The health of the Waikato River and catchment

Information for the Guardians Establishment Committee

March 2008

Environment Waikato
REGIONAL COUNCIL

Table of contents

List of figures

List of tables

1 Introduction

Environment Waikato has produced this series of technical papers on the Waikato River catchment at the request of the Office of Treaty Settlements. The purpose is to provide information to the Guardians Establishment Committee on the state of the environment of the Waikato River and the surrounding catchment.

The Waikato River system is the longest and most significant river system in the country, extending from the upper tributaries of Lake Taupo at the southern boundary of the Waikato region to the sea at Port Waikato on the west coast.

For the purposes of this report, Environment Waikato has provided information that covers the entire Waikato catchment, particularly the area of interest to the Guardians Establishment Committee as described in the Agreement in Principle between the Office of Treaty Settlements and Waikato-Tainui.

The Guardians' Vision and Strategy will apply to the Waikato River from Huka Falls to Te Puuaha (the mouth), and the Waipa River from Puniu River to Ngaruawahia.
This area covers more than 873,000 hectares and contains more than 1000 km of streams and rivers. The entire Waikato catchment and the area of interest to the Guardians Establishment Committee is shown in the following map.

This report provides an overview of the state of the environment and the pressures that different human activities have on the health of the river and its catchment. As such, they do not contain all detailed material available nor do they address all aspects of the river's health.

The technical overview papers cover the following:
i. Description of the Waikato River and its hydrology
ii. Land and soil
iii. Ecology
iv. Water quality
v. Wetlands
vi. Shallow lakes
vii. Operational river and catchment management

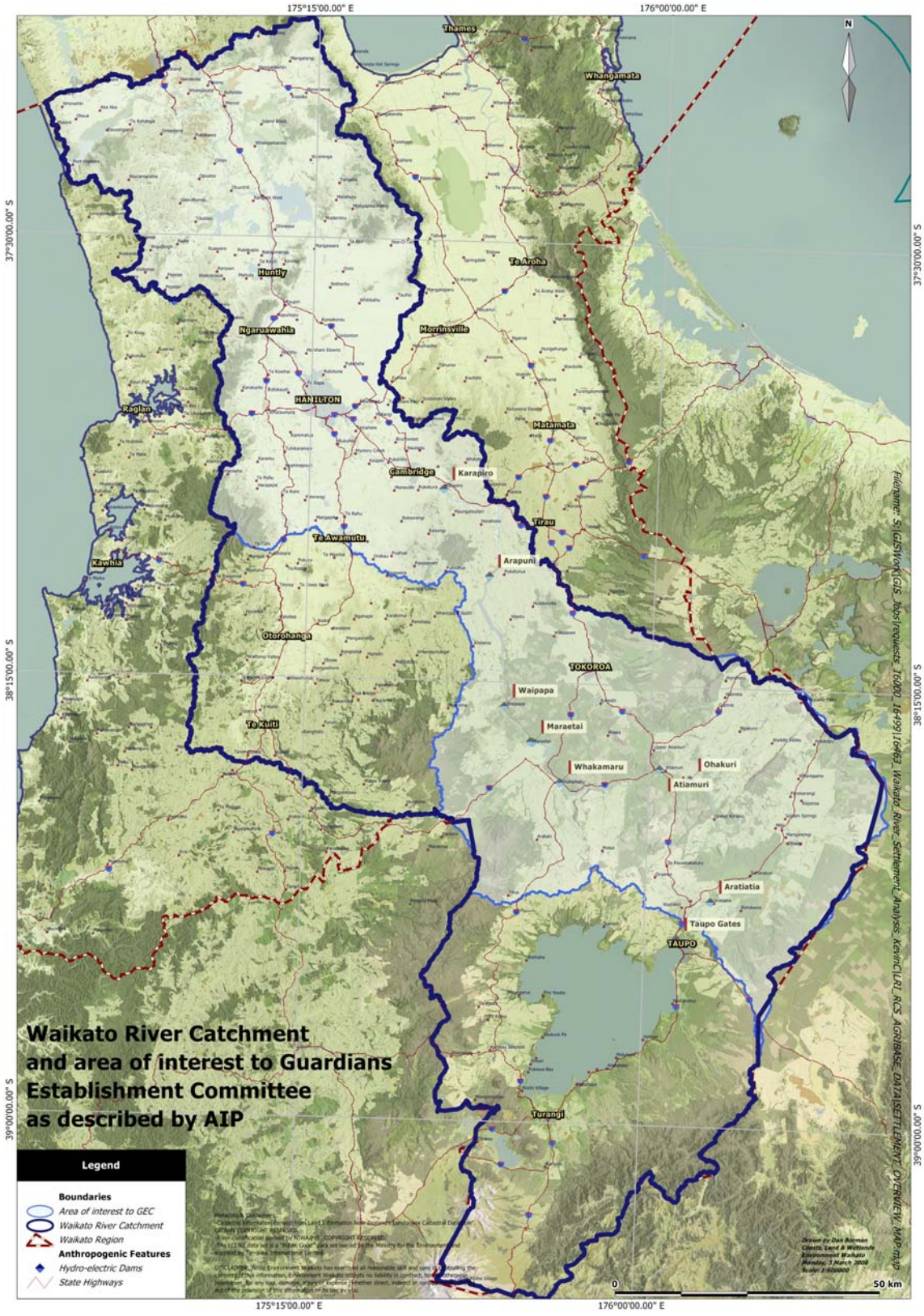
In addition, we have appended three ancillary reports that may assist the Guardians Establishment Committee. These cover:

a. Plant and animal pests
b. Recreational use of the Waikato River
c. Consents and permitted activities in the Waikato River catchment

For the purposes of some papers we have considered it necessary to include some aspects of the catchment outside the area of interest to the Guardians Establishment Committee to provide a complete picture of the pressures impacting on the river system.

Care has been taken to reduce technical detail as far as possible to make the reports easier to read by non-technical experts. We suggest that if more detail is required, further information on the health of the Waikato River can be found on the Environment Waikato website (www.ew.govt.nz) and the State of the Environment report (1998).

Further resource management issues, objectives and responses are set out in the Regional Policy Statement and Waikato Regional Plan. These have been established following extensive consultation with the Waikato community and form the basis of our current management of the Waikato River system. Environment Waikato would be pleased to provide further information on any of this material.


175°15'00.00" E
176°00'00.00" E
37°30'00.00" S
38°15'00.00" S
39°00'00.00" S
Thames
Whangamata
Te Aroha
Huntly
Ngaruawahia
Morrinsville
HAMILTON
Raglan
Matamata
Cambridge
Karapiro
Tirau
Te Awamutu
Kawhia
Arapuni
Otorohanga
TOKOROA
Waipapa
Te Kuiti
Maraetai
Whakamaru
Ohakuri
Atiamuri
Aratiatia
Taupo Gates
TAUPO
Turangi
N
Waikato River Catchment
and area of interest to Guardians
Establishment Committee
as described by AIP
Legend
Boundaries
Area of interest to GEC
Waikato River Catchment
Waikato Region
Anthropogenic Features
Hydro-electric Dams
State Highways
0
50 km
Filename: S:\GIS\Work\GIS_Jobs\requests_16000_16499\16463_Waikato_River_Settlement_Analysis_Kevin\CLRI_RCS_AGRIBASE_DATA\SETTLEMENT_OVERVIEW_MAP.mxd

2 Description of the Waikato River and its hydrology

2.1 Catchment description

The Waikato River is New Zealand's longest river, and is also arguably its most heavily used. It arises on the slopes of Ruapehu in the central North Island at an elevation of 2797 metres above mean sea level (amsl) where it begins as the Waikato Stream. The Waikato Stream then joins the Tongariro River before entering Lake Taupo (elevation 357 amsl).

Lake Taupo, with a surface area of 623 km^2 (62,300 ha) is the largest freshwater lake in the southern hemisphere, and on average, water takes about 10 years to pass through the lake.

At its exit to Lake Taupo the river becomes the Waikato River proper, and it travels northward from Taupo through a natural incised ignimbrite gorge. In its pre-developed state this reach was characterised by steep slopes, swift flows, and many rapids. The river surface falls from 357 metres amsl at Taupo to 22 metres amsl at Karapiro.

From Karapiro to Ngaruawahia the river begins to emerge from the incised gorge in to a wide and shallow floodplain with a flat slope. The river surface drops from 22 metres amsl to 10 metres amsl at Nguaruawahia. From Ngaruawahia to the sea the river in its pre-developed state was characterised by a wide shallow channel, low and flat flood plains, with shallow lakes, and peat wetlands. Prior to drainage and flood protection development, the low lying land adjacent to the river flooded frequently, with flow reversals into many of the adjacent wetlands and lakes providing buffering of peak flows in the river.

Before it enters the Tasman Sea through a narrow channel at Port Waikato, the river passes through the delta, (a myriad of small interconnected channels and islands formed by deposition of sediment), and then passes in to Maioro Bay.

The largest tributary of the Waikato River is the Waipa which arises in the Rangitoto Ranges in the southern King Country and travels northwards via Otorohanga, Pirongia and Whatawhata to join the Waikato River at Ngaruawahia.

Some of the main features of the Waikato River are summarised in Table 1.

Table 1: Waikato River Main Features

Feature	Value	Rank in comparison to other New Zealand Rivers
Length	425 km [(1)]	1st
Catchment Area	14,456 km^2 [(3)]	2nd
Mean Flow	400 m^3/s [(1,4)]	4th
Minimum Flow	138 m^3/s [(2,5)]	
Maximum Flood Flow	1870 m^3/s [(1, 5, 6)]	~18th

(1) NWASCO (1979)
(2) Young and Foster (1986)
(3) Measured by GIS from GIS_ALL.REC_CATCHMENT layer.
(4) Measured at Mercer
(5) Measured at Ngaruawahia,'
(6) Flood of January 1907.

2.2 Hydrology

Mean annual rainfall over the catchment ranges from around 1200 mm per year in the catchment lowlands to over 3200 mm per year on the upper slopes of Ruapehu. It is estimated that in the Lower Waikato, the annual loss to the atmosphere due to evaporation and transpiration from plants is around 650mm per year, which is about half the annual rainfall.

At any one time large quantities of water are stored within Lake Taupo, the hydro lakes, and other numerous natural lakes throughout the catchment. In addition the peat wetlands of the Lower Waikato also provide larges amounts of storage. This large storage feature ensures that the peak flood flows in the Waikato River are generally much less than for other comparable catchments throughout the country. It also means the river is less susceptible to drought and low flows than other comparable rivers. While the Waikato River ranks fourth in New Zealand in terms of mean flow, it only ranks around 18th in terms of maximum flood flow. While the large storage volume has the ability to ameliorate peak flood flows, the negative is that floods tend to have very long durations (this was particularly so prior to drainage, flood protection and development of much of the floodplain). The floods of the 1950's had a devastating impact in the Lower Waikato, and this was mainly because of the extended periods of time for which land and infrastructure was inundated.

The key hydrological characteristics of the Waikato River at different points along the river between Port Waikato and Lake Taupo are shown in Figure 1, Figure 2, Figure 3 and Figure 4. it should be noted that travel times are for the river in its current state, i.e. with the Waikato Hydro Lakes in place. The travel times from Taupo to Karapiro with the river in its natural state would have been of the order of 1-2 days.

