evidence, Mighty River Power Resource consent hearing

Housing has been built around the lakes and property values have risen as a result of lake views. These assets and the benefits they bring to the wider community would be severely affected if the Waikato River was to be managed in its ‘more natural state’ or if the dams were removed or operated as a ‘run of river’ system. The costs of mitigating such risks would be substantial, involving for example, flood protection works, re-engineering infrastructure, and compensation.

1.5 Water levels and flow peaking regimes:

The resource consent conditions under which MRP operates have set maximum and minimum levels at the Taupoo Gates (357.25 and 355.85 m ASL), minimum flows at Karaapiro outlet (>140 m^3/s as ½ h average and always >120 m^3/s, with some seasonal variations) and requirements to assist Environment Waikato in its role as flood manager. An example of the latter is condition 5.9 that requires that when the discharge from Karaapiro exceeds 500 m^3/s and/or the flow at Ngaaruawaahia exceeds 850 m^3/s Karaapiro hydro reservoir is operated so that flows downstream of Karaapiro are similar to or less than those that would have occurred without the hydro operations in place.

MRP’s consents place no restrictions on rates of flow ramping (the rate at which flows are varied) to generate hydro-electric power to meet fluctuations in power demand. Ramping results in higher flows at Karaapiro outlet during the daylight hours that influence natural water levels downstream to about Ngaaruawaahia. Due to travel time over the 30 km to Hamilton, this results in typically highest flow in the city at midnight and lowest flows during the day. Since the mid-1990s the hydro-electric scheme has been run in a manner that has increased daily flow fluctuation and hydro lake water levels (Fig. 1). The magnitude of flow fluctuations at Hamilton increased between the mid-1990s and 2003. Between 1975 and 1997 median weekly flow fluctuations were 100 m^3s^{-1} or less. Since the beginning of 2000, the annual median flow fluctuation has been 135 and 160 m^3/s, about 50 percent higher than the 1975–1997 median (Figure 1).

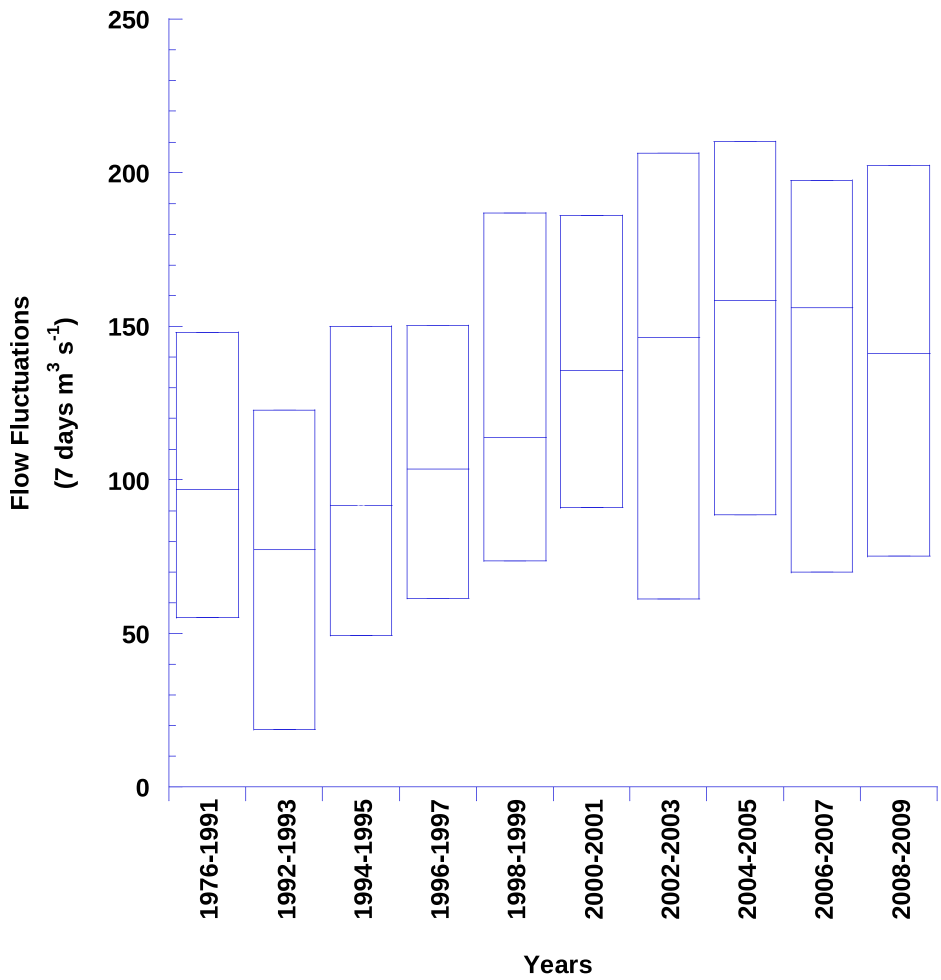


Figure 1: Box plot of weekly flow fluctuations in the Waikato River at Victoria Bridge 1976-2009. The box shows the magnitude of flow fluctuations that are exceeded 10 percent (top) and 90 percent (bottom) of the time and the bar indicates the median weekly flow fluctuation**.**

MRP argued at the 2003 hearing for renewal of its consents to operate the Waikato hydro system[2] that the ability to use hydro peaking freely is vital to the profitability of the company and important for efficiently managing the smooth supply of energy within the country and reduce the need to use greenhouse gas emitting energy sources. This need has likely increased with the increased use of wind power that fluctuates markedly in supply, requiring buffering by other sources.

Issues relating to the effects of increasing ramping that were raised in evidence to the MRP hearings and the consents Assessment of Environmental Effects (AEE) (NIWA, 1999) included:

- Potential effects on increased streambank and riverbed erosion (although this appears to be a minor issue (see Hicks and Hill, 2010)).

[2] Evidence of D. Heffernan and J Truesdale, Mighty River Power resources consents hearing.

- Reduced macrophyte abundance in lakes and the river between Karaapiro and Ngaaruawaahia (with flow on effects on invertebrate and fish habitat and food supply).

- Increased size of the varial zone on lake and river margins, where sediments are exposed to air for part of the day, with potential negative effects for sediment character, invertebrates (particularly non-mobile net-building caddis-flies at Aratiatia and Arapuni tailraces and snails), fish spawning (particularly smelt) and strandings, and aesthetics.

Table 2 shows the predicted effect that ramping has on the varial zone and river habitat.

Table 2: Predicted effects of Karaapiro flow regimes on width of varial (daily dewatered) zone through Hamilton city (Jowett, 2003).

Flow fluctuations (m^3s^{-1}) (Median, 10 and 90% Range)	Varial zone width (m)	Area of suitable macrophyte habitat (m^2/m)	Representing
100, 180–280	10	1.43	1975-95 average
140, 160–300	13	1.1	early 2000's
200, 140–340	17.5	0.56	max. allowed pre- consents

Anecdotal evidence on ramping effects presented at consultation hui identified additional impacts of low flow levels during the day and unpredictable changes in water level on waka ama (boat strandings/groundings), swimming, and potential effects on kooura that use river edge habitats in medium to large rivers (Hicks, 2003). The abundant common freshwater snail *Potamopyrgus antipodarum*, that was considered a core component of the Waikato River fauna but is vulnerable to ramping effects (due to its preference for macrophytes and slow velocity areas that occur along margins (Jowett et al., 1991)) has declined at the Hamilton Traffic Bridge over the period from 1991–2009 (National Rivers Water Quality Network, NIWA unpublished data).

The hearing commissioners to the MRP consents took the view that the potential impacts described were insufficient to out-weigh the overall benefits of the hydro-electric scheme and granted the consents with the level controls described above and requirements for ongoing monitoring the review impacts.[3]

[3] Mighty River Power Taupo-Waikato Consents Decision Report (2003) EW Document #: 852012.

1.6 Impact of hydro dams on fish movement

Prior to the construction of the hydro dams, the Horahora Falls (near the current Horahora Bridge, 15 km upstream of Karaapiro Dam) would have been a natural barrier to upstream movement by non-climbing fish (e.g., smelt and iinanga) whereas the Arapuni Falls (25 km upstream of Karaapiro Dam) were the likely barrier to most climbing fish (tuna, lamprey, climbing galaxiids), although kooaro appear to have been able to move throughout the river system. Thus the Karaapiro Dam has limited natural upstream fish movement by 15–25 km. However this is mitigated by the elver transfer programme that collects migrating elvers at the Karaapiro dam face in December to March each year and transfers them to each of the hydro dams except Ohakurii (avoided due to potential for geothermal-derived metal contamination of tuna).

Whilst the transfer programme has facilitated the tuna fisheries in impoundments above the lakes, it does not contribute to the spawning runs to the sea because most downstream migrating tuna are killed on passing through the power station turbines (see Appendix 5: Tuna).

1.7 Impact of impoundments on traditional features

The hydro dams have drowned many natural features (e.g., rapids, cliffs, geothermal features) and sites of cultural significance to Maaori.

1.8 Impact of impoundments on algal growth

The eight Waikato River hydro dams have the vast majority of the total storage within the Waikato catchment, totalling 570 million m^3 equivalent to 16.5 days of the average Waikato flow at Mercer (400 m^3/s). Impoundment increases the residence time of water flowing from the catchment to the sea, thus allowing more time for phytoplankton biomass to develop in response to light and nutrients, with associated changes in water colour and clarity (Rutherford et al., 2001).

The Waikato River Catchment Water Quality Model (WRWQM, Rutherford et al., 2001) has predicted the influence of the dams on factors including water travel times and water quality along the river mainstem. The WRWQM predicts that the dams increase the travel time between Taupoo and Karaapiro from 62 hours to 830 hours under summer low flow conditions and from 48 hours to 375 hours under winter high flow. These increases in residence time were predicted to result in 3-4-fold increases in suspended algal biomass (phytoplankton, measured as chlorophyll *a*) at Karaapiro and to reduce the water clarity at Karaapiro by 35 percent (2 m to 1.3 m) during summer low flows and 10 percent during winter high flows.

2. Actions

Possible actions raised during the consultation process and during the MRP consent hearings include the following:

1. Reducing the magnitude of flow peaking below Karaapiro Dam: Restricting the hydropeaking operation of Karaapiro Dam to the 1976-1991 level, whilst allowing the existing permitted operating regime of the dams upstream to continue.

2. Ceasing use of all the hydro dams for electricity generation and opening their sluice gates so that the river reverts to natural levels.

3. Removing all the hydro dams so that the river reverts to natural levels and natural longitudinal connectivity is restored.

These actions would be accompanied by complex resource consenting and other legal issues.

3. Costs

Direct costs to the Waikato River Authority would be relatively low (mainly legal) for the reduction in hydro peaking to 1976-1991 levels. However, there would be flow on costs to the economy from likely higher electricity prices, the difficulty finding a replacement system that can respond to hourly fluctuations in peak power demand, and to increased GHG emission taxes arising from the use of non-hydro electric generation.[4] Costs would be at least an order of magnitude higher for the options of returning the river to a natural level and flow regime and dam removal. This would create a need to replace 13 percent of the national electricity supply (up to 25 percent of daily peak supply) that is strategically located closer to the centres of peak electricity demand than other major hydro-electric power sources (located in the South Island). Evidence presented at the MRP hearings suggested that the cost of replacing the Waikato hydro system generating capacity would be in excess of $4 billion in 2003 dollars assessed over the next 35 years.

Dam removal or natural flow options would require substantial expenditure to rehabilitate the exposed areas of dam bed and the dam removal option would involve further engineering expenses for dismantling and disposing of the dams. These options would also have substantial lost opportunity costs due to the loss of utility of amenities that have developed around the hydro dams, including cycleways, outdoor education and boating facilities, and the international rowing facility at Karaapiro. Furthermore, they would also incur costs downstream to deal with the

[4] T.J. Truesdale evidence to Mighty River Power Resource Consent Hearings.

increased flood risk due to downstream movement of sediment stored in the dams and to manage and compensate for effects on infrastructure built around the presence of dams.

4. Timing

Alteration of the hydro-peaking regime would require variation to MRP's existing resource consents. This would almost certainly be appealed, delaying its implementation. There would also be considerable delays before alternative power supply arrangements could be made.

Restoration of natural river levels would also involve considerable legal complexities If these could be resolved it would take two years before a new flow regime was stabilised, but it would take decades before fine sediments were flushed from the system and upstream fish access would still be restricted at Karaapiro Dam. It would likely take decades before alternative electricity generation capacity could be developed. If it was decided to wait until the dams had reached the end of their existing operational life, the removals would likely be staggered over the next century.

5. Outcomes

Reducing the magnitude of flow peaking below Karaapiro would reduce the size of the marginal band of the river that is regularly dewatered (the varial zone) in Hamilton city by about 30 percent and increase the area of suitable habitat for macrophytes by about a similar amount. This is likely to benefit river ecology by reducing the stranding of invertebrates and increasing the macrophyte habitat for them to colonise. However it would also result in the spread of and increased growth of aquatic weed beds which will affect swimming access and boating and other recreational activities.

The options to reduce the hydro-peaking or remove the hydro-electric function of the dams would have substantial negative impacts on the regional and national economy. The reliability and cost of electricity supply would be affected and if fossil fuels had to be used to replace the lost generation New Zealand's green house gas emissions would increase.

Returning the river to a natural level would reduce the residence time of water in the river (and hence algal growth and biomass). However, the net effect is likely to be further reductions in water clarity throughout the river system for a period of decades as sediment stored within the hydro reservoirs was eroded and transported downstream. The deposition of this large amount of sediment in the lower river would increase flooding and navigation hazards and require considerable additional expenditure on dredging and flood protection.

Other impacts would include:

- Dam removal would remove the ability to control flooding through reservoir manipulation and storage.
- Upstream fish passage would not improve, unless the dams were removed, because the outflow through the dams' sluice gates would likely present a velocity barrier.
- Dam removal would change opportunities for recreation and fishing. The loss of the international rowing facility on Karaapiro would be of particular significance.

6. Uncertainties and information gaps

There is uncertainty about the environmental impacts of the increase in flow variability due to increased hydro peaking since the 1990s. Monitoring required under MRP's consents will help to establish the nature and extent of possible effects.

The effects on the regional and national economy of altering the operation of the Waikato hydro scheme to reduce flow fluctuations below Karaapiro or removing the dams and returning the river to a natural flow regime are believed to be prohibitively large, based on general information presented to the MRP consent hearings. A more accurate costing of these effects would require a major economic study, but the preliminary cost estimates presented in the MRP consent evidence are sufficient for an initial assessment of these options.

7. Recommendations

It is concluded that the keystone nature of the Waikato hydro system to the prosperity of the Waikato region and New Zealand means that placing significant restrictions on the system's operation beyond those decided in the 2003 MRP resource consent process is not warranted. The MRP consent conditions include monitoring requirements for specific issues where potential for environmental impacts exist, a review clause if blue-green algal blooms are detected, and requirements for consultation and accommodation with river users around flow management to fit in with specific events. These existing conditions appear sufficient to manage issues resulting from the scheme's operation, without need for the Waikato River Authority's involvement. Similarly dam removal would not restore the Waikato River to its original state and there would be considerable negative effects as sediment and contaminants were flushed from the system. Also, the benefits that the hydro system provides in terms of flood storage and flood management would be lost. For these reasons, dam removal is not recommended either.

8. References

Aggett, J.; Aspell, A.C. (1980). Arsenic from geothermal sources in the Waikato catchment. *New Zealand Journal of Science 23*: 77–82.

Fellows, D.; Macfarlane, D.; Mabin, M. (2007). Waikato River bank erosion study. Report prepared by URS New Zealand Ltd, Christchurch, for Environment Waikato, Document 4208950-Rev A, April 2007.

Hicks, B.J. (2003). Distribution of fish and crayfish in a Waikato stream in relation to basin area. *New Zealand Journal of Zoology 30*: 149–160.

Hicks, D.M.; Hill, R.B. (2010). Sediment regime: sources, transport and changes in the riverbed. *In*: Collier, K.J. (ed.) *The Waters of the Waikato,* pp. 71–86.

Hicks, D.M.; Webby, M.G.; Duncan, M.J.; Harding, S. (2001). Waikato River sediment budget and processes. National Institute of Water and Atmospheric Research Ltd, NIWA Client Report No. CHC01/24. Christchurch, p.

Jowett, I.G.; Richardson, J.; Biggs, B.J.F.; Hickey, C.W.; Quinn, J.M. (1991). Microhabitat preferences of benthic invertebrates and the development of generalised *Deleatidium* spp. habitat suitability curves, applied to four New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research 25(2)*: 187–200.

Kim, N.D. (2010). Arsenic in bed sediments. *In*: Collier, K.J. (ed.) *The Waters of the Waikato*, pp. 80,

McConchie, J.A. (2001). Waikato River geomorphic processes. School of Earth Sciences, Victoria University, Report prepared for Mighty River Power Ltd. Wellington, p.

NIWA (1999). Assessment of the environmental effects of hydro electricity operations on aquatic habitats and biota of the Waikato River. NIWA, NIWA Client Report CHC01/34. Christchurch, 101 p.

Rogan, G.A. (2001). Waikato River: Karaapiro to Hamilton North assessment of the potential effects of low water levels on bridge structures. Report 5/62485, Opus International Consultants Ltd, Hamilton.

Rutherford, J.C.; Williamson, R.B.; Davies-Colley, R.J.; Shankar, U. (2001). Waikato catchment water quality model. NIWA Client Report ELE90229/3. Hamilton, p.

Young, R.; Smart, G.; Harding, J. (2004). Impacts of hydro dams, irrigation schemes and river control works. *In*: Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrell, B.K. (eds). *Freshwaters of New Zealand*, pp. 37.31–37.15, New Zealand Hydrological Society and New Zealand Limnological Society, Christchurch.

Appendix 24: Flow effects

1. Introduction

Flow is a fundamental intrinsic factor affecting aquatic ecosystems. This appendix provides a summary of the various processes that can affect flow as well as the effect that management intervention and potential restoration actions might have on flow regimes. This information has been used in many sections of the main report.

The flow regimes of streams and rivers can be altered by changes in their catchment landuse (e.g., when forestry is replaced by pasture), riparian management, wetland restoration, dams and sand mining. This occurs because of the influences of vegetation type on evaporation and interception losses of incident rainfall and on soil moisture that influences runoff (Duncan and Woods, 2004; Scotter and Kelliher, 2004), water storage within dams, and dampening of flood flow velocities by rough riparian vegetation. Estimates of these effects are summarised in Table 1.

Table 1: Predicted effects on flows of land use change, riparian buffers and wetland restoration – rational for these provided in review below:

Action	**Low flow**	**Estimates annual runoff reduction**	**Maximum flood flows < 100 km^2 catchments**
Pine afforestation of pasture	minus 50%	minus 300-400 mm, 35-45%	minus 30% (5-50%)
Native restoration of pasture	plus 10%	minus 70 mm, 7%	minus 20%
15 m native riparian buffers	minus 3%	minus 30 mm, 3%	minus 10%[1]
5 m riparian buffers	minus 1%	minus 10 mm, 1%	minus 3%
Wetland restoration effect per 1% increase in catchment area as wetland	plus 8%[2]	nil	minus 4%[1]

[1] The actual effects on downstream flooding will be influenced by how reducing the speed of the flood wave affects the phasing of flood waves between major tributaries – in the Waikato the phasing between the mainstem and the Waipa is critical for flood effects in Hamilton (water can back up from the Waipa) and lower river. Understanding this will require careful hydraulic modelling at a later stage.
[2] Based on studies in Illinois (Demissie and Khan, 1993) so moderate level of uncertainty.

These effects have implications for sediment and nutrient yields, water quality, flooding, instream habitat, and availability of water for irrigation and hydropower generation.

Reduction in river bed levels due to sand mining may also reduce flood levels and lower groundwater levels (influencing wetlands). The effect of riverbed lowering on ameliorating flood risk along the lower Waikato was reported by Freestone (2003), while it remains the policy of the Environment Waikato Asset Management Group to control riverbed levels through targeted commercial extraction or maintenance dredging. Downstream from about Huntly, falling riverbed levels, in conjunction with land drainage works and pumping, have drawn down the water table in the peaty wetlands adjacent to the river. As these dry out, the peat under the wetlands shrinks and the land surface subsides – a process that displaces ecological boundaries and re-elevates the flood risk on the floodplain. For example, subsidence rates averaging 65-170 mm/yr from 1967-81 have been reported from Motukaraka Swamp (Freestone, 2003).

Dams also store sediment, and alter downstream water quality and channel morphology (Young et al., 2004). The performance of dams is dealt with in more detail below (see Section 3).

2. Land use and riparian management

2.1 Water yields and low flows

Pasture land use has lower evaporation than native forest or pine forest and hence has greater annual runoff (Fahey et al., 2004). However, because quickflow runoff (i.e., that during rain events) is greater under pasture, subsequent low flows can be lower under pasture than native forest land cover. Changes in annual runoff after whole catchment pine afforestation of grassland in New Zealand range from 30% to 81% (Fahey et al., 2004), in line with the average 44% reduction in streamflow from analysis of many international paired catchment studies of the effects of pine afforestation of grasslands (Farley et al., 2005). Eucalypt plantations had greater runoff reduction effects (average 75%) than pines (average 40%) in Farley et al.'s (2005) comparison.

Flow effects vary during the typical 27-30 year rotation of pine forest planting, growth, harvest and replanting, with these variations most apparent at small catchment scales (<300 ha) where most of the catchment may be logged over two-three years. However, at medium to large scales (>5000 ha in forest), effects of forestry on water yield are normally averaged out because different parts of the area in planted production forest are typically in different phases of the rotation at any one time (in order to provide a sustainable flow of work and product from the forest).

2.2 Annual runoff

The average annual runoff of the Waikato River at Mercer is 900 mm (or 400 m^3/s, based on data in (EW, 2008). This varies within sub-catchments in relation to rainfall (c. 1200 mm in lowlands, c.1700 mm on hills and up to 3200 mm on upper slopes of Ruapehu), vegetation and geology.

2.3 Pine afforestation effects on runoff

At Whatawhata, annual water yield from a pasture catchment (970 mm) decreased 29% (285 mm) by year 6 after planting (mainly pine) 62% of the catchment and averaged 19% (158 mm) less than the adjacent fully native forest catchment (Quinn et al., 2009); similar changes were observed in year 8 after planting (Quinn unpublished data). This indicates a 47% (450 mm) reduction on pasture water yield would have occurred if the whole catchment were afforested, assuming a linear relationship between area afforested and water yield. Annual flow from pasture at Whatawhata was 7% (115 mm) higher than from native forest.

Somewhat lower responses to pasture afforestation by pines were found at Pukukohukohu, in the upper Waikato catchment near Rotorua, where rainfall was similar to Whatawhata but geology differed (pumice soils over impermeable bedrock, c.f. yellow-brown earths over greywacke at Whatawhata). Beets and Oliver (2007) compared paired catchments in native forest and in transition from pasture to pine at Pukukohukohu and found annual water yield from pasture planted in pine decreased, in proportion to the change in leaf area index, by up to 400 mm when leaf area index peaked. They predicted the annual flow from a managed pine site of average-to-high productivity over a 30-year rotation will be 160-260 mm lower than from pasture (i.e., 21-35% lower than average annual runoff from pasture of 745 mm) and 100 mm (17%) lower than from native forest.

Based on these two Waikato studies, it is estimated that the average effect of complete pine afforestation of pasture over the forest rotation would be to reduce annual water yield by about 300 mm. The difference in effects between Whatawhata (c. 450 mm at year 6) and Purukohukohu (maximum 400 mm for mid-late rotation forest, average over 30 year rotation 160-260 mm) result in there being a high level of uncertainty around this estimate.

2.4 Riparian forest effects on runoff

Large riparian buffer forests can also influence streamflows. Evaporative losses from buffers are likely to be larger than for full forests because they have more edge, thus allowing greater wind-driven evaporation (Smith, 1992). In a study in Nelson

(Moutere, rainfall 1020 mm/y), wide riparian pine riparian plantings (25-35 m strip enclosing the stream, i.e., similar to 15 m buffers on each side as proposed for Kyoto compliant carbon forests) that occupied 20% of the total catchment area reduced the annual runoff by 68-104 mm (= 21-55%) when the stands were 8-10 years old. Native riparian plantings are expected to have lesser effects on flow than these pine plantings, based on comparisons of water yield from the native forest/pine at Whatawhata and Pukukohukohu, but we lack direct evidence of how much less. For the purposes of the scoping study, it is assumed that reduction in water yield relative to pasture of 15 m native buffers (total width 30 m, 20 m and 10 m) would be one third Smith's (1992) finding for 30 m wide pine plantings (i.e., mean 86 mm/3 = 30 mm or 3%). Similarly the effects of 10 m and 5 m native buffers (20 m and 10 m total widths) are estimated to be proportionately lower (i.e., 2% and 1%, respectively).

2.5 Low flows

At Whatawhata (Waipa hill country, annual rainfall 1650 mm, 3 km^2 catchments) the annual 7-day low-flow (a commonly used low flow index) was 11% lower in pasture than in an adjacent native forest catchment (Quinn et al., 2009). This suggests a 10% increase in baseflow is likely once pasture is restored to native forest, however regrowing native forest is likely to have greater water demand than old growth forest, so there may be little increase in low flow from conversion of pasture to native forest in the first 50-100 years.

Afforestation of 62% of a pasture catchment at Whatawhata (58% pines + 4% natives) reduced the 7-day low flow by 33% (Quinn et al., 2009). Scaling this to 100% afforestation, assuming that flow reduction is proportional to area afforested, indicates that complete afforestation would result in a low flow reduction of 55% (Quinn et al., 2009). This is greater than the 20% reduction in the 7-day mean low flow in Berwick forest in east Otago (Smith, 1987). In smaller catchments, pine afforestation near Rotorua (Dons, 1987) and Nelson (Duncan, 1995) extended the duration of periods of zero flow.

In contrast to riparian forests, riparian and other wetlands store water and enhance base/low flows (Mitsch, 1992). Hence, as well as reducing contaminant concentrations and loads (Tanner et al., 2005), restoration of wetlands on drainage systems can modify flood and baseflows.

Lowland agricultural areas of the Waikato have been drained extensively using under-field (mole-pipe) systems linked to open drains that typically lower the water table and bypass wetlands. Upland Waikato agricultural areas commonly have valley bottom wetlands at the head of stream channels and riparian wetlands occur where springs emerge. However these wetlands are commonly drained by digging a central channel that lowers the water table to provide more grazing land. Thus there is scope to restore the hydrological functions of wetlands in pasture by creation of artificial wetlands on tile drains and infilling/damming channels cut through wetlands and restoring wetland vegetation buy planting and livestock exclusion.

The relationships between wetland management and flow regimes have not been systematically addressed in the New Zealand context, so the estimates on wetland effects on flows in the predictions table are based on a study in the USA (Demissie and Khan, 1993). Some local evidence indicates that these predictions may be quite conservative for effects on low flow enhancement in lowland Waikato catchments: lowflow yield during the current Waikato drought (mid-march 2010) was >200% higher from a 10 ha catchment with a large wetland (2.3% of catchment area) at its outlet than from the larger total catchment that has low wetland cover (Dr R.J. Wilcock, NIWA, pers. comm.). This catchment, Toenepi near Morrinsville, has similar characteristics to many lowland Waikato streams. This compares with 18% increase (8% x 2.3) predicted based on Demissie and Khan (1993). Specific studies on low flow enhancement of wetlands are needed to better understand their effects in the Waikato.

2.6 Land use and mitigation effects on flood peaks

2.6.1 Afforestation of pasture

Afforestation of pasture is expected to reduce flood flow peaks (by increasing interception and infiltration of rainfall into soil), with benefits for flood hazard management throughout the catchment, particularly in lowland areas. Afforestation of pasture with pines and gorse reduced flood flows by 80% in a small catchment study in Nelson (Duncan and Woods, 2004) and pine afforestation reduced storm flows by about 50% in a small Rotorua catchment (Dons, 1987). There was an indication of reduced peak flows in the first 8 years after the 62% area afforestation at Whatawhata when the median ratio of annual maximum was 20% lower than in 7 years before changes. This suggests complete afforestation may reduce storm flows by about 30%.

Concerns about the hydrological effects of recent conversion of pine forest to pasture in the upper Waikato catchment led to Environment Waikato commissioning, in 2007, a modelling series of studies on potential effects on flooding throughout the downstream catchment of the potential pine-pasture land use change of 12% of the total land area of the Taupo to Karapiro catchment. Findings are summarised on the Environment Waikato website[1]. Although the Environment Waikato coordinated study addresses *deforestation* (pine-pasture land use change), it is useful for

[1] http://www.ew.govt.nz/Projects/landusechangeupperwaikato/

evaluating the level of benefit that would accrue if afforestation of pastures was adopted as a restoration action. Key predictions are summarised in Table 2.

Table 2: Changes in flood peaks predicted by Environment Waikato Technical Panel for a 12% change from pine forest to pasture land use in the upper Waikato River catchment[1].

Landscape scale	Small flood (5-yr rainstorm)	Medium flood (20-y storm)	Large flood (100-yr rainstorm)	Extreme flood (500-yr storm)
Local flooding within Upper Waikato 10–100 km^2 catchment area, 0–80% upstream land use conversion	Significant increase (5–50%) for streams where most of catchment has land use change	Significant increase (5–50%) for streams where most of catchment has land use change	Very significant increase (more than 50%) for streams where most of catchment has land use change	Very significant increase (more than doubled) for streams where most of catchment has land use change
Upper Waikato Taupoo-Karaapiro inflow 4,405 km^2 area, 542 km^2 land use conversion (12%)	Little or no change	Little or no change	From 2–9% increase in peak flow rate (average 4%) 3–5% increase in 72-h flow rate (average 2%)	From 3–16% increase in peak flow rate (average 7%) 2–9% increase in 72-h flow rate (average 4%)
Waikato River at Hamilton 8,230 km^2 area	Little or no change	Little or no change	40–110 mm water level increase 6–21 m^3/speak flow increase	280–530 mm water level increase 70–140 m^3/s peak flow increase

[1] http://www.ew.govt.nz/Projects/landusechangeupperwaikato/

The overall conclusions from the study, as agreed by the Technical Expert panel, are that the effect on flood flows and water levels from land use change in approximately 12% of the Upper Waikato catchment are likely to have:

- Significant to very significant increases in peak flow rate for local flooding in small catchments where full conversion is expected.
- At Hamilton, insignificant impacts during small to medium floods, increases of up to 40-110 mm in peak water level for large floods, and increases of 280-530 mm for extreme floods.
- From Ngaaruawaahia to Rangiriri, insignificant impacts during small to medium floods, increases in the peak flood water level of 20-40 mm during large floods, and increases of 170–270 mm in extreme floods.

Afforestation of pasture is likely to produce reductions on peak flows of similar magnitude to these predicted increases in response to deforestation.

2.6.2 Riparian forest and wetland restoration/revegetation

Riparian forests and wetlands are also expected to attenuate the peak flow of runoff into the stream channel in small rainfall events (Smith, 1992). Furthermore, well-developed riparian vegetation, and particularly forests, has greater hydraulic roughness than short grass and hence retards the progress of flood flows that spill out into the riparian area (Coon, 1998). This may cause increased local flooding of the riparian area and adjacent land, but typically reduces the peak flow in downstream reaches (Anderson et al., 2006). Anderson et al., (2006) predict that 3 m high riparian vegetation in their 50 km long model channel would reduced the downstream flood peak by 10% for 2-year annual return period floods and 13% and 50-year annual return period floods, respectively. Factors expected to influence these effects are the likelihood of overbank flow events (less in deeply incised channels), the width of the riparian area and floodplain, the extent of wetlands, and the roughness (size/density in relation to the flow depth) of the riparian vegetation (Sholtes, 2009).

Demissie and Khan (1993) found 4% reduction in peak flows in relation to rainfall for every additional 1% of catchment area as wetland in their USA study of 30 watersheds, and we have used this relationship for estimating benefits of wetland restoration in this scoping study.

3. Dams and flows

3.1 Introduction

Dams affect the river flow regimes and, in some cases, provide opportunities to manage floods and low flows. Dams can reduce flooding, through storm flow storage (e.g., management of the Waikato hydro dams assist with flood control), and have variable effects on low flows depending on their design, location and operating regimes. Farm dams typically reduce low flows, particularly headwater dams that capture flows of headwater ephemeral streams. Dams can also reduce sediment loads, enhancing water clarity by reducing downstream suspended solids, but can also increase algal phytoplankton biomass (reduces water clarity) by increasing residence time of water in the river (Pridmore and McBride, 1984). Dams also influence downstream channel morphology, particularly by reducing peak flows and sediment supply (e.g., Young et al., 2004; McKerchar et al., 2005). The Waikato hydro dams produce daily fluctuations in lake and river water levels that affect the edge/littoral habitat available for macrophyte growth and habitat for macroinvertebrates and fish. This hydropeaking issue is discussed in more detail in the Appendix 23: Hydro Dams.

3.2 Farm dam rules

The Waikato Regional Plan has a permitted activity rule allowing (with conditions) creation of farm dams in the bed of ephemeral rivers or streams, where: the catchment area is less than one square kilometre (100 hectares), and the maximum water depth of the pond is less than three metres, and/or the dam retains not more than 20,000 cubic metres of water. Larger dams require resource consents.

3.3 Waikato Catchment study area dam numbers

There are 246 dams in the Waikato River catchment study area listed in NIWA's database (McKerchar et al., 2005) developed during 2004–05 (Figure 1). This includes records provided by Environment Waikato and the territorial local authorities, and so appears not to include the numerous small dams created under Environment Waikato's permitted activity rule - this accounts for only eight farm stock water dams being listed as 'permitted activity' dams that do not need to be notified. Average hydraulic residence time (HRT) was calculated for each of the 120 dams for which volume estimates are available, by dividing the volume by the mean inflow, calculated from the upstream catchment area and the average specific discharge of 28 $L/s/km^2$ (EW, 2008). Only three dams had 'high' HRT (after McKerchar et al., 2005; > 100 days). Twenty-three had 'medium' HRT (6–100 days), corresponding to interception of 1–25% of runoff, and the majority (91) had low HTS with little effect on flow regimes. Median HRT was greatest for silt detention dams and least in recreational/aesthetic and tailings/mining dams (Table 3). The Waikato hydro dams have HRTs between 1.5 days (Aratiatia) and 10.5 days (Ohakurii). Rural and urban water supply dams had the greatest range of HRT: this was greatest for the WaterCare dams in the Hunua Ranges. Rural and urban water supply dams had the greatest range of HRT: this was greatest in the Watercare dams in the Hunua Ranges that provide water supply to Auckland. A farm dam built within the permitted activity rule (i.e., 20,000 m^3 volume, mean depth 2 m, 50 ha catchment with 1,000 mm runoff) would occupy c. 2% of the catchment and have an HRT of 15 days.

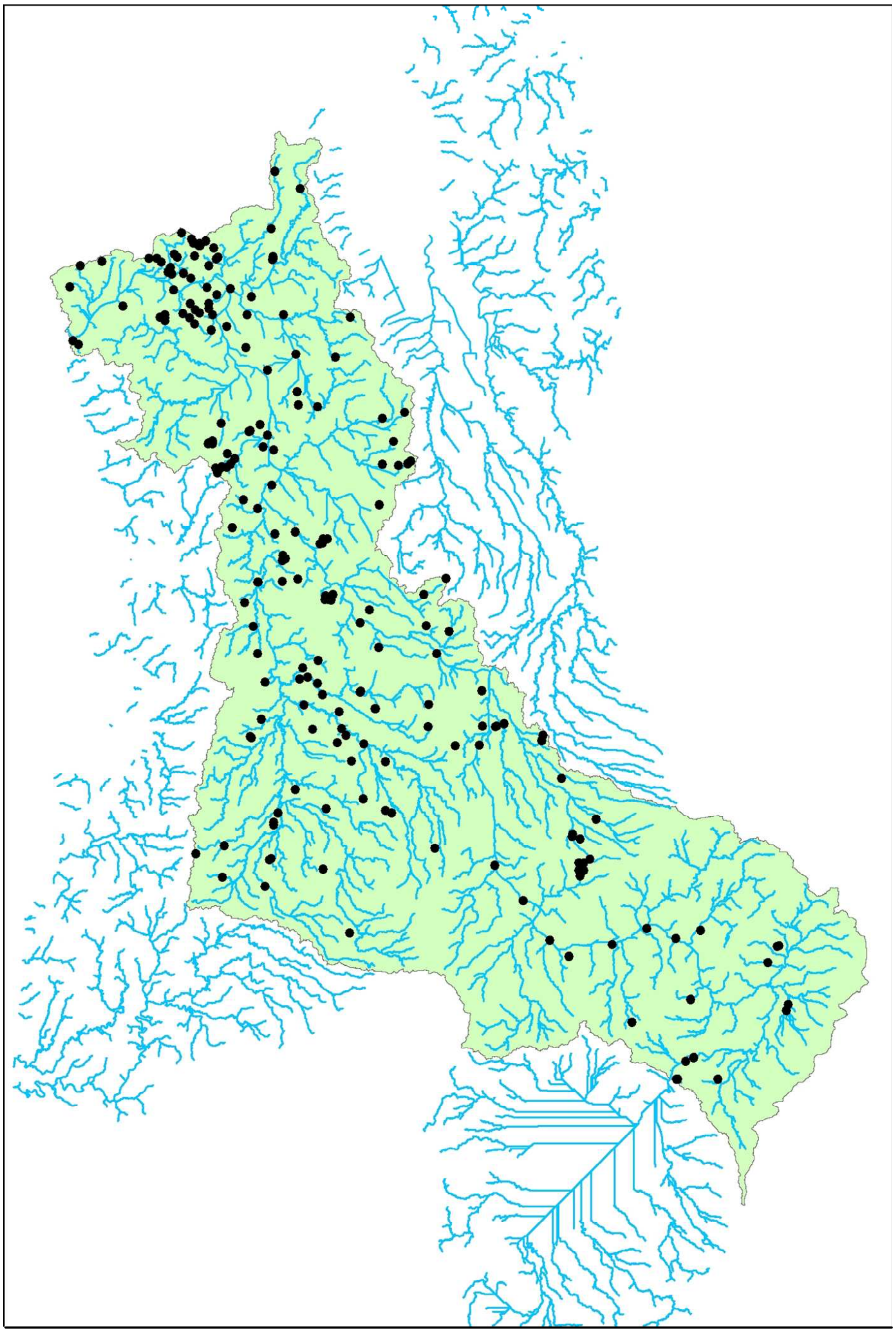


Figure 1: Location of dams listed in the NIWA database within the Waikato River catchment area (shaded in green) overlain on the River Environment Classification (REC) stream network showing ≥3rd order streams.

Table 3: Summary of dams within the Waikato River catchment study area in the NIWA database (McKerchar et al., 2005). Types ordered by median hydraulic residence time (HRT).

Dam type		**HRT (days) median, range, n for which HRT calculated**	**Volume stored by type in dams for which estimates are available (Million m^3)**
Silt detention	17	16, 7–27, n=17	0.1
Farm stock water	8	8.4, 0.6–10.5, n = 8	0.06
Flood control	62	6, 0.1–64, n=13	>1.5[1]
Waikato hydro dams	11	5, 1.5–10.5, n=8	570
Irrigation	45	3.5, 0.1–208, n = 45	0.8
Water supply (urban and rural)	18	0.9, 0.02–416, n=18	56
Recreational/aesthetic	70	0.7, 0.05–3.8, n=21	>0.26[2]
Tailings/mining	2	0.9, n=1	negligible

[1]Volumes available for only 20% of dams of this type, so actual storage may be c. 5x higher.
[2]Volumes available for only 37% of dams of this type, so actual storage may be c. 3x higher.

The eight Waikato River hydro dams have the vast majority of the total storage within the catchment totalling 570 million m^3, equivalent to 16.5 days of the average Waikato flow at Mercer (400 m^3/s) (Table 3). The next largest store of 56 million m^3 is in the water supply dams, while other dam types have estimated storages if less than 1.5 million m^3.

3.4 Farm dams

3.4.1 Farm dam numbers

The actual number of farm dams in the study area is undoubtedly under-estimated in the NIWA database (Table 3). Some large areas of the Waikato are probably unsuitable for creation of small dams due to problems with sealing them in areas of peat and pumice soils. However, Fish & Game NZ staff spoken to considered that most hill-land farms have at least one or two dams for waterfowl or aesthetic purposes (pers. comm. Ben Wilson, Fish and Game NZ, Hamilton). A scan of 60 1 km^2 areas of hill farm around the Waikato catchment on Google Maps satellite images located 32 dams, confirming that these are under-represented in the NIWA database. Farm dam creation was subsidised by Acclimatisation Societies in the 1970–80's (pers. comm.). Currently, Fish and Game NZ is active in wetland restoration (particularly to enhance waterfowl) in the eastern part of Whangamarino wetland, where 25 ponds have been developed recently.

3.4.2 Farm dams as a water quality management tool

NIWA has included ponds on headwater/ephemeral streams as a mitigation tool for control of sediment and nutrients in NPLAS (Nitrogen and Phosphorus Load Assessment System). Pond performance was simulated by Rob Collins using BUCSHELL. Time series of sediment loads were generated for four soil drainage types and three rainfall records. The loads were passed through ponds of various sizes (pond volume in m^3 as a percentage of catchment area in m^2), assuming a single settling velocity of 0.000001 m/s, corresponding to a fine sediment (coarse clay). The model assumes that there is no infiltration through the base of the pond. The depth was 1.5 m, with vertical sides. A preliminary set of simulations showed that there was little effect of slope in terms of percentage removal of sediment, so slope was not included as a factor thereafter.

The results are shown in the Figure 2 and 3 below. As the rainfall increases, the pond performance deteriorates, as there are higher hydraulic loadings. As the soil drainage gets worse, the performance also deteriorates, for similar reasons. Also, as the pond size increases, the performance improves. Note that these results are for fine sediment only.

The performance decreases exponentially ($1-E = \exp(aS)$) where S is the size and E is the efficiency (Figure 3). This will be useful for interpolation of results for different pond sizes.

Nitrogen and phosphorus removal efficiency are estimated to be c. 50% of that for fine sediment, due to dissolved fractions and particulate fractions associated with very fine sediment.

Colin Stace (soil conservationist, Environment BOP) commented that it is hard to get more than 0.3% storage in detention ponds in steeper areas. This is expected to increase in flatter areas.

Dams on perennial streams can have negative effects on some aspects of downstream water quality by increasing water temperature and reducing dissolved oxygen (Maxted et al., 2005). These can be avoided by locating dams off-channel and in ephemeral channels.

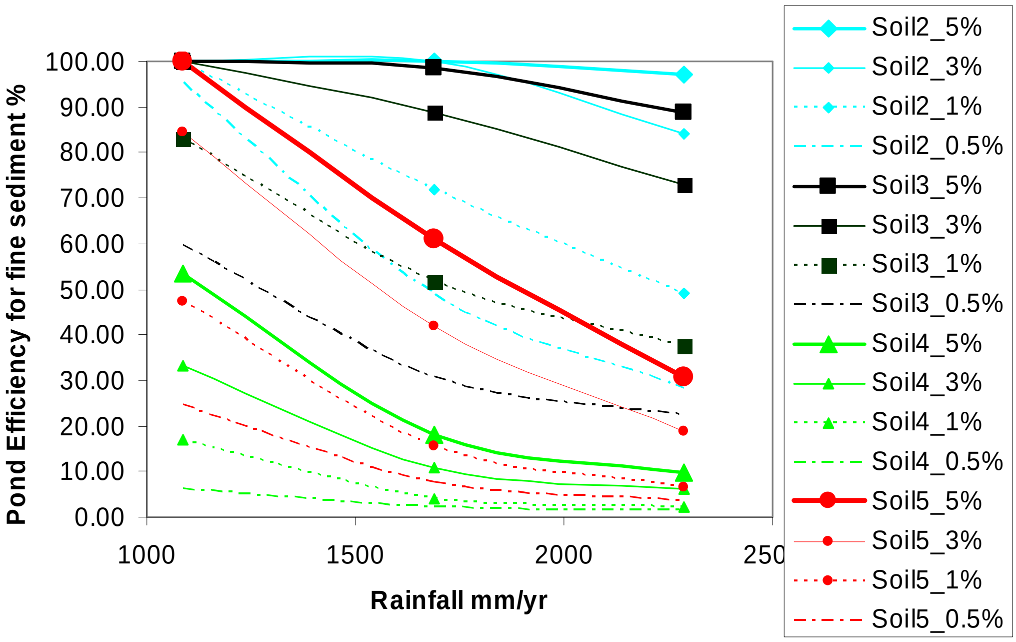


Figure 2: Simulation results for pond performance for fine sediment removal as a function of pond size (% of catchment area drained) and catchment soils. Soil 2=very well drained; 3 = well drained; 4 = poorly drained; 5 = average drainage.