2.3 Modifications to the hydrology of the river

Attempts to modify and control the river began with the arrival of the first Europeans. One of the first activities was clearance of land for farming and other uses. This would have increased river flows across the whole range (low flows, average flows, and maximum flood flows).

The floodplain of the Lower Waikato River originally consisted of shallow lakes and peat wetlands, and drainage of these was also an early development activity. This would not have impacted significantly on low or mean flows in the river; however it would have increased the size of small and medium floods because of loss of flood plain storage.

Both in pre-European times and in the 19th and early 20th Centuries, the lower river was a major transport route. A number of river improvement works were undertaken with the aim of improving the navigability of the river. These included river training and dredging.

In the late 1950's the Lower Waikato Flood Protection Scheme was initiated following the devastating floods of 1953, 1956 and 1958, and this has had significant impacts on the hydrology of the river. The scheme protected approximately half of the 32,000 ha of floodplain in the lower river valley, but retained large areas to be used for flood storage. The retained storage areas included Lake Waikare (34 km2) and the major part of the Whangamarino wetland (65 km2). The scheme featured construction of stopbanks, pump stations, flood gates and other control structures. In addition, a major river training programme was instigated to narrow the lower river with the aim of scouring a deeper more hydraulically efficient channel. The impact of the scheme on the hydrology of the river has been to increase peak flood flows, but reduce the duration of major floods. Because of the loss of floodplain storage, the peak flows are not smoothed out as much as they used to be, but less water is now ponded for long periods of time.

Hydro electric power development during the early and mid 20th Century has played a major part in the development of the river. The first works focussed on the reach between Karapiro and Lake Taupo because the steep gradients and narrow incised river valley provided ideal conditions for hydro development. The first dam, Arapuni was commissioned in the early 1930's, and the last, Waipapa Dam was commissioned in April 1961. Another significant impact associated with hydro development was the installation of the control gates at Lake Taupo to control outflows from the lake. River flows in the reach between Taupo and Karapiro are now largely totally controlled to suit electricity generation requirements.

In addition to the Waikato River Hydro Electric Power Development, a major power scheme was initiated on the Tongariro River and Lake Rotoaira in the 1950's. This scheme, the Tongariro Power Development, also has significant impacts on the hydrology of the Waikato River because it diverts "foreign" water from the Whanganui and Rangitikei Rivers into the catchment above Lake Taupo. The average diversion flow is approximately 32 m^3/s, which increases the mean flows in the river at Ngaruawahia by almost 10%.

Sand mining from the bed of the Lower Waikato River has been undertaken since the 1950's. The effect has been to lower the bed of the river and the water surface, and this has had impacts on the hydrology of wetlands and lakes adjacent to the river. The lowering of water levels in the river has resulted in drainage of wetlands, lowering of lakes, and reduced flushing of lakes and wetlands during floods.

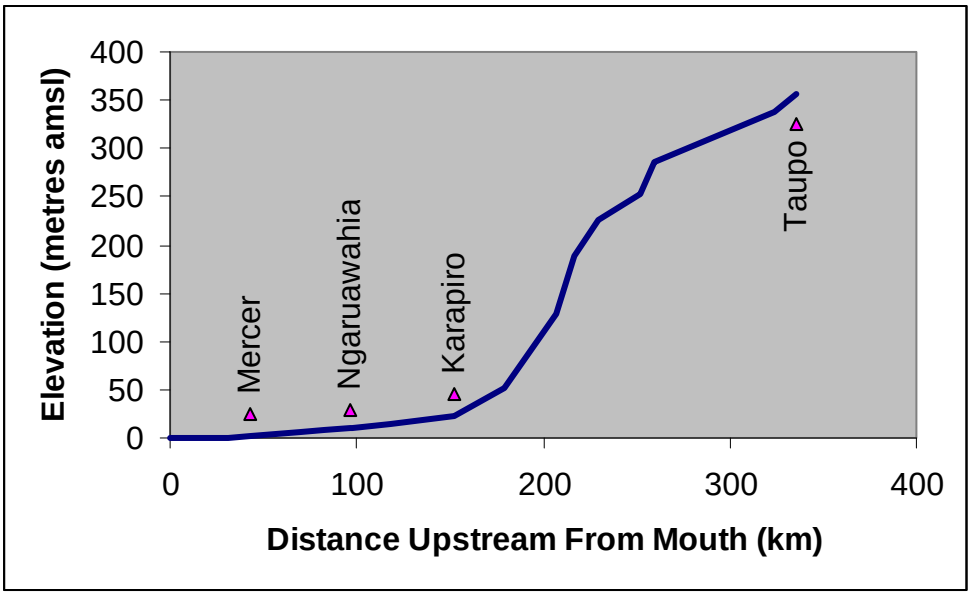


Figure 1: Waikato River - Profile of Water Surface Elevation

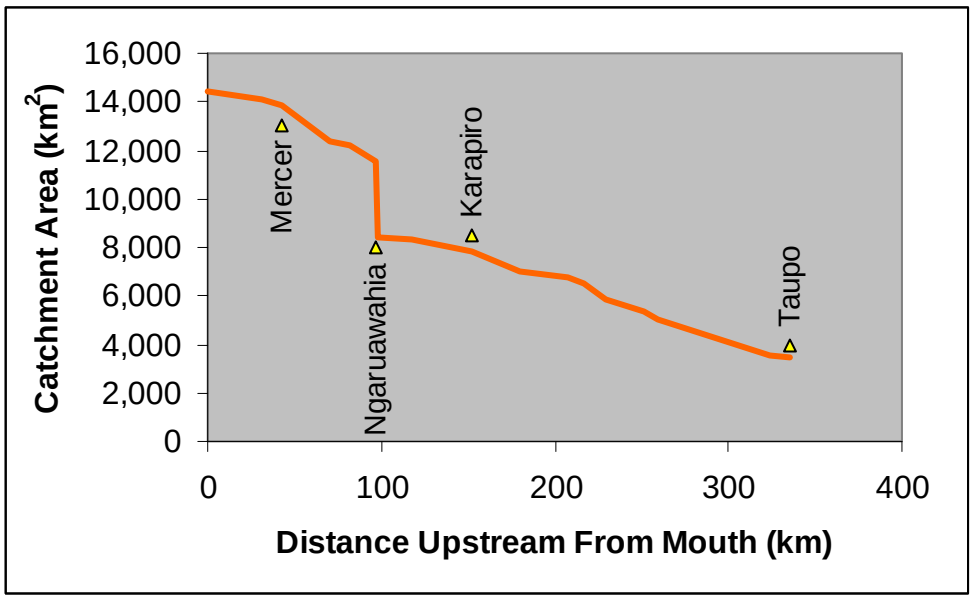


Figure 2: Waikato River Catchment Area versus Distance Upstream of the Mouth

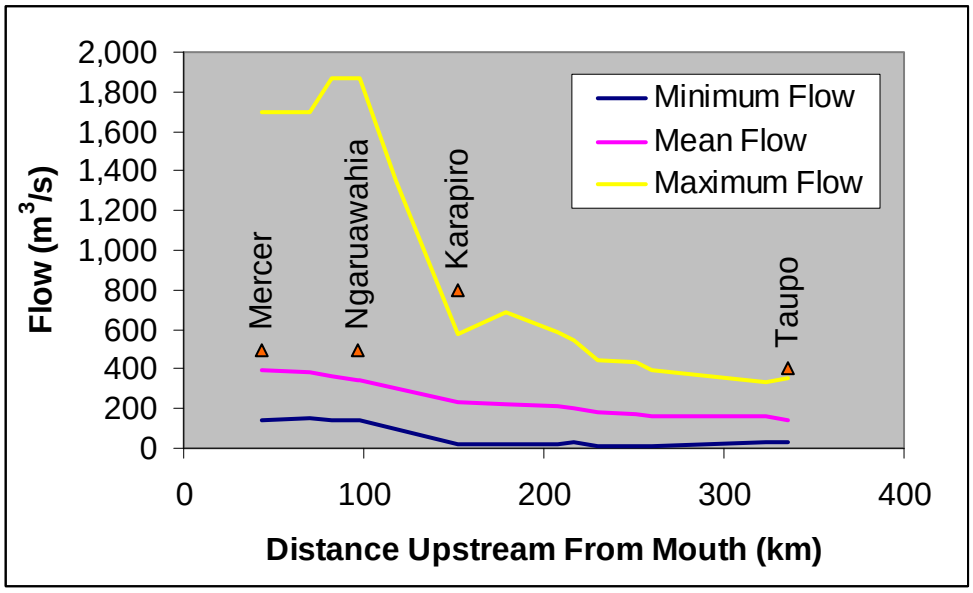


Figure 3: Maximum Minimum and Mean flows versus Distance Upstream of the Mouth

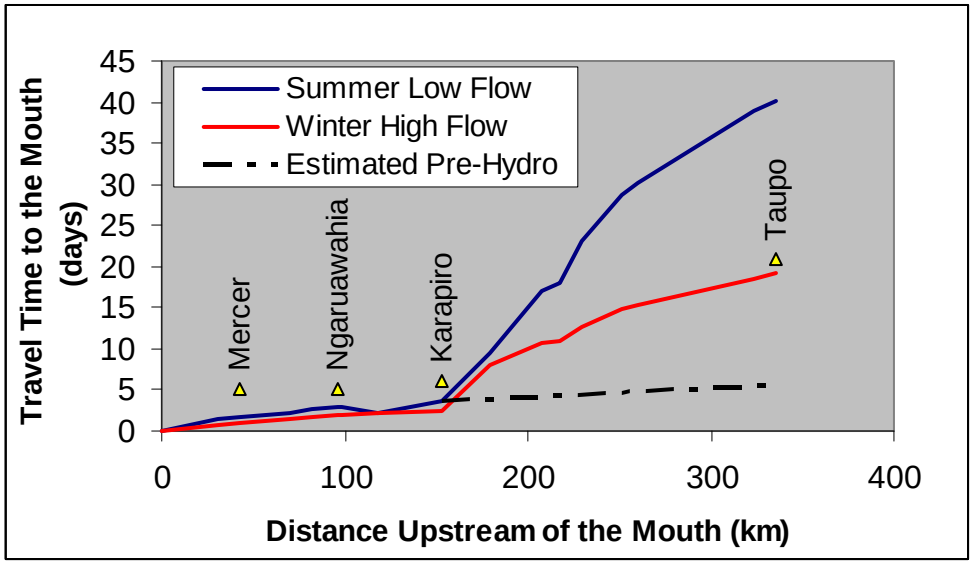


Figure 4: Waikato River Travel Times

2.4 References

1) Acheson, AR, 1968. *River Control and Drainage in New Zealand*. Ministry of Works New Zealand, 1968.

2) NWASCO, 1979. *The Waikato River: A Water Resources Study.* Water and Soil Technical Publication No. 11, 1979. Prepared by the Waikato Valley Authority for the National Water and Soil Conservation Organisation.

3) McKenzie JH, 1980. *The Men and the River – The Waikato Valley Authority – An Historical Review of the first 21 years*. Waikato Valley Authority 1980.

4) WVA, 1981 *The Waters of the Waikato*, Proceedings of a Seminar held a the University of Waikato 20-22 August 1981. University of Waikato Centre for Continuing Education and the Waikato Valley Authority.