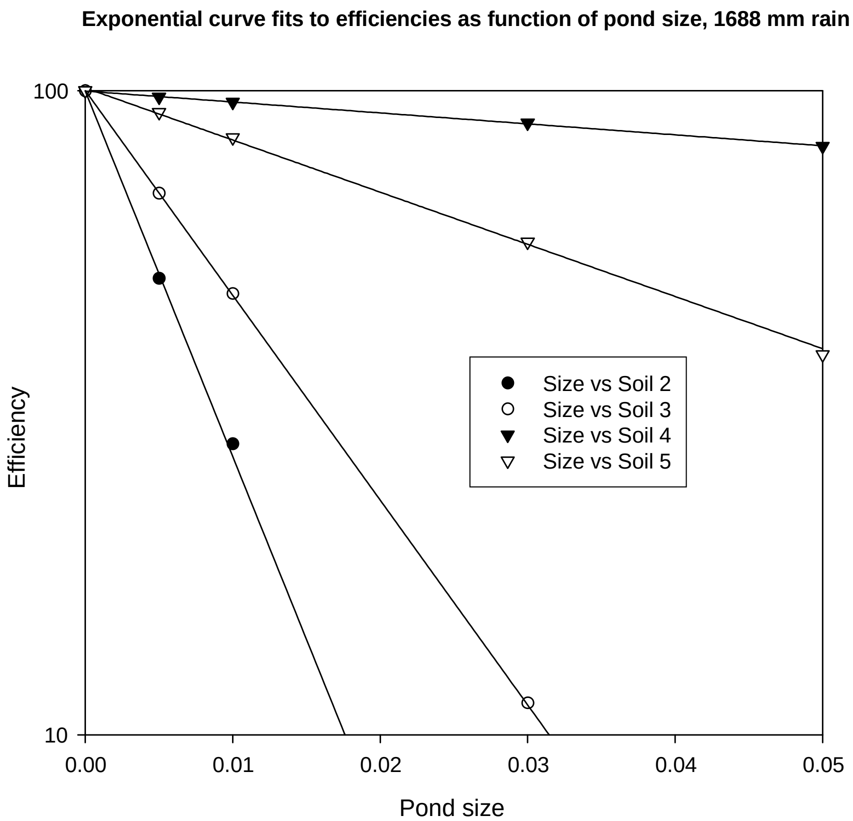


Figure 3: Fine sediment removal efficiency curves for a typical Waikato hill rainfall in relation to pond size and soil type.

This analysis suggests that there is scope for additional small dam development in ephemeral headwater areas for the purpose of controlling flood flows and trapping sediment and nutrients. Such dams could be designed to enhance benefits for fish (particularly eels), waterfowl and aesthetics (e.g., by incorporating requirements for eel access in the outlet design and slope of the downstream batter of the dam). These dams could also provide stock water by supplying troughs rather than by direct livestock access.

4. Sand mining

Sand and gravel extraction from the bed of the lower Waikato began in the 1940s, largely to service the construction industry. The overall rate of extraction increased up until the mid 1970s, with over 1 million m^3 extracted in 1974. Between 1953 and 2006, the extraction rate averaged 350,000 m^3/yr, which was more than three times the average rate of bed-material entrapment in the hydro-lakes. Most extraction has occurred in the Mercer area but over time the focus has shifted downstream. The historical extraction has created a long hole in the riverbed, lowering average bed levels by up to 2 m in the Mercer – Punihu area, and the extraction volumes between Rangiriri and the coast show a good overall match with surveyed riverbed volume changes. As discussed in Section 1, the lowered riverbed has reduced flooding in this area but it has also lowered the water table in the adjacent wetlands such as Whangamarino and Motukaraka, which in turn has led to subsidence of the wetland peat deposits.

Current sand extraction is confined to the Puni-Tuakau area and is approximately 160-180,000 m^3/yr. This accords with the strategy of the Lower Waikato and Waipa Control Scheme's Asset Management Plan (Environment Waikato, 1997), which sets a sustainable average extraction rate of 180,000 m^3/yr based on best estimates of the bed-material load entering the extraction reach. This management plan includes maintaining a target water-level profile at a reference discharge, thus the hole created by the current mining is expected to infill about as fast as it is dug-out.

Sand mining is being managed by Environment Waikato through resource consents. It is recommended that the WRA keeps a watching brief on the issue.

5. References

Anderson, B.G.; Rutherfurd, I.D.; Western, A.W. (2006). An analysis of the influence of riparian vegetation on the propagation of flood waves. *Environmental Modelling and Software 21*: 1290–1296.

Beets, P.N.; Oliver, G.R. (2007). Water use by managed stands of *Pinus radiata*, indigenous podocarp/hardwood forest, and improved pasture in the central North Island of New Zealand. *New Zealand Journal of Forestry Science 37(2)*: 306–322.

Coon, W.F. (1998). Estimation of roughness coefficients for natural stream channels with vegetated banks. US Geological Survey Water-supply paper 2441. p.

Demissie, M.; Khan, A. (1993). Influence of Wetlands on Streamflow in Illinois. Illinois Department of Conservation, Contract Report 561. 47 p.

Dons, A. (1987). Hydrology and sediment regime of a pasture, native forest, and pine forest catchment in the Central North Island, New Zealand. *New Zealand Journal of Forestry Science 17*: 161–178.

Duncan, M.; Woods, R. (2004). Flow regimes. *In*: Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrell, B.K. (eds). *Freshwaters of New Zealand,* pp. 7.1–7.14, New Zealand Hydrological Society and New Zealand Limnological Society, Christchurch.

Environment Waikato (1997). Lower Waikato Waipa Control Scheme asset management plan: discussion document. Environment Waikato, Hamilton.

EW (2008). The health of the Waikato River and catchment. Information for the Guardians Establishment Committee. Environment Waikato. Hamilton, 63 p.

Fahey, B.; Duncan, M.; Quinn, J. (2004). Impacts of forestry. *In*: Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrell, B.K. (eds). *Freshwaters of New Zealand*, pp. 33.31–33.16, New Zealand Hydrological Society and New Zealand Limnological Society, Christchurch.

Farley, K.A.; Jobbagy, E.G.; Jackson, R.B. (2005). Effects of afforestation on water yield: a global synthesis with implications for policy. *Global Change Biology 11*: 1565–1576.

Freestone, H.J. (2003). Statement of evidence of Horace John Freestone in the matter of applications by Mighty River Power to the Waikato Regional Council for resource consents in respect of the Waikato hydro system.

Maxted, J.R.; McCready, C.H.; Scarsbrook, M.R. (2005). Effects of small ponds on stream water quality and macroinvertebrate communities. *New Zealand Journal of Marine and Freshwater Research 39*: 1069–1084.

McKerchar, A.; Shankar, U.; Hicks, M. (2005). Water harvesting: an ideal use of floodwaters? *Water & Atmosphere 13(2)*: 24–25.

Mitsch, W.J. (1992). Landscape design and the role of created, restored, and natural riparian wetlands in controllong nonpoint source pollution. *Ecological Engineering 1(1-2)*: 27–47.

Pridmore, R.D.; McBride, G.B. (1984). Prediction of chlorophyll a concentrations in impoundments of short Hydraulic Retention time. *Journal of Environmental Management 19*: 343–350.

Quinn, J.M.; Croker, G.F.; Smith, B.J.; Bellingham, M.A. (2009). Integrated catchment management effects on runoff, habitat, instream vegetation and macroinvertebrates in Waikato, New Zealand, hill-country streams. *New Zealand Journal of Marine and Freshwater Research 43(3)*: 775–802.

Scotter, D.R.; Kelliher, F. (2004). Evaporation and transpiration. *In*: Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrell, B.K. (eds). *Freshwaters of New Zealand,* pp. 3.1-3.10, New Zealand Hydrological Society and New Zealand Limnological Society, Christchurch.

Sholtes, J. (2009). Hydraulic analysis of stream restoration on flood wave propagation. Thesis. University of North Carolina 102 p.

Smith, C.M. (1992). Riparian afforestation effects on water yields and water quality in pasture catchments. *Journal of Environmental Quality 21(2)*: 237–245.

Tanner, C.C.; Nguyen, M.L.;Sukias, J.P.S. (2005). Nutrient removal by a constructed wetland treating subsurface drainage from grazed dairy pasture. *Agriculture Ecosystems & Environment 105*: 145–162.

Young, R.; Smart, G.; Harding, J. (2004). Impacts of hydro-dams, irrigation schemes and river control works. *In*: Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrell, B.K. (eds). *Freshwaters of New Zealand*, pp. 37.31–37.15, New Zealand Hydrological Society and New Zealand Limnological Society, Christchurch.

Appendix 25: Boat Ramps

1. Introduction and methods

There are a number of ways that have been identified to improve access to the Waikato River, such as the provisions of boat ramps, creation of reserves adjacent to the river and creation of river walks. Which of these options is the most suitable will largely depend on the locations chosen at which to improve access.

For example, the Lower Waikato lakes are likely to require improved boat access, but in the Upper Waikato region, the existing boat access may suffice. Another consideration is that most locations on the Waipa River are unsuitable for installing a boat ramp, and in these areas they may choose to spend money on improving access in other ways such as creating reserves next to the river.

For the purposes of this Study it has been assumed that where providing a boat ramp is not possible, an equivalent amount will be spent on other measures to improve access to the river.

A generic boat ramp that is assumed to be suitable for use throughout the Waikato Region has been identified by the Study team. The dimensions and materials have been based on a number of existing boat ramps in and around Hamilton.

A typical boat ramp installation is shown below:

Figure 1: Roose Commence Boat Ramp (Hamilton) - BECA.

2. Goals

The purpose of this paper is to:

- Identify and cost a generic boat ramp that can be assumed to be suitable at a number of locations around the Waikato River catchment.
- By providing a cost for a boat ramp, estimate an equivalent cost for the creation of reserves and walkways adjacent to the river.

3. Actions

There are several existing boat ramps around Hamilton City. These have been used as a basis to determine the requirements of a generic boat ramp design and construction. The generic boat ramp chosen is made of concrete and is single width. An adjacent parking area or approximately 1,000 m^2 has been allowed for. No toilet or washdown facilities are allowed for.

No specific locations for the future construction of boat ramps have been determined at this stage. In lieu of this information, the Study team has assumed that four boat ramps (or equivalent access measures) will be constructed in each economic region of the Study area.

4. Desired outcome

There is improved access to the Waikato River for recreational and other users.

5. Risks and probability of success

Construction of boat ramps will improve access to the Waikato River. However, there are a number of reasons why a boat ramp at a specific location may deviate from the generic boat ramp chosen.

Construction of a boat ramp will need to be tailored to its specific location, and need to take into account a number of factors including:

- The degree of water level fluctuation.
- Direction of the current relative to the bank (i.e., position of eddy currents).
- Stability of adjacent riverbank and local soil conditions.
- The depth of water required to launch.

The location will also influence how frequently each ramp is used. More popular ramps may warrant double width construction, increased parking area and provision of toilet and washdown facilities.

Land purchase and resource consent costs have not been allowed for. These will be location dependent and will vary significantly throughout the Study area.

Where construction of boat ramps is not possible, but improved access to the river is still desired, it is assumed that the money for a boat ramp could be used on other measures to improve access. These measures have not been well identified, and any measure which requires substantial earthworks or construction is likely to exceed the cost to provide a boat ramp.

6. Costs and timelines

Since the locations of new ramps for boat access to the river have not been determined the Study team used generic costs based on figures provided by Hamilton City Council for a ramp that was designed to be installed at the Waipa Delta. Hamilton City Council advised us that their estimate for a replacement ramp at the Waipa Delta would cost between $300,000 and $400,000. The costs were developed in 2009 and are considered to be a reasonable estimate. The Study team therefore suggests using a cost of $400,000 per boat ramp to estimate total costs (Table 1).

Each ramp will require parking facilities. It is assumed that flat land is available adjacent to the boat ramp site. It is also assumed the car park requires negligible earthworks and will be constructed using a 200 mm sub base, 100mm base course and 25 mm asphalt seal. Asphalt seal has been selected as it is harder wearing and will withstand the effects of heavy turning vehicles better than either a chip seal or unsealed surface. Based on 1,000 m^2 parking area, including margins and fees the estimated cost of each car park would be in the vicinity of $60,000.

Therefore an estimated cost of $460,000 has been applied for each boat ramp and parking facility. This does not allow for the specific costs of road access, toilets, washwater or any other general amenities.

It is assumed, for the purposes of the Study, that new boat ramps would be owned by the local council. They would be responsible for the upkeep and maintenance of the ramp and any associated facilities. Operating costs have not been determined for a boat ramp at this time, but it is expected to require only minor repair work over a 30 year time frame.

It is expected that a single boat ramp would take 8–12 weeks to construct, assuming there are no site issues (e.g., adverse ground conditions, flooding etc.).

The following table summarises the cost estimates to install boat ramps in each of the four zones of the Waikato River catchment.

Table 1: Cost estimate for construction of new boat ramps.

Economic region	Number of Boat Ramps (or equivalent)	Total Capital Cost	Annual Operating Cost
Lower Waikato	4	$1,840,000	Minor
Waipa	4	$1,840,000	Minor
Middle Waikato	4	$1,840,000	Minor
Upper Waikato	4	$1,840,000	Minor
Total	16	$7,360,000	Minor

7. Mechanisms and statutory framework

Access to and along the Waikato River has been identified as a priority issue for recreational purposes such as boating and fishing, amenity, traditional cultural uses and spiritual reasons. There is increasing public demand and interest for access to the Waikato River, as illustrated by the Government's national cycle trail project which has identified a section of the trail, called the Waikato River Trail, to run alongside the River. Impediments to access are largely a result of land being in private ownership or private lease, where access is fenced off and/or denied. A range of methods are available to obtain and enhance access to the river and its margins, including:

- Designation process under the Resource Management Act (RMA).
- Esplanade reserves, esplanade strips, access strips.
- Marginal strips.
- Reserves.
- Non-statutory approaches to securing access e.g., Te Araroa Trust.

Appendix 26: Significant Sites

1. Introduction

The degradation of significant and historic sites within the Waikato River catchment was raised during the Waikato River Independent Scoping Study as an issue, particularly for the five river iwi. These sites are of special cultural significance to Maaori and their loss or degradation has a negative effect on spiritual and cultural relationships iwi have with the Waikato River. Historic sites also contribute to the wider Waikato community's cultural landscape and sense of local and regional cultural identity.

Many sites of significance to the five river iwi have been damaged or destroyed over the last 100 years in a variety of ways. These sites include waahi tapu, urupaa, historic access points and river crossings, kaainga, paa, gardens and named river features. The extent of the degradation described by iwi at the consultation hui ranged from total destruction and physical loss (e.g., paa, kaainga, marae and waahi tapu inundated all along the Waikato River), to irreversible damage (e.g., ngaawhaa and geysers being filled with concrete), restricted or denial of access (e.g., waahi tapu located on private land) and lack of respect (both knowingly and unknowingly) (e.g., http://www.ew.govt.nz; O'Sullivan and Te Hiko, 2010; Waitangi Tribunal, 1985 and 1993).

Vision and Strategy

The Vision and Strategy outlines the importance of initiating and promoting the protection, restoration and enhancement of significant sites throughout the Waikato River catchment, including those of the five river iwi (where they so decide). Strategies 6 and 7 set out tot:

- Recognise and protect waahi tapu and sites of significance to Waikato-Tainui and other river Iwi (where they so decide) to promote their cultural, spiritual and historic relationship with the Waikato River.
- Recognise and protect appropriate sites associated with the Waikato River that are of significance to the Waikato regional community.

The methods listed in the Vision and Strategy to implement Strategies 6 and 7 include (but are not limited to):

- Surveys of waahi tapu and other significant sites (where appropriate) within the Waikato region to protect and recognise their cultural and historic significance and importance.

Hydro power generation (both the construction of hydro dams and their continued operation) is viewed by iwi as the most dominant and pronounced cause and/or perceived cause of degraded or destroyed significant and historic sites in the Waikato River catchment (e.g., O'Sullivan and Te Hiko, 2010; Waitangi Tribunal, 1993). Land confiscation, development (including housing, roading, telecommunication and railway infrastructure), geothermal power generation, quarries, poor management and private land ownership were also raised as pressures impacting significant sites by the river iwi. Although these pressures have resulted in many significant sites being lost, knowledge of these sites and the spiritual connection iwi have with them remains though the physical connection has been damaged or destroyed.

The Maaori Heritage Council's vision statement *Tapuwae* is intended to guide the work of the New Zealand Historic Places Trust (NZHPT) in its activities in relation to Maaori heritage (NZHPT, 2009). This vision outlines the importance of Maaori heritage places and knowledge to New Zealand's cultural and social wellbeing and envisages a future in which Maaori heritage is recognised as an integral component of our national and cultural identity and a foundation of New Zealand's economic and environmental sustainability. Maaori heritage includes the knowledge, stories and experiences that people have when engaging with these places and therefore encompasses the experiences and consciousness that is created and maintained through people's interactions with these significant sites. The vision statement recognises:

1. That too often, Maaori heritage is undervalued at a national level and by non-Maaori communities.
2. That iwi and Maaori communities need assistance with understanding and protecting their heritage and how it can contribute to their health and wellbeing.
3. That many property owners and developers have a poor understanding of heritage generally, and of Maaori heritage specifically (NZHPT 2009).

Within the Waikato catchment a number of significant and historic sites are currently recognised and protected under the New Zealand Historic Places Trust (see Table 1). Further information regarding these sites can be accessed through the Historic Places Trust Register (http://www.historic.org.nz/TheRegister/). Waahi tapu are registered but this information is not available online.

Local authorities also have databases of sites in the Waikato region that are recognised as having archaeological significance. Local authorities may use this data for resource management purposes to carry out its functions for archaeological site management and protection under the Resource Management Act 1991.

Table 1: Number of historic sites that are currently recognised and protected under the New Zealand Historic Places Trust (excluding registered waahi tapu and waahi tapu areas).

Local authority	Total number of registered historic sites	Estimated number of registered historic sites in the Study area	Examples include
Taupo District Council	3	0	–
Rotorua District Council	14	0	–
South Waikato District Council	25	19[a]	• Arapuni Dam • Arapuni suspension bridge • Waotu-Puketurua Playcentre building
Otorohanga District Council	15	10	• Middens and Paa • Kiokio School • Otorohanga Railway Station
Waitomo District Council	16	16	• Paa • Waitomo Hotel (THC) • Courthouse (Te Kuiti)
Waipa District Council	66	66	• Paa • World War One memorials • Victoria Street Bridge (Leamington)
Hamilton City Council	40	40	• Pascoe building • Buffalo Hall • Fairfield Bridge
Waikato District Council	44	41	• Paa • Middens, Pits and Terraces • Turangawaewae House • Rotowaro Carbonisation Works
Franklin District Council	12	1	• 'Pioneer' Gun Turret and War Memorial

[a], This number includes sites registered in Lichfield and Putaruru, places that are on the boundary of the Study area.

2. A description of the prioritised action(s)

All river iwi, to various extents and in various documentation, have identified, catalogued and mapped sites of significance to them. In many cases this information has been submitted to and held in confidential files by local authorities and the Historic Places Trust, e.g., waahi tapu and archaeological sites. Local authorities use this data for resource management purposes to carry out functions for site management and protection under the Resource Management Act 1991.

The NZHPT (2009) outlines four key elements to be addressed in promoting the identification, protection, preservation and conservation of Maaori heritage, including:

- The identification and protection of existing Maaori heritage places. An awareness of these places amongst those who seek to develop land and/or make decisions about them is vital to prevent the further damage and destruction of significant sites.
- Maintenance, reconstruction and creation of appropriate knowledge about Maaori heritage.
- Creation of sustainable and meaningful experiences involving Maaori heritage.
- Creation of new interpretations and understanding of the significance of Maaori heritage to communities.

The five river iwi want to see expanding awareness within the wider Waikato region of the importance of significant sites by developing and improving the understanding, appreciation and recognition of these places. In order to maintain the integrity of significant sites it is vital that each river iwi (with input from whaanau and hapuu) or wider community organisation retain control over how their significant sites are identified, addressed and managed.

Action A. Development of significant site management plans by each river iwi covering, for example, identification, priorities for restoration, signage, publicity and education.

Knowledge about the physical environment was often committed by Maaori to memory using place names as a way to record and transfer information about local, social, cultural and environmental history from one generation to the next (Reed 2002, Orbell 1985, King et al., 2007 & 2008). Associated with the physical loss of some sites, there has also been a dislocation of many place names. This has heightened concerns that there has been a loss of knowledge pertaining to the original place names, locations and histories of some significant sites particularly amongst rangatahi. The NZHPT acknowledges that "through the actions of the ancestors, such places embody their mana, mauri and wairua, irrespective of the physical evidence which survives". Therefore, it is important that the strategic plans developed by iwi are supported so that "knowledge of the whakapapa, kōrero, and matauranga Māori surrounding such places sits alongside scientific assessments when heritage management decisions are being made" (NZHPT 2009). The river iwi note that significant sites are not currently given enough recognition and protection, and said the use and integrity of Maaori place names should be better enabled and supported throughout the catchment.

Action B. Following completion of Action A:

- Development of signage.
- Encourage support for site restoration actions.
- Update significant sites management plan with place names to be appropriately documented and confirmed through New Zealand Geographic Board.

3. Action Report Card – Significant and historic sites

Action Report Cards summarise monitoring information that measures the success of a single action or a number of closely related actions. To enable stakeholders to track progress towards development and implementation of actions to restore significant and historic sites in the Waikato River catchmen, the following targets, indicators and scores are recommended.

Significant and historic sites				
Action	**Measure or indicator**	**Target**	**Current state**	**Score**
A	Significant site management plans have been developed by each Waikato River iwi	5	2	C
B	Appropriate signage and support of site restoration actions and update significant sites management plan is established, with place names to be appropriately documented and confirmed through NZ geographic board	To be determined	–	D
Outcome				
	Knowledge of historic and significant sites is incorporated into general and restoration planning and consent processes	–	–	C
	Knowledge on key historic and significant sites is passed on to rangitahi and the wider community in an appropriate form	–	–	D

3.1 Current state

In the table above the 'current state' of these actions have been preliminarily scored based on the information gathered as part of this Study:

- **Action A:** The current state of this action has been preliminarily scored by the Study team as a C (i.e., fair). This score reflects that all river iwi, to various extents, within various documents, have identified, catalogued and mapped many of their sites of significance. In many cases this information has been submitted to and held in confidential files by local authorities and the Historic Places Trust, e.g., waahi tapu and archaeological sites. Local authorities use this data for resource management purposes to carry out functions for site management and protection under the Resource Management Act 1991.

- **Action B:** The state of this action has been preliminarily scored by the Study team as a D (i.e., poor). This score reflects that some significant and historic sites are currently recognised and protected within the catchment, although not always to the level of satisfaction expressed by the river iwi during the consultation hui. For example, some significant sites have been destroyed and will never be able to be restored. The targets to measure restoration success and the satisfaction of the river iwi with the levels of recognition and protection of significant sites will need to be decided by iwi upon the completion of their strategic plans. The Study team considered it inappropriate to assign such targets on behalf of the iwi. This is their right.

4. How will the action(s) be accomplished?

The NZHPT's Māori Heritage Council recognises the complexities faced by iwi, hapuu and whaanau when identifying and establishing measures of protection, restoration and/or enhancement of significant sites. Thus, the Council is willing to support and assist tangata whenua in negotiating (where appropriate) the various measures and legislative channels necessary to undertake the actions listed above. That legislation includes (but is not limited to); the Historic Places Act 1993, Resource Management Act 1991 and Te Ture Whenua Māori Act 1993.

5. Where in the Waikato River catchment should the actions occur?

Significant and historic sites are located throughout the Waikato River catchment. However, it is envisaged that each of the five river iwi will determine where future restorative activities are focussed through their respective waahi tapu and significant site management plans. Some signage will be linked to river walkway and cycleway developments. The proposed visitor centres and Waikato Museum will be a key sources to impart information to the public on significant and historic sites.

6. What is the cost of the action(s)?

The estimated costs of the proposed significant and historic site actions include:

Action	Description	Set up costs	On-going costs (i.e., after set up)
A	Development of waahi tapu and significant site management plans by each river iwi.	$100k/iwi	—
B	Appropriate development of signage and support of site restoration actions and update significant sites management plan with place names to be appropriately documented and confirmed through NZ geographic board.	—	$300k/iwi

7. Who could do it and how long would it take?

The targets listed in the Vision and Strategy in regards to the timeframe for completion of this initiative is:

- Within 3 years: Waahi Tapu and Significant Sites Management Plans have been completed.

8. What are the interactions with other activities (co-benefits, drawbacks)?

The actions proposed here will increase the involvement and participation of Waikato River iwi and the wider Waikato community in restoring the health and wellbeing of the Waikato River. These outcomes will contribute to the restoration of Aspiration 4 – Significant and historic sites "*That significant and historic sites along the Waikato River and its lakes, wetlands and tributaries are restored and protected*", Aspiration 1 – Holism "*That the management of the Waikato River and its lakes, wetlands and tributaries to protect their health and wellbeing is conducted in a holistic, integrated way*" and Aspiration 2 – Engagement "*That people feel engaged with the Waikato River and its lakes, wetlands and tributaries, and processes, initiatives or actions to restore and protect their health and wellbeing*".

9. An analysis of uncertainties and information gaps

The Study team considered it inappropriate to assign restoration targets in relation to **Action B:** "*Appropriate development of signage and support of site restoration actions and update significant sites management plan with place names to be appropriately documented and confirmed through the New Zealand Geographic Board*" as this can only be appropriately completed by each individual river iwi. Although the Study team has tentatively scored this action as a D (i.e., poor) this is merely a preliminary score and will need to be revised once the river iwi determine their own target.

10. References

King, D.N.T.; Goff, J.; Skipper, A. (2007). Māori environmental knowledge and natural hazards in Aotearoa–New Zealand. *Journal of the Royal Society of New Zealand 37(2):* 59–73.

King, D.N.T.; Skipper, A.; Tawhai, W.B. (2008). Māori environmental knowledge of weather and climate change in Aotearoa – New Zealand. *Climatic Change 90(4):* 385–409.

New Zealand Historic Places Trust Pouhere Taonga (2009). Tapuwae. The Maaori Heritage Council Statement on Maaori Heritage: A Vision for Places of Maaori Heritage. September 2009. 21 p.

New Zealand Historic Places Trust Pouhere Taonga (2004). Heritage Management Guidelines for Resource Management Practitioners. 82 p.

Orbell, M. (1985). The natural world of the Maori. Auckland, New Zealand, William Collins Publishers. 230 p.

O'Sullivan, S.J.; Te Hiko, N.H. (2010). Raukawa and the river. *In*: Collier, K.J.; Hamilton, D.; Vant, W.N.; Howard-Williams, C. (eds). *The Waters of the Waikato*, pp. 9. Hamilton.

Reed, A.W. (2002). *The Reed dictionary of New Zealand placenames*. Auckland, New Zealand. Reed Publishing.

Waitangi Tribunal (WAI 8). *The Manukau Claim.* Brooker & Friend, Wellington.

Waitangi Tribunal (WAI 33). *The Pouakani Report 1993*. Brooker & Friend, Wellington.

Appendix 27: Engagement

1. Introduction

During the Waikato River Independent Scoping Study issues were raised about the current policy setting and decision-making processes related to the Waikato River, its lakes, tributaries and wetlands. A lack of effective and/or meaningful engagement, poor community relationships, ineffective communication and unsuccessful conflict resolution procedures were all indentified as impacting on the community's ability to be involved decision-making processes and implementation of actions to restore and protect the health and wellbeing of the Waikato River.

This sense of disengagement of communities from the Waikato River is the result of a number of different factors. For Waikato-Tainui, land confiscation in the 1860's severely reduced their association with the land and the awa, and breaches of the Treaty of Waitangi by the Crown denied their rights and interests in, and Mana Whakahaere over the Waikato River, compromising their ability to ensure the river's wellbeing (NZ Government 2010, Waikato-Tainui Deed of Settlement). The movement of people from rural to urban areas has also reduced regular contact with natural waterways and rural life. The history of pollution due to poorly managed sewage and other point sources (from at least 1903 until the 1970-80's (More, 1976)) also contributed to urban dwellers and others "turning their backs on the river" (Gibbons, 1977). The perception that the river is unsafe to swim appears to have persisted with many people long after severe microbial pollution problems were resolved. The development of hydro-lakes flooded many sites of cultural significance for Maaori and affected their ability to carry out traditional cultural activities associated with the river (O'Sullivan and Te Hiko, 2010).

Restoring the health and wellbeing of the Waikato River requires increased engagement as well as changes in many people's understanding, perceptions and the social norms that drive improved behaviours (e.g., Rhodes et al., 2002; Parminter et al., 2006; Ison and Watson, 2007). Achieving this will require an integrated approach to engage different audiences (e.g., youth, urban dwellers, farmers, industries, managers and different ethnicities).

New initiatives should be linked to and build on, existing programmes being run in primary schools (e.g., there are over 100 Waikato schools involved in the enviroschools[1]) and resources provided by local government (e.g., Environment Waikato's 2002 Clean Streams Guide), Hamilton City Council's Gully Restoration Guide (Wall and Clarkson, 2002)), industries (e.g., DairyNZ Farm Enviro Walk), Non-

1 http://www.ew.govt.nz/for-schools/Waikato-Enviroschools-newsletters

Governmental Organisation's (e.g., NZ Landcare Trust's guide for silt traps on peat lake tributaries (Berry and Dresser, 2010))[2] and Crown Research Institutes (e.g., NIWA's guide on Wetland treatment of tile drainage (Tanner et al., 2010)).

Linking to the Vision and Strategy

The Vision and Strategy for the Waikato River includes the implementation of strategies 8 and 10, which are to:

- Actively promote and foster public knowledge and understanding of the health and wellbeing of the Waikato River among all sectors of the Waikato regional community.

- Establish new, and enhance existing, relationships between Waikato-Tainui, other river iwi (where they so decide), and stakeholders with an interest in advancing, restoring and protecting the health and wellbeing of the Waikato River.

The methods listed in the Vision and Strategy to implement Strategy 8 and 10, within a 3 year timeframe include (but are not limited to):

- The development of curricula for schools in the Waikato region focusing on the restoration and protection of the health and wellbeing of the Waikato River.

- The development and delivery of postgraduate scholarship programmes focused on the restoration and protection of the health and wellbeing of the Waikato River.

- The development of a public education programme focused on the restoration and protection of the health and wellbeing of the Waikato River.

- Promote greater public knowledge and understanding of river iwi relationships with the Waikato River.

- Promote greater public understanding of the relationship of the wider community with the Waikato River.

- Facilitate and encourage participation to enable sharing between national and international river enhancement experiences that will foster and assist in the restoration and protection of the health and wellbeing of the Waikato River.

[2] http://www.landcare.org.nz/user-content/2300-silt-trap-fact-sheet.pdf

Many community members made a number of positive suggestions about how these issues might be addressed and also indicated a willingness to be involved in the implementation of actions to restore and protect the health and wellbeing of the Waikato River. Feedback gathered in the Study indicates that ‘hands on’ involvement in the restoration and protection of the Waikato River will help improve community wellbeing through re-engagement.

Feedback also suggested that in order to effectively participate in the restoration of the river, a number of capacity building, education and training programmes need to be implemented and that these programmes needed to target a variety of age groups, audiences and a range of learning preferences. In addition, inadequate access to information and funding, were also highlighted as barriers to contributing to decisions and policy development on the current management of the river.

These suggestions are supported by research showing that environmental education plays a major role in encouraging responsible behaviour needed for sustainable resource management and environmental protection, while also enabling people to participate effectively (Bay of Plenty Regional Council, 1999; Environment Waikato, 1996; Hamilton City Council, 1998; Matamata-Piako District Council, 1999; MfE, 1995; MfE, 1998; MfE, 1999; Northland Regional Council, 1998; Parminter et al., 2006; Tasman District Council, 2000; Wellington Regional Council, 1998).

Targeting school curricula to enhance student knowledge and developing positive attitudes towards the health and wellbeing of the Waikato River is promoted in association with the existing Enviroschools/Kura Taiao programme and the EMAP waterways programme (www.emap.rsnz.orgs). These aim to influence student’s awareness, knowledge, attitudes and skills and to build a network of schools/kura committed to environmental learning, action and creating sustainable communities. Furthermore, research shows that educating children also educates their parents (Connor et al., 2006).

2. A description of the prioritised action(s)

A wide variety of actions were proposed and incorporated into this Study to increase the awareness, knowledge, capacity, and involvment of all stakeholders within of the catchment in the restoration of the health and wellbeing of the Waikato River. The actions listed below target a variety of age groups, audiences, and a range of learning preferences and can be broadly grouped under the following:

- Education, training and research.
- Communication and publicity.

- Partnerships and coordination.

Environmental education in schools

The development of a cross-curriculum resource (both primary and secondary levels), in collaboration with the Ministry of Education, will engage school children, parents and teachers throughout the catchment, to promote greater public knowledge and understanding of the restoration and protection of the health and wellbeing of the Waikato River.

In addition to the involvement of the Ministry of Education, collaboration with existing environmental education initiatives, including Enviroschools[3], the Royal Society Environmental Monitoring and Action Project (EMAP)[4]), the Royal Society Teachers Fellowship Scheme[5], Learning Media[6] and Environment Waikato's Environmental Education for schools[7] will greatly benefit the development of this cross-curriculum resource. The Environmental Education Directory of New Zealand[8] provides further links to environmental education resources that have been developed around New Zealand.

Actions designed to provide Waikato River focused cross-curriculum materials as well as professional development and support for primary and secondary teachers include:

Action A. Provide Waikato River focused cross-curriculum materials and professional development and support for primary and secondary teachers:

- Prepare Waikato River focused cross-curriculum resources for primary and secondary schools (Te Reo Maaori, preparation, publishing and distribution).
- Develop supplementary activities (primary and secondary) to add to Waikato River cross-curriculum resource pack every year.
- Develop associated professional development workshops for school teachers.

[3] http://www.enviroschools.org.nz
[4] http://www.emap.rsnz.org.nz
[5] http://www.royalsociety.org.nz
[6] http://www.learningmedia.co.nz
[7] http://www.ew.govt.nz/For -schools
[8] http://www/eednz.org.nz

Marae-based training courses

The hui with the five river iwi confirmed that successive generations have utilised the Waikato River, extensively drawing upon its resources to sustain themselves. In doing so they have acquired in-depth knowledge of species, their relationships, ecosystem functions and learnt how to modify their practices to accommodate changing ecological conditions. Whaanau and hapuu at all the hui stated their commitment to restoring the health and wellbeing of the River and their landscapes. The participation of tangata whenua in 'on-the-ground' restoration and monitoring projects is an ideal opportunity for helping to re-connect whaanau and hapuu (especially tamariki and rangatahi) with the river, which will aid the restoration of wellbeing in these communities.

Implementation of the following actions would see environmental restoration activities combined with cultural affirmation, knowledge transmission and Te Reo revitalisation. The aspirations of the five river iwi include:

- Re-vegetation, protection or reintroduction of culturally-important species.
- Conservation of valued landscapes including re-establishing connections.
- Where supported by whaanau, hapuu and iwi promoting greater understanding of historical associations with the Waikato River.

The development and delivery of a series of marae-based training courses are proposed as a means of providing access to the knowledge, skills and opportunities for tangata whenua to actively participate in the restoration and protection of the health and wellbeing of the Waikato River. Ideally these waananga, coordinated by the Waikato Regional Authority and the five river iwi, would occur alongside new and existing restoration initiatives (e.g., Te Kanae Kakariki Trust) so that the 'hands on' component of the training workshops can be undertaken as part of the overall restoration programme. The types of training courses to be delivered include, but are not limited to: traditional fishing methods, riparian planting, fencing and management (including culturally purposeful planting), project management and coordination, monitoring and evaluation, the Resource Management Act, tuna and whitebait biology and pest species management (e.g., willow and koi carp eradication).

The development of enterprises associated with the restoration of the Waikato River, (e.g., native plant nurseries that are managed by iwi and supply riparian planting programmes throughout the catchment) will also provide capacity building and employment opportunities for the five river iwi. Ideally, these will be organised in partnership with education providers, such as the New Zealand Qualifications

Authority (NZQA), so that participants receive a formal qualification upon completion of these training initiatives.

Action B. Provide access to the knowledge, skills and development opportunities for five river iwi to actively participate in the restoration and protection of the health and wellbeing of the Waikato River:

- Provide marae-based waananga/training courses.
- Establish iwi-based restoration training and employment development enterprises, e.g., native plant nurseries, koi carp removal programme.

Research capacity and coordination

The Vision and Strategy outlines objectives to increase research capacity and the coordination of the delivery of appropriate research initiatives to increase current knowledge and understanding of the health and wellbeing Waikato River. Such research may include the application of maatauranga Maaori in the development of tools to restore the health and wellbeing of the Waikato River and the restoration of taonga species, particularly those where key information gaps have been identified (e.g., kaaeo/kaakahi, kooura, piiharau).

The new *"Waters of the Waikato"* book (Collier et al., 2010) is to be launched at Turangawaewae Marae in 2010 as part of the Koroneihana celebrations (Friday 20 August 2010). This book provides a rich resource of information regarding the biophysical and management issues facing the Waikato River. Therefore, this resource could provide a valuable contribution to the content of a series of 'fact-sheets' for distribution to the general public.

The coordination of research (including undergraduate and postgraduate studies) can be assisted by establishing an academic chair focused on the restoration of the Waikato River (similar to role of Professor David Hamilton and the Te Arawa Lakes). This role would help facilitate and coordinate research targeted on the restoration and protection of the health and wellbeing of the Waikato River amongst tertiary institutions such as the Waikato-Tainui College for Research and Development and the University of Waikato. This role would also assist in the development and maintenance of local, national and international research networks (including indigenous expertise) that can be applied to the restoration and protection of the health and wellbeing of the Waikato River.

Action C. Increase Waikato River-related research capacity, and coordinate the delivery of appropriate research initiatives to increase current knowledge and understanding of the health and wellbeing Waikato River:

- Support tertiary student scholarships (masters, PhD, and/or postgraduate) undertaking targeted Waikato River-related research.
- Establish an academic Chair to facilitate and coordinate research relevant to the restoration and protection of the health and wellbeing of the Waikato River and to foster local, national and international research networks.

Communication and publicity

Based on the information collected during the Study, it was identified that the Waikato River Authority (WRA) will need to coordinate opportunities to communicate and engage with stakeholders in order to change behaviours where necessary. This process will involve identifying and addressing barriers to change, whilst simultaneously promoting the benefits of new behaviours to stakeholders in the Waikato River catchment. The overarching aim of these communication and publicity initiatives is to keep the community informed so they can make sound judgements and implement new improved behaviours from their own learned perspective. Topics for discussion could include:

- **Iwi relationships with the Waikato River** – including the economic, social, cultural and spiritual relationships of river iwi in accordance to their tikanga and kawa.
- **Community relationships with the Waikato River** – including the economic, social, cultural and spiritual relationships of the many communities along the Waikato River.
- **Increasing awareness of rubbish reduction and pollution management initiatives** – (a) to assist point source management by informing stakeholders of the issues and how they can contribute to solutions and (b) finding ways to consult, engage, include and motivate communities in order to ensure their help in reducing pollution and rubbish.
- **Protection and conservation** – helping to improve the community's knowledge of healthy waterways, native fisheries, flora and fauna and enlisting the community's support and participation to protect these taonga.
- **Significant sites** – including waahi tapu (where the fiver river iwi so decide) as well as significant and historic sites of the wider Waikato community –

expanding awareness of the presence of these significant sites by developing and improving understanding, appreciation and recognition.

In order to provide more permanent opportunities to promote greater public knowledge and understanding of Waikato River amongst all stakeholders in the community it is proposed that Waikato River-focused public education centres (one in Scenario 2, five in Scenario 3) are implemented. These centres will provide both schools and the general public with Waikato River and five river iwi relevant services which include, but are not limited to:

- Information and education facilities.
- Exhibitions (e.g., that have been developed to portray the significance of the Waikato River to the five river iwi).
- Guided fieldtrips.

At present **c**ommunication with stakeholders throughout the Waikato River catchment is maintained through a variety of newsletters, press releases and web sites. However, the next level of information available tends to be too detailed and/or too hard to get hold of (e.g., technical and legal documents). To bridge this gap the Study team recommends that 'issues and options' articles be written by an experienced journalist to be published in a wide variety of media, including newspapers and magazines.

Appropriately written 'how to' handbooks on activities that enhance the Vision and Strategy, such as riparian management, wetland restoration, contaminant source management on farms, monitoring and assessment methods would also be beneficial if they were made freely available to the public. These will build on existing resources, such as those mentioned earlier. More extensive communication and publicity measures include the production of a Waikato River restoration and protection-focused magazine that is widely distributed throughout the catchment and/or the production of a Waikato River restoration and protection-focused series of 30 minute long documentaries appropriate for distribution via DVD and/or television.

It is proposed that a Waikato River Festival is held biannually (alternately hosted by each region within the catchment, i.e., Waipa, Lower Waikato, Middle Waikato and Upper Waikato). The programme for this 2-3 day event would include an international river symposium (involving local, regional, national and international restoration initiatives) and includes cultural activities (where the five river iwi so decide) such as Kapa Haka, as well as water sports, entertainment and other activities.

Action D. Improve and increase communication and publicity focused on the health and wellbeing of the Waikato River:

- Provide Waikato River public education centre(s) (one in Scenario 2 and five in Scenario 3).
- Commission a professional journalist to develop 'issues and options' articles on key aspects of the restoration of the Waikato River and publish in a variety of media (including newspapers and magazines).
- Collaborate with existing agencies to adapt and extend existing 'how to' handbooks on activities that enhance the Vision and Strategy (e.g., riparian management, wetland restoration, contaminant source management on farms and monitoring and assessment methods).
- Develop a Waikato River focused magazine, distributed throughout the catchment.
- Commission the delivery of Waikato River-focused documentaries suitable for television and/or DVD release.
- Develop a Biannual Waikato River Festival – with a programme that includes an international river symposium, cultural activities, watersports and other activities.

Partnerships and coordination

Some local authorities have non-statutory processes on restoration that include grants or funding to help meet the costs of remedial actions. For example, the Environment Waikato Clean Streams initiative has made funding available to farmers to exclude cattle from streams and reforest riparian areas. The Waikato Catchment Ecological Enhancement Trust (WCEET) assists organisations, agencies and individuals with projects that foster and enhance the sustainable management of ecological resources in the Lake Taupoo and Waikato River catchments. In addition, a number of national and regional government, iwi authority, industry and voluntary strategies, action plans, projects and awards (e.g., National Wetland Trust, Maungatautari Ecological Island Trust, Waikato Biodiversity Forum, Hakarimata Restoration Trust, and Ecosourced Waikato) currently exist within the Waikato River catchment. The Waikato River Authority will need to coordinate and administer grants to community groups, iwi and industry for restoration and monitoring and link its activities with existing funding agencies.

The actions proposed here aim to complement existing initiatives, by:

- Developing and strengthening partnerships between stakeholders.

- Improving the coordination of restoration activities undertaken throughout the catchment.
- Improving access to funding for restoration activities.
- Providing more awards for stakeholders undertaking river, lake, riparian and wetlands activities that improve health and wellbeing of the Waikato River.

Actions designed to strengthen and increase partnerships and coordination of activities that improve the health and wellbeing of the Waikato River include:

Action E. Increase partnerships and coordination of activities that improve the health and wellbeing of the Waikato River:

- Improve coordination of community groups focused on Waikato River restoration and protection by supporting a coordinator.
- Support annual community meetings/mini fora in support of joint restoration initiatives.
- Build partnerships with industry located within the Waikato River catchment (e.g., DairyNZ, MeatNZ, Fonterra, Federated farmers, AFFCO, Kinleith) to coordinate activities that enhance the vision and strategy through the development of an industry-lead joint accord.
- Provide seed funding to support collaborative industry-led and community-led projects.
- Sponsor new awards for river, lake, riparian and wetland restoration projects that improve health and wellbeing of the Waikato River to complement existing awards.

3. How will the action(s) be accomplished?

The diversity of actions outlined here require input from the five river iwi, local authorities, education providers, research organisations, industry, community groups and government, coordinated by the Waikato River Authority.

4. Where in the Waikato River catchment should the actions occur?

Engagement was an issue expressed throughout the entire Waikato River catchment and the actions presented here require a whole of catchment approach. However, it is acknowledged that each region within the catchment, (i.e., Waipa, Lower Waikato, Middle Waikato and Upper Waikato) may request specific services or activities to be tailored to meet their priority needs.