5) Mulholland, WM, 1983. *Lower Waikato Waipa Control Scheme Review : Part A – hydraulic Hydrological Evaluation.* Waikato Valley Authority Technical Report No. 25.

6) NWASCO, 1986. *Inventory of New Zealand Lakes, Part I: North Island*. National Water and Soil Conservation Authority, 1986.

7) Young, D and Foster B, 1986. *Faces of the River.* TVNZ Publishing 1986.

8) Davenport M, Dell P, Irving J, Loe K and Mulholland M, 1988. *Tongariro River – Overview*. Waikato Catchment Board Technical Report 1988/13.

9) Webby MG, Ong Su-Wuen, and Currie, BH, 2001. *Effects on Water Levels and Flows of Proposed Future Operation of the Waikato Hydro System.* Opus International Consultants Limited 2001.

10) Brown, E, 2005. *Hydraulic Travel Times of Major Waikato Rivers.* Environment Waikato Technical Report 2005/4.

3 Land and soil

3.1 Land use and impacts on the condition of land and soils in the Waikato River catchment

3.1.1 Introduction

This report outlines the state of the land and soils in the Waikato River catchment and comments on the main factors that currently influence these qualities, concluding with general observations on the effects of land management on soil and water quality.

Large areas of land in the Waikato region have been cleared for agriculture, particularly pastoral farming, and farming is an important contributor to the Waikato and national economy. If farming can be described as the backbone of the Waikato economy then soils are the backbone of farming. It is estimated pastoral and crop farming in the Waikato directly contributes 13.7% of the regional GDP with dairying alone contributing 10.9%. In terms of intensity (area and number of cows) dairying has increased by 25% in the past 10 years. In 2006 nearly 26,000 people were employed contributing 46% of the national wealth (GDP) from farming.[1] In a regional context 17% of the regional workforce depend directly on agriculture for their livelihood. A total of 29% of people working in other sectors indirectly benefit from the revenue generated by agriculture and spent elsewhere in the regional economy. This wealth is based partly on the quality of the soils in the region.

A large proportion of the Waikato river catchment is intensively farmed. Recently there has been increased intensification of pastoral agriculture within the catchment and conversion of commercial forestry land into pastoral farms. These changes, and any future land conversion changes, will continue to affect the condition of land and soils, and consequently impact on water quality in the Waikato River catchment.

3.1.2 Characteristics of the Waikato River catchment

The Waikato River Catchment from the point of outflow of Lake Taupo comprises an area of around 1.09 million hectares (1.43 million hectares including the Lake Taupo catchment). Land cover in the Waikato River catchment below the outflow of Lake Taupo is predominantly pasture (62%), planted forest (19%) and indigenous forest (10%).[2] Within the catchment there are about 22,200 km of rivers and streams of which 64% flow through pasture, 15% through planted forest and 10% through indigenous forest. The majority of stream length is associated with 1st and 2nd order tributaries. The soils and geology are dominated by Taupo pumice and other volcanic ashes and related deposits often overlying sedimentary or volcanic rock. About 13% of the catchment is steep (>25 degrees) of which about 35% (49,800 ha) is in pasture.

3.1.3 Measuring soil quality

Intensive land use can affect our soil resources and impact on the health of streams and rivers. The two main soil quality issues affecting streams and rivers are soil compaction and excess nutrients in the soil.

[1] Market Economics Ltd 2006 *Waikato Region Economy-Environment Futures Report*. TR 2006/51 Environment Waikato

[2] Land Cover Data Base 2. (LCDB2) data set owned by the Ministry for the Environment and supplied by Terralink International Limited.

Compaction

Moderate soil compaction under pastures is widespread across the Waikato region.[3] This is of concern as it decreases soil productivity and increases run-off. Excessive stocking rates and/or mismanagement leads to trampling of soil, breaking up the soil structure and compressing spaces in the soil. Different soils have differing abilities to withstand trampling, sandy soils being less vulnerable than clay-rich soils. When a soil is compacted by trampling water is no longer able to easily seep through the soil, but instead ponds on top. This leads to runoff of topsoil and contaminants (such as faeces, nutrients and fertiliser) into streams. It decreases soil fertility, leading to an increased requirement for fertiliser. Wet conditions aggravate the damage to soils from trampling resulting in major changes to the soil structure.[4]

Soil compaction in the Waikato region is an increasing problem. A study of 133 sites in the Waikato region between 1998 and 2004 found that compaction of dairy pastures in 2004 had increased.[5] Half the dairy farms surveyed did not meet the soil structure target. Research shows that infiltration under grazed pasture is 10 times less than that under pine forest.[6] Any land use that impacts soil structure will potentially increase runoff to the detriment of water quality. With about 15,000 ha recently converted from production forestry to pasture, and more conversions planned, the implications for further impacts on soil and water quality in the Waikato River catchment is significant.

Excess soil nutrients

Intensive farming, particularly dairying, has expanded markedly in the past 10 years. Production (milk solids) and cow numbers have increased greatly since 1998, as has farm size (Figure 5).[7] While the number of dairy farms has increased by 19% over this period, the average size has gone from 81 to 118 ha (an increase of 46%). Cow numbers per farm have increased by a similar amount (41%), while average farm production has increased by 64%. Much of this increased production may be attributed to brought-in feed, the quantities of which have doubled over the period from an average of 400 kg/ha to 800 kg/ha.

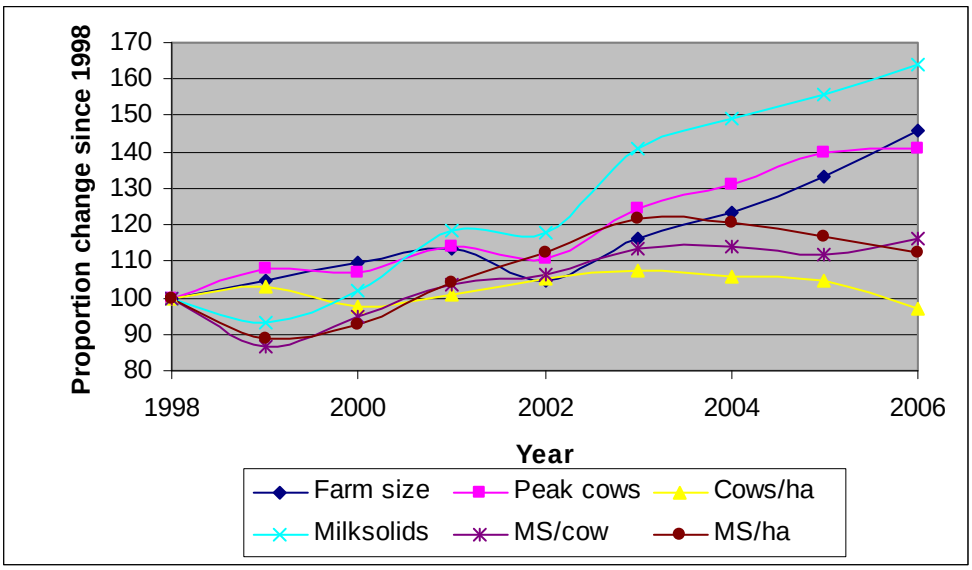


Figure 5: Dairy farm trends in the Waikato region between 1998 and 2006

Increasing pastoral production has also been reliant on farmers using more fertiliser, in particular nitrogenous fertilisers (Figure 6)[8]. Clover root weevil *(Sitona lepidus*), first

[3] Hill, R., Smith, P, Stevenson, B., and Sparling, G. 2006. *Soil quality monitoring in the Waikato Region*. New Zealand Society of Soil Science http://www.nzsss.rsnz.org/
[4] AgResearch. 2003. *Managing Treading Damage on Dairy and Beef Farms in New Zealand*
[5] Hill, R. and Sparling, G. 2004. *Soil quality in the Waikato.* Environment Committee presentation. EW Doc. #935299
[6] Taylor, M., Mulholland, M., and Thornburrow D. 2008. *Infiltration of water into soil under forestry and agriculture in the upper Waikato catchment*. NZ Soil News Vol 56. No 1.
[7] Dexcel. 2007. *Economic Survey of New Zealand Dairy Farmers*
[8] Roberts, A. 2007. *National fertiliser sales for Ballance and Ravensdown*

identified in New Zealand pastures in 1996, has had a severe impact on the survival and ability of clovers to fix nitrogen.[9] Farmers have found nitrogenous fertilisers valuable to manage this loss, enabling stock numbers to be maintained or increased.

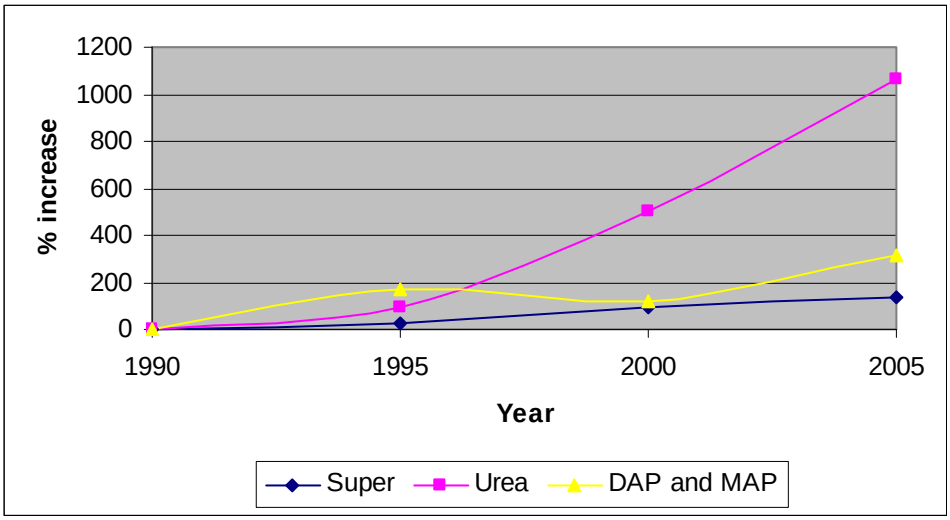


Figure 6: National fertiliser usage (superphosphate, urea and DAP/MAP) between 1990 and 2005

There is a strong relationship between increasing stock numbers and the amount of nitrogen detected in rivers (Figure 7)[10]. Some of the increase may be directly as a result of fertiliser application although it is most likely that the majority is attributable to the larger number of cows that can be supported with the extra grass growth - more cows produce more urine and it is the high concentrations of nitrogen in urine patches that cause nitrogen to be in a form that is easily lost from the land in drainage water, through a process known as leaching. The impacts of high soil nitrogen levels from intensive pastoral land uses in the Waikato River catchment on water quality are described in the water quality paper later in this report.