5. What is the cost of the action(s)?

Table 1: The estimated costs of the proposed engagement actions include:

Action	Description	Costs ($Mill, NPV)
A	Waikato River focused cross-curriculum materials for primary and secondary schools, updates and professional development to support long term implementation	$2,3
B	Marae-based training workshops	$6.5
	Iwi-based restoration training and employment development initiatives, e.g., native plant nurseries, koi carp eradication programmes	
C	Provide scholarships (postgraduate and undergraduate) for students undertaking Waikato River-related research restoration	$6
	Academic chair to coordinate research undertaken on the Waikato River and foster national and international networks	
D	Five Waikato River public education centres	$7.6
	"Issues and options" articles on key aspects of the restoration of the Waikato River and publish in a variety of media (including newspapers, magazines)	$4.5
	'How to' handbooks on activities that enhance the vision and strategy (e.g., riparian management, wetland restoration, contaminant source management on farms, monitoring and assessment methods)	
	Waikato River focused magazine, distributed throughout the catchment	
	Waikato River focused documentaries suitable for television and/or DVD release	
	Biannual Waikato River Festival	$1.8
E	Improve coordination of community groups focused on Waikato River restoration and protection by supporting coordinator to achieve better integration of efforts across catchment	$2
	Support annual community meetings/mini fora in support of joint restoration initiatives	
	Build partnerships with industry to coordinate activities that enhance the vision and strategy through the development of an industry-lead joint accord	$0.32
	Facilitate collaborative industry-led and community-led restoration projects	
	Biannual vision and strategy restoration awards for industry-led and community-led projects	$0.61

6. Who could do it and how long will it take?

The Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010 and the Ngati Tuwharetoa, Raukawa, and Te Arawa River Iwi Waikato River Bill establishes and grants functions and powers to the Waikato River Authority. The purpose of this authority is to:

- Through the Vision and Strategy set the primary direction to achieve the restoration and protection of the health and wellbeing of the Waikato River for future generations.
- Promote an integrated, holistic and co-ordinated approach to the implementation of the Vision and Strategy and the management of the Waikato River.
- Fund rehabilitation initiatives for the Waikato River in its role as trustee for the Waikato River Clean-up Trust.

The targets listed in the Vision and Strategy in regards to the timeframe for the completion of these initiatives includes:

- Within 3 years: The curricula for schools in the Waikato Region include a focus on the restoration and protection of the health and wellbeing of the Waikato River.
- Within 3 years: Public education programmes focused on the restoration and protection of the health and wellbeing of the Waikato River are implemented. The programme will include updates on the state of the health of the Waikato River, and actions that residents can take to positively influence the health and wellbeing of the Waikato River.
- Within 3 years: Postgraduate scholarships are developed.
- Within 3 years of the postgraduate scholarship being established: At least two postgraduate degrees have been successfully completed. Appropriate undergraduate programmes will include within their courses a focus on the restoration and protection of the health and wellbeing of the Waikato River.
- Within 5 years: One international river symposium has been held in the Waikato Region with a focus on the restoration and protection of the Waikato River.
- Within 6 months, and thereafter at least every 6 months: Mini fora are held locally.

7. What are the interactions with other activities (co-benefits and drawbacks)?

The actions proposed here will increase the involvement and participation of five river iwi and the wider Waikato community in restoring the health and wellbeing of the Waikato River. In particular these outcomes will contribute to the restoration of Aspiration 1 - *"That the management of the Waikato River and its lakes, wetlands and tributaries to protect their health and wellbeing is conducted in a holistic, integrated way"* and Aspiration 2 - *"That people feel engaged with the Waikato River and its lakes, wetlands and tributaries, and processes, initiatives or actions to restore and protect their health and wellbeing."*

8. An analysis of uncertainties and information gaps

It is crucial that the Waikato River Authority facilitate opportunities to communicate and educate stakeholders in order to change behaviours where necessary. This process will involve identifying and addressing barriers to change, whilst simultaneously promoting the benefits of new behaviours to stakeholders in the Waikato River catchment. The role of the Waikato River Authority will be pivotal to creating and maintaining long-term collective stakeholder 'buy in' (i.e., acceptance, recognition of importance, understanding and participation) regarding the final actions selected.

9. References

Bay of Plenty Regional Council (1999). *Environmental Education Strategy for Environment B.O.P. 1999-2005*. Bay of Plenty Regional Council, Whakatane.

Berry, N.; Drsser, M. (2010). Keeping our Water Clean Factsheet. Accessed July 2010 from http://www.landcare.org.nz/user-content/2300-silt-trap-fact-sheet.pdf.

Connor, J.; Hay, M.; Coleman, G. (2006). Extension through education programs with kids - who are we educating? Presented at the Practice change for sustainable communities: Exploring footprints, pathways and possibilities. Proceedings of APEN International Conference, 6-8 March 2006 ISBN 1 920842 31 4, Beechworth, Victoria, Australia.

DairyNZ (2008). Farm Enviro Walk: Your on-farm environmental health check. DairyNZ Ltd, 2008. Retrieved October 2008, from http://www.dairynz.co.nz/page/pageid/2145839052

Environment Waikato (1996). *Learning to Care for Our Environment: A Preliminary Implementation Strategy for Environmental Education*. Environment Waikato Regional Council, Hamilton.

Environment Waikato (2002). Guide to managing waterways on farms. Environment Waikato, Hamilton. http://www.ew.govt.nz/projects/clean-streams/

Gibbons, P.J. (1977). *Astride the river: A history of Hamilton.* Whitcoulls for Hamilton City Council, Christchurch. 381 p.

Hamilton City Council (1998). *Learning to Create a Sustainable City: Strategy for Environmental Education.* Hamilton City Council, Hamilton.

Henderson, S. (1992). Precollege education: A vital component if sustainable agriculture is to take root. *In*: Olson, R.K. (ed.). *Integrating sustainable agriculture, ecology, and environmental policy*, pp. 153-161. Food Products Press, Binghamton, New York.

Ison, R.; Watson, D. (2007). Illuminating the possibilities for social learning in the management of Scotland's water. *Ecology and Society 12(1)*: 21 online URL: http://www.ecologyandsociety.org/vol12/iss21/art21/.

Matamata-Piako District Council (1999). *Learning to Care for Our Environment: An Environmental Education Strategy for the Matamata-Piako District Council*. Matamata-Piako District Council, Te Aroha.

Ministry for the Environment (MfE) (1995). *Environment 2010 Strategy: A Statement of the Government's Strategy on the Environment.* Ministry for the Environment, Wellington.

Ministry for the Environment (MfE) (1998). *Learning to Care for Our Environment: Me Ako ki te Tiaki Taiao – A National Strategy for Environmental Education.* Ministry for the Environment, Wellington.

Ministry for the Environment (MfE) (1999). *Environmental Education: A Guide for Programme Providers – How to Develop, Implement and Evaluate Strategies and Programmes.* Ministry for the Environment, Wellington.

More, D. (1976). *Between the river and the hills: Waikato County 1876-1976*. Wilson and Horton, Auckland. 383 p.

New Zealand Government (2010). Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act. 128 p.

Northland Regional Council (1998). *Environmental Education Strategy*. Northland Regional Council, Whangarei.

O'Sullivan, S.J.; Te Hiko, N.H. (2010). Raukawa and the river. *In*: Collier, K.J.; Hamilton, D.; Vant, W.N.; Howard-Williams, C. (eds). *The Waters of the Waikato*, p. 9. Hamilton.

Parminter, T.; Waters, C.; Mortimer, C. (2006). Examples of extension and policy strategies developed using theories of human behaviour and social marketing. Presented at the Practice change for sustainable communities: Exploring footprints, pathways and possibilities. Proceedings of APEN International Conference, 6-8 March 2006, Beechworth, Victoria, Australia.

Tanner, C.C.; Sukias, J.P.S.; Yates, C.R. (2010). New Zealand guidelines: Constructed wetland treatment of tile drainage. NIWA Information Series No. 75, 48 p.

Tasman District Council (2000). *Draft Environmental Education and Advocacy Strategy.* Tasman District Council, Richmond.

Wall, K.; Clarkson, B. (2001). Gully restoration guide: A guide to assist in the ecological restoration of Hamilton's Gully systems. Hamilton City Council, Hamilton. 52 p.

Wellington Regional Council (1998). Environmental Education Strategy: Working Paper. Unpublished Internal Document, Wellington Regional Council, Wellington.

Appendix 28: Impediments

1. Purpose

The purpose of this report is to summarise some of the statutory and non-statutory impediments to the range of priority actions being proposed to contribute to the enhancement of Waikato River as part of the Waikato River Independent Scoping Study. The priority actions are outlined in further detail in Table 7.3 (see Section 7). This appendix provides a description of the statutory framework and discusses how these influence or impact on some of the impediments identified in Table 7.3 (see Section 7).

A brief outline of the statutory framework is included below. The statutory impediments outlined below were identified during workshops with council staff from within the Waikato region in December 2009 and at an internal workshop about 'Statutory Impediments to the Waikato River Independent Scoping Study Actions' in May 2010. The impediments are grouped into statutory or non-statutory categories. The statutory impediments all relate to actions that are regulated or influenced by legislation. Non-statutory impediments relate to all other impediments.

2. Statutory framework

Many of the recommended priority actions in the Study (and which inform the review of the Vision and Strategy for the Waikato River) are influenced by the Resource Management Act 1991 (RMA), Local Government Act 2002 (LGA) or Land Transport Management Act (LTMA) processes. The diagram below outlines some of the relevant legislation, associated documents and some of the relationships between these.

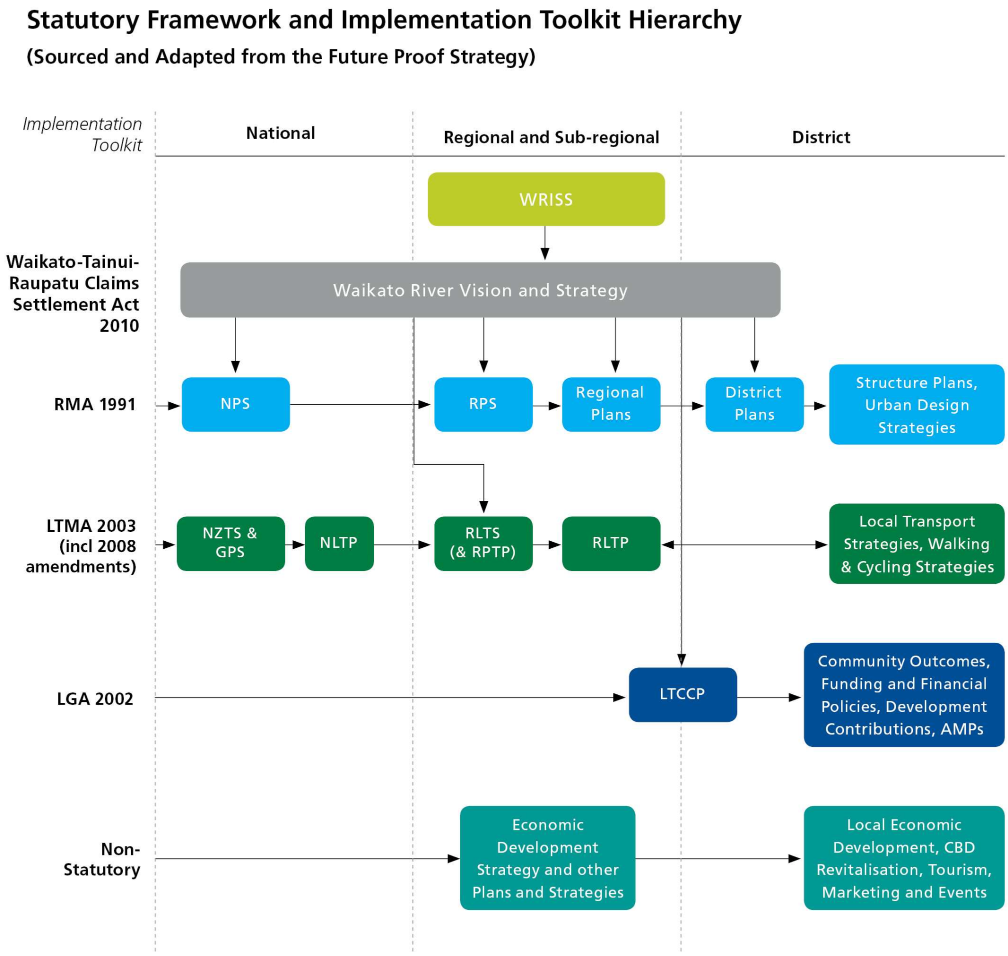


Figure 1: The relationship between the Vision and Strategy for the Waikato River and the Resource Management Act 1991

Under the RMA the key planning documents are national policy statements (NPS), regional policy statements (RPS) and regional and district plans. Where an NPS exists it sets national policy direction. An RPS sets the region-wide policy direction and cannot be inconsistent with an NPS. Regional Plans and District Plans must give effect to the RPS.

The Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010 (which came into effect in May 2010) and the Ngati Tuwharetoa, Raukawa, and Te Arawa River Iwi Waikato River Bill direct Environment Waikato to incorporate the Vision and Strategy for the Waikato River into the Waikato Regional Policy Statement without a formal Schedule 1 RMA process of submissions and hearings. The Vision and Strategy content also prevails over any inconsistent provision of a National Policy Statement. The Waikato Regional Council is also required to update the RPS (if necessary) so that it is not inconsistent with the Vision and Strategy without going through the Schedule 1 RMA process.

2.2 Vision and Strategy reviews

The first review of the Vision and Strategy is required to commence not more than 3 months after the settlement date. Subsequent reviews are necessary no earlier than 5 years later, then 10 years thereafter. The reviews are required to consider whether the Vision and Strategy includes specific targets and measures for achieving the overarching purpose of the settlement agreement. These reviews are required to follow a consultation and submission process outlined in the Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010.

Once the review has been completed all Councils within the region are required to review their own RMA documents to consider whether changes to the Vision and Strategy result in the need for a change their respective RMA documents (RPS, Regional and District Plans).

Such reviews are required to go through formal Schedule 1 RMA processes and therefore will be also subject to submission, hearing and potentially appeals to the Environment Court – meaning it could be months/years until such time as all documents are aligned with the Vision and Strategy. Having said that, where a plan change is supported by the Vision and Strategy, there will be less room to contest the content of the policy statement or plan change process.

2.3 Impact on resource consent process and existing consents and designations

Regional and District Plans outline which activities require resource consent. A resource consent application requires an assessment against the RMA, objectives, policies and rules of relevant RMA documents and an Assessment of Effects on the Environment – this will now include a need to provide commentary of the proposed activity in terms of its consistency with the Vision and Strategy.

Depending on the activity status for which resource consent is required, the resource consent may be notified and go through a submission and hearing process. Should a hearing committee need to be established for applications of interest to the Waikato River Authority, the Panel is required to be made up of an equal number of Waikato River Authority appointed decision makers as those appointed by Council. An independent chairperson also needs to be jointly appointed.

3. Study recommendations – RMA impediments

RMA process impediments are identified below. It is noted typically RMA issues tend to be related to concerns about 'additional cost', 'additional time' and 'increased uncertainty' impacts on business and communities as a result of the consent processes. Many of the Study's recommendations for priority actions have such implications.

3.1 Need for resource consents

Many of the priority actions recommended by the Study involve physical works or activities that will require resource consents to be obtained from either District or Regional Councils (or both).

Resource consent requirements are often seen as an impediment because they add uncertainty, time and cost to a project or activity. In the case of the Study's recommendations, resource consents will typically be required by a Regional Plan for activities that involve dredging, water takes or diversion, geothermal water takes and reinjection, discharges to land, water or air and significant earthworks in proximity to water bodies. At the district level, resource consents will typically be required for 'out of zone' buildings and structures, vegetation removal and earthworks.

Consents/designations will therefore likely be required for restoration actions such as those that will improve access to and around the river (e.g., to construct and operate the river walkway, visitor centers, reserves, boat ramps, alter drainage systems, improve flood protection, alter hydro power schemes to facilitate/improve fish passage or alter geothermal power schemes to re-inject geothermal water).

Many existing activities, such as point source discharges from industrial activities and municipal wastewater, are operating to consented regimes. If a higher level of treatment or alternative disposal methods are required this will involve reviewing and amending the existing consent conditions, reconsidering the consent at the time the existing consent period expires and capital costs to alter site activities. Costs associated with both the resource consent process and the technological improvements required to improve the quality of the point source discharge. For example, obtaining new or renewing existing wastewater treatment plant consents can often be a lengthy process, with many taking more than 10 years to work through from the initial concept and strategy development stage, community consultation, consenting and then implementation. This means there are often significant 'lag' periods between any improvement processes commencing to the time where quality improvements actually occur.

3.2 Permitted activities

District and Regional Plans can identify activities that are permitted provided they meet the standards set out in the plan. Currently farming activities such as pastoral dairy farming and clear felling forestry in high catchment areas are a permitted activity in most plans within the region. Many of the Study's recommended actions look to change and/or improve rural land management practices by way of education and voluntary actions. (e.g., industry approaches and potentially self regulation).

Permitted activity standards don't reinforce the requirement for change. Conversely radical changes of approach to regulating historical (and economically important) land use practices are likely to be unacceptable – and will be costly to look to propose via the RMA process as evidenced by Variation 5 to the Waikato Regional Plan. It was proposed in 2005 and is still under appeal to the Environment Court now.

3.3 Monitoring

The effectiveness of standards and rules in District Plans and resource consent conditions are required to be monitored to ensure that they achieve the intended environmental result. Resource consent conditions also require monitoring to ensure they are being complied with.

However monitoring tends to be poorly resourced, which results in poor data being gathered to inform strategy and policy review and refinement. Collection of data aligned with the Study's objectives, strategies and actions will be imperative if the effectiveness of the Study's recommended priority actions is to be able to be critically reviewed. This will likely require increased time (and cost) to be invested in this activity.

3.4 Lack of national guidance

As noted in the recent SKM study for the Ministry for the Environment titled 'Regional Council Practice for Setting and Meeting RMA-Based Limits for Freshwater Flows and Quality', a key impediment around water allocation and water quality is the lack of national guidelines around setting such standards.

This causes significant delays and disagreements when developing them on a region by region basis. The Study noted that Councils feel there is a need for direction on national water quality/quantity issues including a clear outline of what is important at the national level. It also noted that the majority of councils think national guidelines on water quality limits are needed to reduce arguments around methods and limits and avoid duplication of effort.

4. Study recommendations - LGA 2002 implications and impediments

Councils in New Zealand are required to prepare a Long Term Council Community Plan (LTCCP) every three years. The LTCCP is guided by 'Community Outcomes' which are an expression of a community's desired outcomes in terms of the present and future social, economic, environmental and cultural well-being of the community. Councils consult with their community when developing the LTCCP and, once adopted, the LTCCP can be changed only after appropriate consultation with the community. The LTCCP outlines details of all of the Council's activities and how these activities contribute to the desired Community Outcomes. It also outlines the Council's budget, explaining what the Council plans to spend over the next ten years.

The recommended actions outlined in the Study propose a number of new activities for Environment Waikato and District Councils to act on – many of which will not have been identified in their current LTCCPs. Activities like walkways, boat ramps, visitor centers and wastewater treatment process changes will ultimately cost the local communities more (e.g., through increased rates, development contributions etc.). Many Councils are reporting difficulties with servicing existing community activities identified in their LTCCPs, with many activities being deferred. The likely ability of these Councils to introduce additional work activities into their 10 year plans will be a challenge.

5. Study recommendations – LTMA implications

The Study's recommended actions propose a number of new activities for road controlling authorities to act on – many of which will not have been identified in their current activity plans or budgets.

Improved treatment for point source road runoff discharges and culvert upgrades to provide fish passages are such examples. They will require budgeting for – both in Long Term Council Community Plans (LTCCPs) where Councils are RCA's, but also by the New Zealand Transport Agency in the case of State Highways and potentially the Department of Conservation (where conservation land is affected).

6. Non statutory impediments

6.1 Political and community resistance

Political and community aspirations are based on a community's values. These values can differ within, and between, regional and local contexts. Implementing region-wide changes can therefore be met with political and/or community resistance at the regional and/or local level. An example of this is in relation to non-point source discharges. As noted in the recent SKM study referred to above, regulation of non-point source discharges is controversial and requires attitudinal change and buy-in by politicians and stakeholders.

6.2 Cost of implementation

Many of the Study's recommended actions will incur costs to implement. The costs can be broken into several categories and may be incurred by a number of parties.

In broad terms there may be a capital and operating cost to purchase land, build, operate or maintain the action and a cost to gain resource and/or building consent for the activity. There may also be opportunity costs associated with an action with communities and businesses having a limited pool of resources to make decisions, and act if necessary, if they think a recommended action will affect viability of their service provision or commercial operations.

For example, if all treated wastewater was disposed to land this will raise the question about who pays and who benefits, the quality improvement resulting form the action and cost versus the significant improvement to cultural values.

When considering new consents or the renewal of any existing sewage discharge consents the Territorial Local Authorities (TLAs) or other applicants are generally required to investigate and report on the technical and economic feasibility of implementing a land disposal scheme. Many Council's in the Waikato are understood to have assessed the technical and economic feasibility of land based disposal to be too costly for their communities to develop and then maintain. These findings are presented in their Assessment of Effects on the Environment (AEE) which are taken into consideration by regional councils at hearings and the Environment Court during appeals. This will be a key consideration for any actions the Waikato River Authority chooses to fund in its role as trustee for the Waikato River Clean-Up Trust.

There has been a recent example of this in Gisborne where a technical solution which met community and cultural objectives was developed as a concept and granted consent but the cost to then implement the scheme was shown to be prohibitive and would have significant adverse social and economic effects on the community the improvement was intended to serve. The projected increase in rates was unacceptable to the community and an alternative, less costly solution had to be developed, in consultation with the wider community and iwi, and then reconsented.

6.3 Coordinated planning

Another potential impediment to some of the recommended actions is lack of coordinated planning. For example there currently no regional Access Plan that outlines the priorities for access throughout the region, the purposes access might be required e.g., for cultural, aesthetic, or sporting purposes and prioritising resources (time, money, people etc.) to implement effective solutions. A coordinated plan would enable all agencies to work towards common priorities and objectives.

Another impediment noted by the Study team is the lack of integration between RMA processes and the LTCCP, whereby some non-regulatory methods identified in RMA documents never make it into the LTCCP, and conversely many effective non-regulatory methods funded by the LTCCP are not directly referenced in an RMA plan.

It is noted that an Integrated River Management Plan is a key activity arising from s35 of the Waikato–Tainui Raupatu Claims (Waikato River) Settlement Act 2010. The purpose of this plan is primarily centred on management of aquatic life, habitats and natural resources and hazard management. However, this Plan could be extended to become a document that is used to better coordinate the priority actions the Waikato River Authority decides to fund – e.g., by informing funding criteria and decision making of the Trust, RMA decision making and, potentially, other agency activity planning as well (e.g., LTAs, EW, NZTA etc.).

6.4 Training

The lack of trained RMA commissioners with specific knowledge of the Vision and Strategy for the Waikato River and the statutory powers of the Waikato River Authority is also identified as an impediment to the successful implementation of the recommended priority actions. Training of Waikato River Authority (or river iwi) accredited commissioners will be a necessary ongoing commitment (and is also a legal requirement to comply with s25 of the Waikato–Tainui Raupatu Claims (Waikato River) Settlement Act 2010).

6.5 Knowledge and education

A lack of knowledge or information about how to mitigate adverse farming effects or undertake improvements can also be an impediment. Environment Waikato, farm advisors and industry groups currently play a role in education.

Readily available information showing good practice examples and technologies that are endorsed by the Regional Council and/or an independent industry organisation, similar to Energy Efficiency and Conservation Authority (EECA), would help. The voluntary uptake of such advice may be greater if it is seen to come from an independent advisor as opposed to the agency enforcing compliance.

6.6 Attitude change and industry collaboration

An unwillingness by the Waikato community to change behaviours or attitudes could be a key impediment to the successful implementation of many of the recommended priority actions but illustrating the benefits of change is one way to instigate gradual attitudinal change e.g., illustrating the benefits of an action to the quadruple bottom line, international market drivers for sustainability and the national 'clean, green' image.

Working with industry, rather than against it, is a positive method to work towards industry-wide changes. There are existing successful examples of collaboration with industry such as the Dairy Industry Clean Streams Accord between Fonterra, Regional Councils, Ministry for the Environment and Ministry of Agriculture and Forestry which sets a national-level framework for reducing the impacts of dairying on the quality of New Zealand's water bodies. One of the targets often quoted in relation to this Accord is the target to exclude stock from streams by 90 percent by 2012.

7. References

Sinclair; Knight; Merz (2010). Regional Council Practice for Setting and Meeting RMA-Based Limits for Freshwater flows and Quality. Ministry for the Environment. National Summary Report.

Appendix 29: Monitoring and Evaluation

1. Introduction

Monitoring and evaluation of restorative actions to restore and protect the health and wellbeing of the Waikato River are essential to:

- Measuring success: Assessing progress towards the implementation of restorative actions and achieving a healthy and well Waikato River.
- Supporting adaptive management: Ongoing reviews of progress allow strategies to be adapted to meet targets if the expected progress does not occur.
- Providing accountability: The Waikato River Authority will need to provide transparency and accountability for actions it chooses to fund (in its role as trustee for the Waikato River Clean-up Trust).
- Engaging communities: Community-based environmental monitoring programmes assist individuals, community groups and organisations to actively participate in caring for their surrounding environmental resources and assets.

1.1 Monitoring and evaluation as stated in the Vision and Strategy

The development and implementation of a Cultural Health Index (CHI) for the Waikato River is clearly outlined in the Vision and Strategy. The Vision and Strategy includes the implementation of strategies 2–4, which are to:

- Establish what the current health status of the Waikato River is by utilising maatauranga Maaori and latest available scientific methods.
- Develop targets for improving the health and wellbeing of the Waikato River by utilising maatauranga Maaori and latest available scientific methods.
- Develop and implement a programme of action to achieve the targets for improving the health and wellbeing of the Waikato River.

The methods listed in the Vision and Strategy to implement strategies 2–4 within an 8 year timeframe include (but are not limited to):

- Develop and implement a Cultural Health Index (CHI) for the Waikato River to understand environmental matters and the mauri of the Waikato River. The CHI will incorporate maatauranga Maaori and latest available scientific methods to direct and prioritise resources for restoring and protecting the health and wellbeing of the Waikato River.
- Monitoring undertaken by statutory agencies and other stakeholders to determine if there are deficiencies in their information, including an analysis

of adverse cumulative effects, required to understand threats to the health and wellbeing of the Waikato River.

1.2 Community based environmental monitoring

The United Nations Environment Programme stresses public participation as an essential component of sustainability (Au et al., 2000). Community based environmental monitoring programmes assist individuals, community groups and organisations to actively participate in caring for their surrounding environmental resources and assets (e.g., India[1] and Canada[2]). Such initiatives provide the coordination, networks, knowledge, training and support required by communities to monitor, track and respond to issues of common concern (Conrad and Daoust, 2008; McKenzie et al., 2000; Whitelaw et al., 2003).

Community involvement regarding the identification of relevant indicators to monitor progress towards environmental management goals is increasingly recognised, within literature by academics and environmental managers alike as an important component of sustainable and effective management (Fraser et al., 2006; Jollands and Harmsworth, 2006; Leach et al., 1999; Reed et al., 2008; Whitelaw et al., 2003). A shift towards participatory 'bottom-up' approaches combined with conventional 'top-down' systems is evident internationally. This is largely due to the failure of 'top-down' systems to realise sustainable environment management (Fraser et al., 2006; Sharpe and Conrad, 2006).

In an assessment of participatory processes (i.e., 'bottom-up approaches') on indicator identification and environmental management, Fraser et al., (2006) drew three key conclusions that are relevant to the Waikato River Independent Scoping Study. They are:

- That the process of engaging people to identify locally relevant indicators not only provided valuable databases for making management decisions, but also an opportunity for community empowerment and education that current conventional approaches fail to provide.
- Multi-stakeholder processes must formally feed into decision-making forums or they run the risk being viewed as irrelevant by policy makers and stakeholders.
- Since ecological boundaries rarely meet with political jurisdictions, it is necessary to be flexible when choosing the scale at which monitoring and decision-making occurs.

1.3 Cultural Health Index for Maaori

Part 2 of the Resource Management Act (particularly sections 5, 6(e), 7(a) and 8) refers to the relationship Maaori have with the environment. Resource management

[1] http://www.sipcotcuddalore.com
[2] http://www.envnetwork.smu.ca

agencies are required to recognise and provide for the culture and traditions of Maaori relating to ancestral lands, water, sites, waahi tapu and other taonga. They must also have particular regard to kaitiakitanga and take into account the principles of the Treaty of Waitangi. Thus, as a Treaty partner Maaori interests are recognised as being distinct from those of other stakeholders. Given these statutory provisions, Maaori expect resource managers to recognise and provide for their cultural beliefs and practices and that they are included and actively involved in environmental management processes (Tipa and Teirney, 2006).

Although many resource management agencies attempt to recognise cultural practices, many struggle with the intangible or metaphysical aspects of Maaori values, thus, finding it difficult to understand what these represent and how to adequately or appropriately recognise and provided for them (Tipa and Teirney, 2003). Tipa and Teirney (2003 and 2006) have developed the Cultural Health Index (CHI) to facilitate the participation of iwi in land and water management processes and decision making. Utilising tools such as the CHI recognises that only Maaori are able to provide the clarity needed by resource managers when dealing with Maaori spiritual and cultural issues and, significantly, supports application of the Treaty of Waitangi principle that "*the spiritual and cultural significance of a freshwater resource to Māori can only be determined by the tangata whenua who have traditional rights over the river*" (Ministry for Environment, 1987) (Tipa and Teirney, 2003). The CHI responds to these beliefs by enabling Maaori to identify waters of special significance and use an assessment tool which is grounded in Maaori beliefs and values to ensure cultural data informs management of that Taonga (Tipa and Teirney, 2006).

The Cultural Health Index articulates cultural values, assesses the state of the environment from a cultural perspective, and assists with establishing a role for Maaori in environmental monitoring. However, Maaori also need to know that contemporary resource managers support the use of tools such as the CHI, recognise the validity of the data collected and will respond to the information provided (Tipa and Teirney, 2003). The CHI provides information that can be used as the basis for discussions between tangata whenua and territorial authorities or industry. To appreciate the detail within the CHI scores and, therefore, the issues in greater detail, resource managers and tangata whenua need to work together. By analysing the scores (e.g., A-0/2.1/4.2) of the index, tangata whenua are able to diagnose issues, decide on priorities and determine the remedial actions they see as necessary to restore or enhance the cultural values of the site. The CHI also provides the ability to monitor changes and improvements after restoration has been carried out at a stream site (Tipa and Teirney, 2006).

2. A description of the prioritised action(s)

The scope of this Study includes providing guidance on how to develop a monitoring programme to support the restoration of the health and wellbeing of the Waikato River. Monitoring is discussed in some detail in Section 8. Specific monitoring actions include:

a. The development of Cultural Health Indices and monitoring programmes.

b. Creating and maintain a repository of environmental monitoring equipment that can be used by volunteer monitors.

c. Developing regional or centralised database(s) for storing environmental monitoring and background data for use by each iwi, including a dedicated person managing and supporting it.

d. Establishing a system of regular Report Cards, to monitor and communicate the progress of restoration activities.

2.1 A Cultural Health Index for the five river iwi

Tipa and Teirney (2006) provide guidelines outlining how to identify areas for evaluation, setting up a CHI programme and the collection and analysis of data. It is important to note that thus far this index has only been utilised in streams and rivers (TDC, 2007; Tipa and Teirney, 2003 and 2006; Young et al., 2008) and further research will be required to extend to other areas (as part of Action A). Each river iwi will need to develop their own CHI to assess the cultural and biological health of a stream or catchment of their choosing. This includes:

- Development of appropriate indicators to be included in the CHI framework.
- Design and implementation of monitoring programmes (e.g., monitoring specific values and at specific sites of importance).
- Databases (web-based for increased accessibility) for each iwi to securely store the CHI monitoring information over the long-term.

Action A. The development and implementation of a Cultural Health Index (CHI) for the Waikato River includes the following components:

- The development of cultural indicators by each river iwi.
- Development and implementation of cultural health monitoring programmes by each river iwi.

Maaori have already been developing indicator and monitoring tools, mainly in response to the RMA and as part of the Ministry for the Environment environmental indicator programme (TDC, 2007; Tipa and Teirney, 2002, 2003 and 2006; Townsend et al., 2004; Young et al., 2008). A large number of potential indicators that could be used by individual iwi when they develop their own CHI's for the Waikato River were captured during discussions at the hui (for more information see Appendix A at the end of this paper). These lists of indicators provide a valuable resource to facilitate the development of Cultural Health Indices by the five river iwi.

The majority of these indicators were unable to be scored by the Study team at this time because the relevant information does not yet exist but they are identified in the sample Report Cards provided in Appendix 30: Report Cards to highlight key knowledge gaps. This is not unique to this Study and a similar approach was undertaken in an assessment of wellbeing that was used to engage communities in forestry planning in Western Canada (Fraser et al., 2006).

As mentioned previously, it is for the five river iwi to identify the range of Cultural Indices that they want to see developed that are consistent with their values and aspirations. It is unrealistic to expect one CHI (and in effect a one size fits all approach) to be developed that is applicable in its entirety to all five iwi. But it is essential that cultural indices are integrated and reported alongside scientific and economic data in the Report Cards developed, otherwise holistic assessments of the health and wellbeing of the Waikato River will not be achieved. It is, therefore, recommended that combinations of the indicators presented in Appendix A (at the end of this paper) be packaged together to provide a subset of cultural indices that are assessed by all five river iwi. It is suggested that this agreed subset of cultural indices (approved by all five river iwi) are then monitored and the information collated is provided to the Waikato River Authority for collation into the Aspiration Report Cards (see Section 8). The five river iwi may also choose to monitor more cultural indices than is supplied to the Waikato River Authority as they see fit.

Three potential Cultural Indices are presented below. These are merely examples for illustrative purposes, to show how this tool could be developed and used by the five river iwi and incorporated into the Aspiration Report Cards.

For example, utilising Tipa and Teirney's (2006) CHI framework and the list of potential indicators provided by the five river iwi (see Appendix A at the end of this paper) a 'Cultural Recreational Index' could be constructed by iwi to monitor the progress of the restoration actions in realising Aspiration 6 - Swimming and Boating, (i.e., improving the use of the Waikato River and its lakes, wetlands and tributaries for recreational purposes).

A 'Cultural Recreational Index' could comprise the following indicators, or selection of:

Cultural Recreation Index
Examples of indicators that could be incorporated
Iwi satisfaction regarding access to boat ramps, their location and condition.
Number of negotiated access agreements over private land.
Number of safe swimming sites.
Satisfaction of iwi users in relation to waka ama/waka taua with: (a) flow levels, (b) ability to enter and exit water safely, (c) level of weed and algae present and (d) water quality.
Satisfaction of iwi users with experience given presence of invasive species.
Whaanau and hapuu confirm (Yes/No) that the valued features of key sites/river reaches are protected.
Satisfaction of iwi with ability to use preferred skills, practices and methods when interacting with the river.
Use of the Waikato River for waka ama

The ability of the river to sustain taonga species is vitally important if the health and wellbeing of the Waikato River is to be restored (Aspiration 11 – Taonga species). A possible index to assess the health of taonga species from the perspective of tangata whenua could comprise the following measures, or selection of, as part of a 'Cultural Species Index':

Cultural Species Index
Examples of indicators that could be incorporated
Presence/absence of valued species (e.g., kai, cultural materials and other taonga species).
Number of taonga species to be in gradual decline, threatened or endangered.
Cultural materials (fit for purpose) available at appropriate sites.
Yes/No having to purchase customary kai species (renowned species) for marae.
Level of contaminants and food safety.
Number of waterbodies without pest fish, numbers/kg of pest fish removed.
Number (and area) of new reserves established.
Number of koohanga (nursery) for valued species that are protected/restored/created e.g., proportion of whitebait spawning sites in the Waikato River that are protected compared to agreed historical baseline.
Percentage of the customary rights exercised (e.g., permits granted).

Some participants at the consultation hui held during the Study prioritised increasing the participation and engagement of their members in the restoration of the Waikato River (Aspiration 2) and may therefore benefit from development of a 'Cultural Participation Index' which could comprise the following indicators, or selection of:

Cultural Participation Index
Examples of indicators that could be incorporated
Number of iwi commissioners: (a) trained, and (b) practicing.
Number of whaanau engaging in cultural activities at specific sites (e.g., waananga, programmes, generational).
Number of new monitoring sites introduced that reflect cultural indices or Report Card indices.
Increase in hapuu and iwi environmental officers.
Whaanau and hapuu monitoring of restoration activities.
Increase in iwi participation in restoration activities on public and private land.
Number of whaanau and hapuu members engaged as volunteers in restoration activities.
Number of whaanau and hapuu members engaged as employees in restoration activities.
Number of section 33 transfers (ratio of approved *vs* total applications).
Whaanau, hapuu and iwi are satisfied with their ability to participate and influence decisions and achieve outcomes benefitting the river.
Total number of restoration projects initiated compared to number of programmes iwi initiated.
Increase in Maaori/cultural specific degrees for freshwater and aquatic sciences.
Increase in funding for marae based restoration activities.

2.2 Environmental monitoring equipment for communities

In Nova Scotia the Community Based Environmental Monitoring Network has developed partnerships with other organisations to create the Environmental Stewardship Equipment Bank. The goal of this initiative is to provide equipment for environmental monitoring to any person who requires it but would otherwise not be able to access it. The Community Based Environmental Monitoring Network provides this service to help augment monitoring costs and enable more community groups and individuals to be involved in environmental monitoring.

To assist individuals, community groups and organisations to actively participate in the monitoring and evaluation of the health and wellbeing of the Waikato River, a proposed action is the formation of repositories of monitoring equipment which would be available to iwi and the wider community. These repositories would be maintained by the Waikato River Authority and borrowed by volunteer monitors to:

- Enable the collection of monitoring information for use in Report Card assessments.
- Increase engagement of in the restoration of the health and wellbeing of the Waikato River.

Action B. Develop and maintain a repository of environmental monitoring equipment that can be borrowed by volunteer monitors to meet report card assessments required for funded projects and general state monitoring at a variety of scales.

2.3 Environmental monitoring database network

The development of databases (web-based for increased accessibility) for each river iwi to securely store the CHI data and other environmental monitoring information collected over time will be crucial to supporting the implementation of monitoring programmes such as the CHI (see Action D). Training workshops will also need to be held for iwi members who are responsible for the management and maintenance of these databases.

A further action includes the implementation of a centralised database that is able to securely hold the information submitted by the five river iwi, volunteer groups and local authorities. It is recommended that this is managed by a dedicated person within the Waikato River Authority.

Action C. Database for storing environmental monitoring and background data:

- Database for storing environmental monitoring and background data for use by each iwi.
- Create centralised database, coordinated by a dedicated person managing and supporting it.

3. Action Report Card – Monitoring and evaluation

Action Report Cards summarise monitoring information that measures the success of a single action or a number of closely related actions (see Section 8). To enable stakeholders to track the development and implementation of monitoring and evaluation actions the following targets, indicators and scores for the current state of the proposed actions are recommended:

Monitoring and evaluation				
Action	**Measure or indicator**	**Target**	**Current state**	**Score**
A	Implementation of cultural health monitoring programmes by each river iwi	5	0	E
B	Repository of equipment are available and being used by iwi and community groups for monitoring	10	2.5	D
C	Iwi databases established and contributions held by a centralised database for Waikato River monitoring data	6	0.5	C-

3.1 Current state

In the table above the 'current state' of these actions has been preliminarily scored based on the information gathered as part of this Study:

- **Action A:** The current state of this action is scored as an E (i.e., very poor). While it is recognised by the Study team that some river iwi are engaged in developing cultural health indicators and associated monitoring programmes, this progress is not common to all five river iwi and therefore this action has not yet been implemented in a coordinated manner as set by the targets outlined in the Vision and Strategy.

- **Action B:** The state of this action is currently scored as a D (i.e., poor). This score is to reflect that although some monitoring equipment does exist and is being used by community monitoring and restoration groups (e.g., the Stream Health Monitoring and Assessment Kit (SHMAK)), its use and knowledge of its availability is disparate and uncoordinated. The target for the number of monitoring equipment repositories has been set at total of 10 (one for each iwi and five that are available throughout the catchment for community groups involved in restoration activities).

- **Action C:** The state of this action is currently scored as a C- (i.e., fair). This score is to reflect the existence of environmental information that is currently collected and managed by the local authorities within the Waikato River catchment (e.g., Environment Waikato). However, the ultimate target is for each river iwi to have a database to securely store data that is collected as part of their cultural health monitoring programmes, a selection of which is provided to a centralised database for the purpose of reporting restoration progress.

4. How will the action(s) be accomplished?

The Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010 and Ngati Tuwharetoa, Raukawa, and Te Arawa River Iwi Waikato River Bill outlines co-management arrangements that are to be implemented including: (1) Integrated river management plans, (2) Environmental plans, and (3) Joint management agreements. The joint management agreements provide for the local authority and iwi to work together in carrying out a number of duties and functions. In relation to monitoring, these joint management agreements include meeting no less than twice per year to:

- Discuss and agree on priorities for monitoring, methods for and extent of the monitoring and discuss the potential for the river iwi to participate in the monitoring.
- Discuss appropriate responses to address the outcomes of the monitoring, including the potential for review of RMA planning documents and enforcement under the RMA including criteria for commencement of prosecutions, applications for enforcement orders, the service of abatement notices and the service of infringement notices.
- Agree appropriate procedures for reporting back to iwi on the enforcement actions taken.
- Discuss and agree on role of the river iwi Trusts in a 5 yearly review in section 35(2A) of the RMA.
- Discuss potential for persons to be nominated by the river iwi Trusts to participate in enforcement action under the RMA.

In terms of monitoring the Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010 and the Ngati Tuwharetoa, Raukawa, and Te Arawa River Iwi Waikato River Bill also establishes and grants functions and powers to the Waikato River Authority to:

- Monitor the carrying out, effectiveness and achievement of the Waikato River Authority.
- Monitor the implementation, effectiveness, and achievement of the Vision and Strategy, including any targets and methods.
- Monitor the implementation, effectiveness, and achievement of clean-up initiatives funded by the Waikato River Clean-up Trust.
- Report every 5 years on the results of the monitoring.

5. Where in the Waikato River catchment should the actions occur?

The development and implementation of a Cultural Health Index for the Waikato River is clearly outlined in the Vision and Strategy. The targets listed in the Vision and Strategy in regards to the timeframe and extent of the Waikato River catchment to be covered by this initiative are:

- Within 2 years: 25 percent of the Waikato River has been incorporated within a CHI monitoring programme.
- Within 4 years: The CHI has been incorporated within the monitoring regime for the Waikato River.
- Within 8 years: 100 percent of the Waikato River is subject to the Waikato River CHI monitoring programme.

6. What is the cost of the action(s)?

The estimated costs of the proposed monitoring and evaluation actions include:

Action	Description	Set up costs	On-going costs (i.e., after set up)
A	Development of Waikato River iwi-specific cultural indicators	$250k/iwi	
	Implementation of cultural indicator monitoring programmes by each Waikato River iwi		$100k/iwi/year
B	Develop and maintain a repository of quality equipment for environmental monitoring		$80k/year
C	Develop a database appropriate for storing environmental monitoring data collected by each Waikato River iwi	$250k	--
	Database training (workshop) for Waikato River iwi representatives	$30k	--
	Develop a centralised database, that is managed and supported by a dedicated person	$200k	$80k/year

7. Who could do it and how long would it take?

The timeframes for the implementation of the CHI by the five river iwi are clearly outlined in the Vision and Strategy (see Sub-Section 6 above). The actions proposed here require the involvement and input from all iwi and the Waikato River Authority.

8. What are the interactions with other activities (co-benefits, drawbacks)?

The actions proposed here will increase the involvement and participation of iwi and the wider Waikato community in monitoring and evaluating the health and wellbeing of the Waikato River. These outcomes will contribute to the restoration of Aspiration 1 – Holism "*That the management of the Waikato River and its lakes, wetlands and tributaries to protect their health and wellbeing is conducted in a holistic, integrated way*" and Aspiration 2 – Engagement "*That people feel engaged with the Waikato River and its lakes, wetlands and tributaries, and processes, initiatives or actions to restore and protect their health and wellbeing*."

9. An analysis of uncertainties and information gaps

The five river iwi need to know that resource managers support the use of tools such as the CHI, recognise the validity of the data collected and will respond to the information provided (Tipa and Teirney, 2003). Some of this uncertainty will be addressed through the implementation of the Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010 and the Ngati Tuwharetoa, Raukawa, and Te Arawa River Iwi Waikato River Bill. Intellectual property agreements between the river iwi and local authorities may be required to ensure that the information supplied by iwi is used only for the purposes that are jointly agreed upon.

10. References

Au, J.; Bagchi, P.; Chen, B.; Martinez, R.; Dudley, S.A.; Sorger, G.J. (2000). Methodology for public monitoring of total coliforms, *Escherichia coli*, and toxicity in waterways by Canadian high school students. *Journal of Environmental Management 58*: 213–230.

Conrad, C.T.; Daoust, T. (2008). Community-based monitoring frameworks: Increasing the effectiveness of environmental stewardship. *Environmental Management 41:* 358–366.

Fraser, E.D.G.; Dougill, A.J.; Mabee, W.E.; Reed, M.; McAlpine, P. (2006). Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. *Journal of Environmental Management 78:* 114–127.

Harmsworth, G. (2002). Coordinated Monitoring of New Zealand Wetlands, Phase Two, Goal 2: Maori environmental performance indicators for wetland condition and trend. Report prepared for Lincoln University. Landcare Research, Palmerston North. 66 p.

Jollands, N.; Harmsworth, G. (2006). Participation of indigenous groups in sustainable development and monitoring: rationale and examples from New Zealand. *Ecological Economics 62:* 716–726.