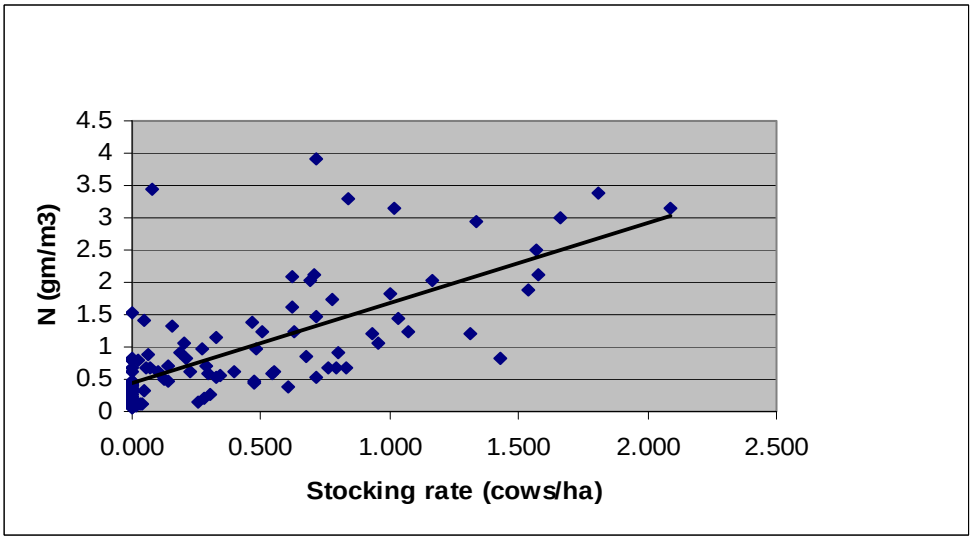


Figure 7: Relationship between stocking rate and the amount of nitrogen in rivers

The amount of nitrogen entering our waterways is increasing, particularly from dairy operations (Figure 8).

[9] Willoughby, B. and Addison, P. 1997. *Clover root weevil (Sitona lepidus) – a threat to the sustainability of white clover in New Zealand*. Proc NZ Grasslands Assoc.
[10] Environment Waikato survey data

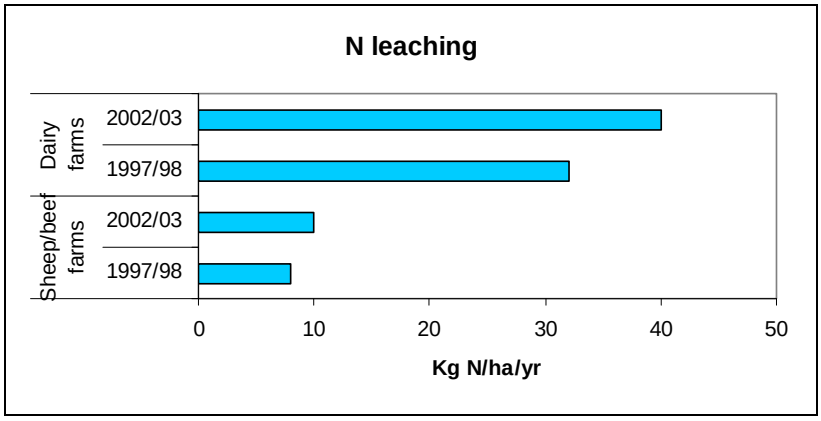


Figure 8: Leaching of nitrogen from dairy and sheep/beef farms sampled in 1997/98 and 2002/03.

Superphosphate fertiliser is commonly applied to supply phosphorus for pastures. If plant available phosphorus levels in the soil exceed the pastures' ability to utilise it, the excess may be washed into waterways (attached to sediments or in other forms). Phosphorus that is readily available to plants in the soil is measured as Olsen P (Figure 9). Our regional soil information suggests that in volcanic soils in the region, most continue to have high to excessive Olsen P levels (higher than needed to sustain good grass growth). On other types of soils, there has been a slight decrease in the proportion of soils with high to excessive Olsen P levels. In the Waikato River catchment, most soils are volcanic indicating that there is potential for losses of P to waterways.

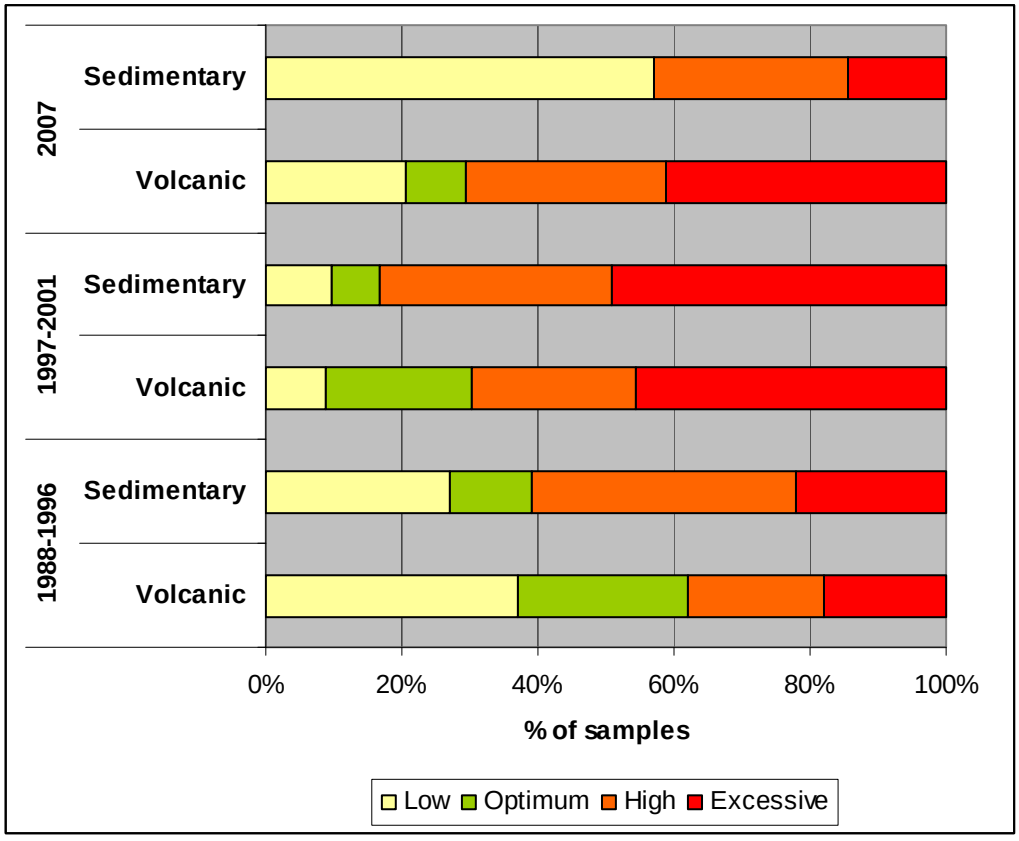


Figure 9: Proportion of soil samples with low to excessive Olsen P levels from farms in the Waikato region between 1988 and 2007

Environment Waikato regularly measures seven soil quality parameters at 100 sites throughout the region and compares these with targets derived for maintaining productivity of land or environmental factors. Overall, 34% of sites sampled in the region comply with soil quality targets (Table 2). About two thirds of sites have one or

more items of concern[11]. Dairy and sheep and beef pasture were of greatest concern. Compaction was the biggest problem[12].

Table 2: Proportion of compliant sites for soil quality for the main farming activities in the Waikato region in 2005.

Activity	% compliant
Dairy	27
Sheep and beef	36
Plantation forestry	44
Horticulture and cropping	54
Overall	**34**

Soil contaminants

Soils may be contaminated by human activities. Examples include: stock dip sites where many years ago, organo-chlorine insecticides such as DDT and lindane were used to protect stock against ectoparasites; industrial sites where paints were manufactured and disposed; wood treatment sites; and areas where pesticides have been mixed or disposed. In 2006 there were 258 contaminated sites identified in the Waikato region of which 140 had either been remediated or were under observation.[13] There are collection and disposal systems in place today to ensure that inappropriate disposal of unwanted agrichemicals do not become a source of soil contamination in the future.

Arsenic and mercury in the sediments of the lake beds on the Waikato River primarily originate from geothermal activity with about half the quantities coming from waste water from geothermal power generation near the head waters. Concentrations that exceed accepted guidelines have been measured from the Wairakei Power Station to Hamilton. However, they do not pose a human health risk except through the consumption of watercress should it be harvested near the source of the contamination. [14]

Monitoring fertiliser usage, soil quality and land use trends enables the identification of the most pressing management issues to maintain and improve soil health and water quality. The first step is to keep the soil in place.

3.1.4 Soil erosion

Inadequate soil management will lead to soil loss. In the lower Waikato River catchment in around Pukekohe, between 7 and 30 tonnes of topsoil per hectare are lost on cropping land every year through erosion. As well as loss of a resource that may have taken thousands of years to form, soil loss has the potential to increase suspended sediment and phosphorus in waterways.

Forty percent of the Waikato River Catchment (below the outfall of Lake Taupo) has land with potential to erode if not managed correctly (~420,000 ha). About one third (30%) of rural land in the region has had soil disturbance[15] and this proportion is probably relevant for the Waikato River Catchment. Bare soil exposed by natural processes and land use activities was estimated in 2003 to be about 1%, which equates to about 12,000 ha in the river catchment. Soil disturbance from land use activities is located mainly in dairy and drystock pastures. It is caused by heavy grazing of pasture and extensive farm tracks. Lesser amounts occur in forest

[11] Sparling, G. 2005. *Environmental Indicators for Land: Overall Soil Quality in the Waikato Region 1998-2004*. Landcare Research
[12] Hill, R. 2005. *Soil and land use change*. EW Doc. #1020529
[13] *Environment New Zealand 2007*. Ministry for the Environment publication ME 847
[14] Kim, N. 2005. Statement of evidence to Environment Court under RMA (1991) with respect to contaminated beds of waterways. EW Doc. # 1091456
[15] Hicks, D. L. 2003. *Soil Intactness Assessment of the Waikato Region: 2003*. *TR 2003/14*. Environment Waikato, Hamilton.

plantations due to topsoil exposure by logging and associated tracking under intensive uses which entail soil cultivation. Soil disturbance from natural processes is small under intensive uses, dairy pasture and forest plantations. It is located mainly in drystock pastures, where the causes are landslides and earthflows in hill country, or gullies and streambank erosion in pumice soils on flat to rolling country.

Research has identified a range of soil conservation practices that are effective in keeping soils in place and maintaining soil health.

3.1.5 Soil conservation

Environment Waikato has put in place soil conservation works that occupy about 12,700 ha in the Waikato River Catchment. A major proportion of the soil conservation has been in the Lake Taupo and upper Waikato River catchments (about 62%). This reflects the historic susceptibility of the pumice soils to erosion following large scale conversion from forest and scrub to pasture from the 1940s. If done correctly, soil conservation on erosion-prone land reduces the amount of bare ground and the potential for sediment production.[16] Monitoring results from a catchment scale study have shown a sediment rate reduction of 40% within two years.[17] Environment Waikato promotes soil conservation practices on erosion-prone land (land units 6e, 7 and 8 as classified by the Land Use Capability Classification).[18] For the Waikato River catchment this equates to an area of 270,000 hectares or about 20% of land in the catchment.

Subsidence rates and carbon loss in peat soils following conversion to pasture are a concern. Subsidence rates average 3.4 cm per ha per year in the Waikato region, mostly attributable to consolidation with 37% attributable to peat mineralization with an associated carbon loss.[19]

In 2002, it was estimated that one third of the total bank length of waterways running through pastoral land in the Waikato River Catchment was fenced. Additionally, 45% of the total bank length had some form of riparian vegetation other than pasture. However, within the Waikato River catchment there remained about 1,420 km of eroding streambanks on pastoral land.[20] Throughout the catchment, riparian fencing and riparian vegetation is most prevalent in the upper catchment and decreases down the catchment. Streambank erosion increases down through the catchment. This reflects the greater amount of soil conservation work in the upper catchments. Catchment monitoring indicates that the stability of streambanks is greatly enhanced when stock are excluded. For example, in a catchment in the lower Waikato River, bank stability improved by 40% within a few years of the riparian margins being fenced.[21]

There are additional benefits associated with riparian planting and fencing. These include; a less direct pathway for nutrients, sediment and faecal coliforms to enter the waterway, less disturbance of the stream bed by stock trampling and an increased opportunity for biodiversity gains[22].