Leach, M.; Mearns, R.; Scoones, I. (1999). Environmental entitlements: Dynamics and institutions in community-based natural resource management. *World Development 27(2):* 225–247.

McKenzie, L.J.; Lee Long, W.J.; Coles, R.G.; Roder, C.A. (2000). Seagrass-watch: Community based monitoring of seagrass resources. *Biol. Mar. Medit. 7(2):* 393–396.

Pauling, C.; Lenihan, T.M.; Rupene, M.; Tirikane-Nash, N.; Couch, R. (2007). State of the Takiwā: Te Ahuatanga o Te Ihutai: Cultural Health Assessment of the Avon-Heathcote Estuary and its Catchment.

Pauling, C. (2008). Ngā Wai Pounamu: Cultural Health Assessment of South Island Waterways. Paper presented at the Environmental Defence Society Conference: Conflict in Paradise: the Transformation of Rural New Zealand. June 2008. 15 p.

Pauling, C.; Arnold, J. (2009). Cultural Health of the Lake*. In: Te Waihora/Lake Ellesmere: State of the Lake and Future Management.* Hughey, K.F.D.; Taylor, K.J.W. (eds). EOS Ecology, Christchurch. 77–84.

Reed, M.S.; Dougill, A.J.; Baker, T.R. (2008). Participatory indicator development: what can ecologists and local communities learn from each other. *Ecological Applications 18:* 1253–1269.

Sharpe, A.; Conrad, C. (2006). Community based ecological monitoring in Nova Scotia: Challenges and opportunities. *Environmental Monitoring and Assessment 113:* 395–409.

Taranaki District Council (TDC). (2007). A cultural health index for Reservoir Creek. Indicators for recognising and expressing Tangata Whenua ki Whakatu values. June 2007. 35 p.

Tipa, G. (1999). *Taieri River Case Study*. Technical Paper No. 58. Ministry for the Environment, Wellington.

Tipa, G.; Tierney, L. (2002). Mauri and mahinga kai indicators project: developing a Cultural Health Index. Unpublished report. Tipa and Associates, Dunedin.

Tipa, G.; Tierney, L. (2003). A Cultural Health Index for Streams and Waterways: Indicators for recognising and expressing Māori values. ME475, June 2003. Ministry for the Environment, Wellington.

Tipa, G.; Tierney, L. (2006). Using the Cultural Health Index: How to assess the health of streams and waterways. ME711, February 2006. Ministry for the Environment, Wellington.

Tipa, G.; Tierney, L. (2006). A Cultural Health Index for Streams and Waterways: A tool for nationwide use. ME710, April 2006. Ministry for the Environment, Wellington.

Townsend, C. R.; Tipa, G.; Teirney, L. D.; Niyogi, D.K. (2004). Development of a tool to facilitate participation of Maori in the management of stream and river health. *EcoHealth 1:* 184–195.

Whitelaw, G.S.; Vaughan, H.; Craig, B.; Atkinson, D. (2003). Establishing the Canadian Community Monitoring Network. *Environmental Monitoring and Assessment 88:* 409–418.

Young, R.; Harmsworth, G.; Walker, D.; James, T. (2008). Linkages between cultural and scientific indicators of river and stream health. Motueka Integrated Catchment Management (Motueka ICM) Programme Report. November 2008. 39 p.

11. Appendix A

Types of indicators that could be included by the river iwi in their Cultural Health Indices:

This list of potential indicators was identified during the Study, the majority of which reflect the issues and aspirations that the river iwi identified during the consultation hui held in July/August 2009 and February 2010. They are presented in no particular order of priority.

Examples of indicators that could be incorporated
Iwi satisfaction regarding access to boat ramps, their location and condition
Number of negotiated access agreements over private land
Appropriate controls on access are initiated in areas of high risk and sites of significance
Number of culturally specific sites restored
Ability to implement and enforce local-based management measures such as raahui
Presence/absence of valued species (kai, cultural materials and taonga species
Percentage of the customary rights exercised (e.g., permits granted)
Cultural materials (fit for purpose) available at appropriate sites
Distribution and abundance of valued species compared to historical baseline
Number of whaanau engaging in cultural activities at specific sites (e.g., waananga, programmes, generational)

Examples of indicators that could be incorporated
Iwi are satisfied that protocols for harvesting customarily important kai species are (a) appropriate and (b) observed
Yes/No having to purchase customary kai species (renown species) for marae
Level of contaminants and food safety
Number of safe swimming sites
Water quality standard is the food gathering standard
Satisfaction of iwi users in relation to waka ama/waka taua with (a) flow levels, (b) ability to enter and exit water safely, (c) level of weed and algae present and (d) water quality
Identified springs/groundwater meet drinking water standards
Number of marae that have access to healthy drinking water
Number of taonga species to be in gradual decline, threatened or endangered
Satisfaction of iwi users with experience given presence of invasive species
Number of waterbodies without pest fish, numbers/kg of pest fish removed
Number of reintroductions of taonga species
Number of new monitoring sites introduced that reflect CHI or report card indices
Increase in hapuu and iwi environmental officers
Increase in whaanau and hapuu monitoring activities
Increase in iwi participation in restoration activities on public and private land
Number of iwi hearings commissioners (a) trained and (b) practicing
Number of section 33 transfers (ratio of approved *vs* total applications)
Number of economic development opportunities initiated by whaanau, hapuu and iwi directly related to the river and/or resources
Percentage of Maaori lands being used as whaanau, hapuu and iwi desire
Whaanau, hapuu and iwi are satisfied with their ability to participate and influence decisions and achieve outcomes benefitting the river
Total number of restoration projects initiated compared to number of programmes iwi initiated
Whaanau and hapuu confirm (Yes/No) that the valued features of key sites/river reaches are protected
Percentage of cultural materials available and used today compared to historically
Number of whaanau households that still gather kai and cultural materials

Examples of indicators that could be incorporated
Number of traditional practices that can be reinstated as a result of restoration activities
Number or percentage of rangatahi perceiving species and cultural practices as still relevant and meaningful today
Whaanau and hapuu are satisfied at the level of protection in place for sites of significance
Whaanau and hapuu confirm (Yes/No) that linkages between key sites/river reaches and other sites in significant cultural landscapes are protected
Number of damaging activities at or in the vicinity of identified sites of significance
Number of placenames changed at request of iwi
Number of corrections to incorrect/dislocated placenames
Number of whaanau and hapuu members engaged as volunteers in restoration activities
Number of whaanau and hapuu members engaged as employees in restoration activities
Whaanau and hapuu are satisfied at how the river is being treated
Whaanau and hapuu have a sense of pride in how the river looks
Whaanau and hapuu believe the river is a health environment with which they and communities can interact
Whaanau and hapuu are satisfied with the nature and extent of publicly available information advising of their association with the river
Number of programmes in place for transmission of knowledge (e.g., waananga)
Number of iwi participants in each programme
Number of whaanau who still engage in cultural practices. Percentage of rangatahi engaged in cultural practices
Traditional sites recorded are restored or have a action plan
Satisfaction of tangata whenua that range of healthy habitats used in river and along riverbank (e.g., shelter, tuna burrows covered etc.)
Number of koohanga for valued species that are protected/restored/created
Proportion of whitebait spawning sites in the Waikato River that are protected
Islands identified by iwi are maintained and protected as islands
Number (and area) of new reserves established
Number of regulatory barriers removed (e.g., policies, bylaws, methods, rules removed)
Satisfaction of iwi with ability to use preferred skills, practices, methods when interacting with the river

Examples of indicators that could be incorporated
Iwi specific flow preferences identified
Whaanau, hapuu and iwi satisfied at river flow regimes
Iwi satisfaction with balance of floods/freshes/low flows
Iwi satisfied that flow variability and changing currents do not pose safety risks
Area of land (ha) exposed to frequent flooding (historical compared to today)
Increase in Maaori/cultural specific degrees for freshwater and aquatic sciences
Increase in funding for marae-based restoration activities

Appendix 30: Report Cards

1. Introduction

This paper provides a full set of sample Report Cards for the aspirations outlined in Section 6. These Report Cards can be used to 'audit' priority actions. They use both 'action' indicators and 'state' indicators. As explained in Section 8.2.1, 'state' indicators describe the heath and wellbeing of the Waikato River, and can be scored from monitoring data or predicted from models. 'Action' indicators describe how far a particular restoration action has been carried out.

When carrying out restoration, it is important that monitoring is put in place as soon as possible to assess and manage the restoration actions, including describing the baseline state for health and wellbeing. At this point of time, there is very little data available to score indicators on the current state, so 'action' indicators are used as surrogates (as described in Section 8.2.2). In the following Report Cards, state indicators have been used where possible, along with action indicators. The action indicators could be scored at this time, but many of the state indicators will need development and could not be scored at this time. Exceptions were most water quality indicators and some ecological indicators where there is monitoring data. If a proposed indicator could not be scored, it was still listed in the example Report Cards as a 'placeholder'.

As Report Cards evolve, with experience and ongoing restoration, a subset of the most useful indicators will emerge and can be used. Guidance for developing and scoring indicators is given in Appendix 29: Monitoring and Evaluation.

The Report Cards can be prepared for any part of the Waikato River. In the following examples, we have used monitoring data and predicted water quality for the Waikato River at Horotiu in the Lower Waikato, except where this was inappropriate, and this is indicated (e.g., shallow lakes).

These sample Report Cards illustrate a way forward for the Waikato River Authority. A similar type of Report Card, the Cultural Health Index (CHI) (also see Appendix 29: Monitoring and Evaluation), also contains measures for both the health and wellbeing of the Waikato River, and reporting the overall benefits of restorative actions. As recommended in Section 8, the five river iwi may wish to identify the range of Cultural Health Indexes that they want to see developed, and the type of indicators to be included, that are consistent with their aspirations. These types of Report Cards are described in the Section 8 and Appendix 29: Monitoring and Evaluation.

Environment Waikato have also prepared Report Cards for many indicators, and the Study team has drawn on their methology where relevant.

Note that Regional and National Prosperity aspiration indicators (Aspirations 14 and 15) were not scored. Actual data is used.

2. Report Cards

The sample Report Cards provided below are listed in the following order:

Table	Report Card
1A	Fisheries and Kai - Whitebait
1B	Fisheries and Kai - Tuna
2	Taonga Species
3A	Ecological Integrity - Lakes
3B	Ecological Integrity – Riverine Habitat
4	Aesthetics
5	Swimming and boating
6	Human Health
7	Water Quality
8	Water Allocation
9	Significant and Historic Sites
10	Access
11	Spiritual Values
12	Holism
13	Engagement

Table 1A: Fisheries and Kai - Whitebait Report Card

	Measure or indicator	Target		Current	Score
Action Indicators (see Appendix 6: Whitebait)					
1	Adult iinanga prime stream habitat (km).	800		350	C-
2	Iinanga spawning habitat (bank length km).	20		10.5	C
3	Weeds managed appropriately in low-land drains to enhance adult iinanga habitat (km).	3,460		1,800	C
4	Number of impassable tidegates made fish-friendly in prime potential habitat area at Aka Aka (number).	23[a]		0	E
5	Number of road culverts passable to migrant iinanga (number).	180		70	D
6	Number of farm culverts passable to migrant iinanga (number).	5,000		2,000	D
7	Total stream length of potentially prime habitat for banded kookopu with restored riparian vegetation (km).	310		250	B
8	Number of farm culverts passable to migrant banded kookopu (number).	4,000		2,560	C
9	Restore shallow lake habitat (see Ecological Integrity – Lakes).	2 large riverine lakes		Very poor habitat	E
10	Whitebait habitat score (weighted summary of above).	See above		See above	D-
11	The impact of pest fish on juvenile whitebait is reduced.	Research completed		Research underway	D
12	All aspects of the whitebait fishery come under the control of a single regulatory agency.	Legislation enacted		Several agencies	E
13	For individual fishers, average catch per unit effort.	20g/hr	2g/hr	D	B
14	Total catch.	TBD	TBD	TBD	TBD
15	Water clarity suitability (measured by ariari board, m).	1	0.6[b]	C	A

Table 1A: (cont.) Fisheries and Kai - Whitebait Report Card					
	Measure or indicator	**Target**		**Current**	**Score**
State Indicators				**Current**	**Future**
16	Abundance restored to allow marae to provide locally caught whitebait (number of events).	20[c]	0	E [c]	B[c]
17	Access to traditional fishing sites.	Iwi[d]	D[c]	D[c]	B[c]
18	A measure of activities associated with knowledge transfer.	Iwi[d]	Iwi[d]	Iwi[d]	Iwi[d]

For action indicators, the current score only is given because all actions should score 'A' if completed successfully.
Grey text indicates best professional judgement.
TBD = To Be Developed.
[a]Total number, some may already be partially passable..
[b]Measured at Tuakau.
[C] Strictly speaking these can only be scored by river iwi, but tentative scores were given by the Study team based on feedback from the consultation hui.
[d]Iwi – these can only be scored by river iwi. However, actions recommended for Engagement (see Section 5) include that every year 2 workshops be conducted for each river iwi on restoration methods including traditional fisheries.

Table 1B: Fisheries and Kai - Tuna Report Card					
	Measure or indicator	**Target**	**Current**	**Score**	
Action Indicators (see Appendix 5: Tuna)					
1	Creation of tuna pond habitat (ha).	200	0	E	
2	Creation of tuna wetlands habitat (ha).	500	0	E	
3	Weeds managed appropriately in low-land drains to enhance tuna habitat (km).	3,460	1,800	C	
4	Continue existing elver transfer (number).	2.00E+06	0	A	
5	On-growing transferred elvers (number).	8E+05	0	E	
6	Fish-friendly pump stations (number).	65	0	E	
7	Fisheries legislation on minimum and maximum sizes.	Amended		E	
8	Create reserves in restored Lake Whangape and <3rd order streams.	Regulations amended	None	E	
9	The tuna habitat in the Waikato River catchment is doubled (ha).	5,000	2,500	C	
State Indicators				**Current**	**Future**
10	Total catch	200	100	C	A
11	Abundance restored to allow marae to provide tuna (tonnes).	40	10	D[a]	A[a]
12	Access to traditional fishing sites and/or ability to implement and enforce local-based management measures such as raahui.	Iwi[b]	Iwi[b]	Iwi[b]	Iwi[b]
13	Iwi satisfaction with quality and quantity.	Iwi[b]	D[a]	D[a]	B[a]
14	A measure of activities associated with knowledge transfer.	Iwi[b]	Iwi[b]	Iwi[b]	Iwi[b]

For action indicators, the current score only is given because all actions should score ‘A’ if completed successfully.

Grey text indicates best professional judgement.

TBD = To Be Developed.

[a]Strictly these can only be scored by river iwi, but tentative scores were given by the Study team based on feedback from the consultation hui.

[b]Iwi – these can only be scored by river iwi. However, actions recommended for Engagement (see Section 5) include that every year 2 workshops be conducted for each river iwi on restoration methods including traditional fisheries.

Table 2: Taonga Species Report Card					
	Measure or indicator	**Target**	**Current**	**Score**	
Action Indicators					
1	Tuna habitat (see Tuna).	See Tuna	Fair	D-	
2	Whitebait habitat (see Whitebait).	See Whitebait	Fair	D-	
3	Proportion stream length with RMC score ≥4 weighted for stream size (%).[a]	85	45	C	
4	Knowledge of causes of the decline in kooura, kaaeo and piiharau and restoration actions.	Research projects including marae-based monitoring	Some existing programs	D	
5	Knowledge of successfully rearing and reintroducing kooaro and giant kookopu.	Research being done	Some existing programs	C	
State Indicators				**Current**	**Future**
6	Whitebait catch.	TBD	TBD		
7	Tuna catch.	200	100	C	A
8	Kooura numbers, biomass and distribution (tau kooura).	TBD	TBD	TBD	TBD
9	Kaaeo density in shallow lakes and Waikato mainstem (aerial density).	TBD	TBD	TBD	TBD
10	Piiharau occurrence and size distribution (occurrence/size).	TBD	TBD	TBD	TBD
11	Kooaro occurrence and size distribution in Upper Waikato streams (occurrence/size).	TBD	TBD	TBD	TBD
12	Giant kookopu occurrence and size distribution in urban streams (occurrence/size).	TBD	TBD	TBD	TBD
13	Native bird surveys (aerial density).	TBD	TBD	TBD	TBD
14	Plant species of traditional significant to iwi (cultural plant index in riparian/wetlands).[a]	Correct mix of plants (to be developed by iwi)	TBD	D	
15	Plant species as habitat and food resources for taonga species (habitat plant index in riparian/wetlands).[a]	Correct mix of plants (to be developed by iwi)	TBD	D	

Grey text indicates best professional judgement.
TBD = To Be Developed.
For action indicators, the current score only is given because all actions should score 'A' if completed successfully.
[a]Also a state indicator.

Table 3A: Ecological Integrity - Lakes Report Card				
	Measure or indicator[a]	**Target**	**Current**	**Score**
Action and State Indicators (see Appendix 12: Shallow Lakes)				
2 of the 4 dune lakes (data used from Lake Otamatearoa)				
1	Proportion lake perimeter with RMC score ≥ 4 (%).	90	50	C
2	Submerged plant Index (LakeSPI).	75	18	D
3	Emergent plant index.	TBD	No data	
4	Lake Trophic Status (TLI).	Mesotrophic	Mesotrophic	B
5	Water clarity (m).	1.6	~3	A
6	Dissolved oxygen (% saturation).	80	Unknown	B
7	Pest fish (CPUE[b]).	Goldfish only	Goldfish only	A
8	Community satisfaction with access and use (social survey).	TBD	TBD	TBD
4 of 35 peat lakes (data used from degraded peat lakes)				
1	Proportion lake perimeter with RMC score ≥ 4 (%).	90	30	D
2	Submerged plant Index (LakeSPI).	75	0	E
3	Emergent plant index.	TBD	No data	E
4	Lake Trophic Status (TLI).	Mesotrophic	Super- and hypertrophic	E
5	Water clarity (m).	1.6	<0.4	E
6	Dissolved oxygen (% saturation).	80	Unknown	B
7	Pest fish (CPUE[b]).	Eliminate	Variable	D
8	Community satisfaction with access and use.	TBD	TBD	D
9	Catchment nutrient inputs (loads).	TBD	TBD	E
10	Internal lake nutrients inputs (loads).	TBD	TBD	E
11	Water depth (m).	TBD	TBD	D[c]

Table 3A: (cont.) Ecological Integrity - Lakes Report Card				
	Measure or indicator[a]	**Target**	**Current**	**Score**
2 of 3 large riverine lakes (data used from Lake Whangapee)				
1	Proportion lake perimeter with RMC score ≥ 4 (%).	85	10	E
2	Native submerged vegetation cover.	75	0	E
3	Emergent plant index.	TBD	0	E
4	Lake Trophic Status (TLI).	Mesotrophic	Super- and hypertrophic	E
5	Water clarity (m).	1.6	Highly turbid	E
6	Dissolved oxygen (% saturation).	80	Unknown	B
7	Pest fish (CPUE[b]).	Sustainable numbers (TBD)	Prolific	E
8	Community satisfaction with access and use (social survey).	TBD	TBD	E
9	Catchment nutrient inputs (loads).	TBD	TBD	E
10	Internal lake nutrients inputs (loads).	TBD	TBD	E
Lake Ohakurii				
1	Proportion lake perimeter with RMC score ≥ 4 weighted for stream size (proportion).	0.85	0.25	D
2	Invasive Impact Index (part of Lake SPI).	60	96	E
4	Lake Trophic Status (TLI).	Oligotrophic	Mesotrophic	C
9	Nutrient inputs (loads).	TBD	TBD	D
11	Internal lake nutrients inputs (loads).	TBD	TBD	E

Grey text indicates best professional judgement
TBD = To Be Developed
[a]For additional maatauranga Maaori indicators see Taonga Species Report Card.
[b]CPUE = catch per unit effort

Table 3B: Ecological Integrity - Riverine Report Card					
	Measure or indicator	**Target**	**Current**	**Score**	
Action Indicators					
1	Tuna habitat (see Tuna habitat score[a]).	See Tuna	-	D-	
2	Whitebait habitat (see Whitebait habitat score[a]).	See Whitebait	-	D-	
3	Proportion stream length with RMC score ≥4 weighted for stream size (%).	85	45	C	
State Indicators				**Current**	**Future**
5	Turbidity (NTU).	5	2.7	A	A
6	Dissolved oxygen (% saturation).	80%	98%	A	A
7	Temperature (^{o}C).	20	21.8[c]	A	A
8	Periphyton cover in tributaries (%).	TBD	TBD	TBD	TBD
9	Shade in tributaries.	TBD	TBD	TBD	TBD
10	Macrophyte cover and type.	TBD	TBD	TBD	TBD
11	Sediment composition.	TBD	TBD	TBD	TBD
12	Algal blooms (chlorophyll µg/L).	10	16	B	A
13	Satisfaction of tangata whenua of the range of suitable habitat in river and along riverbank (e.g., shelter, tuna burrows covered).	TBD	TBD	TBD	TBD
14	Ecosystem Health (macroinvertebrate indices).	Satisfactory	See notes	D	A
15	Fish biodiversity.	2.8	2.2	C	B

Grey text indicates best professional judgement.
TBD = To Be Developed.
For action indicators, the current score only is given because all actions should score 'A' if completed successfully.
[a]Tuna and whitebait habitat restoration are used as indicators of restoration of riverine and associated wetland habitat (but not shallow lakes) in general.
[c]Maximum temperature at Horotiu in 2008.

Table 4: Aesthetics Report Card					
	Measure or indicator[a]	**Target**	**Current**	**Score**	
State Indicators[a]				**Current**	**Finish**
1	Riparian vegetation - proportion stream length with RMC score ≥ 4 weighted for stream size (%).[b]	85	45	C	A-
2	Colour of water (change in Munsell colour units).	<10	16.3	C-	B-
3	Clarity of water (m).	1.6	1.28	B	A
4	Sediment composition.	TBD	TBD	TBD	TBD
5	Community satisfaction with appearance of river.	TBD	TBD	TBD	TBD
6	Rubbish.	TBD	TBD	TBD	TBD

TBD = To Be Developed.

[a]The indicators for aesthetics are all state indicators except for one which is both an action and state indicator. Here the efficacy of the priority actions: fencing, restricting stock access, planting and bank protection, are assessed by their effects on riparian aesthetics, water colour and clarity, sediment muddiness, community satisfaction and rubbish, but the actions themselves are described and assessed in the Water Quality Report Card.

[b] See Appendix 11: Riparian Aesthetics.

Table 5: Swimming and Boating Report Card					
	Measure or indicator	**Target**	**Current**	**Score**	
Action Indicators					
1	Strategic Access, Boating and Swimming Plan (completion).	Completed	Some policies and rules	C	
2	Strategic Access, Boating and Swimming Plan (implemented).	Implemented	No plan	E	
3	Snags removed at strategic locations.	10	Some removal	D	
4	Aquatic weeds (sites controlled).	40	2	D	
5	Satisfactory flows for regattas (agreements in place).	Agreements	Some agreements	C	
State Indicators				**Current**	**Future**
7	*E. coli* (numbers per ml).	<126	82	A	A
8	Clarity (m).	1.6	1.28	B	A
9	Toxic algal blooms (chlorophyll concentration µg/L).	10	16	C-	A
10	Duck itch (survey of parasites at weed control sites).	TBD	TBD	TBD	TBD
11	Satisfaction in relation to waka ama/waka taua with (a) flow levels (b) enter and exit water safely (c) level of weed/algae present (d) water quality.	TBD	TBD	TBD	TBD
12	Satisfaction with Waikato River Iwi with ability to use preferred skills, practices and methods when interacting with the river.	TBD	TBD	TBD	TBD
13	Surveys of recreational activity and satisfaction.	TBD	TBD	TBD	TBD

TBD = To Be Developed.

For action indicators, the current score only is given because all actions should score 'A' if completed successfully.

Table 6: Human Health Report Card

	Measure or indicator	Target	Current	Score	
Action Indicators					
1	No sewage discharges to water (number).	0	30	E	
2	Duck itch (sites weeds controlled).	40	2	D	
3	Streams fenced on dairy to exclude all livestock and native buffers established (%).	100	Unknown	TBD	
4	Streams >= 3rd order fenced on sheep and beef to exclude all livestock and native buffers established (%).	100	Unknown	TBD	
5	Septic tanks (cleaning frequency).	2–3 years	2–6 years	C	
6	Marae with treated water (number).	67	0	E	
7	Proportion geothermal fluids discharged (%).	0	~50	C	
8	Food basket health risk.	Food advisory	TBD	TBD	
9	Arsenic release risk.	No significant release	TBD	TBD	
State Indicators				**Current**	**Future**
10	*E. coli* (numbers per ml).	126	82	A	A
11	Toxic algal blooms (chlorophyll µg/L).	10	16	B	A
12	Food basket health risk (mercury concentrations in food).	Survey data	TBD	TBD	TBD
13	Hg in hair samples in the river iwi.	TBD	TBD	TBD	TBD
14	Food basket health risk (arsenic concentrations in food).	Survey data	TBD	TBD	TBD
15	Arsenic release risk (arsenic in hyperlimnion µg/L).	TBD	TBD	TBD	TBD
16	Arsenic release risk (DO in hyperlimnion).	5	TBD	TBD	TBD
17	Arsenic risk (arsenic in water µg/L).	11	35	D	A
18	Duck itch (survey of parasites at weed control sites).	No parasites	TBD	TBD	TBD
19	Iwi satisfaction with food basket health risk (social survey).	TBD	TBD	TBD	TBD

Grey text indicates best professional judgement.
TBD = To Be Developed.

Table 7: Water Quality Report Card					
	Measure or indicator	**Target**	**Current**	**Score**	
Action Indicators					
1	Streams fenced to exclude cattle and banks stabilised (proportion %).	100	22[a]	D+	
2	Streams fenced on dairy to exclude all livestock and native buffers established (%).	100	Unknown	TBD	
3	Streams >= 3rd order fenced on sheep and beef to exclude all livestock and native buffers established (%).	100	Unknown	TBD	
4	Proportion of farm area where P fertiliser optimised to soil tests (%).	100	Unknown	TBD	
5	Proportion of dairy farm area where nitrification inhibitors (%).	100	Unknown	TBD	
6	Proportion of dairy farm area where nitrogen fertiliser is not applied during winter (%).	100	Unknown	TBD	
7	Proportion of dairy farm laneways which drain to streams diverted (%).	100	Unknown	TBD	
8	Proportion of runoff from dairy farms routed though 1% wetlands.	100	Unknown	TBD	
9	Proportion of treated sewage discharges that have advanced nutrient (P) and pathogen removal (%).	100	TBD	TBD	
State Indicators				**Current**	**Future[b]**
10	TP (µg/L N).	500	400	A	A
11	TN (µg/L P).	35	50	B	A
12	Chlorophyll (µg/L).	10	16	B	A
13	Colour (Munsell colour change, Munsell units).	10	16	C	A
14	Turbidity (NTU).	5	2.7	A	A
15	Community satisfaction with water quality (social survey).	TBD	TBD	TBD	TBD

TBD = To Be Developed.
[a]Storey (2010).
[b]Predicted by the Waikato Catchment Model (see Appendix 13: Water Quality).

Table 8: Water Allocation Report Card				
	Measure or indicator	**Target**	**Current**	**Score**
Action Indicators				
1	Holism, ecological effects, tangata whenua values, cumulative effects, assimilative capacity, efficiency.	Variations in RPV6 ratified	Not ratified	E
2	Water quality targets are met under reduced flows (concentrations).	Targets are met for TP, TN, *E. coli*, clarity and colour	Not ratified	E
3	Effects of land use change and riparian management impacts on allocable flows.	Land use change effects on water yield have been considered when setting environmental flows	Not taken into account	E
State Indicators (preliminary suggestions only)[a]			**Current**	**Finish**
4	Water take plans all optimised to efficient water use.	TBD	TBD	TBD
5	Nutrient plans developed for all irrigation of crops and farmland.	TBD	TBD	TBD
6	Tangata whenua values have been considered in all consents (e.g., proportion of time flow within prescribed ecological and iwi-specific range).	TBD	TBD	TBD

TBD = To Be Developed.
[a]Choice of indicators should wait until the Regional Plan Variation 6 is finalised.

Table 9: Significant and Historic Sites Report Card					
	Measure or indicator	**Target**	**Current**	**Score**	
Action Indicators					
1	Waahi Tapu and Significant Sites Management Plan (completion).	Plan	TLA plans	C	
2	Joint Management Agreements between iwi and TLAs (completion).	Significant and historic sites included in JMAs	None signed	C	
3	Appropriate signage (percent completion).	Where it is appropriate and in Plan	0%	D	
4	Restoration at high priority sites identified in the Management Plan (percentage completion).	Percentage completion	0%	D	
State Indicators				**Current**	**Finish**
5	The community understands the historical and cultural associations of sites with the Waikato River (social surveys).	TBD	TBD	TBD	TBD
6	Iwi/community are satisfied that significant sites are protected (and where appropriate) recognised.	TBD	TBD	TBD	TBD
7	Iwi satisfied that valued features of key sites/river reaches are protected.	TBD	TBD	TBD	TBD

Grey text indicates best professional judgement.
TBD = To Be Developed.

Table 10: Access Report Card					
	Measure or indicator	**Target**	**Current**	**Score**	
Action Indicators					
1	Strategic Access Plan is completed for the Waikato Region covering access to the Waikato River, legal impediments, including riparian reserves, access and use for boating, footpaths and cycleways, and riparian vegetation.	Plan completed	Local district plans	C	
2	Access along, the banks of the Waikato River and its tributaries is improved and thereby uses for recreational purposes such as walking and cycling increased.	Various	Access excellent in places, poor in others	C	
3	Access is improved to historic sites, collection sites for kai and cultural materials, and to other sites of cultural significance where river iwi so decide.	Footpaths-some private, some public.	Access excellent in places, poor in others	D	
4	Access to and from the Waikato River is improved by adding to the existing number of reserves and boat ramps, or improving existing facilities, thereby improving and increasing use for boat launching, swimming and leisure activities.	Works completed	Access excellent in places, poor in others	C	
State Indicators				**Current**	**Finish**
5	Proportion of mainstem Waikato and Waipa with walkways and cycleways.	TBD	TBD	TBD	TBD
6	Community satisfied with access (social survey).	TBD	TBD	TBD	TBD

Grey text indicates best professional judgement.
TBD = To Be Developed.

Table 11: Spiritual Values Report Card

	Measure or indicator	Target	Current	Score	
State Indicators[a]				**Current**	**Future**
1	The relationships of iwi, their culture and traditions with the Waikato River which are taonga to them, and integral to their tribal identities (social survey).	Recognised and provided for	TBD	TBD	TBD
2	The relationships of the wider Waikato community, their culture and traditions with the Waikato River (social survey).	Recognised and provided for	TBD	TBD	TBD
3	All statutory plans recognise and provide for iwi and wider Waikato community economic, social, cultural and spiritual relationships with the Waikato River.	All plans	TBD	TBD	TBD

TBD = To Be Developed.
[a]Spiritual Values are mostly addressed through meeting other aspirations.

Table 12: Holism Report Card			
	Measure or indicator	**Target**	**Score**
Action Indicators[a]			
1	Precautionary principle in all plans, policies and decision making.	Plans, policies and rules have been audited and changed if necessary so that decision making is guided by the precautionary principle.	C
2	Plans, policies and rules take into account cumulative effects including multiple stressors.	Technical methods have been developed and adopted. Plans, policies and rules have been audited and changed if necessary to guide decision making	D
3	Plans and policies take into account cultural, spiritual, social and economic relationships of iwi and wider community with the Waikato River.	Plans have been audited and changed if necessary	B
4	Decision making is guided by effective national policy and guidelines.	Effective national policy and guidelines are in place	D
5	An integrated statutory management plan for the Waikato River has been implemented that encompasses physical, chemical, biological, social, economic, cultural and historic matters, at regional, sub-catchment and farm scale.	Plans have been audited and changed if necessary	E
6	Co-management agreements have been established between iwi and local authorities.	Co-management agreements established	B
7	The methods used by local authorities are standardised.	The same procedures, guidelines and standards are used by local authorities where possible	B
8	Actions to restore the Waikato River are being coordinated through the development and implementation of non-statutory management plans.	Plans have been developed (see Boating and Swimming etc.)	D
9	Joint industry-community accords have been established.	Accords established	D

Grey text indicates best professional judgement.
TBD = To Be Developed.
[a]In the Holism Report Card, all the indicators are both ‘action’ and ‘state’ indicators.

Table 13: Engagement Report Card			
	Measure or indicator	**Target**	**Score**
Action Indicators			
1	Representatives from each iwi have completed training course for Commissioners (number trained).	2 per iwi per year	D-
2	Commissioner-run workshops and group training sessions for each iwi (number).	1 per iwi per 2 years	E
3	Waikato River focussed public education centres.	Wanaanga established	E
4	Training workshops on restoration methods including riparian fencing and planting, monitoring, traditional fisheries (number).	2 per Iwi per year	C
5	Financial support and resources to co-ordinators working with iwi and community groups to facilitate better integration of community-based restoration and monitoring initiatives.	Co-ordinators supported	C-
6	Repository of equipment that can be used by iwi and community groups for monitoring the progress of restoration.	Equipment available	D
7	A centralised database and auditing system for monitoring data.	Iwi and centralised databases established, audited and available	D
8	Culturally appropriate monitoring tools.	Available for use by iwi	E
9	Partnerships between WRA, industry and community groups to help restore and protect the Waikato River.	Partnerships established	D
10	Partnerships with international organisations working on river restoration.	Partnerships established	C-
11	Scholarship on the Waikato River and research to fill important information gaps preventing restoration.	Agreement with University of Waikato and Waikato-Tainui College for research and development, number of scholarships, Waikato River academic chair appointed	C+
12	School cross-curriculum resources on restoration.	Prepared and delivered	D

Table 13: (cont.) Engagement Report Card				
	Measure or indicator	**Target**	**Score**	
13	Professional development workshops for school teachers.	1 per year	E	
14	Marae-based enterprises that include vocational training centred on restoration.	Enterprises established and supported	D	
15	Articles and videos promoting the restoration and protection of the Waikato River.	Number of articles and videos	D+	
16	A Waikato River festival held every 2 years to publicise restoration efforts and the value of the Waikato River to the community.	Organised and run	C	
17	Awards are made that celebrate the success of restoration projects.	Organised and awards made	D	
State Indicators			**Current**	**Future**
18	Communities (iwi, hapuu, whaanau and individuals) have the knowledge, skills, attitudes and values that result in sound environmental behaviour (social surveys).	TBD	C	TBD
19	Knowledge (maatauranga Maaori and science) gained from research, good practice and existing relationships with the Waikato River is being effectively transferred and used (social surveys).	TBD	TBD	TBD
20	The unique relationship that the five river iwi have with the Waikato River is understood and recognised within the wider community and regional organisations (social surveys).	TBD	TBD	TBD
21	Communication and publicity initiatives effectively promote greater public knowledge and understanding of the health and wellbeing of the Waikato River (social surveys).	TBD	TBD	TBD

Grey text indicates best professional judgement.
TBD = To Be Developed.

3. Overall Report Card

The following report card is a weighted average of indicator scores derived for the ladder diagrams (see Section 6), and is the Study team's assessment of the current state of the Waikato River. The average score is D+, assuming aspirations have equal weightings.

Aspiration	Score
Fisheries and Kai	D-
Taonga Species	D-
Ecological Integrity	D
Aesthetics	C+
Swimming and Boating	C-
Human Health	C
Water Quality	D+
Water Allocation	C
Significant and Historic Sites	C-
Access	C
Spiritual Values	D+
Local Prosperity	Not scored
National Prosperity	Not scored
Holism	C-
Engagement	D
Average	**D+**

4. Scoring restoration indicators

4.1 Whitebait

Indicator	Methods Outline
1. Adult iinanga prime stream habitat (km)	This indicator measures the amount of potential high quality iinanga habitat in rivers and streams, which is simply recorded at the start of restoration action and updated as restoration proceeds. The scores A, B, C, D, E were linearly distributed between ≥800 km (=’A’) and <25% of target (<200 km =’E’).
2. Spawning habitat	This indicator measures the amount of potential spawning habitat. Historical length unknown, but if all banks in the river with appropriate tidal range and salinity had been utilised, spawning could have occurred within 30 km, but it is likely that only about 20km was used at any one time. The scores A, B, C, D, E were linearly distributed between ≥20 km (=’A’) and <20% of target (<2 km =’E’).
3. Lowland stream habitat	Amount of potential stream habitat below Karaapiro Dam is 6,400 km (riverine with slope <3%). The current state of this potential habitat is largely unknown, but expert opinion suggest 25% is in good condition, 25% needs planting on northern side (plus fencing if that hasn’t occurred already), the rest to managed by physical and herbicide removal of macrophytes. In the example Report Cards the scores A, B, C, D, E were linearly distributed between the target ≥6400 km (=’A’) and <25% of target (<1600 km =’E’). The indicator for this action needs more robust scoring, using data collected actual surveys of these streams and drains to map the course of the restoration actions and the type of actions chosen.
4. Iinanga tide gate migration barriers	This indicator assesses the barriers to migration posed by tide gates. There are presently 23 gates potentially restricting access to prime iinanga spawning and adult habitat. Issues are physical access, barriers at key migration times and barriers posed by the water quality behind gates (especially low DO concentrations). Scoring this indicator in the example Report Cards is based on proportion of gates that pose significant barriers. The scores A, B, C, D, E were linearly distributed between ‘0’ gates (=’A’) and >20 gates (=’E’). In the future, this indicator may need to be developed using a combined index from a survey that measures physical access, barriers at key migration times and the quality of the water behind gates, using the following scheme or its equivalent. Physical access: total barrier=2, partial barrier = 1, no barrier = 0. Barrier at migration times total barrier = 2, partial barrier = 1, no barrier = 0. Poor water quality: DO < 2 mg/L = 2, DO 2 – 6 mg/L = 1, DO > 6 mg/L = 0. The overall score = mean area weighted gate scores and individual gate grades (from combined score) so that: A Score = 0; B Score = 1; C Score = 2 ; D Score = 3 ; E Score 3–6. A mean area weighted gate scores might also be developed that takes into account the area of habitat behind each gate.

Indicator	Methods Outline
Whitebait (cont.)	
5, 6, 8. Iinanga and banded kookopu culvert barriers (number)	Scoring indicators for culverts barriers was based on number of culverts that pose barriers. The scores A, B, C, D, E were linearly distributed between <10% of total number of culverts as barriers (='A') and 80% of total culverts (='E'). Once restoration actions get underway, surveys (to identify barriers) could record the information in a GIS layer, which then could be used to estimate the total area inaccessible to iinanga and banded kookopu. The indicator would then be scored based on these areas.
7. Adult banded kookopu habitat (km)	The historical habitat in the Lower Waikato was unknown but may have been extensive if many streams and wetlands had forest cover. The present total length of first order streams providing prime habitat for banded kookopu = 308 km. The scores A, B, C, D, E were linearly distributed between ≥300 km (='A') and <25% of target (<50 km ='E').
9. Shallow lake habitat	See Ecological Integrity – Lakes.
10. Whitebait habitat score	The total whitebait productivity restored by removing barriers and restoring stream habitat was calculated by summing the area accessible, accounting for increased productivity from restoration actions, and also accounting for increased spawning and return of adults. **This indicator combines and integrates the above 9 other action indicators.**
11. Research on pest fish impacts	The indicator for this action used in the example Report Cards was scored 'A' if the research was funded and being carried out.
12. Whitebait fishery under one regulatory agency	The indicator for this action used in the example Report Cards was scored 'A' when this was completed.
13, 14. Whitebait catch and catch effort	Measuring populations of whitebait is challenging because fish move around and numbers are highly dependant on factors affecting the population in the ocean phase of their life cycles. This indicator method would be developed by collecting information from surveys of whitebaiters to estimate total catch and condition of the whitebait fishery. This requires that a management authority can be established with the legislative right to do this and has the resources to achieve it. There are considerable challenges to address to develop these indicators, in terms of accurate information, natural variability and off-site factors. It would take many years (10–20) to obtain sufficient information to address these challenges. The CPUE scores in the example Report Cards were based on expert opinion and surveys of fishers through Bay of Plenty rivers (Saxton et al., 2010).

Indicator	Methods Outline
Whitebait (cont.)	
15. Water clarity (ariari board)	Water clarity can be measured using ariari boards, which is of direct relevance to fishers and the five river iwi. The method would need development and the relationship determined between it and the usual scientific measure (e.g., black disk, turbidity) measures.
16. Satisfaction for hospitality	Number of times that traditional hospitality is met by providing locally-caught whitebait to guests. This is an issue involving quality and quantity and would need to be developed by the Lower Waikato iwi. The number of times in the example Report Cards were based on 8–10 marae in Lower Waikato for own poukai and supply to Koroneihana.
Access to traditional fishing sites	Satisfaction with restoration of traditional fishing sites. This requires changes in legislation. The indicator would be developed from social surveys with local iwi (see http://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems/social-research).
17.Knowledge transfer	This is an internal matter for iwi and needs development by individual iwi.

4.2 Tuna

Indicator	Methods Outline
1, 2. Pond and wetland habitat	This indicator simply measures the area of pond and wetland habitat created on farms and in marginal low-lying pasture. The scores A, B, C, D, E were linearly distributed between the target of 700 ha (='A') and present day (0ha ='E').
3. Lowland stream habitat	See Whitebait.
4. Upstream transfer of elvers	In the example Report Cards, the scores A, B, C, D, E were linearly distributed between the target for on-growth of 2E+06 elvers (='A') and no transfer (='E').
5. Upstream passage and on-growing of juvenile tuna	In the example Report Cards, the scores A, B, C, D, E were linearly distributed between the target for on-growth of 800,000 elvers (='A') and no on-growth (='E'). In the future, the indicator for this action could be numbers or weight of tuna returns. For example, optimistic but realistic returns could be 60 tonnes (presently they are recorded as 2 tonnes).
6. Pump stations as spawning migration barriers	This indicator assesses the barriers to adult (spawners) tuna migration posed by 65 pumping stations. In the example Report Cards, the scores A, B, C, D, E were linearly distributed between the target of zero barriers (='A') and present day (>50 pump barriers ='E'). Future scores should be based on area or length of channel behind the pumps that have safe downstream passage in place.
7. Fisheries legislation on size	The indicator for this action used in the example Report Cards was scored 'A' when this was completed.
8. Reserves (ha)	This indicator would directly measure the area of reserves created (as part of measures seeking to ensure 40% of the original spawning stock can reach the sea). In the future, this indicator could be alternatively based on surveys of tuna numbers and sizes in the reserves.
9. Tuna habitat doubled	The total tuna productivity restored by removing barriers and restoring stream habitat was calculated by summing the area accessible, accounting for new areas and increased productivity from restoration actions, and increased return of elvers from the sea. **This indicator combines and integrates the above 8 other action indicators.**

Indicator	Methods Outline
Tuna (cont.)	
10. Commercial catch	This indicator assesses the total number and size distribution of fish caught and also released (i.e., adult spawners). The overall aim of the restoration strategy is to sustainably double the weight of fish caught, but this will depend on the actions chosen. This indicator and its grading would be developed once it is clear what strategies have been put in place, the time line for these strategies and the further development of the habitat restored/fish biomass model from these strategies. The monitoring method would collect information from surveys of tuna fishers to estimate total catch and condition of the fishery. This requires that a management authority can be established with the legislative right to do this and has the resources to achieve it.
11. Cultural catch	This indicator is similar to the one above and would be monitored in the same way, but relates to river iwi being able to supply tuna as part of manaakitanga.
12. Access to traditional fishing sites	This index would need to be developed by river iwi.
13. Ability to implement and enforce raahui	This index would need to be developed by river iwi, and is related to establishment of reserves and new fisheries regulations.
14. Satisfaction with quality and quantity	The index would be developed from social surveys with river iwi (see http://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems/social-research).
15. Knowledge transfer	This is an internal matter for iwi and needs development by individual iwi.

4.3 Taonga Species

Indicator	Methods Outline
1, 2, 6, 7. Whitebait and tuna habitat and catch	See Whitebait and Tuna.
3. Riparian vegetation	See Aesthetics.
4, 5. Research on kooura, kaaeo, piiharau, kooaro and giant kookopu	The indicator for this action used in the example Report Cards was scored 'A' if the research was being carried out.
8. Tau kooura	Kooura (freshwater crayfish) are often common in pastoral and forested headwater streams, in edge-habitats along mid to high order streams and rivers, and in deeper areas of lakes. However, there is a lack of information on abundance along the Waikato mainstem and in Waikato lakes. Abundance is best assessed by tau kooura in lakes, spotlighting (rama-kooura) in wadeable areas of lakes and streams, or electric fishing in wadeable streams. This monitoring method would be based on population/size distribution, using traditional methods. It will need development with river iwi.
9. Tau Kaaeo/Kaakahi	Shallow lakes were once extensively colonised by freshwater mussels, but these have been almost completely lost through lake deterioration. It would be straightforward to develop an indicator based on kaaeo coverage (density) of the lake bed with river iwi. The present grade for most shallow lakes is 'E'.
10. Piiharau	A suitable indicator and scoring method would need to be developed from the proposed research programme.
11. Kooaro	A suitable indicator and scoring method would need to be developed from the proposed research programme.
12. Giant kookopu	A suitable indicator and scoring method would need to be developed from the proposed research programme.
13. Native bird densities	There are well established methods for bird surveys, and there are national and local surveys of birds (especially with interest around the release of bellbirds in the Hamilton area and because of initiatives to re-establish tui). This indicator would need development, however, because it is not possible to determine what would constitute a 'restored' ecosystem, given the fact that riparian restoration only is contemplated here, there are many other restoration efforts occurring nationally and because of the many factors that determine bird populations (e.g., predators and predator controls). It is therefore not a fundamental indicator for state but something that should be monitored, documented and developed as restoration proceeds.
14. Cultural materials fit for purpose	Plant species that have traditional significant to river iwi. This cultural plant index in riparian zones and wetlands will need to be developed by river iwi.
15. Plant species suitable for habitat	Plant species that have particular value as habitat and food resources for taonga species. This habitat plant index in riparian zones and wetlands will need to be developed by Iwi in conjunction with DOC.