As soil conservation actions must be tailored for individual property needs, the diverse nature of the Waikato River catchment means that pressures and potential solutions for intercepting pollutants before they reach waterways must also be tailored.

[16] Hill, R. 2007. *Lower Waikato zone – Catchment Environmental Monitoring update 2006/07*. Report to the Lower Waikato Liaison Committee EW Doc. #1154182
[17] McKerchar, A. and Hicks, M. 2003. *Suspended sediment in Waitomo Stream*. NIWA report CH2003-014
[18] *New Zealand Land Resource Inventory*
[19] Schipper, L.A. and McLeod, M. 2002. *Subsidence rates and carbon loss in peat soils following conversion to pasture in the Waikato Region, New Zealand*. Soil Use and Management 18,91-93
[20] 2002 *Riparian Characteristics Survey of the Waikato Region*. Unpublished analysis
[21] *Project Watershed success Lower Waikato Matahuru catchment*. Media release. EW Doc. #1182434-v1
[22] *Revised Science-based criteria for identifying priority sites for the riparian project*. unpublished information EW Doc. #707307

3.1.6 Catchment pressures – sediment and nutrients

The diverse physical resources and land uses in the Waikato River catchment means the amounts and types of contaminants generated and sensitivity to pollution will vary in different areas (Figures 10 and 11).

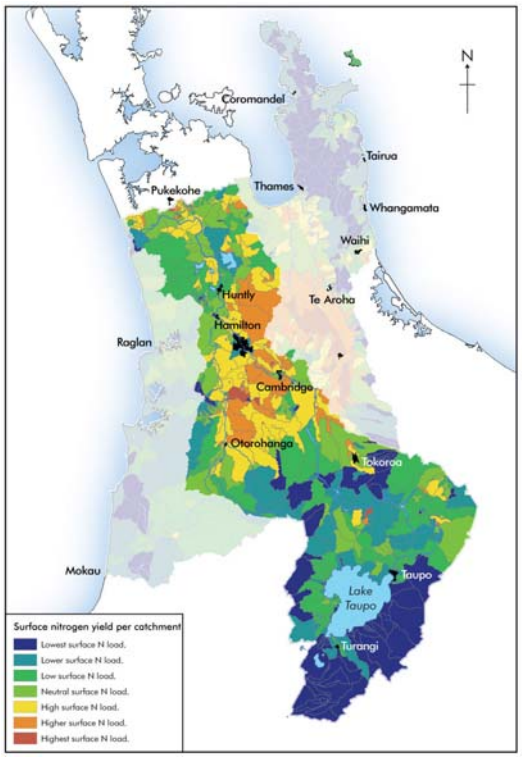


Figure 10: Surface nitrogen load per catchment

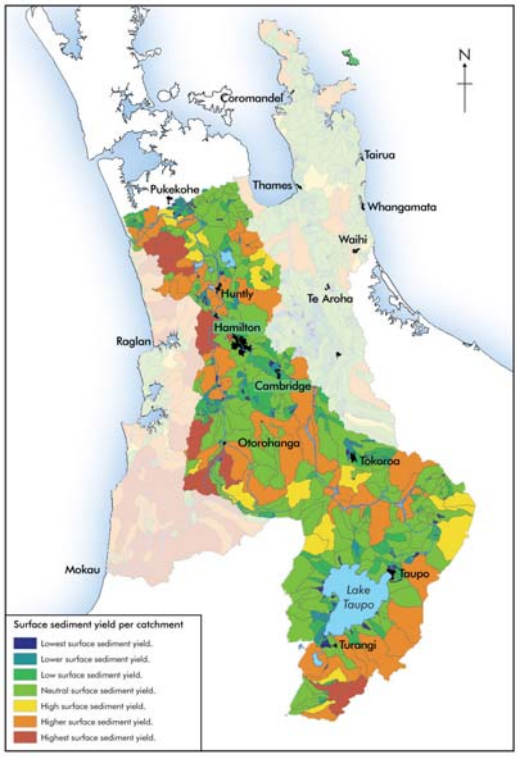


Figure 11: Sediment yield per catchment

Throughout the Waikato River catchment, intensive farming results in poorer soil structure and higher loadings of nutrients to soils (and consequent higher risk to waterways from affected runoff and groundwater). Erosion and sediment loss occurs throughout the catchment although the risks of erosion are greatest in steeper land, especially in the Waipa River catchment and areas of the lower Waikato catchment (e.g. Matahuru catchment that flows into Lake Waikare). There is also significant erosion potential in the pumice country of the Upper Waikato catchment, although soil conservation schemes have decreased erosion and sedimentation substantially. However, there is a risk of further erosion in land that is converted from forestry to pasture in the Upper Waikato catchment if appropriate soil erosion controls are not implemented. Increases in nutrients from forestry to pasture conversions in the Upper Waikato will also contribute to more nutrients and other contaminants lost from land to the Waikato River catchment, affecting water quality further downstream. Market gardening in the Franklin District in the lower Waikato River contributes nutrients and sediment to waterways if not managed appropriately.

The linkage between land use, soil quality and water quality is important for future maintenance or enhancement of water quality. The Lake Taupo variation has recognised this and introduced new rules to cap nitrogen loss from land to prevent increases in nitrogen lost to the lake. In some of our most productive landscapes, where water quality is poor and affected by nutrient losses through permeable volcanic soils, it may be difficult to achieve substantial land-based improvements without substantial changes to the current farm systems. Without these changes it will remain a challenge to maintain current water quality.

3.1.7 Summary

There is a close linkage between land use, soil and land quality and water quality in the Waikato River catchment. The main factors affected by land use are soil quality,

sediment losses and erosion, nutrient losses from land and the importance of riparian management.

Soil quality – there are indications that aspects of soil quality are being affected by land use in the region. Land management changes will be needed to prevent this downward trend from continuing and to achieve profitable farming while maintaining suitable soil quality for future use. The link between land and water is important for considering future uses of land.

Sediment from the land - many areas of the catchment have high erosion and sediment loss. A large amount (39%) of the land in the Waikato River catchment has high potential to erode if not managed well. The risk is greater on steeper pastoral land but can be reduced if soil conservation practices are used. Sediment loss affects productivity of land as well as water quality.

Nutrient losses from land use – the use of fertilisers containing nitrogen and phosphorus has enabled more intensification of land use, particularly pastoral land uses, and resulted in more nutrients entering streams and rivers. The water quality paper addresses consequences for waterways in the region.

Riparian fencing and vegetation – Contaminants such as sediment, faecal coliforms and phosphorus enter the waterways from the stream bank and the surrounding riparian area. At present 33% of the waterways running through pastoral land in the Waikato River Catchment (in the area below the outfall of Lake Taupo) are fenced. Monitoring shows fencing and planting these margins reduces stock access, improves the stability of streambanks and reduces the contaminants reaching the water.

4 Ecology

4.1 State of and pressures on the ecology and biodiversity of the Waikato River and its tributary streams

4.1.1 State

For river systems, ecological patterns change and human pressures tend to accumulate in a downstream direction. As a result of these influences, larger rivers typically support different assemblages of aquatic species than smaller streams, and they also integrate the diverse range of human activities occurring upstream as well as alongside them. In terms of biodiversity (the full range of native plants and animals living in the environment), and ecology (the interaction of species with the environment and each other), it is convenient to picture the Waikato River as being characterised by different sections, although the ecological changes between some sections may be gradual. The summary below gives a brief overview of the current biological and physical state of these sections. In aggregate, the Waikato River and the streams and rivers flowing into it (including the Waipa River) support 19 species of native fish and 13 species of introduced fish (Speirs 2001, http://www.ew.govt.nz/enviroinfo/water). Different combinations of species occur in sections of the main river and in the smaller tributary streams draining into it.

Lake Taupo and its tributaries: The headwaters of the Waikato River originate in Tongariro National Park and Kaimanawa Forest Park and drain catchments still in their natural state although receiving periodic disturbance from volcanic eruptions. These upper river tributaries are characterised by invertebrate communities dominated by mayflies, stoneflies and caddisflies, but fish communities are restricted because of the long distance inland and impediments to passage for migratory native species further downstream. Only two native fish species are known to occur naturally in this part of the river (common bully and a land-locked population of koaro), and the nationally endangered blue duck also lives in some unmodified tributaries. Three species of salmonids (brown and rainbow trout and brook char) occur in this upper section and provide a highly valued sports fishery. The native common smelt was introduced into Lake Taupo to provide food for trout and more recently catfish have invaded this lake (Speirs 2001). The Tongariro Power Development diverts water into and out of this catchment, but is largely run-of-river with little storage in the catchment, and therefore it does not have a large-scale effect on river flow regimes. Agricultural development impacts stream environments in tributaries of the lower Tongariro River and the eastern shore of Lake Taupo. Riparian protection is now widespread in the area (see Riparian section) and can be expected to lead to improvements in stream habitat and water quality over time.

Middle river: Below Lake Taupo the river has a high gradient and was originally characterised by gorges and extensive rapids. Electricity generation is now a major modifier of river habitat, discharging heat from a geothermal plant and creating eight impoundments that have converted much of this river section to still-water or very slow flowing environments down to Karapiro. Parts of the river that retain fast-flowing water can experience rapid fluctuations in water level due to hydropeaking operations which have also contributed to the development of some unusual communities of native shoreline plants. These impoundments are characterised by invertebrate species typical of slow-water and depositional environments (e.g., snails, midges, worms, small crustaceans) and a limited native fish community comprising native eels and common bully, augmented by introduced rudd, catfish and goldfish. The Karapiro Dam creates a barrier to upstream movement for several native migratory species, as well as some

troublesome introduced fish (e.g., koi carp), although several rapids and falls along this middle section would also have created natural barriers for most of these species. A transfer operation below Karapiro Dam results in some eels continuing to access habitat above some of the dams. The impoundments can support high abundance of exotic aquatic macrophytes which occasionally interfere with recreational opportunities and electricity generation, and some support regionally important populations of birds, notably the New Zealand scaup (Sagar & Kelly 2005).

Landuse change in this middle section of river, both historic deforestation of indigenous vegetation and more recent pine-pasture conversion, has converted tributary streams shaded by forest and receiving inputs of wood and leaves important for invertebrate life, to open channels experiencing high levels of light and sometimes abundant growths of aquatic plants. Many tributary streams in the middle river are spring-fed, and although this means some can stay cool during summer despite being exposed to direct sunlight, the resulting stable flows are often unable to flush sediment deposited on the streambed from land conversion practices or subsequent stock damage. The banks for these streams often comprise unconsolidated pumice which is easily eroded leading to unstable channels once the root-binding properties of riparian trees are no longer present. Although few native fish occur in this section of stream, many of the larger tributaries support valued trout habitat and spawning areas which are susceptible to adverse effects from sediment deposition. Invertebrate life in these springfed streams typically comprises a diverse range of species dominated by mayflies, stoneflies and caddisflies which live on submerged wood where bottom substrates are unsuitable.