4.4 Ecological Integrity – Lakes

The action indicators for lakes can all be addressed by stage indicators.

Indicator	Methods Outline
1. Riparian aesthetics	See Aesthetics
2. LakeSPI	'LakeSPI Index' is a measure of the condition of native plants, the impact of invasive plants and grazing fish and the light climate of a lake determined by nutrients and suspended sediment and thus provides an overall indication of lake condition. The shallow lakes of the Waikato region have been graded using the LakeSPI Index. 'LakeSPI Index' is a measure of both the condition of native plants, the impact of invasive plants and grazing fish, and to some extent, the light climate of a lake (as determined by nutrients and suspended sediment) and thus provides an overall indication of lake condition. The higher the score the better the condition. The two indices that make up the LakeSPI Index are: 'Native Condition Index' – This captures the native character of vegetation in a lake based on diversity and quality of indigenous plant communities. A higher score means healthier, deeper, diverse beds. 'Invasive Impact Index' – This captures the invasive character of vegetation in a lake based on the degree of impact by invasive weed species. A higher score means more impact from exotic species. A lake scoring full points for all LakeSPI indicator criteria would result in a LakeSPI Index of 100%, a Native Condition Index of 100% and an Invasive Impact Index of 0%. For the purposes of placing them within the Report Cards, lakes have been categorised into five main groups indicating overall lake condition based on the LakeSPI Index. Lakes are grouped as being in an A 'excellent', B 'high', C 'moderate', D 'poor' or E 'non-vegetated' condition. Absence of submerged vegetation usually indicated severely degraded conditions of water clarity, sediment disturbance and or pest fish disturbance (see Edwards et al., (2009) and http://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/Lakes/lake10-keypoints/).
3. Emergent vegetation	Shallow lakes often have a band of emergent vegetation at the lake shore – an important component of the lake ecosystems. Grazing by pest fish and cattle, and/or competition from exotic weeds can destroy this vegetation. Emergent vegetation distribution is lake specific and depends on the depth distribution and exposure. The indicator would be limited to lake edge only, and would need to consider a wider range of lakes to calibrate the scoring method, in particular locating the upper (A) and lower grades (D, E). The indicator and its scoring could be considered as a proportion of potential/historical extent, where A = >80% of potential, B = 50-80% of potential. C = 20-50% of potential, D = >5%, <20% of potential, E = <5% or dominated by aliens (e.g., Iris pseudacorus).

Indicator	Methods Outline
Ecological Integrity – Lakes (cont.)	
4. Lake Trophic Index (TLI)	Nutrients, water clarity and algal levels determine a lake's trophic state which in turn reflects how well a shallow lake can support native freshwater plants and animals. The Lake Trophic Index of a lake is calculated for each of the four trophic indicators: chlorophyll a (Chla); secchi depth (SD); total nitrogen (TN); total phosphorus (TP). The method has been adopted as a Ministry for the Environment protocol (Burns et al., 2000). It is currently available for only 13 lakes in the Waikato region. The measure compares and integrates measures of nutrients, phytoplankton and clarity. Grade — Lake Type — Trophic Level Index A — Microtrophic — 2.0 A — Oligotrophic — 2.0–3.0 B — Mesotrophic — 3.0–4.0 C — Eutrophic — 4.0–5.0 D — Supertrophic — 5.0–6.0 E — Hypertrophic — 6.0–7.0 (See http://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/Lakes/lake4-keypoints/).
5. Water clarity	See Swimming and Boating.
6. Dissolved oxygen	See Ecological Integrity – Riverine Habitats.
7. Pest fish	Pest fish are major pressures on wetlands, lakes and riverine ecosystems, through predation of, or competition with, native fish, overgrazing of native plants and aquatic weeds, bottom disturbance and increasing turbidity. The presence/absence of each of the destructive fish is a measure of state and pressure on lakes. At present lakes are graded A (no pest fish presence) or E (pest fish presence), because if present, they are assumed to be able to increase to full pest populations. A more refined indicator will need development when fish populations are controlled effectively by intensive netting. This likely to be based in catch per unit effort (CPUE), and will need calibration as to what is a sustainable level. This refined indicator may also need to take into account several pest species.
8. Lake usage	Social surveys of lake usage and satisfaction will need to be developed using social surveys.

Indicator	Methods Outline
Ecological Integrity – Lakes (cont.)	
9. Catchment nutrient loads	Catchment loads can be measured, although this requires an extensive monitoring effort. Instead nutrient loads could be predicted using appropriate models such as OVERSEER see (Appendix 9: Farms) which also incorporate the effects of restoration actions.
10. Internal lake load	To be developed. The TLI can be used as an indicator for total load which includes the internal lake load.
11. Water level indicator	The Waikato peat lakes habitats are particularly vulnerable to water level lowering. Environment Waikato monitors the type of water level control structures in peat lakes in the Waikato region. Control structures are one effective way of protecting water levels within the peat lakes. Most lakes without control structures are considered at high risk to the lowering of water levels. Their indicator shows that: Of the 31 peat lakes in the Waikato region, 55 percent (17 out of 31) are not protected 45 percent (14 out of 31) are protected by engineered water level control structures (see http://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/Lakes/lake5-keypoints/). Additional measures to protect these lakes could be creating wide riparian buffer zones (e.g., 50 m) to allow vegetation to accumulate and to control drainage to the lake. These factors need further consideration and an indicator that integrates restoration measures may need to be developed.

4.5 Ecological Integrity – Riverine Habitats

Indicator	Method
1. Tuna habitat	See Tuna habitat score.[a]
2. Whitebait habitat	See Whitebait habitat score.[a]
3. Riparian vegetation	See Aesthetics.
4. Turbidity (NTU)	See Water Quality.
5. Dissolved oxygen	Dissolved oxygen is necessary for aquatic animals to breathe. Oxygen levels can be compromised by organic enrichment, lake stratification and excessive plant growth. This, in turn, reflects nutrient enrichment, which is a consequence of land use and its management. Scoring this indicator is based on Environment Waikato's classification of dissolved oxygen (% of saturation) as unsatisfactory <80% saturation (see http://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/River-and-streams/riv1-report-card/). Scores for the Report Cards were based on measured values relative to these targets. The scores A, B, C, D, E were linearly distributed between >80% (='A') and =<20% (='E').
6. Temperature	High water temperatures, occurring in plumes of hot wastewater, or during the afternoon of hot days in mid-summer in streams lacking riparian shade, can be stressful to aquatic animals including native fish and invertebrates (Parkyn et al., 2009). Restoration will restore riparian shade to streams which will reduce high temperature excursions. Environment Waikato categorise optimum temperatures for spawning (May to September) as excellent <10°C; satisfactory 10–12 °C; unsatisfactory >12 °C; and optimum temperatures for fish and macroinvertebrate health (October to April) as excellent <16°C; satisfactory 16–20 °C; unsatisfactory >20 °C. An indicator could be developed based on these categories and monitoring data although it is probably the summer temperatures that are more important for assessing ecological integrity.
7. Periphyton cover in tributaries (%)	Periphyton is a complex assemblage of benthic algae, bacteria and fungi that grows on surfaces in streams. Periphyton is an important food source for stream biota. However, nuisance growths of periphyton can occur where there is ample light and nutrients. These growths can make the streambed habitat unsuitable for sensitive invertebrate species and make the stream unattractive for swimming and angling (Parkyn et al., 2010). Methods for monitoring periphyton are well established (Collier et al., 2007 Harding et al., 2009). An appropriate scoring system could be developed for Waikato tributaries.

Indicator	Method
Ecological Integrity – Riverine Habitats (cont.)	
8. Shade	Shade plays an important role in the regulation of stream light and temperature, with profound effects on in-stream plant growth, ecosystem metabolism and the relative suitability of the habitat for differing biota (Parkyn et al., 2009). Shade should increase with riparian planting. Shade can be measured with specialised equipment or light meters. A suitable indicator could be developed based on the amount of optimum shade for different restoration objectives (e.g., tuna, iinanga, banded kookopu, piiharau, cultural materials and temperature limitations) using paired light meters (Parkyn et al., 2010).
9. Macrophyte cover and type	Macrophytes are important components of stream ecosystems. They provide habitat and cover for invertebrates and fish and a surface for colonisation by algae and bacteria. They also reduce water velocity and encourage the deposition of fine particles and their roots help to stabilise the streambed. However, they can also have negative impacts. Dense growths of macrophytes in streams, particularly of invasive introduced species, can smother benthic habitats, reduce stream biodiversity, impede water flow, and their photosynthesis-respiration cycle can cause wide fluctuations in dissolved oxygen and pH (Parkyn et al., 2010). In-stream macrophyte growth in streams is strongly controlled by light availability and should respond to riparian planting. A macrophyte indicator could be developed similar to LakeSPI which measures cover and relative occurrence of native and exotic species. Alternatively, it could incorporate three other simple indices: Macrophyte Total Cover (MTC), Macrophyte Channel Clogginess (MCC) and Macrophyte Native Cover (MNC) developed for the macrophyte cover rapid assessment method of Collier et al., (2007) for wadeable streams.
10. Sediment composition	Stream-bed particle size is a strong driver of the biological community in streams. Fine sediments (sand and silt) are generally considered unsuitable for the majority of invertebrates (except for certain taxa such as worms, molluscs, some midges) and may affect native fish also. Most native fish use the stream bed for shelter, foraging and nesting, thus benefit from large particles (cobbles and boulders) (Parkyn et al., 2010). Excessive amounts of very fine sediments (silt) affects aesthetics because they feel unpleasant to walk in and can turn the water turbid. Restoration action to afforest unstable lands, keep stock out of streams, reduce bank erosion and filter overland runoff should reduce fine sediment inputs. While there are a number of methods for determining sediment composition, a new method is currently being developed for fine sediments (Parkyn et al., 2010). An indicator could be developed from this new method, along with consultation with river iwi (over aesthetics) and an understanding of what should be the natural sediment composition at any particular site or reach.

Indicator	Method
Ecological Integrity – Riverine Habitats (cont.)	
11. Algal blooms (chlorophyll µg/L)	See Water Quality.
13. Ecological health	This indicator measures the presence and numbers of freshwater invertebrates (such as insects, crustaceans and worms) in rivers across the region (see http://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/River-and-streams/riv3-techinfo/). Different types of invertebrates have different tolerances to pollution and are also affected by quality of their habitat. This can be used to tell how good the water and habitat quality is by the types and numbers of invertebrates living in the river. The indicator integrates information from three metrics that reflect the sensitivity and diversity of the invertebrate community at a site, including: • number of sensitive taxa ('species'): mayflies+stoneflies+caddisflies (EPT). • percentage of sensitive taxa: %EPT. • tolerance of taxa to pollution: Macroinvertebrate Community Index (MCI). The indicator is expressed as excellent, satisfactory and unsatisfactory. The example Report Cards have used Environment Waikato's satisfactory/unsatisfactory classification to produce the following grades: A = 80–100% of sites satisfactory or better. B = 60–80% of sites satisfactory or better. C = 40–60% of sites satisfactory or better. D = 20–40% of sites satisfactory or better. E = <20% of sites satisfactory or better. This is highly provisional as it is based on relatively few samples for this metric (about 50).
14. Fish Index Biodiversity Integrity (IBI)	The Fish IBI developed by Joy (2007) could be used to develop this indicator. On a catchment scale, an indicator can be developed based on the Diversity Index for Fish in Rivers (DIFR), which places the Waikato River (from below Lake Taupoo) at 2.7 (Rowe et al., 2010). This is comparable with the nationwide average of 2.6, but it is lower than the value of 3.0 or more which applies to relatively unmodified rivers. In the Waikato River, fish species diversity is biased (upwards) by the high number of exotic species. If these are removed, the measure decreases to 2.2. A value of 2.8 or more (excluding pest fish species) would indicate significant restoration.

4.6 Riparian Aesthetics

Indicator	Method
1. Riparian vegetation	The method is based on the RMC aesthetic ratings (see Appendix 11: Riparian Aesthetics) developed from Environment Waikato's 2007 surveys of streams throughout the Waikato region (Storey, 2010). Riparian management can enhance landscape aesthetics substantially by providing vegetation diversity with ribbons of green within developed pastoral and urban landscapes. Shrubs and trees have generally greater aesthetic appeal than pasture grass, and native vegetation has more appeal than exotic vegetation. However, aesthetics vary highly amongst individuals. RMC rating guide for enhancing stream aesthetics: 0 = bare ground or covered in blackberry and other invasive weeds. 1 = pasture with unconstrained livestock access to the stream, no trees. 2 = fenced pasture grasses without livestock access to the stream; or pasture with livestock access and a 1-2 types of exotic trees (e.g., willows and/or poplars). 3 = varied exotic dominated vegetation, limited livestock access. 4 = native shrubs or wetland is dominant vegetation type. 5 = native forest is dominant vegetation. The score is calculated from the proportion of the stream bank under RMC score ≥4. The scores A, B C, D, are distributed linearly between the maximum of 100% of category 4, 5 (='A') and the minimum is 0% of category 4, 5 (= 'E').
2. Water clarity	See Water Quality.
3. Colour	See Water Quality.
4. Sediment composition	See Ecological Integrity – Riverine Habitats.
5, Community satisfaction	Community satisfaction with appearance of river would be measured by a social survey.
5. Rubbish	Human derived rubbish, either organic or inorganic, can be a major concern for the public and its lack would be a measure of success in engagement in restoration, as well as aesthetics. A monitoring method proposed by Parkyn et al., (2010) monitors rubbish by noting and categorising rubbish that is large enough to be seen by the naked eye. An indicator could be developed by conducting some baseline assessments on reaches, especially in urban areas.

4.7 Swimming and Boating

Indicator	Method
1. Strategic Swimming and Plan	The indicator for this action used in the example Report Cards was scored ‘A’ when the Plan was completed. The present score, ‘C’, was based on present day progress by all river iwi.
2. Strategic Boating and Swimming Plan	The indicator for this action used in the example Report Cards was scored ‘A’ when the Plan was implemented.
3. Snags removed at strategic locations	The indicator for this action used in the example Report Cards was scored ‘A’ when snags were removed at locations identified in the Plan. Presently scored ‘C’ because some snag removal is occurring.
4. Aquatic weeds (sites controlled)	The indicator for this action used in the example Report Cards was scored ‘A’ when the Plan was implemented. Presently scored ‘D’ because weeds are controlled at some locations.
5. Satisfactory flows for regattas (agreements in place)	This action indicator was scored ‘A’ when all agreements have been established. Presently scored ‘D’ because of some existing successful agreements.
6a. *E. coli* (number per 100 ml)	*Escherichia coli* (*E. coli*) bacteria are used as an indicator of the human health risk from harmful micro-organisms present in water, for example from human or animal faeces. The scoring for *E. coli* in the example Report Cards was based on the Regional Plan which specifies median concentrations not exceeding 126 count/100 ml. It was also based on more recent MoH Guidelines (MoH, 2003). These guidelines specify three concentration zones similar to a ‘traffic light’ system. Concentrations <260 counts /100 ml are in the green zone and are acceptable Concentrations ≥ 260 counts /100 ml are in the orange zone and trigger further sampling to investigate these concentration of concern. Concentrations > 550 counts/ 100ml are in the red zone and unacceptable for contact recreation and are equivalent to ‘must close beach’. Scores for the Report Cards were based on measured or predicted values relative to the MoH (1999) Recreational Guidelines of 126 count/100 ml and the MoH (2003) red zone. The scores A, B, C, D, E were linearly distributed between ≤=126 (=’A’) and ≥ 550 (=’E’).
6b. *E. coli* (alternative method)	An alternative method may need to be developed with the more recent MoH Guidelines (MoH, 2003). Note that Environment Waikato have used these guidelines and the following classification for E. coli: excellent <55 /100 ml; satisfactory 55 - 550 /100 ml; unsatisfactory >550 /100 ml (see http://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/River-and-streams/riv2-keypoints/).

Indicator	Method
Swimming and Boating (cont.)	
7. Clarity	Water clarity and underwater visibility is important for recreation such as swimming and boating. It is also important from an aesthetic point of view – most people prefer clear water in rivers and streams. To allow good visibility for swimming, MfE guidelines specify that people should be able to see at least 1.6 m underwater. Clarity is determined by suspended sediment, phytopankton and dissolved colour concentrations in the water. These, in turn, reflect land use and its management, erosion and artificial drainage of peat lands. The targets are described in Appendix 13: Water Quality and are 4 m in the Upper River, 1.6 m everywhere else, except for 1 m in the lower Waikato (below the Waipa confluence). Scores for the Report Cards were based on measured or predicted values relative to these targets. The scores A, B, C, D, E were linearly distributed between ≥target (='A') and 0 m (='E'). Note that Environment Waikato have a classification for clarity of: excellent > 4 m; satisfactory 1.6 – 4 m; unsatisfactory <1.6 m. Their scoring for their report cards is based on number of samples which fall in these categories (see http://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/River-and-streams/riv2-report/).
9. Toxic algal blooms	Blue green algae are potentially toxic, and high concentrations can be associated with acute or chronic toxicity to aquatic animals, watering stock, dogs, and humans through drinking water supplies. Blue-green algae (BGA) have been monitored in the mainstem of the Waikato River and in some of the shallow lakes in the lower river. Monitoring has been based on older MfE Guidelines for BGA cell counts for drinking water supplies of <2,000 counts/100 ml and 15,000 counts/100ml for contact recreation. New guidelines use a traffic light system based on the volume of BGA. However, monitoring information is only now being collected and older data is being converted to this form. This indicator will need development in the future based on the new guidelines, conversion of the historical monitoring data where possible, and new monitoring data. In the Report Cards, the risk of <u>large</u> (and hence problematic) BGA blooms was assessed using chlorophyll data. The Study team determined that the relationships between chlorophyll concentrations and the occurrence, size and extent of BGA blooms suggested that there is a low risk of a large BGA bloom if total chlorophyll was less than 10 µg/L. The scores A, B, C, D, E were linearly distributed between <=target (='A') and ≥ 2 x target (='E').

Indicator	Method
Swimming and Boating (cont.)	
10. Duck itch (survey of parasites at weed control sites)	This indicator would need research and development. The indicator may be the host snail, the parasite or some proven correlatory parameter, such as weed density.
12. Satisfaction with interaction with the river	This indicator for satisfaction with ability to use preferred skills, practices and methods when interacting with the river will need development by five river iwi.
13. Surveys of recreational activity and satisfaction	The index would be developed from social surveys with river iwi and with the wider community (see http://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems/social-research).

4.8 Human health

Indicator	Method
1. Treated sewage discharges to water (volume)	This action indicator is scored through the proportion of treated sewage discharges that are discharged to land, wetlands or through rapid infiltration devices. Currently score 'D' because some WWTP use land disposal or will do so in the future.
2. Duck itch (sites weeds controlled)	The indicator for this action used in the example Report Cards was scored 'A' when the Swimming and Boating Plan was implemented. Presently scored 'D' because weeds are controlled at only 2 locations.
3. Streams fenced on dairy (%)	See Water Quality.
4. Streams >= 3rd order fenced on sheep and beef	See Water Quality.
5. Septic tanks	The action indicator is based on cleaning frequency, and in the Report Cards this was the proportion of septic tanks on 2–3 year cleaning cycle. In the Report Card this was scored 'C' because 60% are already on that cleaning cycle. In the future, it should be based on the proportion of septic tanks that meet satisfactory guidelines in terms of distance to waterways, condition and operation. Such an indicator needs development, through actual surveys of septic tanks near waterways.
6. Marae with treated water	Proportion of marae with water treatment plants. In the Report Card this was scored 'E' because assumed none have water treatment (however this does not imply poor drinking water quality).
7. Geothermal fluids discharged (%)	Existing consent condition should result in no untreated discharges to the river. This indicator records the proportion of geothermal fluids discharged (currently about 50% from Wairaakei).
8. Food basket health risk	The indicator for this action used in the example Report Cards was scored 'A' if the research was being carried out.
9. Arsenic release risk	The indicator for this action used in the example Report Cards was scored 'A' if the research was being carried out.
10. *E. coli* (no. per 100 ml)	See Swimming and Boating.

Indicator	Method
Human health (cont.)	
11. Turbidity (high flows)	Turbidity is routinely monitored and used as an ecological indicator. It may also be used in another way for ecological health. This is based on the fact that there is a relationship between *E. coli* and turbidity (particulate matter) at high flows. *E coli* levels are much higher during high turbidity (suspended sediment), which probably reflect common processes of washoff and association of bacteria with suspended sediment. Most weather and flows during stormflows are not condusive to contact recreation. However, there are some conditions which are suitable for contact recreation that involve elevated turbidity, e.g., high turbidity from localised rain storms upstream, long recession flows during warm, fine weather. This indicator needs development to determine a turbidity (NTU) or clarity (m) where the *E. coli*/turbidity relationship indicates *E. coli* levels of concern. Why do we need this indicator? Turbidity is much easier to measure than *E. coli*, and can be measured continuously and remotely and does not require rapid return of samples to the laboratory. It may also be developed as an indicator for land management action where these actions reduce sediment inputs to receiving waters.
12. Food basket health risk (mercury concentrations in food)	At present there is limited historical data available which suggests some risk (see Appendix 21: Toxic Contaminants). This indicator needs development (together with appropriate government agencies, e.g., NZ Food Safety Authority) from further monitoring and up-to-date information over a greater geographical area, for Hg levels in kai and kai consumption patterns.
13. Hg in hair samples of river iwi	This potential indicator is currently being utilised in a NIWA research project on traditional food sources (Phillips, 2008) to help understand exposure.
14. Food basket health risk (arsenic concentrations in food)	Arsenic is not strongly accumulated in kai except for watercress, where it can be taken up from both the water and the sediments (Robinson et al., 2003). A health assessment of watercress from Lake Ohakurii has indicated that regular consumption of 16g of fresh watercress a week from Lake Ohakurii would be sufficient to exceed the tolerable daily intake (Robinson et al., 2006). The low availability of watercress in the Waikato River mainstem is considered to be a significant limitation to regular dietary consumption. (The hyperaccumulation of As by some aquatic plants, including watercress, also makes these suitable for monitoring ambient As conditions). Indicator grades are yet to be developed after collecting sufficient data. However, the small quantity needed to exceed tolerable daily intake suggest this grade is probably 'E' at present in Lake Ohakurii.
15. Arsenic release risk (arsenic in hyperlimnion µg/L)	This indicator will need to be developed from laboratory mobilization experiments and monitoring of As concentrations in the hyperlimnion (bottom waters).

Indicator	Method
Human health (cont.)	
16. Arsenic risk in water (downstream of Ohakurii)	The risk of arsenic release can also be assessed by monitoring arsenic levels in the river downstream from Ohakurii. This also addresses the desire by Maaori to drink untreated surface water. While this desire is constrained by risk of infection by pathogen organisms, it can also be constrained by arsenic levels. Arsenic concentrations are routinely monitored by Environment Waikato (mean 20 µg/L range 15–40 µg/L; background is ~11 µg/L from Lake Taupoo). The following was summarized from Piper and Kim (2006). Health risk at 50 µg/L - intellectual impairment in children and a significant cancer risk. Rarely (if ever) occurs in river. Cancer risk at 20 µg/L - excess bladder/lung 1:140, excess skin 1:1700. Cancer risk at 10 µg/L - excess bladder/lung 1:300 (MoH, 2005; drinking water guideline). Cancer risk at 5 µg/L - excess bladder/lung 1:500. Cancer risk at 3 µg/L - excess bladder/lung 1:900. Any indicator would need development with MoH, but a suggested approach could be based on comparing mean concentrations in water with cancer or health risk, e.g., A <3 µg/L - very low cancer risk, achievable by conventional water treatment. B 3–10 µg/L - low cancer risk, background (Lake Taupoo gates). C 11–20 µg/L - low – moderate cancer risk, these concentrations occur frequently in river. D 21–50 µg/L - moderate cancer risk, these concentrations occur frequently in river at the present day. E >50 µg/L - significant cancer risk and intellectual impairment in children.
17. Arsenic release risk (DO in hyperlimnion)	Dissolved oxygen in the hyperlimnion with concentrations <2 mg/L is strong indicator of developing anoxic conditions. This indicator will need development through surveys of depth profiles of dissolved oxygen in Lake Ohakurii, and other lakes downstream. See Ecological Integrity – Riverine Habitats.
18. Duck itch parasite	See Swimming and Boating.
19. Iwi satisfaction with food basket health risk	The index would be developed from social surveys with local iwi (see http://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems/social-research).
Viruses (potential future method)	Based on direct measures of human adenoviruses and retroviruses. These viruses are indicators for human viral pollution, septic tanks and poor WWTP treatment. They are very difficult and costly to monitor. A major issue at present is the methodology which keeps changing (and improving). Different methods are not directly comparable. This indicator could be developed in the future.

Indicator	Method
Human health (cont.)	
Cryptosporidium (potential future method)	Cryptosporidium is a human pathogen, largely derived from dairy cows. It is therefore an indicator of human pathogen pollution, a specific zoonose, protozoan pollution and contamination of waterways by dairy cows. It is, however, difficult to measure. It could be developed as an indicator in the future when stable, routine methodology becomes available.

4.9 Water Quality

Indicator	Method
1 – 9. Farm actions	All the farming actions (e.g., fencing, planting and fertiliser controls) are scored by the proportion of farm area or waterways length which have successfully employed those actions.
10. Total nitrogen	Nitrogen is a nutrient for plants. Excessive amounts can encourage the growth of aquatic plants to nuisance levels, especially algae. Total nitrogen is a direct measure of the extent of nutrient enrichment and the risk of algal blooms. These reflect land use and its management, and WWTP discharges. The targets for TN are described in Appendix 13: Water Quality and are 300 µg/L for the Upper River (above Karaapiro Dam) and 500 µg/L elsewhere. Scores for the Report Cards were based on measured or predicted values relative to these targets. The scores A, B, C, D, E were linearly distributed between <=target (='A') and ≥ 2 x target (='E'). Note that Environment Waikato have a classification for total nitrogen as: excellent <100 µg/L; satisfactory 100–500 µg/L; unsatisfactory >500 µg/L. Their report card scoring is based on number of samples which fall into these categories (://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/River-and-streams/riv1-report-card/).
11. Total phosphorus	Phosphorus is a nutrient for plants. Excessive amounts can encourage the growth of aquatic plants to nuisance levels; especially algae. Total phosphorus is a direct measure of the extent of nutrient enrichment, and the risk of algal blooms. These reflect land use and its management, and WWTP discharges. The targets for TP are described in Appendix 13: Water Quality and are 20 µg/L for the Upper River (above Karaapiro Dam) and 35 µg/L elsewhere. Scores for the example Report Cards were based on measured or predicted values relative to these targets. The scores A, B, C, D, E were linearly distributed between <=target (='A') and ≥ 2 x target (='E'). Note that Environment Waikato have a classification for total phosphorus as: Excellent <10 µg/L; Satisfactory 10–40 µg/L; unsatisfactory >40 µg/L. Their report card scoring is based on number of samples which fall into these categories (://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/River-and-streams/riv1-report-card/).
12. Clarity	See Swimming and Boating.
13. Colour	The colour of the water is important for aesthetic reasons. The river changes from blue, clear water at the Taupoo Gates, to greeny-blue in the lower hydrolakes and Middle Waikato River, to yellow green then yellow-brown in the lower river. The targets for colour are <10 Munsell units below the values that are predicted to have existed in the river in the 1920s prior to the dams being built or peat land being drained (see Appendix 13: Water Quality). Scoring in the Report Cards was based on a linear scale: where it is measured or otherwise a predicted change in Munsell units scores. The scores A, B, C, D, E were linearly distributed between <=target (='A') and ≥ 2 x target (='E').

Indicator	Method
Water Quality (cont.)	
14. Turbidity (NTU)	Turbidity is a measure of the murkiness of water, reflecting the amount of sediment and algae in the water. High turbidity reduces the amount of light available for plants to photosynthesise. It also makes it difficult for fish and other animals to see their prey (but may protect prey). It inhibits native fish migrations, especially banded kookopu. Turbidity is determined by suspended sediment and phytopankton concentrations in the water. These, in turn, reflect land use and its management, and erosion. Turbidity should be less than 5 NTU (turbidity measurement scale) for water to support plant growth. This indicator was not scored in the Report Cards, but could be based on Environment Waikatos Classification for turbidity at low flow of unsatisfactory >5 NTU. Note that Environment Waikato have a classification of excellent <2 NTU; satisfactory 2–5 NTU; unsatisfactory >5 NTU. Their report card scoring is based on number of samples which fall into these categories (://www.ew.govt.nz/Environmental-information/Environmental-indicators/Inland-water/River-and-streams/riv1-report-card/).).
15. Chlorophyll	Chlorophyll is used as a measure of total algal biomass. High levels can affect aesthetics, clarity and colour and also be indicative of high risks of cyanobacteria (blue-green algae) blooms. Targets for the Waikato are outlined in Appendix 13: Water Quality, and were based on trigger level of 5 µg/L, warning level of 10 µg/L and water filter-clogging levels of 20 µg/L. A target of 5 µg/L was set for the Upper Waikato, and 10 µg/L elsewhere. Scores for the Report Cards were based on measured or predicted values relative to these targets. The scores A, B, C, D, E were linearly distributed between <=target (='A') and ≥ 2 x target (='E').
16. Cyanobacteria (Blue-green algae)	See Swimming and Boating

4.10 Water Allocation

The need for, and the type of indicators used for assessing water allocation will need to be determined once the Regional Plan Variation 6 (RPV6) is in place. Possible indicators may relate to water take being optimised to efficient water use and the impact of irrigation on nutrient exports from farmland. These would require expert development (e.g., in the latter case, irrigation may affect other indicators (e.g., nutrients, clarity, chlorophyll, blue green algal blooms) and restoration outcomes. River iwi may wish to develop an indicator that assesses whether tangata whenua values have been considered in consents for water takes. The Study team considers it prudent to await the outcome of RPV6 before considering indicator development.

4.11 Significant and Historical Sites

Indicator	Method Outline
1. Waahi Tapu and Significant Sites Management Plan	The indicator for this action used in the example Report Cards was scored 'A' when this was completed. The present score, 'C', was based on present day progress by all river iwi.
2. Joint Management Agreements (JMA) between iwi and TLAs	A short-term indicator could be based on the proportion of JMAs signed (% completion). In the long term, a performance indicator could be developed which is a measure of ongoing satisfaction with relationships. In the example Report Cards, it was assumed that while none have been signed, there has been significant progress in relationships between river iwi and TLAs (hence 'C').
3. Signage meets Management Plan (% completion)	An indicator could be based on the proportion of sites that have adequate signage and correct place names consistent with the Management Plan. In the example Report Cards it was assumed that existing signage contributes to this indicator, but much needs to be done (hence 'D').
4. Restoration of sites meets Management Plan (% completion)	An indicator could be based on the progress of restoration consistent with the Management Plan % completion. In the example Report Cards it is assumed that existing restoration had moved the score to 'D'.
5. The community understands the historical and cultural associations of sites with the River (social surveys)	This indicator will need development through social surveys.
6. Iwi/community are satisfied that significant sites are protected (and where appropriate) recognised	This indicator will need development through social surveys.
7. Iwi satisfied that valued features of key sites/river reaches are protected	This indicator will need development through social surveys.

4.12 Access

Indicator	Method Outline
1. Access Management Plan	The indicator for this action used in the example Report Cards was scored 'A' when this was completed. The present score, 'C', was based on present day access initiatives by TLAs.
2. Proportion of mainstem Waikato and Waipa with walkways and cycleways meets management plan (% completion)	The proportion of riverbanks that have pathways and cycleways consistent with the Management Plan. Presently scored 'C' because access is excellent in some areas and patchy in others.
3. Access to historic sites, collection sites for kai and cultural materials meets management plan (% completion)	The proportion of riverbanks that has access consistent with the Management Plan. Presently scored 'C' because access is excellent in some areas and patchy in others.
4. Number and distribution of reserves meet management plan (% completion)	The proportion of riverbanks that has reserves consistent with the Management Plan. Presently scored 'C' because of existing reserves.
5. Number and distribution boat ramps meet management plan (% completion)	The proportion of riverbanks that has boat ramps consistent with the Management Plan. Presently scored 'C' because of existing boat access.
6. Iwi satisfaction with access	This is probably best assessed through a cultural recreation index (see Appendix 29: Monitoring and Evaluation).
7. Community satisfied with access (social survey)	This indicator will need development through social surveys.

4.13 Spiritual Values

<table>
<tr><th>Indicators</th><th>Method Outline</th></tr>
<tr><td>1. The relationships of river iwi, their culture and traditions with the Waikato River which are taonga to them, and integral to their tribal identities (social survey)</td><td rowspan="2">These two state indicators would need to be developed from social surveys with river iwi and the wider communities (see http://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems/social-research).</td></tr>
<tr><td>2. The relationships of the wider Waikato community, their culture and traditions with the Waikato River (social survey)</td></tr>
<tr><td>3. All statutory plans recognise and provide for river iwi and wider Waikato community economic, social, cultural and spiritual relationships with the Waikato River</td><td>See Holism.</td></tr>
</table>

4.14 Regional and National Economic Wellbeing

This is a specialist area and would be assessed using economic models to estimate net regional and national value and employment added. We recommend that this is updated every 5 years.

4.15 Holism

Indicator	Method Outline
1. Precautionary principle in all plans, policies and decision making	Plans that have been audited and changed if necessary (% complete).
2. Plans, policies and rules take into account cumulative effects including multiple stressors	Plans have been audited and changed if necessary (% complete).
3. Plans and policies take into account cultural, spiritual, social and economic relationships of river iwi and wider community with the Waikato River	Plans have been audited and changed if necessary (% complete).
4. Decision making is guided by effective national policy and guidelines	WRA determines where national policy and guidelines are needed, makes recommendations with other regional authorities and monitors outcomes (% complete).
5. An integrated statutory management plan for the Waikato River has been implemented that encompasses physical, chemical, biological, social, economic, cultural and historic matters, at a regional, sub-catchment and farm scale	Plans have been audited and changed if necessary (% complete).
6. Co-management agreements have been established between river iwi and local authorities	Co-management agreements established (% complete).
7. The methods used by local authorities are standardised	Procedures, guidelines and standards are used by local authorities where possible.
8. Actions to restore the Waikato River are being co-ordinated through the development and implementation of non-statutory management plans	See Swimming and Boating, Significant and Historic Sites, and Access.
9. Joint industry-community accords have been established	Accords identified and established. In the short term, the indicator could be the number successfully established. In the long term, a performance indicator could be developed which is a measure of ongoing satisfaction with relationships.

4.16 Engagement

Indicator	Method outline
1. Iwi Commissioners trained	Ongoing action based on numbers trained per year or total numbers of active commissioners. It should be refined after optimum numbers is determined.
2. Commissioner-run river iwi workshops	Ongoing action based on number of training courses.
3. Waikato River focussed public education centres	Number of visitor centres, but could change in the future to number of visitors.
4. Training workshops on restoration methods	Number of workshops and workshop attendees.
5. Financial support and resources to co-ordinators working with iwi and community groups	No grading, financial support stated. Performance indicator will need to be developed.
6. Repository of equipment that can be used by iwi and community groups	No grading, but a performance indicator (e.g., equipment register.
7. Centralised databases and auditing system for monitoring data	% completion.
8. Culturally appropriate monitoring tools	Not graded but register of CHI developed and reported to WRA.
9. Partnerships between WRA, industry and community groups	After partnerships have been identified and established, a performance indicator could be developed which is a measure of ongoing satisfaction with relationships.
10. Partnerships with international organisations working on river restoration	Partnerships identified and established. Goals for a performance indicator would need to be developed, such as visits, joint projects, and scientific papers. Annual report presented to WRA.
11. Scholarship on the Waikato River and research	Not graded, but number of projects, papers, reports, honours and assessment of output usefulness for restoration recorded.
12. School cross-curriculum resources on restoration	Curriculum needs identified and developed (% completion).
13. Professional development workshops for school teachers	Not graded. Number of participating teachers recorded.
14. Marae-based enterprises that include vocational training centred on restoration	After enterprises established and supported, performance indicators could be developed based on the nature of the activities.
15. Articles and videos promoting the restoration and protection of the Waikato River	Not graded, but an assessment on the number/quality of articles and videos is presented to WRA and public.

Indicator	Method Outline
Engagement (cont.)	
16. A Waikato River festival held every 2 years to publicise restoration efforts and the value of the Waikato River to the community.	Not graded, but a detailed assessment is presented to the WRA and public after each festival.
17. Awards are made that celebrate the success of restoration projects	Not graded, but a report would be presented to the WRA annually.
18. Communities (iwi, hapuu, whaanau and individuals) have the knowledge, skills, attitudes and values that result in sound environmental behaviour (social surveys)	The next four state indicators are the primary methods for assessing engagement. These indicators would need to be developed from social surveys with river iwi, and the wider communities (see http://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems/social-research).
19. Knowledge (maatauranga Maaori and science) gained from research, good practice and existing relationships with the Waikato River is being effectively transferred and used (social surveys)	
20. The unique relationship that the river iwi have with the Waikato River is understood and recognised within the wider community and regional organisations (social surveys)	
21. Communication and publicity initiatives effectively promote greater public knowledge and understanding of the health and wellbeing of the Waikato River (social surveys)	

5. References

Burns, N.M.; Bryers, G.; Bowman, E. (2000). Protocol for monitoring trophic levels of New Zealand lakes and reservoirs. Ministry for the Environment, Wellington, New Zealand. 137 p.

Collier, K.; Kelly, J.; Champion, P. (2007). Regional guidelines for ecological assessments of freshwater environments: aquatic plant cover in wadeable streams. Environment Waikato Technical Report 2006/47. 25 p.

Edwards, T.; Clayton, J.; de Winton, M. (2009). Assessment of the ecological condition of lakes in the Waikato region using LakeSPI – 2009. Environment Waikato Technical Report: TR 2009/14.

Harding, J.S.; Clapcott, J.; Quinn, J.; Hayes, J.; Joy, M.; Storey, R.; Greig, H.S.; 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, New Zealand, 133 p.

Joy, M. (2007). A New Fish Index of Biotic Integrity using Quantile Regressions: the Fish QIBI for the Waikato Region. Environment Waikato Technical Report: TR 2007/23.

MFE (2003). Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. Ministry for the Environment, Wellington. June 2003.

MoH (2005). Drinking water standards for New Zealand 2005. Ministry of Health, Wellington, New Zealand.

Parkyn, S.; Collier, K.; Clapcott, J.; David, B.; Davies-Colley, R.; Matheson, F.; Quinn, J. Shaw, W.; Storey, R. (2010). The Restoration Indicator Toolkit: Indicators for Monitoring the Success of Stream Restoration. Report published by NIWA (in press).

Phillips, N. (2008). Risks of contaminated wild kai. *Water and Atmosphere 16(1)*: 9.

Piper, J.; Kim, N. (2006). Arsenic in groundwater in the Waikato Basin. Environment Waikato Technical Report 2006/14.

Robinson, B.; Duwig, C.; Bolan, N.; Kannathasan, M.; Saravanan, A. (2003). Uptake of arsenic by New Zealand watercress (*Lepidium sativum*). *Science of the Total Environment 301*: 67–73.

Robinson, B.; Kim, N.; Marchetti, M.; Moni, C.; Schroeter, L.; van den Dijssel, C.; Milne, G.; Clothier, B. (2006). Arsenic hyperaccumulation by aquatic macrophytes in the Taupo Volcanic Zone, New Zealand. *Environmental and Experimental Botany 58*: 206–215.

Rowe, D.; Grayling, S.; Davison, B. (2010). Fish communities in New Zealand River catchments: Development of a Diversity Index for Fish in Rivers (DIFR). Report prepared for NIWA (in prep.).

Saxton, B.A.; Rowe, D.K.; Stancliff, A.G. (1987). Species composition and relative importance of whitebait fisheries in 13 Bay of Plenty rivers. N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report No. 79. 63 p.

Storey, R. (2010). Riparian characteristics of pastoral streams in the Waikato region, 2002 and 2007. NIWA Client Report: HAM2010-022. Hamilton, 57 p.

Turner, N.; Cressey, P.; Lake, R.; Whyte, R. (2005). Review of non-commercial wild food in New Zealand, ESR report for New Zealand Food Safety Authority, Wellington.

Appendix 31: Economic Modelling

1. Introduction

In this paper, the assessment of the economy-wide effects resulting from the introduction of measures to clean up the Waikato River is undertaken through a modelling framework that is based primarily on economic input-output (IO) analysis. Today, IO analysis is one of the most widely applied methods in economics, with the approach being especially popular in the study of regional-level economics (Miller and Blair, 2009). One of the core strengths of IO analysis is that it captures the complex interactions and interdependencies occurring between different actors within an economy. This means that it is possible to consider a vast number of the indirect or flow-on effects that occur throughout an economy as a result of any type of economic change. IO analysis also enables economic impacts to be evaluated at the level of individual sectors or industries, thus providing a disaggregate picture of the nature of economic impacts.

2. Selection of an appropriate modelling framework

As stated above, this paper utilises IO analysis to assess the economic impacts on the Waikato and New Zealand economies associated with the proposed restoration actions under Scenarios 2 and 3 (refer Section 6 of the main report). The full details of this approach are contained in the remainder of this paper.

It is important to note that alternative methodologies do exist for assessing economic impact; with the key alternative being the use of Computable General Equilibrium (CGE) modelling. The authors of this paper are widely published in the application of both input-output (see, for example, McDonald and Patterson (2004), Patterson and McDonald (2004), McDonald et al., (2006), Patterson et al., (forthcoming) and Smith and McDonald (forthcoming) and computable general equilibrium (see, for example, Zhang et al., (2008) and Yeoman et al., (2009)) techniques. Key studies undertaken by the authors include the official 1999 and 2003 America's Cup EIAs (Economic Impact Analysis) for the Office of Tourism and Sport/Ministry of Tourism, the EIA of the 2011 Rugby World Cup for the NZRFU, EIAs for Auckland International Airport, Exercise Ruaumoko and numerous others.

Based on this experience the authors would like to note several key reasons for the adoption of IO rather than CGE in this study:

- *Paucity of regional/national data*. The development of a CGE model would require the creation of a multi-regional Social Accounting Matrices (SAMs), if both regional and national impacts were to be reported. No multi-regional SAMs have been generated in New Zealand to date[1]. The production functions used by CGE models require elasticities of demand for each factor component (i.e., K, L). While this data exists in unit statistical records held by SNZ, it is however not readily available. Similarly, no regional, and only limited *ad hoc* national, data exists for elasticities employed for household/government/etc. utility functions – a further requirement of CGE models.

- *Comparative statics and transitional dynamics*. The key advantage of CGE over IO is that dynamic behaviour can be simulated, including impacts associated with investment and employment and price change. A key limitation however is that most current CGE models utilize only a comparative static framework based on recursive dynamics i.e., the long run impact. Unfortunately, this tells us little about the transitional dynamics associated with the driving shocks.

- *Scenario analysis versus optimisation*. The key advantage of the IO over the CGE approach is that it is well suited to studying transitional dynamics through year-by-year comparisons.

- *Timeframe and budget*. Final key reasons for the selection of IO rather than CGE were the constraints of time and budget for this study.

3. Methodology

Prior to describing the specifics of the methodology, it is helpful to provide readers, particularly those not familiar with input-output analysis, with a brief introduction to the IO framework[2]. This introduction is provided in Section 3.1. The remaining sections of the methodology describe the way in which the three scenarios[3] are incorporated into an IO framework, including the major assumptions that are applied.

3.1 Input-Output Analysis

At the core of any IO analysis is a set of data that measures, for a given year, the flows of money or goods among various sectors or industrial groups within an economy. These flows are recorded in a matrix or 'IO table' by arrays that summarize the purchases made by each industry (its inputs) and the sales of each industry (its outputs) from and to all other industries. By using the information contained within such a matrix, IO practitioners are able to calculate mathematical relationships for the economy in

[1] Several attempts are however currently underway in academia (see, for example, xxxx (2009)).
[2] Those who wish to learn more about input-output analyses can refer to authors such as Miller and Blair (2009),
[3] Refer to Section 6 of the main report for a detailed description of the three scenarios which were analysed. Note that this appendix refers to Scenario 1 as BAU (business as usual), Scenario 2 as BMP (best management practice) and Scenario 3 as EBMP (extended best management practice). The BAU, BMP and EBMP terms were subsequently dropped in the final report but the nature of the scenarios and the actions they cover have not changed.

question. These relationships describe the interactions between industries, specifically, the way in which each industry's production requirements depend on the supply of goods and services from other industries. With this information it is then possible to calculate, given a proposed change to a selected industry, all of the necessary changes in production that are likely to occur throughout supporting industries within the wider economy. For example, if one of the changes anticipated for the Waikato region were to be an increase in the amount of dairy farming, the IO model would calculate all of the increase in outputs required from industries supporting dairy farming (e.g., fertilizer production, fencing contractors, farm machinery suppliers), as well as the industries that support these industries.

Typically the variables that drive an IO model - in other words, the variables that are used as inputs and which determine outcomes of all other variables - are the variables that are referred to as 'final demands'. Final demands constitute the value of each industry's output sold to final markets for production. These final markets are comprised primarily of consumption purchases by households, sales to government, private domestic investment and exports. The value of milk solids sold by dairy farmers to the dairy processing industry, for example, does not constitute a sale to final demands, whereas the value of cheese that is produced from these milk solids by the dairy processing industry and sold as exports is recorded under final demands.

As with all modelling approaches, IO analysis relies on certain assumptions in its operation. Among the most important is the assumption that the input structures of industries (i.e., technical relationships) are fixed. In the real world, however, technical relationships will of course change over time as a result of new technologies, relative price shifts causing substitutions, and the introduction of new industries. For this reason IO analysis is generally regarded as most suitable for short-run analysis, where economic systems are unlikely to change greatly from that which generated the initial data. It can however be noted that in this Study, some effort has been made to incorporate structural differences in the economy between the three scenarios assessed, through the generation of differing IOs for each scenario (this is discussed further below).

3.2 Incorporating the scenarios into the modelling framework

The following sections outline the way in which the scenarios are captured in the modelling framework, and the process used to calculate final economic impact results for each scenario. Essentially, the scenarios are incorporated into the model by using financial information produced in the accompanying appendices of this Study as inputs to the model, along with a series of assumptions regarding the funding arrangements for restoration actions. This is explained in more detail in the following sections of this appendix. As a summary, Figure 1 below (which uses Scenario 2 (BMP) as an example) shows the way in which information produced in the appendices (depicted in the blue boxes in the diagram) flows into the IO model. The primary components of the IO model are depicted in the grey boxes. The final results that are produced by the model (depicted in orange at the centre of the diagram) are the value added and employment effects associated with the scenario. Note that all results are reported in terms of the net change from the business as usual scenario – Scenario 1. For example, the value added impact reported for Scenario 2 (BMP) is not the total value added in the economy under the scenario, but rather the difference in value added between Scenario 1 (BAU) and Scenario 2 (BMP). Table 1 shows how the various types of capital and operating expenditures for bundle of restorative actions (e.g., to do with tuna or shallow lakes) were implemented into the IO framework.

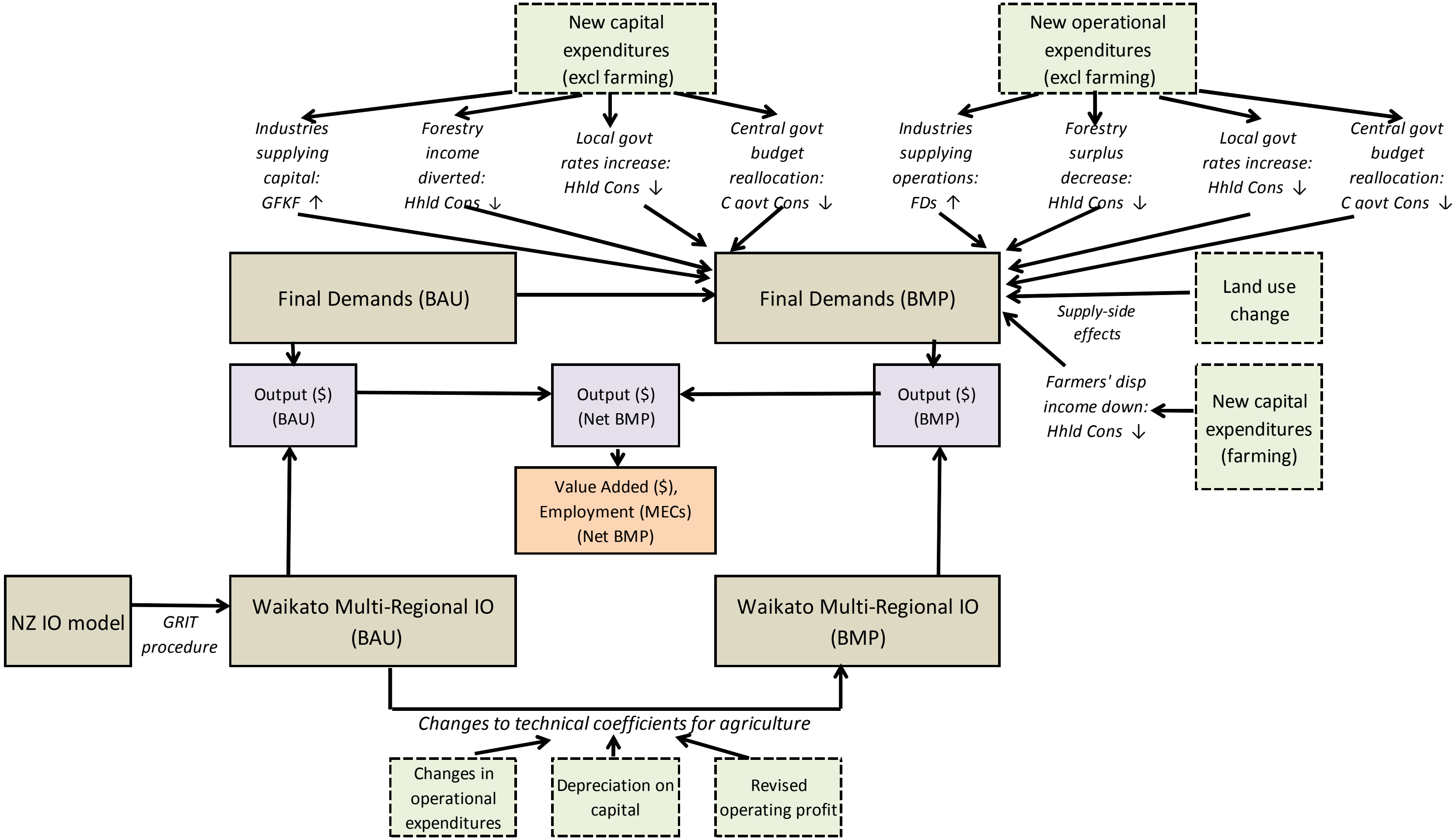


Figure 1: Summary of the modelling framework and input data used to estimate the economic impact of Scenario 2 (BMP).

Table 1: Figure 2 Implementation of capital and operating expenditures into the MRIO framework.

		Capital Expenditure					*Operating Expenditure*				
	Land use change [1]	Is there a change in Gross Fixed Capital Formation? [2]	Is there an associated change in industry investment? [3,8]	Is there an associated Central Government budget reallocation? [4,7]	Is there an associated change in Local Government rates? [5,7]	Are adjustments for depreciation on the capital expenditure necessary? [6]	Are there significant structural changes in the input mixes of Waikato region industries? [8]	Are there significant changes in the operating surplus of industries per unit of output? [9]	Are there changes in industry output associated with operational activities? [10-]	Is there an associated Central Government budget reallocation? [11]	Is there an associated change in Local Government rates? [5]
Farming	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No
Forestry	Yes	Yes	Yes	No	No	No[12]	No	Yes	Yes	No	No
Shallow Lakes	Yes[13]	Yes	No	Yes	No	Yes[14]	No	No	Yes	Yes	No
Aesthetics	Yes[13]	Yes	No	Yes	No	No	No	No	Yes	Yes	No
Eels	No	Yes	No	Yes	Yes	Yes[15]	No	No	Yes	Yes	Yes
Whitebait	No	Yes	No	Yes	Yes	Yes[16]	No	No	Yes	Yes	Yes
Engineering	No	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Social and Cultural	No	Yes	No	Yes	No	Yes[17]	No	No	Yes	Yes	No

Notes

1 This refers mainly to agricultural/forestry land use conversion between the sheep and beef farming and forestry, but to a lesser degree land lost in meeting the mitigation actions. It is captured in direct terms by estimating the net change in gross output associated with the land use change. Downstream economic impacts are captured through the use of a Ghosh inverse matrix.

2 This refers to an increase in capital expenditure. This is implemented by an addition to the appropriate industry forming the capital in the GFKF final demand column.

3 This refers to a change in the funds available to households for investment due to loan servicing by farmers/foresters. This is implemented by a pro-rata change in capital purchases by households in the GFKF final demand column. This change effects not only household capital purchases in the Waikato region, but also purchases by Waikato residents from the rest of NZ.

4 This refers to a central government budget reallocation due to increased loan servicing as required to pay for the capital expenditure. The additional expenditure on loan payments is financed by equivalent reductions in central government investment elsewhere. This is implemented by substractions from the GFKF column of final demands. The impact is felt throughout all of NZ.

5 This refers to an increase in local government rates due to increased loan servicing as required to pay for the capital expenditure or increased payments for operational expenditure. This is implemented by a pro-rata subtraction from household consumption final demand of the increased rates value. This impact is greatest in the Waikato region.

6 In some cases it may be necessary to depreciation the capital expenditure through time. This is implemented by adding the depreciation value to the Consumption of Fixed Capital row. A real depreciation rate of 5.51% p.a. is assumed i.e., 8.50% p.a. nominal with an adjustment for inflation of 2.84% p.a. The inflation rate was determined using a six year average (2004 to 2010) of inflation as recorded by the RBNZ.

7 Loans include both principle and interest. A real interest rate of 5.51% p.a. is assumed i.e., 8.50% p.a. nominal with an adjustment for inflation of 2.84% p.a. The inflation rate was determined using a six year average (2004 to 2010) of inflation as recorded by the RBNZ. All loans are assumed to have a 20 year term.

8 Structural changes are accounted for by updating the technical coefficients in the MRIO based on information contained in the Farming building block.

9 This refers to change in the operating surplus of an industry due to changes in operating expenditure. The impacts associated with the gain/loss in income are implemented by adjusting up/down the household consumption component of final demands on a pro-rata basis.

10 This refers to changes in operational expenditures leading to associated increases/decreases in the demand for output of industries providing operational activities. This is implemented by additions/subtractions to the total final demands of each industry providing operational activities.

11 This refers to a central government budget reallocation due to increased funding of operational expenditure. This is implemented by pro-rata subtractions to the entries in the consumption of central government services final demand column. This impact is felt throughout NZ.

12 Capital costs associated with planted forest are not normally depreciated. IRD allows for land development costs to be spread over time as per depreciation. This is implemented through a decrease in operating surplus, but without the corresponding increase in consumption of fixed capital.

13 Land lost to riparian margins accounts for 1761ha in the shallow lakes building block, and a further 1450ha in the aesthetics building block.

14 Depreciation is calculated for the following items infiltration filters, weirs, netting, wave barriers, toilets, jetties etc.

15 Depreciation is calculated for retrofitted culverts, retrofitted flood pumps, and netting used for protection from hydro intakes.

16 Depreciation is calculated for fish friendly tide gates and culverts.

17 Depreciation is calculated for the following items foot/cycle paths, capital items associated with historic sites, education of wananga, and monitoring databases.

3.2.1 Development of a Waikato "Input-Output" table

As already stated, at the core of an IO modelling framework is a matrix recording transactions between different actors within an economy. Each column of the matrix reports the monetary value of an industry's inputs, while each row represents the value of an industry's outputs. Sales by each industry to final demand categories (i.e., households, local and central government, gross fixed capital formation, etc.) are also recorded, along with each industry's expenditure on primary inputs (wages and salaries, consumption of fixed capital, gross operating surplus etc.). Clearly the data requirements for constructing these IO matrices are enormous, and it is partly for this reason that IO tables are only produced in NZ on an infrequent basis. The latest available IO table for the NZ economy is based on data for the 1995-96 financial year (Statistics New Zealand, 2001). A subsequent supply-use table, which contains much of the information required to generate an IO table, is however also available for the 2002/03 financial year (Statistics New Zealand, 2007).

The first major step required for the assessment of economy-wide effects is to generate an appropriate IO table for use in the study. Essentially two major tasks were involved: (1) production of an updated IO table for NZ; and (2) regionalization of the national table so as to produce an IO table for the Waikato region. In terms of the first task, Market Economics Ltd (MEL) has produced an IO table for NZ for the year ending March 2007. This is the latest year for which all economic data required to produce an updated table is available. The NZ IO is essentially derived by converting the 2002/03 national supply-use table to an IO table, and then updating this table to 2006/07 using data contained within the National Accounts (i.e., gross output, value added and taxes by industry), as well as international merchandise (imports and exports of products classified according to the harmonized system) and Balance of Payments (imports and exports of services) data. Relationships between industries, or technical coefficients,4 are assumed to remain consistent with those in the 2002/03 table.

In terms of the second task, the Generating Regional Input-Output Tables (GRIT) procedure (Jansen et al., 1979; West et al., 1980) was relied on to produce a regional table from the 2006/07 national table. This method consists of a series of mechanical steps that reduce national input-output coefficients to sub-national (regional) equivalents with reference to available regional data. In this case reference was made particularly to employment by industry, population and household income data for the Waikato region.

[4] Refer to Section 3.2.2 for a description of technical coefficients.

A final important point to note about the IO framework utilized in this study is that it is multi-regional. This means that the model considers not only the relationships between economic actors within the Waikato region, but also the relationships between economic actors within the Waikato and those in the rest of NZ. This multi-regional approach provides a means to evaluate the nation-wide implications of the possible clean-up options. The IO model utilized for each scenario contains 48 different economic industries by three different regions (Waikato region, rest of the North Island and rest of NZ).

3.2.2 Incorporating Economic Structural Changes into the Input-Output Table

The IO table developed for the Waikato region contains information on the production requirements of each industry in the Waikato economy. By selecting a column pertaining to a specific industry from the table, it is possible to view the total value of inputs purchased by that industry, from all other industries. For illustration, a simplified version of the dairy cattle farming column in the Waikato IO table is provided in Table 2 below. This table shows, for example, that Waikato dairy farmers purchased around $320 million of services from tertiary industries in the 2006/07 financial year.

Table 2: Inputs to Dairy Cattle Farming in the Waikato Region, 2006/07 ($mil)

		Dairy Cattle Farming
Industries	*Primary Industries*	236
	Chemical manufacturing	26
	Other manufacturing	217
	Tertiary industries	319
Primary inputs		1,042
Total		1,840

Table 3: Technical Coefficients for Dairy Cattle Farming in the Waikato Region, 2006/07

		Dairy Cattle Farming
Industries	*Primary Industries*	0.13
	Chemical manufacturing	0.01
	Other manufacturing	0.12
	Tertiary industries	0.17
Primary inputs		0.57
Total		1.00

As part of the process of constructing an IO model, it is necessary to take the information contained within an IO matrix and derive so-called ‘technical coefficients’. These technical coefficients indicate how much input is required to produce one dollar’s worth of output for any quantity of production, and are derived assuming continuous, linear relationships between the inputs and outputs of each industry. In order to calculate the technical coefficient for inputs of tertiary industries into dairy cattle farming in the example above, it is necessary to simply divide the total input of tertiary industries to the dairy cattle farming industry, by the total output (also equal to the total input) of dairy cattle farming (refer to Table 3). The technical coefficient of inputs from tertiary industries into dairy cattle farming is thus 0.17.

In this study, the technical coefficients derived from the Waikato IO table are assumed to apply to Scenario 1 (BAU). A core task undertaken for the assessment of the economy-wide effects associated with Scenario 2 (BMP) and Scenario 3 (EBMP) has then been to develop a modified table of technical coefficients for each of the two scenarios. Due to the nature of the scenarios, it has only been considered necessary to alter the technical coefficients for the farming industries, as it is these industries that primarily undergo structural change in the two scenarios. In summary, the process for modifying the technical coefficients for farming industries involves three steps:

Step 1 Separate-out data for the Waikato River Reaches from the base IO table.

In the base input-output table, the data pertaining to each industry is an aggregation of the data for all business activities across the region classified within that particular industry category. The first major step required for the modification of the IO table for agricultural industries is thus to disaggregate the data for each industry into two components: (1) data which relates to activities located within the Waikato River reaches (WWR); and (2) data which relates to activities located in the rest of the Waikato region (RWR). The result for dairy cattle farming, for example, is that instead of the IO table containing one column of data that specifies the value of each input to the industry, two columns of data are provided in the IO table– the first specifies the value of inputs into dairy cattle farming that is located within the WRR, while the second contains the value of inputs into dairy cattle that is located in the RWR.

Data on value added by industry type and by location is used for disaggregating the input column of each agricultural industry into two columns for the WRR and RWR respectively[5]. Very simply, for each agricultural industry the proportion of a total input value ($2007) in the base industry input column that is allocated to the WRR is equivalent to the proportion of that industry's total regional value added that is estimated to have been produced from within the WRR.

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[5] Statistics New Zealand's Annual Enterprise Survey (AES; www.stats.govt.nz) contains data on employment counts (ECs) by meshblock at the very detailed 6-digit ANZSIC industry level. Market Economics Ltd has created modified employment counts (MECs) based on this data, which unlike standard ECs, include estimates of the numbers of working proprietors for each industry types. Total value added for horticulture and fruit growing and forestry and logging for each of the two areas WWR and RWR are estimated by first collating the total number of MECs for each 6-digit ANZSIC type across the two areas, and then multiplying by the average NZ value added per MEC for each 6-digit ANZSIC industry. An adjustment is also made to account for differences in productivity between regions by using agglomeration elasticity scalars (Mare and Graham, 2009). Finally the value added is aggregated across all 6-digit ANZSIC industries that make up horticulture and fruit growing and forestry and logging respectively.

Step 2 Adjust input transactions to reflect new costs structures for agricultural industries

Scenario 2 (BMP) and Scenario 3 (EBMP) entail some quite significant structural changes for farming in terms of the quantities of various inputs that are required per unit of farming output produced. The application of nitrification inhibitors to dairy farming pastures will, for example, require an increase in the input costs for agricultural chemicals. Similarly, increased costs are also proposed under Scenario 3 as a result of the additional labour required for the management of herd shelters during winter. By contrast, some reduction in operational costs are also presumed for dairy farming under both scenarios as a result of improved nutrient management, enabling a greater proportion of the nutrients contained within animal effluent to be captured and recycled, thus reducing fertilizer requirements. In Step 2, each of these new operational costs identified for Scenario 2 and 3 are either added to (where operational costs increase) or subtracted from (where operational costs decrease) the inputs column of the appropriate WRR agricultural industry in the scenario's IO table.

Scenarios 2 and 3 also imply changes in capital expenditures for farming. Additional capital costs are, for example, associated with fencing, construction of herd houses and so on. Importantly, an industry's purchases of capital are not included within the industry's inputs column in an IO table, although the depreciation on capital (called 'consumption of fixed capital') is included (i.e., under the primary inputs category). This approach is consistent with standard accounting practice in that depreciation on capital is viewed as an expense for industries (i.e., an input in the IO table). In order to capture the additional capital expenditures for farming in the IO tables of Scenarios 2 and 3, it is thus necessary to make appropriate adjustments to the depreciation inputs for each industry. A depreciation schedule listing all additional capital items purchased by each agricultural industry is used to calculate the additional depreciation on capital incurred by each agricultural industry for each year of the study under the two scenarios. A real depreciation rate of 5.51 percent is applied across all capital items for the purposes of these calculations. Having calculated the depreciation for each year, these values are then averaged across the whole of the study period so as to derive an average increase in depreciation for each agricultural industry for the two scenarios. These values are used to adjust the IO tables for Scenarios 2 and 3[6].

Operating profit is another important primary input category included in the inputs column for each industry. It should be noted that for every change in operational costs for farming, there will be an associated impact on operating profit. Say for example, if

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[6] Note that we have not included expenditures on planting in the depreciation calculations. These costs are classified as land development expenditures and thus do not attract depreciation.

the fertilizer costs for Waikato dairy farmers were to decrease but we were to assume that the price received for milk solids were to remain constant, the net result for dairy farmers would be an increase in operating surplus. It is thus necessary to also make appropriate changes to the operating surplus entries in the IO tables to reflect the operational changes proposed for farming. Appendix 9: Farms provides estimates of the revised cash operating profit generated by each farming type, per hectare, according to the new agricultural practices proposed under each scenario. This information is used as a starting point for adjusting the operating surplus entries in the IO tables to reflect the new scenarios.[7] Appropriate additions and subtractions are also made to the new estimates of operating surplus to account for the changes in operational expenditures proposed under the two scenarios as well as the additional depreciation on new capital items.

Step 3 Recalculate technical coefficients

The above steps result in the production of a new column of input transactions for each agricultural industry in the WRR and for each scenario. In the final step, these input transaction columns are added back together with the appropriate parent industry input transaction column, thereby producing two new IO tables for Scenarios 2 and 3 respectively. Having completed these tasks, it is then possible to calculate coefficient matrices for the two scenarios.

3.2.3 Estimating Future Final Demands

As stated above, primary demand variables constitute a core input into the IO model. For each of the three scenarios investigated in this study it has therefore been necessary to generate a set of annual final demand projections by economic industry, covering the period 2011 to 2040. For Scenarios 2 and 3, the final demand projections for a particular year are developed by taking the final demand data from the base IO table, and then making appropriate additions and subtractions to capture the implications of each scenario occurring in that year. For Scenario 1 (BAU), the final demand projections are simply assumed to remain constant with those of the base year[8].

The additions and subtractions that are made to the final demand variables for Scenarios 2 and 3 are undertaken essentially to capture the capital and operational expenditures

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[7] A series of steps are first required to convert cash operating profit to operating surplus. These include the removal of tax from the data, application of price deflators, and the apportionment of profit among the two primary input categories 'compensation of employees' and 'operating surplus'.

[8] Over the course of the study period it is likely that there will be a number of external factors causing final demands variables to grow and change over time, such as demands for commodity exports, oil prices, government policies and so on. Given that these factors will impact on each scenario equally, and that we are only interested here in calculating the net changes between scenarios, it has not been necessary to attempt to incorporate these influences in the future projections of final demands.

derived for the various restoration actions. Some changes in final demand variables are further necessary to capture changes modelled in the analysis of farming systems (see Appendix 9: Farms). The methods used to capture these changes in final demands are discussed in more detail below.

3.2.3.1 Capital Expenditures

For all of the various restoration actions considered (see accompanying appendices) there are numerous capital items that are proposed to be introduced under Scenarios 2 and 3. Examples include the flood pumps and hydro screening necessary for tuna restoration (Appendix 5: Tuna), boat ramps (Appendix 25: Boat ramps), marae water treatment facilities (Appendix 17: Marae water supply), and the new education wananga (Appendix 27: Engagement). For the sake of consistency and convenience, all capital items from these appendices are treated in a similar manner. Two steps are required in order to incorporate the capital items into the IO model:

Step 1 –Increase Gross Fixed Capital Formation

When an industry sells output for the purposes of forming new fixed capital items, this sale is included in the final demands category called gross fixed capital formation (GFKF). The first step required for the inclusion of a capital item in the IO model is therefore to determine which industries are responsible for supplying the capital item. In terms of footpaths and cycle paths it is for example assumed that 100 percent of the costs of the capital are supplied by the construction industry. For those industries deemed to be responsible for supplying, sales to GFKF are then increased by a value equivalent to the costs of the capital items supplied. Note that for plant and machinery capital items it is assumed that 20 percent of the value of the capital is obtained from offshore.

Step 2 – Allocate Funding for the Provision of Capital Items

The next step is to derive and apply assumptions around the funding of capital items. For the majority of the capital expenditures specified in Scenarios 2 and 3, it is assumed that central government is responsible for providing an appropriate funding source. There are, however, a few capital items specified in the scenarios, such as the capital required for improved municipal wastewater treatment, where it is considered that funding is more likely to come from local government.[9] Overall, summing all capital expenditures identified, it is assumed that 24 percent is provided by local government

[9] If it is assumed instead that capital assumed are funded by the private sector, considerable additional work would be required to calculate the impacts due to the necessity to capture structural changes in the IO table. Not only would it be necessary to incorporate these changes in the IO table for each scenario, it would also be necessary to construct new IO tables for each year of the study.

and 76 percent by central government under Scenario 2, while under Scenario 3 the funding split is 7 percent local government and 93 percent central government.

Having determined who pays for capital, it is then necessary to determine the way in which capital is funded. In this study it is assumed that all new capital items are paid for over time through a loan system. The total loan payments incurred by central and local government for each year of the study are calculated by assuming that a loan payback period of 20 years and a real interest rate of 5.5 percent are applicable to all capital items.

In order to generate a budget that is sufficient to cover the additional loan payments associated with new capital items, it is assumed that local government undertakes an increase in household rates[10]. A corollary of the rates increase is that Waikato households will have reduced funds available for the consumption of other goods and services. This effect is captured in the IO model by decreasing all purchases by Waikato region households (i.e., household final demands) on a pro-rata basis by a total amount equivalent to each years' additional loan payment.

In terms of central government, it is assumed that the additional loan payments required to finance new capital are met by reductions in central government investment elsewhere. This is implemented by reducing GFKF for all regions in NZ, with the total reduction in capital for each year equivalent to that year's additional loan payments.

3.2.3.2 Capital Expenditures (Farming)

The impact of new capital items on farm profitability, as well as the depreciation on new capital items for farming, have already been included in the IO model via the changes made to farming input structures (refer to Section 3.2.2). To complete the treatment of agricultural capital items, it is now necessary to make appropriate adjustments to final demands so as to capture the impacts of funding capital. In this study it is assumed that all additional capital items required by farms under the Scenarios 2 and 3 will be funded directly by farmers. As with the capital items discussed above, it is also assumed that farmers use a loan system to spread the costs of capital across time.

The first step involved in adjusting final demands for agricultural capital expenditures under Scenarios 2 and 3 is thus to calculate the loan payments incurred by farmers for each year of the study. A loan period of 20 years and a real interest rate of 5.51 percent are assumed. Next, it is reasoned that the additional investment required to finance the

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[10] It is possible that local government would also increase rates for businesses in order to fund additional expenditures. Significant additional information would, however, be required to incorporate the effects of a rates increase on businesses within the model, including the distribution of rates payments among industry types and the ownership structures of Waikato businesses.

loan payments will divert farmers' expenditure away from other capital investments. This is affected in the model by adjusting down the GFKF column of final demands on a pro-rata basis, with the total reduction each year equivalent to farmers' additional loan payments.

3.2.3.3 Capital Expenditures (Forestry)

Under Scenario 3 there is additional expenditure required for preparation and planting land for conversion from sheep and beef farming to forestry. In order to incorporate the impacts of these capital expenditures into final demands, it is first necessary to identify which industries that will provide the new capital[11]. It is determined that all planting and land preparation will be undertaken by the Forestry and Logging industry itself, and thus sales by this industry to GFKF are increased to account for the additional capital provision.

The funding for forestry capital items is treated in an analogous manner to farming: It is assumed that land owners are responsible for funding the land preparation and planting costs required for establishing new forest stands, and that this occurs through a loan system with a 20 year payback period and a real interest rate of 5.5 percent. It is also assumed that the funding of these items by land owners will cause a reduction in capital investment elsewhere.

3.2.3.4 Operational Expenditures

A range of operational expenditures will be associated with the various restoration actions proposed for Scenarios 2 and 3, for example, costs for pruning required with increased forestry, Marae based training, ongoing work in restoring stream habitats, and septic tank maintenance. Two major steps are required to include these operational expenditures in the IO model for each scenario.

Step 1 Identify industries responsible for providing operational activities.

The first step requires selection of industries that are most likely to be responsible for undertaking each type of operational activity. Then, in order to incorporate the additional output required by industries undertaking these operational activities, appropriate additions are made to final demands[12]. It is, for example, assumed that

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[11] Although these expenditures are actually classified as land development expenditures, rather than capital expenditures in accounting terms, for this component of the study the distinction is irrelevant.

[12] For the majority of cases, it is appropriate to make the additions within the final demands columns of central and local government sectors. Some operational expenditures (e.g., those associated with Marae water treatment) are, however, more appropriate to include in the final demand column for not-for- profit organizations. For the purposes of calculating the results of this study, it is actually irrelevant which column of final demands the operational expenditures are added to.

Marae based training is most likely to be undertaken by professional consultants included in the business services industry. The final demands by not-for-profit organizations for business services are thus increased by an amount equivalent to the operational expenditure.

Step 2 Allocate funding for operational expenditures

As with capital expenditures, it is assumed that the additional operational expenditures are funded either directly or indirectly by local or central government. Overall, summing the operational expenditures across all restoration actions, it is assumed that 35 percent and 65 percent of expenditures are funded by local and central government respectively under Scenario 2, and 35 percent and 65 percent under Scenario 3. The same assumptions are also applied in regards to the way in which government funds these expenses. In summary, for those operational expenditures funded by local government, it is assumed that there is a corresponding increase in household rates and a decrease in other household consumption. Operational expenditures funded by central government are assumed to cause a corresponding decrease in all other central government expenses (i.e., final demands).

In regards to forestry, it is assumed that all additional operational expenditures are funded by the Forestry and Logging industry itself. It is also assumed that the loss in forestry income resulting from these additional expenditures will impact directly on household consumption. Thus for each scenario, household consumption is adjusted downwards on a pro-rata basis. The total value of the decrease in household consumption is equivalent to the total increase in forestry operational expenditures.

3.2.3.5 Operational Expenditures (Farming)

For the most part, changes in farming operational expenditures under Scenarios 2 and 3 have already been dealt with above in terms of changes to the IO matrices. There is, however, one additional effect resulting from changes in operational expenditures that needs to be implemented via changes to final demands. This effect is the change in consumption expenditures likely to occur as a result of changes in the profitability of farms.

As described in Section 2.2.2 above, changes to both farming practices and operational expenditures under the two scenarios results in revised estimates of operating surplus for each farming activity. In this study, it is assumed simply that any change in operational expenditures from Scenario 1 has an equal but opposite impact on household consumption. Thus for each scenario, household consumption is adjusted upwards on a pro-rata basis, with the total value of the increase in household consumption equivalent to the total reduction in operational expenditures across all farming types.

3.2.4 Depreciation on Capital Items

In order to complete the treatment of capital items from restoration actions it is necessary to deal with depreciation of capital. In economic terms, depreciation represents the decrease in value of a capital stock over a year. As already stated above, it is included in an IO table via the primary input category 'Consumption of Fixed Capital'.

As with the depreciation on capital for farming, the calculation of depreciation for capital items associated with other restoration actions, commences with the compilation of a depreciation schedule. This schedule identifies all capital items to be depreciated, the year in which each item is purchased and the industry that is responsible for the new capital. Using this information it is possible to calculate the additional depreciation expense incurred by each industry for each year of the study, under the two scenarios. Again, a depreciation rate of 5.51 percent per annum is applied in the calculations. Important to note is that many of the capital items included in the restoration actions do not constitute 'fixed capital' and thus are excluded from the depreciation calculations.

Once the additional depreciation for each industry for Scenarios 2 and 3 is calculated, the values are simply added to the primary inputs results for each year of the study[13].

3.2.5 Incorporating Land Use Changes

In most examples of regional economic impact analysis, the focus is on estimating demand-side effects.

In this type of analysis, the aim is to identify where there is a change in demand for the output of a selected industry, and then estimate the change in output of all up-stream industries from which the selected industry depends on for the supply of inputs. In this study we have endeavored to capture not only these demand-side (refer to section 3.3 below) effects, but also the most important supply-side effects associated with each scenario.

Clearly the most important supply-side effects that will occur under Scenarios 2 and 3 are those associated with changes in the amount of land devoted to different types of farming and forestry. In both these scenarios it is envisaged, for example, that there will

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[13] In order to balance the IO table, any increase in primary inputs of an industry must be matched by a corresponding increase in the outputs of the same industry. It is assumed that the necessary increases in output occur in the final demands columns.

be quite substantial lengths of riparian margins that will be retired from farming and instead planted with vegetation. In terms of another example, Scenario 3 also envisages that there will be relatively significant conversions of land from agriculture to forestry. These types of land use changes are likely to impact particularly on industries down-stream from farming and forestry, such as dairy product, meat product and wood product manufacturing. The conversion of livestock farms to forestry under Scenario 3, for example, by creating a reduction in the supply of livestock, is also likely to create a reduction in the output of NZ's meat product manufacturing industry.

In order to capture the supply side effects resulting from land use change, reference is made to Ghosh multipliers (Ghosh, 1958, 1964; Miller and Blair, 2009) that are derived from the base IO table. Essentially these multipliers measure, for every unit of output change in a selected industry i, the corresponding changes in output of all sectors that depend on sector i's product as an input to their own production processes. Of course, the basic assumption in applying this supply-side approach is that the output distributions within the economic system are stable. This means that if the output of a sector is, say, doubled, sales from that industry to all other industries that purchase from that industry will also be doubled. Although this assumption is unlikely to hold for many economic situations (see, for example, Giarrantani 1980, 1981), it is considered to be a relatively reasonable assumption to apply in the assessment of changes to Waikato's agricultural and forestry industries. This is because the industries that will be primarily affected by the supply-side effects are those that use commodities produced by agriculture and forestry to produce manufactured products (i.e., dairy product manufacturing, wood product manufacturing, meat product manufacturing etc.). For these industries it is likely that there will be a relatively constant relationship between the availability of commodities for processing and the value of manufactured products produced.

In short, three steps are required for the incorporation of supply-side effects. The first is to estimate the loss or gain in agricultural output for each agricultural industry resulting from land use change. An assumed constant relationship between output and land use is used for this purpose. Second, the change in output for all down-stream industries is estimated through application of the Ghosh multipliers. Finally, reference is made to mathematical identities to determine the change in final demands necessary to affect the calculated change in output resulting from supply-side impacts (i.e., land use change). Note that the final step is to translate the supply-side impacts into changes in final demands, as it is final demands that are used as inputs into the IO model for the purposes of calculating the final results for each scenario.

3.3 Calculating Economic Impacts

Having derived an IO table and set of final demand projects for each scenario, it is now possible to calculate the economic output ($2007) for each economic industry, both within the Waikato region and the rest of New Zealand. Very simply, the vector of output by industry, X, is calculated according to the equation,

$$X = (I - A)^{-1} Y$$

Where A is the matrix of technical coefficients, I is the identify matrix and Y is the vector of final demands by industry. Note that economic output by industry is the core result produced by the IO model. The output series is then translated into the final reporting variables, i.e., value added ($2007) and employment (MECs), by assuming for each respective industry constant ratios between output and the three reporting variables.

It is interesting to note that in many IO applications, the quantities of goods and services that are consumed by households (i.e., the household components of final demands) are treated as exogenous variables. This means that household demands are determined at the outset by the modeler and there is limited ability to capture feedbacks occurring between changes in industrial output and consumer spending. In the real world, however, households (i.e., consumers) earn incomes in payment for their labour inputs to production processes, and thus it is likely that any impacts on industrial outputs which alter labour income will have flow-on implications to consumer spending. Such effects can be viewed as positive (i.e., reinforcing) feedbacks, since changes in consumer spending will further impact on industrial outputs.

Some of the most important induced impacts in this study arise as a result of additional infrastructure investment. Both Scenarios 2 and 3, when compared to Scenario 1, incorporate considerably larger investment in infrastructure required for the restoration of the Waikato River. Examples include investments in boat ramps, wastewater treatment technologies, riparian margin planting, and so on. For those industries that are responsible for supplying infrastructure, additional household income will be generated associated with the increase in demands for output. On the other hand, negative induced impacts are also associated with the proposed clean-up options. Scenarios 2 and 3 both involve, for example, a reduction in output from the dairy farming industry compared with Scenario 1. This will create associated reductions in consumption by dairy farmers.

In order to capture the feedbacks relating to consumer spending (often referred to as 'induced' impacts in economic impact assessments), this study utilizes an IO model that is 'closed' with respect to the household sector when calculating the impacts of changes in final demands. According to this approach, households are treated in a similar manner to industries in the IO matrix, with a column and row of the matrix recording inputs and outputs of the household 'sector'. Transactions presented along the household row of the matrix record the income generated for households by each industry within the economy in the form of payments for labour, while transactions recorded in the household column of the matrix record the structure of household purchases (i.e., consumption). Now, if it is assumed that the structure of household expenditure among different product types remains constant irrespective of the level of income, it is possible to calculate a vector of technical coefficients for households which can be included in the A matrix described above. When the change in final demands is multiplied by the Leontief inverse, the model will therefore calculate the value of outputs from each industry that will be purchased by households. Household incomes are, in turn, also determined by the level of output of each industry.

4. Results

4.1 Summary Results

The summary results generated from this study are described in Table 4. Based on the modelling approach and assumptions described above, it is calculated that the BMP scenario will generate a relatively neutral economic impact. Over the period 2011-2040, it is estimated that the scenario will result in a net gain in value added for the Waikato region of $20071.26 billion, but a net loss for the rest of NZ of $20071.01 billion. For the country as a whole the positive gain in value added is estimated at around $2007 251 million, equivalent to just 8.4 million or around 0.005 percent of current GDP on average for each year of the study. In terms of employment, the estimated increase for the Waikato region under Scenario 2 is 13,900 MEC job years[14], while for the rest of NZ the estimated loss is 15,850 MEC job years. Overall for NZ it is estimated that Scenario 2 will result in a net loss of employment of 1,950 MEC job years during the course of the study period, equivalent to 65 MECs per year or 0.003 percent of employment.

There are a number of reasons why Scenario 2 generates a relatively neutral economic impact when compared with Scenario 1:

- *High Multipliers for Capital Formation* – Scenario 2 entails increased expenditure on capital items above that of Scenario 1. In this study it has been assumed that all capital items are funded by a loan system, thus entailing relatively significant interest payments. The losses to the local economy associated with these payments are, however, to a large extent balanced by the gains to the economy created through the purchases of capital. This occurs especially because the

[14] A MEC job year is the employment of one person, measured as one Modified Employment Count (see footnote 4 above) for one year.

industries that are responsible for supplying capital (particularly the Construction industry) have relatively high backward linkages in the NZ economy.

- *Reductions in Purchases of Imports* – Related to the above point it is also worth noting that a number of capital expenditures (and operating expenditures) in this study are assumed to be funded by across-the-board reductions in household consumption. This is important because a proportion of total household consumption is directed towards purchases of commodities produced overseas. The displacement of expenditure on these items towards expenditure on commodities produced in NZ acts as net gain for the NZ economy.

- *Increases in Farming Profitability* – The alterations in farming practices (e.g., improved nutrient management) proposed under Scenario 2 result in improved profitability for farming. Although for dairy farmers there is still some reduction in disposable income despite the improved profitability, because of the need to invest greater amounts in capital, for the economy this is more than compensated for by dairy farmer's increased purchases of capital and operational expenditures. These additional expenditures create flow-on impacts through the entire economy and are relatively substantial when aggregated across all farmers within the Waikato river reaches. Overall, the positive economic gains generated from the Farming building block act to counterbalance the losses to the economy generated from the actions described in the other building blocks.

The results calculated for Scenario 3 are less favorable than Scenario 2 in terms of value added and employment impacts. Compared with Scenario 1, it is estimated that Scenario 3 will generate a gain in value added of around $2007602 million (an average of $2007`20.1 million for each year of the study) in the Waikato region, and a gain of 11,590 MEC job years (386.3 per year). For NZ as a whole, the value added loss is calculated as $20074,131 million (137.7 million per year or 0.082 percent of GDP), while the employment effect is calculated as a loss of 56,720 MEC job years (1,891 MEC jobs per year or 0.085 percent of employment).

A core reason for the reduction in value added and jobs under Scenario 3 relates to the effects of land use change. According to Scenario 3, there are significant tracks of land converted from sheep and beef farming to forestry. Under our model these conversions result in output loss for industries closely connected to sheep and beef farming (e.g., meat processing). Although these effects should, in theory, be compensated by an increase in output for industries closely connected to forestry (e.g., wood processing), these effects are generally outside of our study due to the large timeframes required for trees to mature to a state that can be harvested. It should also be noted that the loss of dairy farming land due to restoration actions is slightly higher under Scenario 3 compared with Scenario 2. This acts to further increase the impacts of land use change for Scenario 3.

Another observation that can be made from the summary results is that the economic impacts generated within the Waikato region are generally more favorable than those occurring in the rest of the New Zealand economy. The reasons for this are obvious. On the one hand, it is assumed under both scenarios that operational and capital items will generally be provided by industries located within the Waikato, thus creating positive benefits for the regional economy. On the other hand, it is assumed that a significant proportion of the capital and operational expenditures required for implementing the proposed restoration actions will be funded by central government, thus creating some loss in other central government expenditure throughout the NZ economy.

Table 4: Cumulative and Average Net Economic Impacts, 2011 – 2040. ("Best management practice" equates with Scenario 2 and "Extended best management practice" with Scenario 3).

	Cumulative Net Economic Impacts		Average Net Economic Impacts Per Year	
	Value Added	**Jobs**	**Value Added**	**Jobs**
	$\$_{2007}$m	**MEC[1] Years**	**$\$_{2007}$m**	**MEC[1] Years**
Best Management Practice				
Waikato Region	1,260	13,900	42.0	463.3
Rest of New Zealand	-1,009	-15,850	-33.6	-528.3
Total	**251**	**-1,950**	**8.4**	**-65.0**
Extended Best Management Practice				
Waikato Region	602	11,590	20.1	386.3
Rest of New Zealand	-4,733	-68,310	-157.8	-2,277.0
Total	**-4,131**	**-56,720**	**-137.7**	**-1,890.7**

Notes
1. Modified Employment Count. This includes both employment counts and working proprietors.

4.2 Distribution of Economic Impacts across Time

Table 5 provides a summary of the way in which the value added and employment impacts under Scenarios 2 and 3 are distributed across time. Not surprisingly, the first year of the study entails substantial positive economic benefits in terms of value added and employment for both scenarios. It is, for example, estimated that there will be around $\$_{2007}$213 million of additional value added generated under Scenario 2 for the Waikato region during 2011, and $\$_{2007}$521 million under Scenario 3 for the same region and year. These results are a reflection of the significant amounts of capital expenditure that are assumed to occur predominantly during the first year of the study. This expenditure on capital not only creates value added and employment growth in industries responsible for supplying capital, it also produces flow-on impacts throughout the rest of the NZ economy.

As it is assumed that capital items are funded over a period through a loan system, the negative economic consequences of capital expenditure are spread out across time. These negative effects (resulting in reductions in expenditure elsewhere) are more noticeable under Scenario 3 as the scenario contains some very large capital items not included in Scenario 2 (particularly dairy herd shelters and hydro-dam intake nets). Note that after 2030 the loss in value added and employment under both scenarios starts to fall away. This occurs because it is assumed that all loans are taken out for a period of 20 years and thus by 2030 a number of the loans have been paid off.

Table 5: Net Economic Impacts 2011 – 2040. . ("Best management practice" equates with Scenario 2 and "Extended best management practice" with Scenario 3).

	Value Added	Change in Value Added						
	2007	2011	2015	2020	2025	2030	2035	2040
Value Added	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m
Waikato Region								
Best Management Practice	14,892	213	57	53	24	23	27	65
Extended Best Management Practice	14,892	521	153	89	-50	-51	-37	96
New Zealand								
Best Management Practice	168,365	310	22	3	-31	-31	4	57
Extended Best Management Practice	168,365	762	75	-109	-318	-318	-173	48

	Employment	Change in Employment						
	2007	2011	2015	2020	2025	2030	2035	2040
Employment	MECs[1]	MECs[1]	MECs[1]	MECs[1]	MECs[1]	MECs[1]	MECs[1]	MECs[1]
Waikato Region								
Best Management Practice	167,731	203	650	634	193	195	262	283
Extended Best Management Practice	167,731	502	2,218	1,420	-862	-861	-654	-564
New Zealand								
Best Management Practice	2,221,400	4,362	78	-163	-618	-594	-84	145
Extended Best Management Practice	2,221,400	11,173	913	-1,507	-4,607	-4,591	-2,532	-1,211

Notes
1. Modified Employment Count. This includes both employment counts and working proprietors.

4.3 Distribution of Economic Impacts across Industries

Table 6 below provides a summary of the value added impacts for each scenario distributed by time and by economic industry. Again the results are relatively predictable. As a general rule, the industries that benefit most across the study period are those that are primarily responsible for providing the additional capital items and operational activities required under the scenarios. The Construction and the Business Services (included under Industry Group 15) industries, for example, which are both significant providers of capital, show significant increases in value added under both scenarios, especially during the first year. Another interesting observation is that the quite significant gains for Industry Group 9 (Other Manufacturing) under both scenarios occurs partly because of the changes in operational costs for dairy farming, resulting in increased purchases of nitrification inhibitor chemicals.

The effects of land use change are also evident in the results for Scenario 3. In these regards it can be noted that the Livestock and Cropping industry, and to a lesser extent the Dairy Cattle Farming industry, exhibits declines in value added across the study period. These impacts clearly flow onto the Meat and Meat Product Manufacturing as well as the Dairy Product Manufacturing industries.