Lower river: Below Karapiro Dam the channel gradient decreases substantially, and the river becomes characterised by a deep main channel often with gently-sloping shelves and beaches, and a riparian fringe of mainly willow trees that can grow out into the river. Hydroelectric operations lead to variable water levels which cause periodic wetting and drying of the gently-sloping shoreline, limiting luxuriant beds of mainly exotic aquatic plants to permanently wetted parts of the channel where sunlight can penetrate. Aquatic plants, even some exotic species, can provide important habitat for the growth of invertebrates in the lower river, as well as providing cover for fish. Human population pressures have led to degradation of streams in and around urban areas, although in Hamilton the gully network provides good riparian cover in many places, and the threatened giant kokopu and long-fin eel are still found there. Continuing urban development increases the amount of stormwater delivered to the Waikato River via these tributaries, but any ecological effects on the main river appear to be localised. Several discharges from sewage treatment plants and industry occur along this section of river (see Water Quality section)

Water level variability is reduced at Ngaruawahia below the confluence with the Waipa River, which delivers highly turbid water to the main river derived largely from landuse activities and areas of instability in the upper catchment. The Waipa River can become turbid enough to limit the upstream migration of some native galaxid fish such as banded kokopu whose juveniles avoid highly turbid water as they swim upstream searching for adult habitat in small forested streams, such as those on Mt Pirongia. Fish access can also be limited by poorly-designed road culverts (see Pressures below). Significant areas of karst geology occur in the Waipa catchment, forming underground aquatic habitats (e.g., Waitomo Caves), and springs and seepages that can have distinctive and high biodiversity values, and are sensitive to disturbance (Collier & Smith 2006, Haase 2008).

The river/floodplain/wetland/lake complex: The lower river downstream of Huntly originally interacted across a broad floodplain during high flows that connected with shallow riverine lakes (e.g. Whangape and Waikere) and wetlands (e.g., Whangamarino and Opuatia). The threatened black mudfish is present in these wetlands but its habitat area has declined substantially due to drainage activities. Flood control measures have now been implemented that regulate this hydrological

interaction so that the natural flow pathways no longer prevail. The wetland/lake complex and the tributaries feeding it form an important part of the commercial eel fishery in the region. The floodplain would originally have provided eel feeding habitat during periods of inundation.

The lower Waikato River and its associated lakes, wetlands and tributaries are heavily colonised by troublesome exotic fish, in particular *Gambusia*, catfish, and koi carp. Koi dominates fish biomass, particularly in the lower Waikato River, and its distribution extends up the Waipa at least as far as Te Kuiti. River invertebrate communities tend to become increasingly dominated by Crustacea with distance below Karapiro, and downstream of Huntly in particular invertebrate biomass can be dominated by the freshwater shrimp *Paratya curvirostris*. Mysid shrimps were once common in the riverine lakes but abundances now appear low.

Tidal section and delta: Water levels in the Waikato River are influenced by incoming and outgoing tides as far upstream as Rangariri, but saltwater intrudes only as far as around Glenbrook. Several fish species that mainly live in salt water, such as black flounder, are found in this lower section where a large number of islands also occur. The main whitebait species**,** inanga, spawn in the tidal section and the young hatch in spring to join the four other whitebait species (banded kokopu, short-jawed kokopu, giant kokopu and koaro) moving upstream. Floodgates and grazing of riverside grasses have limited the extent and quality of potential inanga spawning habitat.

Ecological condition and trend: Ecological condition is sometimes assessed using stream macroinvertebrates to integrate the biological effects of water and habitat quality. Different types of invertebrates respond in different ways to pressures, and information on the types of invertebrate present can be summarised into single numbers or metrics to reflect condition. A commonly used metric is the Macroinvertebrate Community Index or MCI which reflects sensitivity to pollution. Macroinvertebrate data for Waikato catchment streams sampled annually during summer over 1995-2005 indicate that MCI values were below the regional average in the Lower Waikato and Middle/Upper Waikato sites sampled, whereas values were higher than the regional average at the Waipa and Taupo sites. For sites sampled annually over at least 8 years, the data suggest that 75% of the monitoring sites had stable MCI values over this period, while 20% showed signs of improvement and 5% showed signs of decline in ecological condition (Collier & Kelly 2006). Overall, declines in ecological condition seemed greater in smaller lowland streams with highly developed catchments. However, these results are representative only of the sites sampled and not of the Waikato River catchment in general as sites were not randomly selected.

The fish community has also be used to assess the health of small to medium sized waterways (1^{st} – 4^{th} order) in the Waikato catchment by predicting species occurrence from mathematical models. These predictions take into account various factors such as the ability of different species to travel long distances inland, current and historical landcover, and the presence of large barriers to passage, to produce a predictive Fish Index of Biological Integrity (Joy 2007). The results of this analysis rated three-quarters of small-medium sized river length in the Waikato catchment as in poor condition, 21% in moderate-good condition, and 4% in excellent condition based on expected fish occurrence. Information on trends in fish communities is sparse, but as noted below historical data indicate declining whitebait and eel catches, and land clearance and wetland drainage have markedly reduced the distribution of species with specialised habitat requirements.

4.1.2 Pressures on ecological condition

Speirs (2001) identified three key pressures on the distribution of indigenous fish in the Waikato Region: (i) Harvesting, (ii) Exotic species and (iii) Habitat destruction and modification. These are discussed below, with Habitat destruction and modification

broken down into Land-use intensification and riparian degradation, Flow regime modification, and Disruption of fish passage and spawning habitat.

Exotic species: Introduced plants and animals that are not part of the natural environment (exotic species) can affect native species through competition for space and food, and through modification to habitats. Because of the high density and biomass of koi carp in the Waikato River system, particularly in the lower river, they can be expected to have a more significant ecological effect than other exotic fish species. Impacts would be mainly through habitat modification as koi are known uproot aquatic plants and increase water turbidity and bank erosion by their feeding activities. Catfish are known to compete with other species, including trout, whereas *Gambusia* will attack native fish species. The introduction of trout and common smelt into Lake Taupo was associated with the decline of koaro (Speirs 2001). Several introduced invertebrates also occur in the river, with most of these being snails. The exotic *Daphnia dentifera* can now comprise almost half of the abundance of planktonic cladoceran crustaceans (Duggan et al. 2006), and may influence the amount of small floating algae in parts of the Waikato River system.

Harvesting: Reports indicate that glass eel runs are substantially smaller now in the Waikato River compared with records from the 1970's, with a smaller proportion of long-fin eels returning from the sea. This has been paralleled by a decline in the proportion of commercial-sized fish being caught. In addition to harvesting, factors contributing to this decline include habitat loss and reduced access to streams, lakes and wetlands.

Harvesting pressure is also considered to have contributed to the declining numbers of young galaxiids returning from the sea as whitebait. The estimated whitebait catch averaged 46 tonnes between 1931-1950, compared with 14 tonnes between 1968 and 1985, 10.7 tonnes in 1998, and 3 tonnes in 2000 (Speirs 2001). Loss of adult habitat and passage restrictions for species such as banded, short-jawed and giant kokopu, and reduced quality of and access to spawning habitat for inanga (see below) would also have contributed to the declining whitebait catches.

Land-use intensification and riparian degradation: Within the Waikato catchment, 52% of mapped waterway length flows through pasture, 15% through exotic forest, 13% through indigenous forest, and <1% is urbanised. These figures do not take account of recent pine to pasture conversion occurring in the parts of the catchment, and nor do they resolve vegetation changes occurring in riparian areas a few meters away from the stream (see Riparian section for details on this scale). Suitable management of riparian areas to create filtering vegetation for overland flow, and suitable vegetation to provide shade and bank stability can partially mitigate many of the pressures associated with landuse intensification and land management activities that generate sediment.

Water quality issues associated with landuse have been dealt with in the Water Quality section and are not discussed in detail here. In terms of biodiversity and ecological values, water temperature is a key modifier of invertebrate communities with mayflies typically becoming less dominant when daily water temperature maxima exceed around 22^{o}C (Quinn et al. 1994). These temperatures are often exceeded during summer in pastoral streams, and in parts of the main river including below thermal powerstation discharges, although mayflies would not be expected to be naturally common in the lower river. As noted above turbidity, largely reflecting the concentration of fine soil particles in suspension, is also a potentially important water quality variable affecting fish migration, habitat and feeding. Boubee *et al.* (1997) concluded that a limit of 15 NTUs in otherwise clear waterways should ensure that the upstream migration of some of the most common New Zealand native freshwater fish species will not be affected. Around 30% of measured turbidity values in the Waipa River at Whatawhata have exceeded this value (NIWA, unpubl. data).

Flow regime modification: As noted above, the Waikato River has a highly modified flow regime as a result of hydroelectricity generation and the construction of floodgates and stopbanks. Construction of dams to create water storage has transformed high-gradient sections of river to slow-flowing or still-water habitats behind impoundments. Flow management in free-flowing sections and below Karapiro Dam down to the Waipa confluence creates variable water levels that likely influence the range of species that can occur in periodically wetted habitat. Fish communities in the section of river above Karapiro were probably limited originally by natural barriers to migration, suggesting the main effects of hydroelectric development may have been on invertebrate and algal communities originally adapted to fast-water environments.
In the river/floodplain/lake/wetland complex and the tidal section, the natural exchange of water between the main river, its floodplain and the associated lakes and wetlands is likely to have contributed to the energy pathways that fuel riverine and possibly lake productivity, judging from studies carried out in overseas rivers. The construction of 259 km of stopbanks along the main river and 255 floodgates now influence this interaction during high flows and tidal changes. As well as influencing energy pathways, changes in the frequency and duration of hydrological connectivity can influence access for some fish species (see below) and the distribution of pest fish.

Disruption to fish passage and spawning habitat: Floodgates potentially restrict fish access to 212 km of tributary habitat (including some whitebait spawning habitat) below Tuakau Bridge. As well, perched culverts at road crossings mean that some whitebait species and eels can not gain access to potentially suitable habitat upstream, thereby limiting the number of adults that mature and produce eggs for the next generation. Of the 717 culverts assessed by Environment Waikato for fish passage restriction in the Waikato River catchment, 25% were considered to pose barriers to fish migration at some flows.

In addition to reduced access, much of the preferred adult and spawning habitat for the dominant whitebait species, inanga, has been lost due to land development. Inanga typically spawn amongst suitable streamside vegetation in tidally-influenced sections of river, often around tributary confluences or on the banks of embayments and backwaters away from strong currents. Preferred spawning vegetation is streamside grasses, reeds and herbs, and grazing and trampling of this vegetation can impact on spawning success.

Remediating pressures: Human pressures from electricity generation and landuse intensification are the dominant modifiers of ecological and biodiversity values in the Waikato River between Lake Taupo and Karapiro. Pressures on the lower river ecology are more varied and complex. Key management activities that could help moderate the effects of these pressures on the lower river are:

(i) improve land management and riparian protection in the Waipa catchment to reduce sediment loads and turbidity,
(ii) alleviate fish passage restrictions in key catchments with suitable upstream habitat for native galaxid and eel species,
(iii) enhance hydrological linkages with the floodplain/lake/wetland complex in the lower river, and
(iv) extend and enhance whitebait spawning areas in the lower river.