Table 6: Net Value Added Impacts for Selected Waikato Industries, 2011 – 2040.

	2011	2015	2020	2025	2030	2035	2040
	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m	$\$_{2007}$m
Best Management Practice							
1 Other farming and services to agriculture	9	3	4	0	0	0	0
2 Livestock and cropping farming	1	0	0	0	0	0	0
3 Dairy cattle farming	1	0	-1	-1	-1	-1	-1
4 Forestry and logging	5	0	0	0	0	0	0
5 Other primary industries	2	1	1	1	1	1	1
6 Meat and meat product manufacturing	0	0	0	0	0	0	0
7 Dairy product manufacturing	0	0	0	0	0	0	0
8 Other food and beverage manufacturing	0	0	0	0	0	0	0
9 Other manufacturing	30	16	16	8	8	8	9
10 Wood and paper manufacturing	6	2	2	2	2	2	2
11 Utilities	4	2	1	1	1	1	1
12 Construction	58	2	2	0	0	1	1
13 Wholesale and retail trade	16	2	2	0	0	1	1
14 Transport	4	1	1	1	1	1	1
15 Communication, finance, insurance, real estate and business services	60	5	5	1	1	3	3
16 Government	1	21	20	12	10	9	9
17 Other services	6	1	1	1	1	2	2
Total	**203**	**58**	**55**	**25**	**24**	**27**	**28**
Extended Best Management Practice							
1 Other farming and services to agriculture	31	21	18	0	0	0	0
2 Livestock and cropping farming	0	-11	-22	-25	-25	-25	-25
3 Dairy cattle farming	1	-3	-6	-8	-8	-7	-7
4 Forestry and logging	7	48	-6	-13	-11	-10	0
5 Other primary industries	6	2	2	1	1	1	1
6 Meat and meat product manufacturing	0	-7	-13	-15	-15	-15	-15
7 Dairy product manufacturing	0	-1	-2	-3	-3	-3	-3
8 Other food and beverage manufacturing	1	-1	0	0	0	0	0
9 Other manufacturing	65	33	32	7	7	8	9
10 Wood and paper manufacturing	16	8	7	3	3	3	3
11 Utilities	10	2	3	0	0	1	1
12 Construction	162	32	31	2	2	5	7
13 Wholesale and retail trade	39	-1	3	-8	-8	-6	-3
14 Transport	10	9	4	1	1	1	1
15 Communication, finance, insurance, real estate and business services	140	1	15	-5	-5	0	4
16 Government	1	27	24	15	12	11	9
17 Other services	13	-4	1	-1	-1	0	1
Total	**502**	**154**	**89**	**-49**	**-50**	**-37**	**-17**

5. Discussion

This section outlines some of the important caveats and matters for further consideration relating to this study.

(1) Funding Sources for new Operational and Capital Expenditures

When reviewing the results of this study, a matter that requires particular consideration is the issue of project funding. In these regards it should be noted that, in order to undertake a full assessment of the economic impacts associated with Scenarios 2 and 3, it is essential that each proposed restoration action is allocated to an appropriate funding source. It is further necessary to consider the flow-on implications of the additional funding requirements for each funding source, in terms of reduced expenditure elsewhere in the economy. For the purposes of this study it has been necessary to make a set of assumptions regarding which organizations/persons will be responsible for funding each restoration measure (both operational and capital expenditures) and the budget reallocations that will occur to provide this funding. It has, for example, been assumed that farmers will be responsible for funding all farming-related capital and operational expenditures, and that these additional expenditures will be financed through reductions in farmers' capital investments and consumption elsewhere. It has also been assumed that the majority of the new engineering infrastructure envisaged under the two scenarios, such as new wastewater treatment facilities, hydro-dam intake nets, culverts and so on, will be funded by either local or central government. Where central government is responsible for funding, it is assumed that the funds are made available by reductions in other central government consumption and investment.. Where local government is responsible for funding, it is assumed that the funds are made available by increases in rates for regional households. It is further assumed that all capital expenditures are financed by a 20 year loan with a real interest rate of 5.5 percent.

Importantly, the way in which the new expenditures are funded will impact on the distribution of effects across the NZ economy. In these regards, whereas the introduction of additional expenditure for capital and operational activities generally adds positively to the regional economy (by requiring additional output from local industries), the funding of such expenses is generally a negative effect on regional and/or the national economies (as it reduces available funds for consumption and investment elsewhere). Thus, if restoration actions are to be financed predominantly by local government and local residents, then the majority of the negative impacts associated with funding will occur within the Waikato region. Conversely, if central government is primarily responsible for the funding, then the impacts are more likely to be distributed across the entire country, although this will depend on the particular way in which government reallocates its budget to generate the required funds.

Related to the last point, it is worth noting that the results of this study are dependant not only on who it is assumed will be funding the restoration actions but also, and perhaps more importantly, the particular expenditures that it is assumed will be forgone in order to provide sufficient funding. Obviously different types of commodities have different production requirements. Some commodities are produced from production chains that are extensive within the NZ economy, and thus loss of expenditure on these items will generate quite substantial impacts to the NZ economy. Other commodities, however, are produced with relatively little input from NZ industries and therefore reallocation of expenditure away from these items will have relatively little impact. Overall, the particular assumptions employed in the study regarding the way in which funds are provided for restoration actions is an important determinant of the magnitude of the economic impacts.

In conclusion, it is, important to recognize that these assumptions that have been made in this study regarding funding of expenditures are only one set of many plausible funding arrangement options. It is therefore recommended that the study is undertaken again once there is more information available as to the likely funding structures, and for testing out the implications of alternative funding arrangements.

(2) Loans

Related to the above section on funding, it is important to note that all capital expenditures are assumed to be paid for using loans. There are several limitations to this approach:

- *Farming and forestry industries*. No attempt has been made to assess whether or not the farming sectors is able to absorb the loans necessary to pay for the capital-based restoration actions. It is indeed possible that many farmers will not have sufficient income or collateral to secure the loans necessary to undertake the proposed restoration actions; particularly under Scenario 3.

- *Land use conversion under Scenario 3*. It is highly unlikely that the sheep and beef farmers tasked with land use conversion under Scenario 3 will be able to raise sufficient capital to undertake the conversions. Under Scenario 3 it is noted, for example, that Class 3 Sheep and Beef farmers already have a negative cash operating profit. A further deterrent to securing loans is that fact that any conversion to forestry is unlikely, without a fully implemented ETS, to realise any revenues until at 18 to 26+ years after planting.

- *Local government loans*. It has been assumed that loan based borrowing by local government will be funded through rates increases. Other possibilities however include reallocation of the local government budget, central government subsidies, targeted rates, user charges, financial contributions and so on. It is important to note that with the exception of central government subsidies the burden associated with any local government mitigation initiative is likely to rest with Waikato residents.

- *Central government loans.* It is assumed that loans borrowing by central government will be paid for via a budget reallocation. Other alternatives however exist. It is important to note that under a central government funding scheme, the burden of the funding is likely to be shared by all New Zealanders.

(3) Scheduling of capital expenditures

The timing of capital expenditures can have a significant influence on the quantum of the economic impacts realised under each scenario over different years. It has, for example, been assumed in the Discounted Cash Flows (DCF) analysis (which is the primary source of information for this EIA study) that all capital expenditures associated with tuna and riparian aesthetics restoration, and engineering works occur in 2011; respectively these account for $203m and $434m under Scenarios 2 and 3. These capital expenditures will have greatest impact in the 2011 year, after which, without further capital expenditure or growth, the Waikato economy would return to near its pre-2011 state. It is further worth noting that placement of the capital expenditures in the near, rather than distant, future produces the largest impacts in Net Present Value (NPV) terms.

(4) Forestry Harvest Costs and Revenues

This assessment of economic impacts has not incorporated any costs or revenues associated with harvesting the new forest stands proposed for the EBMP scenario. One reason for the exclusion is that, because the study covers only the next 30 years, it is quite possible that the harvests will occur outside of the study period. A second reason is that the harvests are likely to involve substantial changes to the structure of the Waikato economy, but for just a relatively short period over which the harvests occur. Incorporating these structural changes into the IO modelling framework is simply beyond the project time and budget constraints.

In terms of interpreting the results of this study the important point to note is that, had the forests harvests been included, the impact on the results for Scenario 3 would be positive. Obviously the revenues generated from harvesting forests are significantly higher than harvest costs. The net increase in forestry revenues will generate not only higher value added for the Forestry and Logging industry, it will also result in flow on impacts to consumer spending thus generating increases in value added and employment for other industries.

6. References

Ghosh, A. (1958). Input-Output Approach to an Allocation System. *Economica 25*: 58–64.

Ghosh, A. (1964). *Experiments with Input-Output Models: An Application to the Economy of the United Kingdom, 1948-55,* London: Cambridge University Press.

Giarrantani, F. (1980). The Scientific Basis for Explanation in Regional Analysis. Papers of the Regional Science Association 45: 185–196.

Giarrantani, F. (1981). A Supply-Constrained Interindustry Model: Forecasting Performance and an Evaluation. *In:* Buhr, W. & Friedrich, P (eds). *Regional Development under Stagnation*. Baden-Baden: Nomos, pp. 281–291.

Jensen, R.C.; Mandeville, T.D. & Karunarantne, N.D. (1979). Regional Economic Planning. London: Croom Helm.

Maré, D.C.; Graham, D.J. (2009). Agglomeration elasticities in New Zealand. NZ Transport Agency Research Report 376. New Zealand Transport Agency, Wellington, New Zealand.

McDonald, G.W.; Patterson, M.G. (2004). Ecological Footprints and Interdependencies of New Zealand Regions. *Ecological Economics 50*: 49–67.

McDonald, G.W.; Forgie, V.E. & MacGregor, C. (2006). Treading Lightly: Ecofootprints of New Zealand's Ageing Population. *Ecological Economics 56*: 424–439.

Miller, R.E.; Blair, P.D. (2009). *Input-Output Analysis: Foundations and Extensions* (2nd ed.). New York: Cambridge University Press.

Patterson, M.G. & McDonald, G.W. (2004). How Clean and Green is New Zealand Tourism? Lifecycle and Future Environmental Impacts. Land Research Science Series No. 24. Lincoln: Manaaki Whenua Press.

Patterson, M.; McDonald, G. & Smith, N. (forthcoming). Ecosystem Service Appropriation in the Auckland Region Economy: An Input-Output Analysis. Regional Studies.

Smith, N.J.; McDonald, G.W. (forthcoming). Estimation of Symmetric Input-Output Tables: An extension to Bohlin and Widell. Economics Systems Research.

Statistics New Zealand (2001). Inter-Industry Study of the New Zealand Economy 1995–96. Wellington: Statistics New Zealand.

Statistics New Zealand (2007). 2002–03 National Supply-Use Table. Wellington: Statistics New Zealand.

West, G.R.; Wilkinson, J.T. & Jensen, R.C. (1980). Generation of Regional Input-Output Tables for the Northern Territory GRIT II. Report to the Northern Territory Department of the Chief Minister. St Lucia, Queensland: Department of Economics, University of Sydney.

Yeoman, R.; Kim, J. & McDonald, G.A. Computable General Equilibrium Model for Auckland. NZCEE Research Monographs. Palmerston North: New Zealand Centre for Ecological Economics.

Zhang, J.; McDonald, G.; Trinh, S. & Smith, N. Social Accounting Matrix Methodology. NZCEE Research Monograph. Palmerston North: New Zealand Centre for Ecological Economics.

Appendix 32: Non-Market Values

1. Introduction

The objective of this paper is to identify the scope and size of non-market values (NMV) associated with restoring and protecting the health and wellbeing of the Waikato River. The Waikato River provides a range of benefits that are difficult to measure in monetary terms - in economics these are called non-market values. They include positive benefits such as recreation, ecosystem services[1], aesthetics, intrinsic/existence[2], legacy/bequest[3], historical, and cultural/spiritual values.[4] They also include negative benefits (e.g., intensive land use has significant non-market costs in terms of reduced water quality and quantity). The reason these costs and benefits are not currently included in the formal economy (e.g., in GDP) is that there are no markets where they are regularly bought and sold, and hence the price that people are prepared to pay for them cannot easily be determined.

This section complements the economic analysis of the direct costs and benefits undertaken in the economic modelling.

The practical use of economic valuation is assessing incremental change arising from a policy change and not at valuing an entire ecosystem (TEEB, 2009). The purpose of economic valuation in policy decisions is to provide information on the impact of the change and not to value the entire site or resource. For example, in this Study the aim is to value the change in the health and wellbeing of the Waikato River and not to attempt to value all the goods and services provided by the river.

This paper is structured as follows. Firstly, the concept of Total Economic Value is introduced to provide context and a structure to the range of values. This is followed by case study examples of the various types of values grouped under ecosystem services, farming impact on the environment and indigenous biodiversity values. Next, economic impacts are discussed including how NMVs can be incorporated into Gross Domestic Product (GDP) the aggregate measure of economic wellbeing using the concept of the Genuine Progress Indicator (GPI). There is a discussion of the implications of quantifying changes in NMVs for the Waikato River and also a brief overview of the impact of the Emissions Trading Scheme.

[1] Ecosystems provide a range of resources and processes such as drinking water, waste assimilation and treatment, nutrient and soil cycling, pollination, and many others. Collectively these are known as ecosystem services.

[2] Intrinsic/Existence values refer to values ascribed by people to something simply because it exists even if they never experience it directly.

[3] Legacy/Bequest values refer to the values people ascribe to maintaining something for future generations.

[4] This refers to values from all cultures.

2. Total Economic Value

Non-market values are important and need to be considered alongside market values in decision making. The Total Economic Value (TEV), which incorporates both market and non-market values of a natural resource is grounded on the utility of the resource. This utility derived ranges across a spectrum of values grouped as active use and passive use values (see Figure 1).

Active use values are classified as direct use, indirect use and option value.[5] Direct use values are consumptive and production related (e.g., agriculture, fisheries, water supply, engineering) and are mostly captured in market values. Direct use value changes have been quantified and are expressed in monetary terms as NPV where NPV is defined as the discounted sum of direct benefits minus direct costs.

Indirect use values are functional benefits that support or protect direct use activities (e.g., recreation, water retention, nutrient recycling).

Option value relates to the benefits of preserving the natural resource for a potential future direct and indirect use (e.g., native plant biodiversity as future source of medicines).

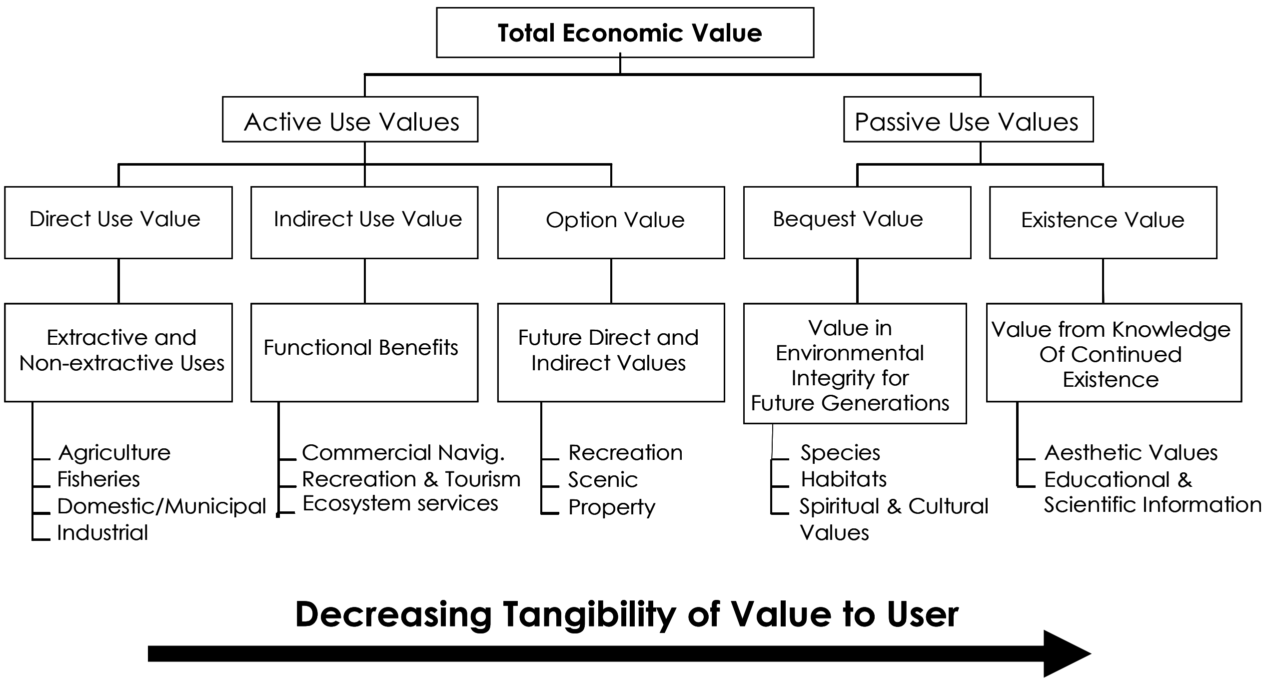


Figure 1: Total Economic Value (sourced from EVRI, 2009).

[5] Studies cited later in the report have slightly different classification of value. One will classify option value under passive use. Another will classify recreation and cultural value as direct use value.

Passive use values are classified as bequest value (e.g., preservation for future generations, include spiritual and cultural values) and existence/intrinsic value (e.g., aesthetic, habitat, biodiversity).

It is important to note that the way in which economists categorise these values is to recognise the spectrum of total economic value. Traditionally, only the direct active use values are estimated in cost benefit analysis because there are market prices that can be applied to quantity changes to estimate changes in value.

Most of the values in Figure 1 must be valued indirectly through non-market valuation techniques. The Study team did not attempt to estimate dollar amounts for non-market values because the relevant data was not readily available and there was not enough time or budget to undertake the necessary survey and analysis work. However, the Study team did undertake a qualitative analysis of the main non-market values (costs and benefits) that may be relevant to the project and this analysis is set out below.

3. Case Studies

3.1 Ecosystem services

Natural capital encompasses ecosystems, biodiversity[6] and natural resources. Natural capital provides benefits that sustain societies through the provision of ecosystem services to society. The foundation of valuing these ecosystem services is scientific information that assesses the physical impact of changes to service provision and places a dollar value on the change. Studies that attempt to estimate the value of ecosystem services focus on active direct and indirect use values. Passive values such as cultural and spiritual values that help make up ‘wellbeing’ are not quantified and this means that estimating the value of ecosystem services in comparison with the direct costs of restoration underestimates the value of restoration.

The value of ecosystem services is context specific and not uniform universally. This means that economic values are not intrinsic to the ecosystem but linked to the utility and welfare it provides. This utility is influenced by the number of people who benefit and the socio-economic context including cultural and spiritual aspects. For example, the service ‘water regulation’ (regulation of hydrological flows such as provisioning of water for agricultural, industrial and transportation use) is an essential component for some locations but only an incidental service in others. Furthermore, the people who were surveyed in the study location may have markedly different incomes and cultural backgrounds that could result in significantly different willingness to pay for changes to environmental values. As a result, applying values estimated for one primary study site to another policy site (which is the

[6] Biological diversity (biodiversity) is the variety of all living things (plants, animals, fungi and microorganisms) and the ecosystems where they live (A strategy for New Zealand’s biodiversity, www.biodiversity.govt.nz).

subject of a decision) using the benefit transfer technique can only be done if suitable adjustments are made that take into account both the differences in the sites and the populations affected (TEEB, 2009).

A policy change does not necessarily result in the loss of ecosystem service(s). Ecosystems have built-in resilience in the face of changing environmental conditions and disturbances. But, while there is uncertainty on threshold levels, the critical point at which the ecosystem is significantly changed, a precautionary approach is recommended (TEEB, 2009).

Ecosystem services can make up a significant component of Total Economic Value. The case studies set out below illustrate this significance.

Case Study 1

The direct and indirect use value of ecosystem services for the Manawatu-Whanganui region has been estimated at $6 billion per annum (2006 dollars) using the rapid assessment method - benefit transfer (van den Belt et al., 2009). Market-based direct use values such as food and raw material production were based on regional GDP figures. Non-market direct (e.g., recreation, water regulation) and indirect use (e.g., erosion control, nutrient cycling) values were derived from a global meta analysis by Costanza et al., (1997).

The ecosystem service value for the Manawatu-Whanganui region is still considered conservative as it does not include some direct and indirect use values for some ecosystem types. More important, it does not account for passive values (e.g., cultural and spiritual aspects of water) due to lack of primary valuation studies (van den Belt et al., 2009). Such passive values can be significant as is shown in the next case study.

Table 1 shows the per hectare annual value of ecosystem services by type of ecosystem. These figures have been updated from 2006 prices using the all groups CPI index.

Case Study 2

A contingent valuation study of the Whangamarino Wetland in an unpublished Master's thesis quoted by Schuyt and Brander (2004) showed passive use values exceeded active use values. As an annual benefit, the passive use (preservation) value of the Whangamarino Wetland was assessed as 2.7 times greater than the active use value (recreation, flood control and fishing). The high passive value might have been influenced by the ecological significance of this wetland.

Table 1: Annual value per hectare of ecosystems services in the Manawatu-Whanganui Region (2010 prices).

Ecosystem service	Direct	Indirect	Total
Wetlands	$5,900	$42,400	$48,300
Estuarine	2,000	24,000	26,100
Horticultural	21,100	100	21,200
Lakes	14,000	6,900	20,900
Rivers	14,000	6,900	20,900
Coastal	600	9,400	10,000
Exotic forests	500	2,000	2,500
Native forests	200	2,100	2,300
Dairy	1,600	500	2,100
Scrub	300	900	1,200
Cropping	900	100	1000
Sheep and beef	300	500	800

Source: updated from van den Belt et al., (2009).

The Whangamarino Wetland presents a case study of the ecosystem services provided by flood control on the Lower Waikato River (DOC, 2007). Its ability to store water during peak flows results in reduced public works on flood gates (estimated at millions of dollars) and less damage to surrounding farmland (avoided flooding of 7,300 hectares estimated at $5.2 million). Other ecosystem services provided by the wetland include:

- Raising water tables for irrigation during dry periods.
- Carbon sequestration (0.5 tonnes per hectare per year from peat bogs).
- Gamebird hunting (tens of thousands of gamebirds each year).
- Recreational and commercial fishing (tuna).
- Attraction for overseas tourism (bird watching).
- Habitat for diverse native wetland birds and other threatened/uncommon wetland birds (hosts 20 percent of New Zealand’s breeding population of native wetland birds).
- Diverse freshwater fish fauna (threatened black mudfish).
- 239 wetland plant species (60 percent indigenous; a number are rare).

Case Study 3

This case study has shown that improving drinking water quality beyond mandated minimum standards can provide benefits that exceed the costs. Such benefits need to include non-market values such as health and quality of life (Silverman, 2007).

The survey conducted before and after a water treatment upgrade in a city in Ohio, United States, revealed:

- Enhanced public satisfaction with a high-profile public interest issue around improved water quality.
- Potential health benefits to the community through risk reduction in exposure to toxic substances.
- While water bills increased, this is more than offset by savings from lower use of bottled water and home water treatment systems.

Case Study 4

Patterson and Cole (1998) estimated the annual value of Waikato Region's ecosystem services at $9.4 billion (1997 dollars), which equates to $12.6 billion in 2010 dollars. Table 2 shows the per hectare values related to the river in 2010 dollars updated from 1997 prices using the all groups CPI index. These estimates include both direct and indirect use values (Environment Waikato, 2010) but not passive values.

This analysis used the same global meta analysis data (Costanza et al., 1997) as the Whanganui study and therefore the same caveats apply.

Table 2: Annual value per hectare of ecosystem services (direct and indirect) in the Waikato River system (2010 prices).

Ecosystem service	Annual value per hectare ($/ha)
Estuarine	62,000
Freshwater wetlands	53,200
Lakes and rivers	26,300
Mangrove	25,400
Forests	3,200
Agricultural/Horticultural	1,500
Scrub/Shrub	700

Source: updated from Patterson and Cole (1998).
Note: these values are comparable with the total column of the previous table.

In a more recent study McDonald and Trinh (2008) applied similar methodology to Patterson and Cole to the Upper Waikato catchment using 2004 prices. Direct values were based on the System of National Accounts (SNA) data and indirect values from Costanza et al., (1997) as refined by Balmford et al., (2002).

These four ecosystem service case studies all use average values based on international meta-analysis. They are useful when considering a change to land use such as converting dairy land to forestry, but unfortunately they are not very helpful in assessing changes to the quality of ecosystem services, which is a significant component of the river clean-up.

3.2 Impact of farming on the environment

Farming has both positive and negative impacts on total economic value. There are positive direct active use values from the income derived from farming and there are negative indirect costs from environmental degradation. In addition, passive use values, such as aesthetics, are also affected. These passive values are the most difficult to assess and can only be quantified using stated preference techniques such as choice modelling to determine willingness to pay (WTP). In the two case studies below a range of non-market values are quantified including indirect, indirect active use values and passive values.

Case Study 5

One such study has been carried out by the University of Waikato and Environment Waikato (Marsh et al., 2009). This survey attempted to estimate the willingness to pay for improvement in water quality in the Karaapiro (Upper) catchment of the Waikato River, focusing on lakes Arapuni and Karaapiro. The research was based on the Choice Modelling method of NMV and resulted in the following attributes being quantified without and with improved water quality:

- Suitability for swimming and recreation (probability of health warnings: 1 in 2 years improved to 1 in 50 years).
- Water clarity (visibility under water: 1 metre improved to 4 metres).
- Ecological health (percentage of excellent readings: <40 percent improved to >80 percent).
- Jobs in dairying (percentage of jobs lost: 0 percent to 20 percent).
- Cost to households ($per year for the next ten years).

In total 178 or 2.3 percent households (HHs) were surveyed in the catchment. The statistical analysis of the survey produced a model with a good fit to the data providing a high degree of confidence in the result. The average WTP for improvement in quality were:

• Suitability for swimming	$161/HH p.a. for 10 years
• Water clarity	$65
• Ecological health	$145
• Jobs in dairying	-$190

Thus the combined WTP to improve water quality was $371 per household per annum for ten years. But if the quality improvements resulted in a 20 percent loss of jobs in dairying then overall WTP was reduced by $190 per household. Over the 7,802 households in the Karaapiro catchment this aggregates to $2.9 million per annum for quality improvements and $1.5 million for loss of jobs, with a Present value (PV) after discounting at 8 percent of $21.0 million and $10.9 million respectively.

It should be noted that the Karaapiro catchment covers the area from Lake Arapuni to the Karaapiro Dam including tributaries and that this is only a fraction of the 'Upper Catchment' used in the Economic Model. This means that the $21 million for Lake Arapuni to the Karaapiro Dam cannot be compared with the direct cost estimates in the Economic model.

Also, these WTP estimates are conservative as they do not include recreational values for the catchment streams, which are to be the subject of further research. Also it is likely that non-residents, such as tourists and recreational users of the lakes, will hold NMV for water quality in the lakes. These values have not been counted and will vary greatly.

When these NMV are put alongside the direct farm costs and benefits for the upper catchment estimated in Scenario 2 and 3 (see Section 6) there is still a considerable gap before benefits exceed total costs of cleaning up the farm nutrient, sediment and effluent issues (see Table 3).

Table 3: Direct Farm costs and benefits for the upper catchment (PV $m).

	Scenario 2	Scenario 3
Capital costs	61.0	385.3
Operating costs	127.1	391.8
Total costs	188.1	777.1
Benefits	12.1	296.0
Net costs	176.0	481.0

Source: Economic model Table x7.

It should be noted that while the direct costs and benefits are quantified over 30 years the indirect and passive values estimated in the choice modelling study were elicited by asking for willingness to pay over only 10 years, thus the two sets of figures are not directly comparable.

Case Study 6

In another study a choice modelling survey was used to explore New Zealanders' willingness to pay (WTP) for sustainable dairy and sheep and beef cattle farming (Takatsuka et al., 2007). This study surveyed randomly selected New Zealand residents to determine their WTP for:

- Improved water quality (0 to 30 percent reduction in nitrate leaching).
- Reduced methane emissions (0 to 30 percent reduction).
- Reduced demands by agriculture for surface water and groundwater (0 to 30 percent reduction in water for irrigation).
- More diverse rural landscapes (0 to 30 percent more trees).

In total 312 of 1,008 survey forms were returned providing a 31 percent response rate and a sample representing 0.02 percent of New Zealand households. The model coefficients were significant at the 10 percent level. However, the adjusted R-squared was low (0.03–0.05) implying that the model had a low level explanation of respondent utility.

The results showed that people were not WTP positive amounts when improvements were made on individual attributes. However they were WTP significant positive amounts when combined improvements (all at 30 percent change) were made in all four environmental areas. The combined WTP for respondents relating to the Waikato was $157 per household per year over five years. This translates to a regional WTP of $107 million in PV terms.

Indigenous biodiversity values

Case Study 7

Patterson and Cole (1999) have estimated that the value of land-based indigenous biodiversity in New Zealand as whole ecosystems was $46 billion per annum (in 1994 dollars). This was broken down into direct use, indirect use and passive use values. Direct uses, valued at $9 billion per annum, included food, raw materials and timber from land use. Indirect uses accounted for the largest value at $30 billion per annum and included ecosystem services such as climate regulation, erosion control, soil formation, nutrient retention, waste treatment, pollination and biological control. Passive use values, estimated at $7 billion per annum, included option value (option for future use), existence/intrinsic value (preserving biodiversity for its own sake) and bequest value (preserving for future generations).

This study indicates that indirect values significantly exceed direct use values, at 65 percent of total value compared with 20 percent, with passive values making up 15 percent.

Case Study 8

Kaval et al., (2007) estimated that households (HHs) in Greater Wellington are willing to pay additional rates per year for biodiversity enhancement (i.e., planting scheme) on private and public land. The survey conducted in 2007, showed the average amounts were $174 per HH per year for planting schemes on public lands and $166 per HH per year on planting schemes on private lands. Over 60 percent of respondents were willing to pay for these schemes.

The information provided in the survey showed that residents feel strongly about biodiversity in New Zealand and are willing to give up a proportion of their income to support it.

Case Study 9

Nimmo-Bell (Bell et al., 2009) has developed a database of non-market values covering four diverse ecosystems and 16 attributes including 13 biodiversity values. The ecosystems and attributes valued included:

- South Island high country — Plants, insects and fish.
- Beech forest — Increased or decreased bird and insect abundance, wasp stings.
- Coastal marine — Shellfish, coastal vegetation, recreational fishing and children's ability to paddle.
- North Island urban lake[7] — Avoidance of hydrilla; loss of charophytes, birds, fish and mussels.

The primary purpose of this database is for Biosecurity New Zealand to estimate the economic value of biosecurity response activities affecting indigenous biodiversity. The database will also be useful for other decision making involving changes to indigenous biodiversity by organisations such as DoC and regional councils.

This study showed the residents of the Waikato are willing to pay significant amounts to prevent exotic weed infestations in waterways and avoid the loss of native species (see Table 4).

Table 4: Willingness to pay by Waikato regional household to protect indigenous biodiversity.

Attribute	WTP per annum over 5 yrs	PV* of WTP/HH	Aggregate over 157,000 HHs
Avoidance of hydrilla	$234	$1,009	$158m
Loss of charophytes	$146	$630	$99m
Loss of a native bird species	$138	$595	$93m
Loss of a fish or shellfish species	$120	$517	$81m

* Discount rate 8 percent, 157,000 households in the region.
Source: Bell et al., (2009).

In another component of this study Kerr and Sharp (2008) showed that people in the South island are willing to pay significant sums for changes to bird and insect populations. An interesting observation from this study is that birds were valued higher than insects and that avoiding the loss of birds or insects was valued more highly than increases in the populations of birds or insects (see Table 5).

Transferring the results from such choice modelling studies is complex and open to many criticisms. However these results indicate that passive values for changes to environmental attributes such as aesthetics and biodiversity are significant and need to be taken into account when considering policy changes that will affect the environment.

[7] Lake Rotoroa (Hamilton lake).

Table 5: Willingness to pay by South Island households for changes in bird and insect populations.

Species	Mean annual value per HH	PV @ 10 percent over 5 years	Aggregate over 300,000 HH
Few birds	-$300	-$1250	-$375m
Plentiful birds	$120	$500	$150m
Few insects	-$150	-$625	-$195
Plentiful insects	$90	$375	$113m

Source: Kerr and Sharp (2008).

4. Economic Impacts of Non-Market Values

A change to Gross Domestic Product (GDP) is a typical way to assess how a nation's well-being is changing. Gross Domestic Product, however, focuses on market values and does not distinguish between desirable welfare-enhancing activities against undesirable welfare-reducing activities (Costanza et al., 2004). For example, expenditure on prisons adds to GDP, while the benefits of reducing the jail population are not counted.

In order to better reflect over-all wellbeing, alternative, more holistic measures have been devised. For example, the Genuine Progress Indicator (GPI) measures net human welfare that covers both positive and negative contributors to human welfare. This includes both market and non-market values. For example, non-market services of parents (i.e., unpaid work) caring for children does not increase GDP but if the parent decides to work and pay for child care, GDP increases. GPI attempts to include unpaid services, such as child care. Genuine Progress Indicator also attempts to include the non-market values provided by the environment.

Genuine Progress Indicator is one approach to estimating changes in total well-being at the national level. Another measure is Gross National Happiness (GNH), which is a unique official statistic monitored in Bhutan (Adams, 2010). In New Zealand, as in other developed countries, there are no official well-being statistics estimated at the regional or national level. However, a GPI has recently been completed for Environment Waikato, but unfortunately the results are not yet available. The work was undertaken by the New Zealand Centre for Ecological Economics (NZCEE) and Market Economics Limited (MEL) as part of the SP1 FRST programme.

In the economic impacts section of this Study the direct benefits and costs associated with Scenarios 2 and 3 are taken two further steps, which are to assess the flow-on effects to the regional community through indirect and induced effects. In the first place, there are the indirect effects on industries supplying goods and services up-stream of the direct effects (e.g., firms supplying fencing materials for riparian planting on farms) and down-stream of the direct effects (e.g., dairy processing). Secondly, there are induced effects as households spend the income from wages from these industries creating another round of economic activity in consumption. Normally only market based costs and benefits are assessed in this way. The analysis could be extended to include non-market values, which would result in a GPI type approach as per the ANCEE and MEL study referred to above.

Restorative actions for improving the health and wellbeing of the Waikato River could be included in a GPI for the region. Such activities would include, for example:

- Reduced nutrient and effluent inflows from dairying.
- Reduced sediment loads from hill country farming.
- Improved drinking water quality on marae.
- Better access to the river for social and cultural activities.
- Improved aesthetics from riparian planting.
- Restoration of the ecological functions of wetlands and shallow lakes.
- Restored tuna and whitebait fisheries.

5. Implications for the Waikato River

The case studies presented indicate that the indirect and passive non-market values are likely to be highly significant and of comparable size to the direct market values. The latter have been quantified in dollar terms but at this stage the former cannot because of the time and budget constraints of this Study.

It is worth mentioning that there are non-market costs as well as non-market benefits. For example, the business as usual scenario could have significant non-market costs in terms of loss of opportunity for recreation, and adverse effects on the environment.

The case studies on indirect values and especially ecosystem services indicate that these indirect values can exceed direct values a number of times. For example, for Case Study 1, Wetlands are estimated to have an annual direct value of $5,900/ha and indirect value of $42,400/ha. On the other hand, Dairy has a direct value of $1,600/ha and an indirect value of $500/ha. On this basis society would be better off shifting dairy land into wetlands. This would involve the community making a trade-off by reducing regional income from dairying and increasing non-market values from wetland through increased ecological services.

At face value this analysis may seem counter-intuitive. If it were true then dairy farms would/should be converted into wetlands. It arises because wetlands are now so scarce that the marginal benefit/cost ratio of preservation/recreation is higher than the marginal benefit/cost of dairy pasture. A strong case may be made to convert some dairy land to wetland. But, at some point, the marginal value of lost dairy production will exceed the marginal value of the benefits from an additional hectare of wetland.

Riparian planting along streams improves ecosystem services. The direct costs under Scenario 2 amount to a PV of $16.1 million. Based on a shift from pasture to native plantings the indirect values change from $500/ha to $2,100/ha (Whanganui data), a net increase of $1,600/ha. aken over the 412 ha converted to native under Scenario 2, this results in a PV of $3.3 million (assuming the benefits are received in years 11 to 30). Similarly, for Scenario 3 where 1,450 ha are converted from pasture to native the direct cost is $43.6 million and the indirect benefit $11.3 million. This comparison does not include the benefits from the improved water quality in the river. Consequently, the benefits of riparian planting ($3.3 million for Scenario 2) and ($11.3 million for Scenario 3) significantly under-estimate the full indirect benefits.

The two scenarios put forward in this report identify combinations of activities that will improve the quality of the river. Scenario 2 is less costly than Scenario 3 and will result in significantly less progress towards the goal of a river that is swimmable and the community are able to take food from it, over its entire length. The Cost Abatement Curves (CAC) provided highlights the trade-off between cost and benefit.

The willingness to pay survey in Case Study 5 indicated that upper catchment respondents were willing to pay in PV term $21 million for improvements in water quality, clarity and ecological health of Lakes Arapuni and Karaapiro.

Case Study 6 indicates that the willingness to pay for improvement in water quality, reduced GHG emissions, reduced demand for irrigation water and more diverse landscapes (all at 30 percent change), when extrapolated over the Waikato region could be in the order of $107 million in PV terms.

Case Study 9 indicates that the willingness to pay for the passive values of waterways (protecting indigenous plant and animal species) in the Waikato region could be in the range of $80 to $160 million in PV terms. Also, actions taken that would increase the number of native birds and insects in the region (e.g., riparian planting and lake restoration) would have benefits of a similar magnitude.

Unfortunately, it is not possible to add these indirect and passive values together in the same way that the direct costs can be added together. This is because of the overlap in types of benefit and the different methodologies used to derive them. Extrapolating from specific case studies derived in different regions and countries assumes that the sites and attributes are similar and the populations are similar. In many instances the validity of such assumptions may not stand up to close scrutiny. Never-the-less the quantum of these indirect and passive values is significant when compared with the direct costs.

Another important qualification with the studies on ecosystem services is that average values are used that have been derived from international meta-analysis, and thus these figures do not take into account the degraded nature of the Waikato catchment's ecosystem services. This suggests that the marginal benefit/cost ratio for restoration activities in the Waikato is likely to be higher than the figures used because of the degraded nature of the Waikato catchment's ecosystem services. However, to confirm this it is necessary to undertake a study to benchmark the actual value of ecosystem services in the catchment and then assess how these values change due to the mitigation activities.

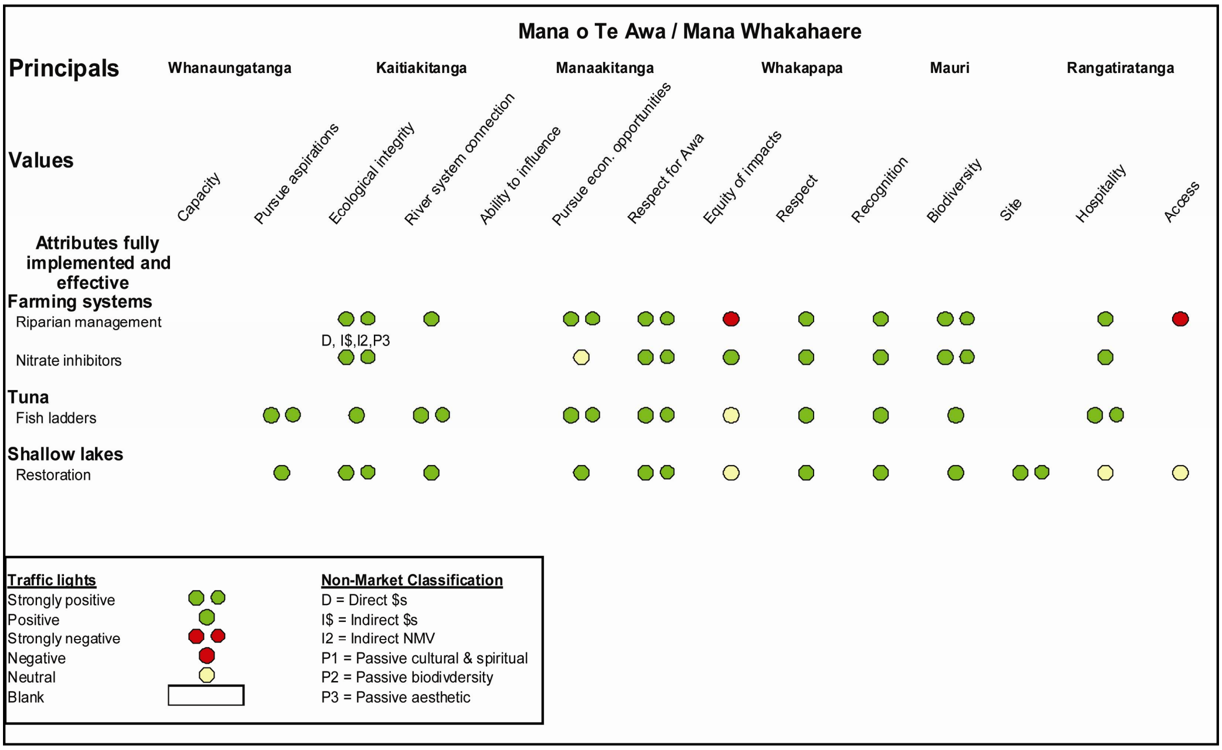
Because non-market valuation studies are expensive and time consuming, very few are undertaken in New Zealand. This means that secondary sources of information are utilised as above, with estimates that do not provide similar degrees of robustness compared with direct cost estimates. One of the key issues is whether stakeholders in the Waikato region share the same views of the environment as the respondents in the case studies (such as the averages sourced from a global meta-analysis). This question would normally be answered by conducting surveys. However, this Study was not in a position to conduct such surveys although it may be possible for surveys to be conducted as part of the 'clean-up' of the Waikato River.

While all peoples place an intrinsic value on indigenous biodiversity, attempting to estimate dollar values for these can be highly sensitive. For Maaori, such intrinsic values are an integral part of their belief system being based on principles such as kaitiakitanga (guardianship). Some things many people regard as being beyond dollar values. For these the political process is the way that society ultimately resolves the trade-offs between conflicting values. However, in order to make sustainable progress political decisions need to be well informed.

One way to compare non-market and market costs and benefits is through the report card. This requires that targets be set for non-market and market indicators, and the current state reported in relation to the target. For example, an important non-market value is safety for swimming for which an indicator is the *E. coli* concentration for which the safe guideline value is a median of 125 CFU per 100 mL. Measurements of 125, 500, 1000, 5000 and 10000 CFU per 100 mL might be assigned scores of A, B, C, D and E. A market indicator might be household income for which values of $60K, $50K, $40K, $30K and $20K might be assigned scores of A, B, C, D and E. In this way different types of indicator can be compared. The validity of this approach depends on being able to select targets and scale indicators in a sensible manner. It does not solve the problem of estimating the value of safe swimming.

Another way to display and compare costs and benefits is to use the 'traffic light' approach. This uses green, amber or red symbols to show how a group of restoration actions affect values or high level principles. An example is provided in Table 6. Here four actions are scored: riparian management, nitrate inhibitors, fish ladders and shallow lake restoration. The classification of non-market values are added for one cell – the impact of riparian management on ecological integrity. Tables can be replicated and used to compare Scenarios 1 to 2 to 3.

Table 6: Example of a 'traffic light' approach - linking actions to values.



The following issues have been identified from the case studies:

- What are the relative orders of magnitude between non-market values – similar order of magnitude?
- Are the potential non-market benefits likely to exceed the net direct quantified costs and benefits estimated in the previous section? – Possibly.
- What further work needs to be done to quantify the non-market values associated with the project – surveys of willingness to pay for changes to river quality?

6. Conclusions

Non-market costs and benefits need to be anchored on the ecological assessment of the changes to the environment and stakeholder perceptions of these changes. This is because the economic assessment of non-market values is essentially grounded on human welfare change.

All restoration activities considered in Scenarios 2 and 3 clearly have positive impacts on non-market values in the catchment.

Based on a review of nine case studies (three in the Waikato) the value of these benefits is likely to be of a similar magnitude to the direct market costs of the restoration actions assessed in the Economic Model. However, the results of the nine studies cannot be compared directly with the costs of restoration because different methods were used and some of the measures overlap.

The benefits estimated by the nine studies reviewed almost certainly under-estimate the true non-market benefits of restoration for two reasons. First, they omit some the values that are important in the Waikato (e.g., fisheries). Second, they include ‘ecosystem services’ that help support communities but they do not consider cultural and spiritual values that are an important part of community wellbeing.

Consequently, the total benefits including ‘ecosystem services’ and the benefits to community wellbeing are likely to be higher than the direct costs of restoration for some of the restoration actions. Those actions where the Study team considers this to be the case are the ‘Priority Actions’ identified in Section 7.

7. Climate Change, the ETS and Forestry and Agriculture - Implications for the Waikato River

Material for this Section has been drawn from MAF’s website.[8]

7.1 Climate Change

‘Climate change’ is the phrase used to describe changing climate patterns that can be attributed to human activity that alter the earth’s atmosphere and are beyond natural climate variations observed over comparable time periods. While New Zealand’s greenhouse gas (GHG) emissions in a global context are small, at 0.2 percent of the world’s total, on a per-person basis the level of emissions ranks New Zealand 12th in the world. Also, the pattern of GHG emissions in New Zealand is quite unlike any other developed country in that methane and nitrous oxide from agricultural activity account for 48 percent of total emissions (MAF, 2010a).

7.2 The Emissions Trading Scheme

In September 2007, the government released a comprehensive statement on climate change which set targets for reducing New Zealand’s greenhouse gas emissions. The announcements included details of a range of initiatives across all sectors, including a proposed New Zealand Emissions Trading Scheme (ETS) and a Plan of Action for Sustainable Land Management and Climate Change (MAF, 2010b). The ETS is a price based mechanism for greenhouse gases and is a key part of overall climate change policy. Forestry is the first sector to be involved in the ETS.

7.3 Forestry in the ETS

The forest estate is already a significant store of carbon and there is potential for this to grow further with farm and larger-scale plantings of both exotic and indigenous

[8] http://maf.govt.nz/climatechange/agriculture/agriculture-in-nzets-guide/page-03.htm#P111_12341 and http://www.maf.govt.nz/sustainable-forestry/ets/

forest species. For this reason, it was the first sector to enter the ETS - effective 1 January 2008 (MAF, 2010c).

Forest owners either automatically (pre-1990) or voluntarily (post-1989) become participants in the ETS depending on the date the forest was established; the type of forest owned (or leased, or held under a forestry right); and whether any deforestation has occurred. Forest land is defined as being at least 1 hectare (ha) with forest species that have (or are likely to have at maturity): a crown cover of more than 30 percent on each hectare; a crown cover with an average width of at least 30 m; and be capable of reaching five metres in height at maturity.

Post-1989 forest owners can register their forest and receive Carbon Accounting Unit (CCU) credits on an annual basis as carbon is accumulated by the forest. These can be sold as Kyoto compliant units. The current price of a CCU is $25 per tonne. The amount of carbon accumulated each year reaches a maximum of around 37 tonnes per hectare a little after mid-way through the 26 year rotation of a typical pruned Pinus radiata regime. These units can be sold as they are earned or banked to meet the liability at harvest when around two thirds of the credits must be paid back. The remaining one third related to the part of the tree remaining in the ground are required to be paid back over time in line with decay and return to carbon dioxide. The delay between selling units and repaying them offers forest owners a cash flow stream that could significantly improve the economics of forestry.

7.4 Agriculture in the ETS

The ETS for agriculture includes greenhouse gases from pastoral agriculture, horticulture and arable production. Methane from livestock emissions and nitrous oxide from animal urine and dung and synthetic fertiliser are the primary sources. Although the agricultural sector as a whole also produces carbon dioxide emissions through energy and fossil fuel use, for the purposes of the NZ ETS, the term 'agricultural emissions' refers to methane and nitrous oxide only.

The ability to trap heat from the sun is measured over a one hundred year period and is called Global Warming Potential (GWP). Carbon dioxide has a GWP of 1. Methane captures the heat from infrared radiation more effectively than carbon dioxide with a GWP of 21. Nitrogen in the form of nitrous oxide is even more effective with a GWP of 310. In New Zealand agriculture, methane is twice as important as nitrous oxide on a total output basis.

Participants can voluntarily report their emissions in 2011 and are required to report their emissions from 2012 though to 2014, but they are not required to pay for their emissions in these years. Agriculture fully enters the scheme in 2015.

Agriculture sector participants will be eligible to receive a free allocation of Kyoto compliant units called New Zealand Units (NZUs) from the Government to help significantly reduce the cost of participation in the NZ ETS. Allocation will be on an ‘intensity’ basis, meaning participants receive an allocation that is linked to their output. The assistance level will start at 90 percent of the sector’s baseline and will phase out at 1.3 percent per annum from 2016. The baseline and other details are yet to be established.

7.5 Implications for the Waikato River

The link between GHG abatement policies and improvement in the quality of the river is that for the most part actions taken to reduce GHG emissions also reduce inputs of N, P, sediment and faecal organisms to waterways, with benefits for water quality (Wilcock et al., 2008).

7.5.1 Forestry

For forest land owners, the ETS is said by the Government to offer significant opportunities for land development and economic growth. However, even after the start of the scheme there is considerable uncertainty surrounding the economics. This is primarily because of the considerable time lag between when CCUs may be sold as the forest grows and when they must be paid back at harvest. If the price of carbon rises in real terms then forest owners could face potentially crippling liabilities. Alternatively if the price of carbon falls over time then forest owners could receive very high returns over the length of the rotation.

Forestry is economically marginal on hill country at present without the ETS. With the ETS the uncertainties around pricing of CCUs could make or break forestry. For example, if Carbon Credits were sold at $25/tonne (each year the credits were generated) and then had to be purchased back at $50/tonne (at the end of the rotation) this could result in forest owners owing large sums. Alternatively if the price went down at harvest forest owners could make large profits.

The table below for a pruned regime over 26 years highlights the range in returns under four price scenarios.

Table 7: The impact of CCU price changes on forestry NPV.

Carbon Credits $/tonne CO_2 (2010 prices)		NPV/ha @ 8 percent
Sell price	**Purchase price**	
25	25	812
50	50	4,300
25	50	-1,405
50	25	6,518

7.5.2 Agriculture

While the forestry sector is seen to be a beneficiary of the ETS, the agriculture sector sees it as a significant threat to international competitiveness. New Zealand is the only country to have committed to an 'all gases all sectors' ETS scheme. Potentially, this places New Zealand agriculture at a disadvantage in international markets as other countries will be, in Global Warming terms, subsidising their agriculture while New Zealand continues its policy of fully exposing agriculture to market forces without subsidies. In the early years of the scheme, during the phase in, the direct impact may be low in financial terms because farmers will not have to pay the full cost. However, the bureaucracy around the ETS is likely to be a significant burden even if the recording is done at the processor level. For the policy to be effective, the costs must be passed back to farmers so that behaviour changes and emissions are reduced.

A major concern of farmers is that the technologies do not exist for them to reduce emissions and that the scheme should not be initiated until these are available.

Considerable research has been conducted on actions that might improve farming emissions and results are starting to become available. De Klein and Eckard (2008) report that of the currently available technologies, nitrification inhibitors, managing animal diets and fertiliser management show the best potential for reducing emissions in the short term. They also note that abatement technologies that increase the efficiency of N within the soil-plant system are likely to increase pasture and/or animal productivity, which in turn, is likely to increase methane emissions. Thus a whole farm systems approach is necessary to ensure that total emissions abatement is achieved.

Monaghan et al., (2007) indicated that under current pricing structures, nitrification inhibitors are likely to be a cost effective option for grazing systems in some parts of New Zealand, while wintering pads generally reduce farm profitability. Given that current technologies may deliver up to 15 percent reduction in N_2O, which translates to only a 2–4 percent decrease in overall emissions, further research is needed before farmers will be convinced to change their management systems.

While nitrate inhibitors are practical on flat land, this is not the case on hill country that is too steep for tractors. This poses an additional challenge for sheep and beef farmers on hill country to reduce emissions. It also improves the relative profitability of forestry on hill country.

Changing land use from intensive pasture based systems to forestry has the potential to have the greatest impact on GHGs, but at a major cost in lost income. Converting dairy systems to forestry can have up to a 90 percent decrease in N while converting sheep and beef to forestry reduces N by around 65 percent. In addition, converting Class 3 sheep and beef can have a beneficial effect on waterways by halving sediment loads (Monaghan, pers. comm., 2010).

Given the significant uncertainty that surrounds the ETS it was decided to exclude it as a consideration in the quantitative analysis of the report. Firstly, while forestry is currently in the ETS agriculture is not and there is no surety over if/when it will be. Secondly, the price likely to be paid for carbon credits over the 30 years of the study is extremely uncertain. Thirdly, the current economic impact (input/output) model is not able to accommodate GHG. And fourthly, New Zealand's approach to GHG may change, for example, to align more closely with the policies of the country's major trading partners.

The consequences of including GHGs in the quantitative analysis would likely be as follows. Firstly, forestry would be more attractive financially (assuming that the price of carbon does not rise significantly between the sale and purchase back of credits at harvest). Secondly, given forestry becomes more attractive there would likely be more sheep/beef to forest conversions on hill country and greater benefits in terms of reduced erosion and nitrogen input. Lastly, it is likely to make pastoral farming less attractive financially than has been estimated in which case there may be less intensive pastoral farming as farmers seek alternative enterprises with lower GHG emissions. This will have benefits in terms of reduced stock numbers, lower nitrogen leaching and lower faecal microbe runoff into waterways.

8. References

Adams, C. (2010). Happiness beats GDP gauge, New Zealand Herald, 17 May 2010.

Balmford, A.; Bruner, A.; Cooper, P.; Costanza, R.; Farber, S.; Green, R.; Jenkins, M.; Jefferiss, P.; Jessamy, V.; Madden, J.; Munro, K.; Myers, N.; Naeem, S.; Paavola, J. Rayment, M.; Rosendo, S.; Roughgarden, J.; Trumper, K.; Turner, R. (2002). Economic reasons for conserving wild nature. *Science 297*: 950–953.

Bell, B.A.; Cudby, C.; Yap, M. (2009). Biodiversity valuation manual: a technical manual for MAFBNZ (Working Paper No. 11). Wellington: Nimmo-Bell & Company Ltd.

Costanza, R. et al., (2004). Estimates of the Genuine Progress Indicator (GPI) for Vermont, Chittenden County and Burlington, from 1950 to 2000. *Ecological Economics* 139–155.

De Klein, C.A.M.; Eckard, R.J. (2008). *Targeted technologies for nitrous oxide abatement from animal agriculture 48*: 14–20.

Department of Conservation (2007). The economic values of Whangamarino Wetland, Department of Conservation, May 2007.

Environment Waikato (2010). The hidden economy. Downloaded on 13 June 2010 from http://www.ew.govt.nz/Environmental-information/About-the-Waikato-region/Our-economy/The-hidden-economy/

EVRI (2009). Environmental Valuation Reference Inventory. Environment Canada http://www.evri.ca/

Kaval, P.; Yao, R.; Parminter, T. (2007). The value of native biodiversity enhancement in New Zealand: A case study for the Greater Wellington Area, University of Waikato, November 2007.

Kerr, G.; Sharp, B. (2008). Biodiversity management: Lake Rotoiti choice modelling study. AERU Research Report No. 310, Lincoln University, September 2008.

MAF (2010a). Agriculture in the ETS. http://www.maf.govt.nz/climatechange/agriculture/agriculture-in-nzets-guide/page-03.htm#P111_12341

MAF (2010b). Sustainable Land Management and Climate Change: Plan of Action. http://www.maf.govt.nz/climatechange/slm/

MAF (2010c). Sustainable forestry. http://www.maf.govt.nz/sustainable-forestry/ets/

Marsh, D.; Davies, A.; Petch, A. (2009). Willingness to pay for water quality in the Karaapiro catchment – a case study of residents. Report to the Environment Committee, Environment Waikato, 31 July 2009, 10 p.

McDonald, G.; Trinh, S. (2008). Upper Waikato region's hidden economy: assessing the value of the region's ecosystem services. Prepared for Environment Waikato, August 2008, 37 p.

Monaghan, R.M.; de Klein, C.A.M.; Muirhead, R.W. (2007). Prioritisation of farm scale remediation efforts for reducing losses of nutrients and faecal indicator organisms to waterways: a case study of New Zealand dairy farming. *Journal of Environment Management 87*: 609–622.

Patterson, M.; Cole, A. (1998). The Economic Value of Ecosystem Services in the Waikato Region. Report prepared for Environment Waikato. Massey University, Palmerston North.

Patterson, M.; Cole, A. (1999). Assessing the value of New Zealand's biodiversity. Occasional Paper Number 1, School of Resource and Environmental Planning, Massey University, February 1999.

Takatsuka, Y.; Cullen, R.; Wilson, M.; Wratten, S. (2007). Values of ecosystem services associated with intensive dairy farming in New Zealand. Contributed paper Australian Agricultural and Resource Economics Society 51st Annual Conference, 13-16 February, 2007, Queenstown, New Zealand.

The economics of ecosystems and biodiversity (TEEB) (2009). The economics of ecosystems and biodiversity for national and international policy makers – Summary: Responding to the value of nature, United Nations Environment Programme, www.teebweb.org.

Schuyt, K.; Brander, L. (2004). The economic values of the world's wetlands, World Wildlife Fund, Gland, Amsterdam, January 2004 quoting.

Kirkland, W.T. (1988). Preserving the Whangamarino Wetland – an application of the contingent valuation method, Masters Thesis, Massey University.

Silverman, G.S. (2007). Community benefits and costs of surpassing drinking water quality standards. *Journal of the American Water Works Association*.

van den Belt, M.; Chrystall, C.; Patterson, M. (2009). Rapid ecosystem service assessment for the Manawatu-Wanganui Region, New Zealand Centre for Ecological Economics.

Wilcock, R.; Elliot, S.; Hudson, N.; Parkyn, S.; Quinn, J. (2008). Climate change mitigation for agriculture: water quality benefits and costs. *Water Science & Technology 58*: 11.

Appendix 33: Restoration Case Studies

1. Introduction

Over the past 30 years there has been a substantial increase in river restoration efforts worldwide (Alexander and Allan, 2007; Giller, 2005) and this has been accompanied by advances in the science of river restoration (Ormerod, 2004; Roni et al., 2002). There are now a number of useful reviews of restoration which help to identify what makes for successful restoration outcomes and commonly occurring problems. However, despite the amount of restoration activity occurring there are few clear success stories and the scientific basis for restoration is incomplete (Brooks and Lake, 2007).

Restoration in the United States

In the United States there has been an exponential increase in river restoration projects since the 1990s and restoration now plays an important part in environmental management. The River Restoration Science Synthesis (NRRSS) project has compiled a database of over 37,000 restoration projects being carried out mainly in the United States (Bernhardt et al., 2005a; Bernhardt et al., 2005b). These range in size from small community-based activities reliant on voluntary and 'in-kind' support through to large restoration projects which have been running for decades and involve expenditure of billions of dollars. The picture that emerges is that a comprehensive analysis of restoration progress in the US is not possible because of lack of records and piecemeal information. Of the 37,000 projects reviewed only 10 percent indicated that monitoring of progress or effectiveness was being carried out, although more expensive projects of the order of about US$1 million were likely to be monitored. This lack of monitoring or sufficient recording of project objectives, budgets, or efficacy means that opportunities to learn from project successes and failures are being lost.

Restoration in the Europe

In Europe waterways and lakes have suffered from various forms of control, manipulation and pollution for the past 6000 years so that there are now few rivers with natural flows and that are in a pristine condition (Nienhuis and Leuven, 2001). In Western Europe eutrophication from intensive agriculture and farming is a particular problem (Gulati and van Donk, 2002). The River Thames in the Britain is one of the first well documented cases of successful restoration. The Thames had become seriously polluted by the early 1800s. Restoration started in the 1960s and largely through the building of sewage treatment plants the fish fauna of the river underwent a remarkable recovery (Gameson and Wheeler, 1977). There are now numerous cases of restoration being undertaken throughout Europe (e.g., see reviews in van Andel and Aronson, 2006; Nienhuis and Gulati, 2002). However, river restoration efforts in Europe are often complicated and compromised, especially for the large rivers because they flow through several countries (e.g., Weiring et al., 2010), and where flood protection and transport are of over-riding priority to restoration (e.g., Buijse et al., 2002).

Restoration in Australia

In Australia the construction of weirs, floodplain levees, dams and inter- and intra-catchment water transfer schemes have had a major impact on natural river systems. Flow regulation affects all the major Australian rivers and such regulation is acknowledged as a major cause of deterioration in many Australian river and floodplain ecosystems (Arthington and Pusey, 2003). There is now a national commitment to ecologically sustainable development and water reform, including restoration.

Brooks and Lake (2007) have collated and synthesized data on restoration projects in Victoria, Australia. Most of the 2,247 projects reviewed focused on riparian management including fencing, off-river watering points (to keep stock out of the riparian zone), native plant revegetation, weed management and willow removal. The rest mainly included bank stabilisation, habitat improvement and channel reconfiguration. Although financial information is often missing, it appears that a conservative estimate of total expenditure (not accounting for 'in-kind' and volunteer support) is that AU$131 million has been spent in Victoria on river restoration over the 1999-2001 period, or AU$44 million per year. Riparian management was the least expensive activity whereas projects involving stormwater management were the most expensive. In rural areas riparian restoration is seen as an effective way to improve water quality by reducing sediment and nutrient inputs, stabilising river banks and limiting channel incision. As found in the US, records of monitoring are often scarce or incomplete. Of the 2,247 Victorian cases examined only 14 percent appeared to include monitoring or evaluation, but information was inadequate for determining whether monitoring was being carried out to check that construction projects remained intact and that planted vegetation had survived. It was also not clear from the information recorded if monitoring data was used to evaluate the success of the project in achieving the restoration goals. Opportunities to use experience gained from past river restoration is limited. Another problem that has occurred is that organisational restructuring and poor data management have resulted in data and historical information relating to restoration projects being lost.

Restoration in New Zealand

Over the last 20 years there have been increasing attempts at restoration of New Zealand freshwater ecosystems (Quinn, 2009) and guidelines for restoration of aquatic habitats have been published (e.g., Collier, 1994; Rowe, 2004; Sorrell et al., 2004; Suren et al., 2004). Quinn (2009) summarised the range of restoration activities occurring in New Zealand, from individual landowners fencing and replanting along riparian zones through to nationally significant projects involving Fonterra and the government (Dairying and Clean Streams Accord) and regional coalitions between Maaori and regional and central government and multi-million dollar budgets (e.g., Lake Taupoo $81.5 million and Rotorua/Te Arawa lakes $144 million). Stream and lake restoration case studies are being documented, and show progress towards many aspirations, on dairy (e.g., Wilcock et al., 2007; 2009) and drystock farms (Dodd et al., 2008 a,b,c; Quinn et al., 2007; 2009). Monitoring of intensive action to restore Lake Okaro has also shown significant benefits since 2003 (e.g., Paul et al., 2008; Özkundakci et al., 2009; Gibbs and Özkundakci, 2010). There are active research programmes on aquatic restoration within New Zealand CRIs, universities[1] and NGOs[2] and there is considerable collaboration between these organisations and with stakeholders.

Restoration and Indigenous Communities

Worldwide there are now many river restoration initiatives focused on the values of indigenous communities and also benefiting from the input of Traditional Ecological Knowledge (TEK). There are numerous websites and on-line resources available which focus on restoration from the perspective of indigenous peoples.

The **Indigenous Peoples' Restoration Network (IPRN)[3]** operates under the auspices of the Society for Ecological Restoration International[4]. The network's mission is:

- "to support native and tribal communities in need of technical assistance for environmental restoration and cultural rehabilitation; and
- to assist leaders and practitioners in their efforts to apply traditional ecological knowledge within their own vision of political, economic, and cultural sovereignty."

Their website provides many useful links to databases, resources, references and indigenous groups and organisations worldwide, including New Zealand, Australia and the Pacific Rim.

In the United States, the **American Indian Environmental Office (AIEO)[5]** coordinates the US Environmental Protection Agency (USEPA) environmental protection efforts in Indian Country, with a special emphasis on building tribal capacity to administer their own

[1] http://www.niwa.co.nz/our-science/freshwater/research-projects/all/restoration-of-aquatic-ecosystems and http://www.lernz.co.nz/index.html
[2] http://www.landcare.org.nz/regional-focus/central-north-island/waikato-lakes-catchments/
[3] Contact with IPRN has been established by Dr Gail Tipa, g.tipa@xtra.co.nz, ph 64 3 4894534
[4] http://www.ser.org/iprn/default.asp
[5] Contact with AIEO has been established by Dr Gail Tipa, g.tipa@xtra.co.nz, ph 64 3 4894534

environmental programs.[6] The American Indian Tribal Environmental Portal provides specific details relating to environmental policies, practices and laws.[7]

Restoration resources and support

In addition to the resources and networks being developed by indigenous groups there are now worldwide initiatives to support and encourage river restoration. The following international centres aim to share technical knowledge and resources on river restoration:

Pacific
Australian River Restoration Centre (ARRC)

Asia
Asian River Restoration Network (ARRN)
Japan River Restoration Network (JRRN)

Europe
European Centre for River Restoration (ECRR)
The River Restoration Centre (UK) (RRC)
Danish Centre for River Restoration (Dansk Center for Vandløbsrestaurering – DCVR)
Netherlands Centre for River Studies (NCR)
Italian Centre for River Restoration (Centro Italiano per la Riqualificazione Fluviale – CIRF)

North America
River Restoration Northwest

Project WET[8] is a nonprofit organisation which aims to support and educate children, parents, teachers and the wider community on water education.[9] Project WET operates worldwide and achieves its aims through training workshops, organizing community events and festivals and building international networks.

The Queensland-based **International WaterForum** is a joint venture between the International WaterCentre, the International Riverfoundation, the University of Queensland, Griffith University, Queensland Government and Brisbane City Council.[10] Their aim is to improve the business of water and river management by facilitating opportunities for education, professional development, knowledge sharing, networking

[6] http://www.healthfinder.gov/orgs/HR3413.htm
[7] http://www.epa.gov/tribalportal/trprograms/env-programs.htm
[8] Contact with Project WET has been established by Dr Gail Tipa, g.tipa@xtra.co.nz, ph 64 3 4894534
[9] http://www.projectwet.org
[10] http://www.watercentre.org/news/international-waterforum

and recognition of excellence within water and river management. The International WaterForum is also responsible for organising the **International Riversymposium**, a conference that focuses on water and river management. The 13th International Riversymposium is scheduled for 11-14th October 2010, in Perth.[11]

Case Studies

There are numerous documented cases of river restoration worldwide. Many of these are of little direct relevance to the Waikato River because of differences in climate, hydrology, and ecology. The following selection of case studies has been chosen because they provide lessons that could benefit restoration of the Waikato River. They have been chosen because they are good examples of:

- Approaches that can be taken (e.g., Glen Canyon, Columbia River Basin, Willamette Basin, South East Queensland).
- The complexity and expense of restoration projects (e.g., Colombia River Basin, Willamette Basin, Murray River, South East Queensland).
- Restoration of traditional fisheries, important to indigenous communities (e.g., Colombia River Basin).
- Engagement with indigenous communities as part of the restoration process (e.g., Colombia River Basin, Willamette Basin, Murray River).
- Community involvement (e.g., South East Queensland).
- Mitigating the impact of hydro dam operation (e.g., Glen Canyon).
- Regional significance (e.g., Murray River, South East Queensland).

Glen Canyon

The Glen Canyon dam case is an example of where it is recognised that science cannot provide certainty of a desired outcome and with collaborative input from the community and stakeholders a Collaborative Adaptive Management (CAM) approach was taken (NRC, 1999). The Glen Canyon dam is located on the Colorado River just south of the Arizona-Utah border. The Colorado River then passes through Marble Canyon before entering the Grand Canyon National Park and flowing into Lake Mead, formed by the Hoover dam. The area is home to several American Indian tribes and as well as its cultural importance it has exceptional ecosystem values and is a World Heritage Site. The Glen Canyon dam and its operations have profoundly altered the hydrology and temperature regime of the river with significant effects on the Colorado River ecosystem and the surrounding desert country.

[11] http://www.riversymposium.com/

The Glen Canyon dam Adaptive Management Program (AMP) was established in 1997 with the aim of co-ordinating research and monitoring of the downstream ecosystem and resources. A Federal Advisory Committee which includes input from stakeholders has responsibility for facilitating the program and making recommendations on actions to improve the downstream ecosystem and resources. Scientific experimentation is integrated into the management actions.

While the Glen Canyon case had been promoted as an example of the successful application of CAM it has also been severely criticised by Susskind et al., (2010). They maintain that the programme has failed to increase the understanding of stakeholders and has not resulted in them making informed management recommendations. The result is that it has not stabilised or improved the river ecosystem, despite the expenditure of several millions of dollars over the past 13 years. Susskind et al., (2010) maintain that this failure has arisen because of fundamental flaws in the set-up of the Adaptive Management Program, with only partial stakeholder representation, confused and uncertain decision making authority and lack of responsibility, and an ineffective dispute resolution process.

Columbia River Basin

The 2000 km long Columbia River is the largest river in the Pacific Northwest. Its catchment lies within seven US States and British Columbia, Canada. The river's ecology and resources make a significant contribution to the economy of the Pacific Northwest region. About eight million people live within the catchment basin and the river has 14 hydropower dams. Traditionally, the Columbia River and its tributaries supported the largest salmon fishery in the world. With the extensive development of the river catchment there has been substantial habitat loss and degradation and contamination by chemical pollutants now pose a risk to fish, wildlife and humans[12].

Some of the local Indian tribes regard salmon to be part of their spiritual and cultural identity, and fishing is still the preferred livelihood of many tribal members. Treaties between individual tribes and the federal government acknowledge the importance of salmon and steelhead and guarantee fishing rights. To mitigate the effects that hydro dams have on fish migration, hatcheries now operated along the river. In 1977 four Indian tribes with treaty fishing rights on the river formed the Columbia River Inter-Tribal Fish Commission (CRITFC)[13] to coordinate their activities in fisheries management and restoration. They have also developed a holistic salmon management plan that aims to increase survival at each stage of the fish's anadromous[14] life cycle.

[12] http://www.cleanwaternetwork.org/sites/default/files/Columbia%20River%20One-Pager%20final.pdf
[13] http://www.critfc.org/
[14] Fish that migrate from the sea up rivers to spawn.

Restoration in the lower river is co-ordinated by the Lower Columbia River Estuary Partnership (LCREP)[15]. This Partnership integrates the restoration activities of multiple stakeholders from 28 cities, 9 counties, and the states of Oregon and Washington. They also have responsibility for implementing the Comprehensive Conservation and Management Plan for the Lower Columbia River.

The US Senate is currently considering legislation that would authorise the US Environmental Protection Agency to provide 'clean-up' technical assistance and help to river stakeholders (including state and local agencies, tribal governments, industry, landowners and environmental groups). The legislation would also authorise a budget of US$40 million annually.

Willamette Basin

The Willamette Basin restoration programme has many parallels with the Waikato River restoration proposal. The Willamette River is 301 km long and is a major tributary of the Columbia River, draining a densely populated region of the Pacific Northwest of the United States. The river and its tributaries form a basin called the Willamette Valley.

The area has been home to several American Indian tribes for at least 10,000 years, many having a close association with the river and depending on it for food, clothing, tools, transportation, and spiritual sustenance. Widespread development and increases in population over the past few hundred years had resulted in the river becoming seriously polluted. Fisheries had declined and the water was unsafe for drinking or swimming.

Faced with continuing catchment basin development and a growing population the Willamette Restoration Initiative (WRI) was charged with developing the Willamette Restoration Strategy (WRI, 2001). The strategy sets out to:

- protect and restore fish and wildlife habitat;
- enhance populations of other declining native species;
- improve water quality; and
- improve management of floodplains.

The WRI's activities are controlled by a board of directors, selected to represent the various interests and perspectives of the wider community, including those of local Indian tribes. The board has representatives of local government, utilities, tribes, academia, watershed groups, soil and water conservation districts, agriculture, forestry, environmental groups, and state and federal government.

[15] http://www.lcrep.org/about-us

The strategy was developed through a collaborative process and represents a holistic, integrated action plan. It incorporates existing restoration initiatives and builds on the existing knowledge of the system. It incorporates a variety of restoration approaches and by recognising the multiple and diverse values held by stakeholders, attempts to balance the goals of a healthy environment, a high quality of life, and a strong economy.

The strategy has identified 27 critical actions which fall into four restoration focus areas of:

- clean water;
- water quantity;
- habitats and hydrologic processes; and
- institutions and policies.

The strategy provides ways to measure restoration progress and to determine if the critical actions are achieving the restoration outcomes intended. Importantly, while the strategy provides a foundation for action it is recognised that a flexible approach is needed and that there needs to be continuous assessment and revision to incorporate improved understanding and possibly changing restoration needs.

An interesting approach taken as part of the Willamette Basin restoration has been the use of alternative futures analysis (Baker et al., 2004). This involved modelling three alternative scenarios which captured future landscapes for the year 2050, based on different development options. The Plan Trend 2050 scenario assumed that current policies and trends continue. The Development 2050 scenario represented a loosening of current policies and a market-driven approach. The Conservation 2050 scenario assumed that ecosystem protection and restoration were accorded higher priority, although still within the bounds of what stakeholders considered realistic. The modeling results have been used to guide the basin-wide restoration strategy.

Restoration of the Willamette basin is recognised as being extremely complicated and requiring long-term commitment. Recent estimates just for restoration of streamside vegetation and streamside habitat throughout the Willamette basin ranged from US$593 million to US$1.2 billion (Michie, 2010).

Murray River

Restoration of the Murray River is Australia's largest river restoration project and is one of the largest restoration projects in the world. The Murray River is 2,756 kilometres long and runs through the three states of Victoria, New South Wales and South Australia. It is navigable for 1,986 kilometres, has four dams, 16 weirs and 15 navigable locks and provides domestic water supply for over 1.5 million households. Aboriginal occupation along the river goes back 40,000 years.

Flow regulation of the river was introduced to make the supply of water more reliable but it has significantly changed the river ecosystem and water quality has deteriorated. Native fish have declined in numbers and in range, vegetation has been affected and some areas of land have become affected by salt. In 2002, in response to this deterioration the Murray-Darling Basin Ministerial Council established the Living Murray program.[16]

The Australian, New South Wales, Victorian, South Australian and the Australian Capital Territory governments together made an initial commitment to the Living Murray Project of A$500 million over a five year period from 2004–05 and a further A$150 million over eight years. The Living Murray has established five programmes through which to direct restoration activities:

- **Water Recovery** which addresses over-allocation of water resources in certain parts of the River Murray system and reclaims water for delivery to icon sites.
- **Water Application** which ensures that water is delivered to achieve ecological benefits at the icon sites.
- **Environmental Works and Measures** which aims at developing infrastructure which will help make the best use of water in the River Murray system.
- **Communication and Community Consultation** which will ensure that local communities, key stakeholders, and the public are able to receive information and offer their input.
- **Indigenous Partnerships** which establishes a partnership programme so that the social, spiritual, cultural, environmental and economic interests of indigenous communities are considered.

South East Queensland[17]

The South East Queensland Healthy Waterways project has several useful parallels with the Waikato proposal especially in the terms of partnerships and collaboration, capacity building, monitoring and reporting. The project was initiated to address concerns about degrading water quality in the waters of Moreton Bay and inland waterways. Deteriorating water quality was linked to sewage discharges and runoff and deposition of fine-grained sediments into Moreton Bay.[18]

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[16] http://www.thelivingmurray.mdbc.gov.au/index.html

[17] Contact with the SEQ Healthy Waterways project has been established by Dr Bruce Williamson, Diffuse Sources, bruce.williamson@diffusesources.com, ph 64 3 5484342

[18] http://www.healthywaterways.org/HealthyWaterways/Home.aspx

Fundamental to the project is the SEQ Healthy Waterways Partnership, a collaboration between government, industry, researchers and the community. In many ways the approaches that are being taken are unique. The partnership includes representatives of 7 state agencies, 3 national agencies, 4 state corporations, 11 local governments, 37 industries, 9 research institutes and 40 community and environmental groups. Together they developed a restoration strategy which includes 12 action plans based on a combination of issue-based, enabling and area-based plans:

Issue Based Action Plans

- Point Source Pollution.
- Non-Urban Diffuse Source Pollution.
- Water Sensitive Urban Design.
- Protection and Conservation.
- Coastal Algal Blooms.

Enabling Action Plans

- Ecosystem Health Monitoring Program.
- Communication, Education and Motivation.
- Management Strategy Evaluation.

Area Based Action Plans

Which focus on Moreton Bay and three separate catchments.

In total there are over 500 actions in the strategy that the partners have committed to implementing.

Another important aspect of this project is the Ecosystem Health Monitoring Program (EHMP). It is one of the most comprehensive marine, estuarine and freshwater monitoring programs in Australia and delivers a regional assessment, or 'Report Card', of the ambient ecosystem health for each of 19 catchments, 18 river estuaries, and Moreton Bay.

Dam decommissioning and removal

With the large number of dams affecting river ecosystems in the US, attention has turned to the option of their removal or ways of mitigating their impacts (e.g., Donnelly et al., 2005; O'Connor et al., 2008). The Federal Energy Regulatory Commission (FERC) has mandated changes in hydro dam operation to address environmental conditions including increased minimum flows, improved fish passage (both upstream and downstream), periodic high flows and riparian protection measures. Where mitigation cannot be achieve dam removal is now seen as a legitimate option for consideration, especially where fish passage needs to be improved. Examples of successful dam removal have occurred in the US, Canada, and Europe.

While there are more than 75,000 listed dams in the US (greater than 1.8 m high) there are also an estimated two million smaller dams (Shuman, 1995). As such, the majority of dams that have been removed and are currently being considered for removal are relatively small, non-hydroelectric dams, particularly run-of-river structures. It is estimated that since 1912 750 dams have been decommissioned with the rate increasing in recent years (O'Connor et al., 2008). It is important to note however that in the US many of the structures being removed have reached the end of safe operational life or are obsolete. For example there are many dams built in the 1800s to power textile mills which have now ceased to operate. The dams no longer serve any useful purpose and their removal is essential if the rivers they dam are to be restored to a natural state.

Lessons from past restoration attempts

Based on the many documented examples of restoration activities there are some general observations and conclusions that can be made about river restoration, what needs to be considered, what makes for a successful outcome, and what needs to be avoided:

1. Restoration is expensive – Restoration projects on a catchment scale can typically require budgets of many millions of dollars.
2. Restoration is long-term – It may be several decades before significant restoration is achieved.
3. Collaboration is needed – Restoration often requires participation, co-operation and collaboration from many parties including state and local government agencies, industry, universities, and representatives of indigenous groups, environmental care groups, sports groups and the wider community.
4. Build on existing initiatives – Attempts should be made to build on existing restoration and environmental management and monitoring activities.
5. Define outcome – The overall outcome that is desired from restoration needs to be defined.
6. Set agreed objectives – It is important to have clearly defined and agreed restoration objectives that will meet the desired outcome, and all partners need to be committed to achieving these.
7. Use traditional knowledge and science – Successful restoration relies on incorporating traditional knowledge (in this case maatauranga Maaori) and science. Also, scientific input must incorporate multi- and interdisciplinary approaches (e.g., drawing on physical, chemical, geomorphological and ecological expertise).
8. Use science – Use the extensive and growing body of restoration science to inform actions, monitoring and analysis.

9. Track expenditure and progress – Records of expenditure and completion of specific restoration activities need to be recorded and audited.
10. Monitor – Progress towards completing restoration activities, achievement of objectives and progress towards the overall outcome need to be monitored and the results publicised.
11. Learn from monitoring – Monitoring results need to be analysed to determine the effectiveness of the actions undertaken.
12. Use adaptive management – Because the outcome of specific restoration actions will not be reliably predictable there needs to be ongoing review of progress and if necessary modification and resetting of objectives and actions.
13. Outreach – There needs to be easy access to project information, objectives, planned actions, resources and monitoring results to all stakeholders and the community.
14. Plan for the future – Restoration projects are typically of a long duration and this needs to be considered when setting up administrative and management systems. Staff turnover and operational restructuring need to be allowed for with robust systems able to survive in the long-term. Planning has to include information security and backup and archiving. Standardised data systems and mandatory reporting are needed and changes in computing systems need to be considered so that information is not lost.

2. References

Alexander, G.G.; Allan, J.D. (2007). Ecological success in stream restoration: Case studies from the Midwestern United States. *Environmental Management 40*: 245–255.

Arthington, H.; Pusey, B.J. (2003). Flow restoration and protection in Australian rivers. *River Research and Applications 19*: 377–395.

Baker, J.P.; Hulse, D.W.; Gregory, S.V.; White, D.; Van Sickle, J.; Berger, P.A.; Dole, D. & Schumaker, N.H. (2004). Alternative futures for the Willamette River Basin, Oregon. *Ecological Applications 14(2):* 313–324.

Bernhardt, E.S.; Palmer, M.A.; Allan, J.D.; Alexander, G.; Barnas, K.; Brooks, S.; Carr, J.; Clayton, S.; Dahm, C.; Follstad-Shah, J.; Galat, D.; Gloss, S.; Goodwin, P.; Hart, D.; Hassett, B.; Jenkinson, R.; Katz, S.; Kondolf, G.M.; Lake, P.S.; Lave, R.; Meyer, J.L.; O'Donnell, T.K.; Pagano, L.; Powell, B. & Sudduth, E. (2005a). Synthesising U.S. river restoration efforts. *Science 308*: 636–637.

Bernhardt, E.S.; Palmer, M.A.; Allan, J.D.; Alexander, J.; Barnas, K.; Brooks, S.; Carr, J.; Clayton, S.; Dahm, C.; Follstad-Shah, J.; Galat, D.; Gloss, S.; Goodwin, P.; Hart, D.; Hassett, B.; Jenkinson, R.; Katz, S.; Kondolf, G.M.; Lake, P.S.; Lave, R.; Meyer, J.L.;

O'Donnell, T.K.; Pagano, L.; Powell. B. & Sudduth, E. (2005b). Synthesizing U.S. river restoration efforts. *Science* supporting online material. http://www.sciencemag.org/cgi/content/full/sci;308/5722/636/DC1

Brooks, S.S.; Lake, P.S. (2007). River restoration in Victoria, Australia: Change is in the wind, and none too soon. *Restoration Ecology 15(3)*: 584–591.

Buijse, A.D.; Coops, H.; Staras, M.; Jans, L.H.; van Geest, G.J.; Grifts, R.E.; Ibelings, B.W.; Oosterberg, W. & Roozen, C.J.M. (2002). Restoration strategies for river floodplains along large lowland rivers in Europe. *Freshwater Biology 47*: 889–907.

Collier, K.J. (ed). (1994). The restoration of aquatic habitats. Wellington, Department of Conservation. 171 p.

Dodd, M.B.; Thorrold, B.S.; Quinn, J.M.; Parminter, T.G. & Wedderburn, M.E. (2008a). Improving the economic and environmental performance of a New Zealand hill country farm catchment: 1. Goal development and assessment of current performance. *New Zealand Journal of Agricultural Research 51(1)*: 127–141.

Dodd, M.B.; Thorrold, B.S.; Quinn, J.M.; Parminter, T.G. & Wedderburn, M.E. (2008b). Improving the economic and environmental performance of a New Zealand hill country farm catchment: 2. Forecasting and planning land use change. *New Zealand Journal of Agricultural Research 53(1)*: 143–153.

Dodd, M.B.; Quinn, J.M.; Thorrold, B.S.; Parminter, T.G. & Wedderburn, M.E. (2008c). Improving the economic and environmental performance of a New Zealand hill country farm catchment: 3. Short term outcomes of land use change. *New Zealand Journal of Agricultural Research 53*: 155–169.

Donnelly, C.R.; King, L. & Phillips, M. (2005). Once removed – decommissioning Finlayson Dam. International Water Power and Dam construction. http://www.waterpowermagazine.com/story.asp?storyCode=2028607

Gameson, A.L.H.; Wheeler, A. (1977). Restoration and recovery of the Thames Estuary. *In:* Cairns, J.; Dickson, K.L.; Herricks, E.E. (eds). *Recovery and Restoration of Damaged Ecosystems.* The University Press of Virginia, Charlottesville (VA): 72–101.

Gibbs, M.; Özkundakci, D. (2010). Effects of a modified zeolite on P and N processes and fluxes across the lake sediment–water interface using core incubations. *Hydrobiologia*: 1–14, DOI 10.1007/s10750-009-0071-8.

Giller, P.S. (2005). River restoration: seeking ecological standards. *Journal of Applied Ecology 42*: 201–207.

Gulati, R.D.; van Donk, E. (2002). Lakes in the Netherlands, their origin, eutrophication and restoration: state-of-the-art review. *Hydrobiologia 478*: 73–106.

Michie, R. (2010). Cost estimate to restore riparian forest buffers and Improve stream habitat in the Willamette Basin, Oregon. State of Oregon Environmental Quality, Water Quality Division, Water Management Section. DEQ 10-WQ-007. http://www.deq.state.or.us/wq/tmdls/docs/WillametteRipCost030310.pdf

Nienhuis, P.H.; Gulati, R.D. (eds) (2002). Developments in Hydrobiology. Ecological restoration of aquatic and semi-aquatic ecosystems in the Netherlands (NW Europe). Kluwer Academic Publishers, The Netherlands. 233 p.

Nienhuis, P.H.; Leuven, R.S.E.W. (2001). River restoration and flood protection: controversy or synergism? *Hydrobiologia 444*: 85–99.

NRC (1999). Downstream: Adaptive management of Glen Canyon Dam and the Colorado River ecosystem. National Academy Press, Washington, DC.

O'Connor, J.; Major, J. & Grant, G. (2005). Down with the dams: Unchaining U.S. rivers. *Geotimes*. March 2008. http://www.geotimes.org/mar08/article.html?id=feature_dams.html

Ormerod, S.J. (2004). A golden age of river restoration science. *Aquatic Conservation: Marine and Freshwater Ecosystems 14*: 543–549.

Özkundakci, D.; Hamilton, D.P. & Scholes, P. (2009). Effect of intensive catchment and in-lake restoration procedures on phosphorus concentrations in a eutrophic lake. *Ecological Engineering*. http://dx.doi.org/DOI:10.1016/j.ecoleng.2009.11.006

Paul, W.J.; Hamilton, D.P. & Gibbs, M. (2008). Low-dose alum application trialed as a management tool for internal nutrient loads in Lake Okaro, New Zealand. *New Zealand Journal of Marine and Freshwater Research 42:* 207–217.

Quinn, J.M. (2009). Special issue on restoration of aquatic ecosystems. *New Zealand Journal of Marine and Freshwater Research (43)*: 653–657.

Quinn, J.M.; Croker, G.F.; Smith, B.J. & Bellingham, M.A. (2009). Integrated catchment management effects on runoff, habitat, instream vegetation and macroinvertebrates in Waikato, New Zealand, hill-country streams. *New Zealand Journal of Marine and Freshwater Research 43(3)*: 775–802.

Quinn, J.M.; Dodd, M.B. & Thorrold, B.S. (2007). Whatawhata catchment management project: the story so far. Proceedings of the New Zealand Grassland Association 69: 229–233.

Roni, P.; Beechie, T.J.; Bilby, R.E.; Leonetti, F.E.; Pollock, M.M. & Pess, G.R. (2002). A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. *North American Journal of Fisheries Management 22*: 1–20.

Rowe, D. (2004). Lake restoration. *In*: Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrell, B.K. (eds). *Freshwaters of New Zealand*. Christchurch, New Zealand Hydrological Society and New Zealand Limnological Society: 39.1–39.16.

Shuman, J.R. (1995). Environmental considerations for assessing dam removal alternatives for river restoration. *Regulated Rivers: Research & Management 11(3-4)*: 249–261.

Sorrell, B.; Reeves, P. & Clarkson, B. (2004). Wetland management and restoration *In*: Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrell, B.K. (Eds). *Freshwaters of New Zealand*. Christchurch, New Zealand Hydrological Society and New Zealand Limnological Society: 40.1–40.12.

Suren A.; McMurtrie, S. & O'Brien, L.M. (2004). River restoration. *In*: Harding, J.S.; Mosley, M.P.; Pearson, C.P.; Sorrell, B.K. (eds). *Freshwaters of New Zealand*. Christchurch, New Zealand Hydrological Society and New Zealand Limnological Society: 38.1–38.20.

Susskind, L.; Camacho, A.E. & Schenk, T. (2010). Collaborative planning and adaptive management in Glen Canyon: A cautionary tale. *Columbia Journal of Environmental Law 35(1)*: 53 p.

Van Andel, J.; Aronson, J. (eds). (2006). *Restoration ecology: the new frontier*. Blackwell Publishing, USA. 341 p.

Wiering, M.; Verwijmeren, J.; Lulofs, K. & Field, C. (2010). Experiences in regional cross border co-operation in river management. Comparing three cases at the Dutch-German border. *Water Resources Management.* January 2010.

Wilcock, R.J.; Betteridge, K.; Shearman, D.; Fowles, C.; Scarsbrook, M.R.; Thorrold, B.S. & Costall, D. (2009). Riparian protection and farm best management practices for restoration of a lowland stream in an intensive dairy farming catchment: a case study. *New Zealand Journal of Marine and Freshwater Research 34(3)*: 803–818.

Wilcock, R.J.; Monaghan, R.M.; Thorrold, B.S.; Meredith, A.S.; Betteridge, K. & Duncan, M.J. (2007). Land-water interactions in five contrasting dairying catchments: issues and solutions. *Land Use and Water Resources Research 7*: 2.1–2.10.

WRI (2001). Restoring a river of life: The Willamette Restoration Strategy Overview. http://ir.library.oregonstate.edu/jspui/bitstream/1957/58/1/WRS_OVER.pdf