4.1.3 References

Boubee, J.A.T.; Dean, T.L.; West, D.W.; Barrier, R.F.G. 1997. Avoidance of suspended sediment by the juvenile migratory stage of six New Zealand native fish species. *New Zealand Journal of Marine and Freshwater Research 31*: 61-69.

Collier, K.J.; Smith, B.J. 2006. Distinctive aquatic invertebrate assemblages colonise rockface seepages in northern New Zealand. *Biodiversity and conservation* 15: 3591-3616.

Collier, K.J.; Kelly, J. 2006. Trends and patterns in the ecological condition of Waikato streams based on the monitoring of aquatic invertebrates from 1994 to 2005. Technical Report TR2006/04, Environment Waikato, Hamilton. (http://www.ew.govt.nz/publications/technicalreports/documents/tr06-04.pdf)

Duggan, I.C., Green, J.D.; Burger, D.F. 2006. First New Zealand records of three non-indigenous zooplankton species: *Skistodiaptomus pallidus*, *Sinodiatomus valkanovi*, and *Daphnia dentifera*. *New Zealand Journal of Marine and Freshwater Research 40*: 561-569.

Haase, M. 2008. The radiation of hydrobiid gastropods in New Zealand: a revision including the description of new species based on morphology and mtDNA sequence information. Systematics and Biodiversity 6: 99-159.

Hicks, B.J., Ling, N., Osborne, M.W., Bell, D.G., Ring, C.A. 2005. Boat electric fishing survey of the lower Waikato River and its tributaries. CBER contract report 39, CEBER, The University of Waikato, Hamilton.

Joy, M. 2007. A New Fish Index of Biotic Integrity using Quantile Regressions: the Fish QIBI for the Waikato Region. *Technical report 2007/23. Environment Waikato, Hamilton* (http://www.ew.govt.nz/publications/technicalreports/tr0723.htm).
Quinn J.M.; Steele, G.L.; Hickey, C.W.; Vickers, M.L. 1994. Upper thermal tolerances of twelve New Zealand stream invertebrate species. *New Zealand Journal of Marine and Freshwater Research 28*: 391-397.

Sagar, P.; Kelly, G. 2005. Numbers and distribution of wetland birds on the upper Waiokato river and Lakes Ohakuri and Arapuni, September 2004 and January 2005. NIWA Client report CHC2005-054.

Speirs D. 2001. The diversity and distribution of freshwater fish and their habitat in major rivers of the Waikato Region. Environment Waikato Technical report 2001/11. Environment Waikato, Hamilton.

5 Water quality

5.1 State

5.1.1 Important concepts

There are a number of important concepts that need to be described before dealing with the state of water quality in the Waikato River system. These include (1) defining just what "water quality" means, and (2) describing the "cleansing" effect of Lake Taupo on the water quality of the Waikato River downstream of the outflow from the lake. These matters are dealt with below.

What is water quality?

The concept of "environmental quality" implies a judgement about the extent to which a given waterbody is suitable for a particular type of use. Water that is "good" for certain uses may be unacceptable for others. For example, water contaminated with sewage may be unsafe to swim in, but still be suitable for industrial cooling.

Environment Waikato's State of the Environment monitoring is aimed at assessing the suitability of waters for (1) ecological health (that is, the ability of the waterbody to support a healthy ecosystem), and (2) contact recreation, such as swimming. All surface waters in the Waikato River system need to be treated before being supplied as drinking water to households; and all community water supplies are treated to meet specified standards.[23] Drinking water quality will therefore not be considered further in this assessment.

Many different characteristics of a waterbody are regarded as being relevant to its water quality. Environment Waikato regards water quality as covering physical and chemical characteristics of natural waters, but also including some important micro-organisms (including bacteria and the microscopic plants called "algae"). Larger organisms are regarded as being part of "aquatic biology". Although this distinction may appear somewhat arbitrary, it is widespread and long-standing.

It is also useful to distinguish between those physical and chemical characteristics of a waterbody that are "natural" or inherent aspects of the water, and those that result from intervention by people (i.e. contaminants or pollutants). Natural aspects include the background temperature, pH and dissolved oxygen conditions, which we need to consider both because they are important for ecological health, and because they can be directly affected by peoples' activities (e.g. via the discharge of wastes).

There are a great many different types of contaminants that may be added to waterbodies, and thus affect their water quality. These include (1) physical contaminants such as heat; (2) chemical contaminants, ranging from simple molecules or ions such as nitrate, through to complex synthetic organic molecules that are used as pesticides and pharmaceuticals; and (3) microbiological contaminants such as the viruses, bacteria and protozoans contained in human and animal faeces, and the microscopic algae that are always present in the environment, and can rapidly-grow and form "blooms" when conditions are favourable.

Finally, it is important to appreciate that several of the chemicals that are usually most abundant in natural waters are generally not of concern, and indeed are often not routinely measured in water quality monitoring programmes. These are the "major ions", including the sodium, magnesium, chloride and bicarbonate ions, which are typically present at concentrations that are many times higher than those of many

[23] Ministry of Health 2005: Drinking-water standards for New Zealand 2005. Ministry of Health, Wellington.

contaminants that may be of concern, such as nitrate ions. In fact, the Waikato River can be correctly described as being "a weak solution of sodium bicarbonate, plus lesser amounts of other chemicals". Although Environment Waikato has recent information on the concentrations of the major ions in the main-stem of the Waikato River and many of its tributaries,[24] this information will not be considered any further here.

How does Lake Taupo make water cleaner?

For this assessment, the Waikato River system is regarded as beginning in the mountains south of Lake Taupo, and including all the tributaries to that lake, as well as the many tributaries that enter the main-stem of the Waikato River downstream of the lake. The largest natural tributary to Lake Taupo is the Tongariro River, while the water that enters the lake via the Tokaanu Power Station also represents a major inflow to the lake.

Because Lake Taupo is so large, the water in the lake is replaced only slowly—if the lake were empty, it would take 10 years or so for it to be filled to the point of overflow by the inflowing streams and the rain that falls directly onto the lake surface. As a result, the lake acts as a "trap" or "settling pond" for certain inflowing materials, including sediment and silt, and forms of the plant nutrients nitrogen and phosphorus. For example, just 20 to 30 per cent of the nitrogen and phosphorus entering the lake from the catchment eventually leaves in the outflowing water.[25] The remainder is lost either by settling to the bottom of the lake, or is emitted as gas to the atmosphere (for nitrogen only). These natural "self-cleansing" processes act to make the water that leaves the lake cleaner than it was when it entered.

Furthermore, because much of the Taupo catchment is either undeveloped or in pine forest, the concentrations of nitrogen and phosphorus in many of the inflows to Lake Taupo are relatively low. In combination with the natural self-cleansing effect of the lake, this means the concentrations of nitrogen and phosphorus in the water flowing out of Lake Taupo into the Waikato River are particularly low. As a result, it is almost inevitable that concentrations of these chemicals will increase as the water continues down the river. Even the natural or background sources of these chemicals in the catchment downstream of Lake Taupo (e.g. via the leaching of soluble phosphorus from volcanic soils,[26] the erosion and runoff of undeveloped soils, and the production of nitrate by lightning) are sufficient to ensure that the concentrations of nitrogen and phosphorus in the main-stem of the Waikato River will be higher than in the source water flowing out of the lake.

That is, some deterioration in the water quality of the Waikato River downstream of Lake Taupo—as represented by an increase in the concentrations of nitrogen and phosphorus (and probably various other chemicals)—is natural or inevitable, regardless of any contamination that may result from human activity.

A similar effect appears to affect bacterial levels in the hydroelectric reservoirs between the outlet of Lake Taupo and Karapiro (and probably in Lake Taupo as well). Concentrations of faecal bacteria, that is bacteria present in human and animal faeces, are slightly-elevated immediately upstream of the first hydrolake (Ohakuri). However, the concentrations of faecal bacteria then fall, and remain low throughout the series of hydrolakes, before increasing in the un-impounded section of the river downstream of

[24] Smith, P. 2006: Waikato River water quality monitoring programme: data report 2005. *Environment Waikato technical report 2006/34*. Environment Waikato, Hamilton. and,
Smith, P. 2006: Regional rivers water quality monitoring programme: data report 2005. *Environment Waikato technical report 2006/29*. Environment Waikato, Hamilton.

[25] White, E.; Downes, M.T. 1977: Preliminary assessment of nutrient loads on Lake Taupo, New Zealand. *New Zealand journal of marine and freshwater research 11*: 341–356.

[26] Timperley, M.H. 1983: Phosphorus in spring waters of the Taupo volcanic zone, North Island, New Zealand. Chemical geology 38: 287–306.

Karapiro.[27] The hydrolakes presumably provide an environment in which these bacteria are more exposed to sunlight than is typical in a river, so they die more rapidly. Furthermore, their removal from the water by settling is probably also enhanced.

5.1.2 Water quality – condition

This section describes the current water quality of the Waikato River system,[28] or its "condition", while the following section describes the long-term changes in the water quality, or its "trend". The first section deals with the question, "what is the water quality like—is it good or poor?" while the second deals with the question, "how has the water quality changed—is it better or worse?"

To simplify this description of water quality, it helps to divide the Waikato River system into the following parts:

- Tributaries to Lake Taupo ("Taupo tribs"), 12 water quality monitoring sites[29]
- Lake Taupo, 1 deepwater site, 18 shoreline sites[30]
- Upland tributaries of the Waikato River, ("Upland tribs"), 12 sites[31]
- Lowland tributaries of the Waikato River (apart from the Waipa) ("Lowland tribs"), 26 sites[32]
- The Waipa River—the major tributary—and its own tributaries ("Waipa"), 16 sites[33]
- The shallow lakes in the Waikato River peatlands and flood-plain ("Shallow lakes"), 8 sites
- The main-stem of the Waikato River between the outflow of Lake Taupo and Karapiro dam ("Main-stem, Upper"), 5 sites,[34] and
- The main-stem of the Waikato River between Karapiro dam and the sea ("Main-stem, Lower"), 5 sites[35]

It is also helpful to distinguish the following aspects of water quality: (1) general river water quality for ecological health, (2) nutrient enrichment and algae in lakes, (3) nutrient enrichment and algae in the main-stem Waikato River, (4) water quality for swimming, and (5) specific contaminants—metals and pesticides.

---

[27] Beard, S. 2007: Waikato River water quality monitoring programme: data report 2006. *Environment Waikato technical report 2007/18*. Environment Waikato, Hamilton.

[28] Note that in 2005 an assessment was made of the extent to which water quality in the Waikato region met the various standards of the Waikato Regional Plan. However, the report concluded that the absence of standards for nitrogen and phosphorus in the Regional Plan meant that this assessment was generally less rigorous than alternative assessments, and that the results implied that water quality was less degraded than was actually likely to be the case. For details, see:
Vant, B. 2005: Water quality in Waikato region freshwaters and compliance with the standards of the WRP Water Management Classes. *Environment Waikato internal series 2005/15*. EW document #1044949.

[29] Site locations shown in Figure 1 and Table 2 of Beard, S. 2007: Regional rivers water quality monitoring programme: data report 2006. *Environment Waikato technical report 2007/12*. Environment Waikato, Hamilton. EW document #1173035.

[30] Site locations shown at
http://www.ew.govt.nz/enviroinfo/water/lakes/laketaupo/waterquality/taupomap/index.htm

[31] Site locations shown in Figure 1 and Table 2 of Beard, S. 2007: Regional rivers water quality monitoring programme: data report 2006. *Environment Waikato technical report 2007/12*. Environment Waikato, Hamilton. EW document #1173035.

[32] Site locations shown in Figure 1 and Table 2 of Beard, S. 2007: Regional rivers water quality monitoring programme: data report 2006. *Environment Waikato technical report 2007/12*. Environment Waikato, Hamilton. EW document #1173035.

[33] Site locations shown in Figure 1 and Table 2 of Beard, S. 2007: Regional rivers water quality monitoring programme: data report 2006. *Environment Waikato technical report 2007/12*. Environment Waikato, Hamilton. EW document #1173035.

[34] Site locations shown in Figure 1 and Table 2 of Beard, S. 2007: Waikato River water quality monitoring programme: data report 2006. *Environment Waikato technical report 2007/18*. Environment Waikato, Hamilton. EW document #1185492.

[35] Site locations shown in Figure 1 and Table 2 of Beard, S. 2007: Waikato River water quality monitoring programme: data report 2006. *Environment Waikato technical report 2007/18*. Environment Waikato, Hamilton. EW document #1185492.

River water quality for ecological health

Environment Waikato has developed an indicator of river water quality for ecological health, based on the following water quality variables: dissolved oxygen (DO), pH, turbidity (Turb), ammonia, temperature (Temp), total nitrogen (N) and total phosphorus (P).[36] The indicator is calculated from the results from Environment Waikato's river water quality monitoring network, involving monthly visits to more than 100 sites on rivers and streams in different parts of the region. Guideline values are used to classify the monitoring results into "excellent", "satisfactory" and "unsatisfactory" categories.[37]

Table 3 is based on this indicator, and shows the proportions of samples from monitoring sites on rivers in the various parts of the Waikato River system that met the guidelines for satisfactory or better water quality during 2002–06.

Table 3: Proportion (%) of results from sites in different parts of the Waikato River system that met guidelines for satisfactory or better river water quality for ecological health during 2002–06. Abbreviations as in text.

	DO	pH	Turb	Ammonia	Temp	Total N	Total P	Average
Tributaries								
Taupo tribs	99	100	95	100	99	69	69	**90**
Upland tribs	97	91	69	94	63	15	2	**62**
Lowland tribs	75	98	30	97	76	12	20	**58**
Waipa	91	99	48	100	82	26	39	**69**
Main-stem								
Main-stem, Upper	100	100	100	100	58	100	95	**93**
Main-stem, Lower	98	100	48	100	53	45	17	**66**

The following broad conclusions can be drawn from the information in Table 3:

- Dissolved oxygen, pH and ammonia levels in the Waikato River system were usually satisfactory or better
- A moderate proportion of results for turbidity and temperature in the system as a whole were unsatisfactory
- A moderate-to-large proportion of results for nitrogen and phosphorus in the system as a whole were unsatisfactory
- The inflows to Lake Taupo usually had results that were satisfactory or better
- A larger proportion of unsatisfactory results were obtained in the other tributaries (Upland, Lowland and Waipa)
- The main-stem of the Waikato River upstream of Karapiro dam usually had results that were satisfactory or better, and
- A larger proportion of unsatisfactory results were obtained for the main-stem of the Waikato River downstream of Karapiro.

To summarise:

1. Tributaries of the Waikato River system generally have satisfactory levels of dissolved oxygen and pH, and concentrations of the toxicant ammonia are low.
2. The water in some of the tributaries is clear, but others have water that is rather more turbid or murky (e.g. Lowland and Waipa tributaries).
3. Water temperature in many of the tributaries is sometimes warmer than is ideal for ecological health, but the Taupo tributaries are generally cool.
4. Concentrations of nitrogen and phosphorus in many of the tributaries were often elevated.

[36] See http://www.ew.govt.nz/enviroinfo/indicators/inlandwater/riversandstreams/riv1/keypoints.htm
[37] See http://www.ew.govt.nz/enviroinfo/indicators/inlandwater/riversandstreams/riv1/techinfo.htm

5. As a result of all this, the water which leaves Lake Taupo and enters the main-stem of the Waikato River in generally excellent condition becomes progressively degraded as it flows downstream, particularly as regards levels of turbidity, nitrogen and phosphorus (although other aspects of water quality, including dissolved oxygen, pH and ammonia, remain at least satisfactory throughout the length of the river).

Nutrient enrichment and algae in lakes

Lake water quality is usually described in terms of "trophic state" which can be best understood as referring to the degree of nutrient enrichment and the associated likelihood that the lake will support abundant levels of nuisance or toxic algae (i.e. microscopic plants). So an "oligotrophic" lake contains low concentrations of the nutrients nitrogen and phosphorus, and thus contains low concentrations of algae, so that the water is usually clear. In a "eutrophic" lake, concentrations of nutrients and algae are high, and the water is green and murky.

Although systems exist to convert nutrient and algal concentrations to arbitrary index numbers,[38] for this analysis it will be sufficient to simply describe and compare the average concentrations between the different lakes.

Table 4 shows the average concentrations of nutrients and algae in samples collected from lakes in the Waikato River system during 2002–06. It also shows average water clarity and blue-green algal numbers (where available).

Table 4: Average concentrations (units mg/m3) of total phosphorus (P) and nitrogen (P) and the algal pigment chlorophyll a (Chla), and water clarity as Secchi depth (m) in lakes in the Waikato River system, 2002–06. For some lakes the average number of blue-gre n algae (BGA) is also shown (in cells/mL).

	Total P	Total N	Chla	Secchi	BGA count
Taupo	6	70	1	15	
Shallow lakes					
Rotomanuka	21	870	13	2.0	no data
Rotoroa	22	730	11	1.8	<1,000
Waahi	80	1800	74	0.4	60,000
Ngaroto	130	2300	66	0.7	31,000
Whangape	150	2300	130	0.3	130,000
Hakanoa	180	2500	100	0.4	44,000
Waikare	340	2300	98	0.2	580,000
Kainui	no data	no data	no data	no data	48,000

The following broad conclusions can be drawn from the information in Table 4:

- Lake Taupo is the main oligotrophic or low nutrient lake in the Waikato River system[39]
- Its nutrient and algal concentrations are low, and the water is clear and blue
- Lakes Rotomanuka and Rotoroa have moderate concentrations of nutrients, so average levels of algae are about ten times higher than in Lake Taupo, and the water is of moderate clarity (and is somewhat brownish due to peat-staining)
- The other shallow lakes all contain very high concentrations of nutrients and algae (including potentially toxic blue-green algae), and the water clarity is poor.

[38] For example, Burns, N.M.; Rutherford, J.C.; Clayton, J.S. 1999: A monitoring and classification system for New Zealand lakes and reservoirs. *Journal of lake and reservoir management 15*: 255–271.

[39] Lakes Rotoaira and Rotopounamu are also oligotrophic, but much less is known about them.

Nutrient enrichment and algae in the main-stem Waikato River

Table 5 shows the average concentrations of nutrients and algae in samples collected from sites on the main-stem of the Waikato River system during 2002–06. It also shows average water clarity and blue-green algal numbers (where available).

Table 5: Average concentrations (units mg/m3) of total phosphorus (P) and nitrogen (P) and the algal pigment chlorophyll a (Chla), and water clarity as Secchi depth (m) at sites on the main-stem of the Waikato River system, 2002–06. The distance downstream (km) of each site from the outlet of Lake Taupo is shown in brackets. For some sites the average number of blue-green algae (BGA) is also shown (in cells/mL).

	Total P	Total N	Chla	Secchi	BGA count
Upper river					
Taupo Gates (0)	6	90	2	no data	100
Ohaaki (36)	14	140	2	6.8	no data
Ohakuri (76)	24	210	6	3.6	2,400
Whakamaru (105)	27	230	9	3.0	no data
Waipapa (126)	32	300	9	2.5	3,300
Lower river					
Narrows (202)	39	420	12	1.9	1,900
Horotiu (226)	50	460	13	1.6	1,400
Huntly (246)	71	670	12	1.1	1,100
Mercer (286)	78	710	18	no data	no data
Tuakau (297)	78	690	21	0.8	1,600

Notes:
1. Secchi depth estimated from measured horizontal visibility of a black disc
2. BGA counts for Waipapa are from samples collected at Maraetai; for Narrows, from samples at Karapiro; for Horotiu, from samples at Hamilton.

The following broad conclusions can be drawn from the information in Table 5:

- As noted above, concentrations of nitrogen and phosphorus increase progressively moving down the main-stem of the river
- As a result, concentrations of algal pigment also increase, and the water becomes progressively murkier (i.e. less clear) and greener
- Moderate numbers of potentially toxic blue-green algae are present from Lake Ohakuri to the sea; high numbers (or "blooms") occurred on two occasions during 2003–06, resulting in public health and drinking water alerts.

Water quality for swimming

Environment Waikato has developed an indicator of river water quality for contact recreation, based on concentrations of a microbial indicator, the faecal bacteria *Escherichia coli* (Ecoli), and water clarity as measured by the horizontal visibility of a submerged black disc.[40] The indicator is calculated from the results from Environment Waikato's river water quality monitoring network, involving monthly visits to more than 100 sites on rivers and streams in different parts of the region. Guideline values are used to classify the monitoring results into "excellent", "satisfactory" and "unsatisfactory" categories.[41]

[40] See http://www.ew.govt.nz/enviroinfo/indicators/inlandwater/riversandstreams/riv2/keypoints.htm
[41] See http://www.ew.govt.nz/enviroinfo/indicators/inlandwater/riversandstreams/riv2/techinfo.htm

Table 6 is based on this indicator, and shows the proportions of samples from monitoring sites on rivers in the various parts of the Waikato River system that met the guidelines for satisfactory or better water quality during 2002–06. It also includes information on water quality at bathing beaches from the Lake Taupo water quality indicator.[42]

Table 6: Proportion (%) of results from sites in different parts of the Waikato River system that met guidelines for satisfactory or better river water quality for contact recreation during 2002–06. Abbreviations as in text.

	Ecoli	Clarity	Average
Tributaries			
Taupo tribs	74	83	79
Lake Taupo (beaches)	98	88	93
Upland tribs	57	36	46
Lowland tribs	35	22	29
Waipa	55	36	45
Main-stem			
Main-stem, Upper	100	91	96
Main-stem, Lower	90	11	50

The following broad conclusions can be drawn from the information in Table 6:

- Ecoli concentrations and water clarity were usually satisfactory or better in the inflows to Lake Taupo (and in the lake itself)
- A moderate-to-high proportion of unsatisfactory results for Ecoli and water clarity were obtained in the other tributaries (Upland, Lowland and Waipa)
- The main-stem of the Waikato River upstream of Karapiro dam usually had results that were satisfactory or better, and
- The main-stem of the Waikato River downstream of Karapiro usually had Ecoli results that were satisfactory or better, but routinely had water clarity results that were unsatisfactory.

Metals and pesticides

Environment Waikato maintains a low-level monitoring programme for metals and pesticides. At quarterly intervals every five years, water samples are collected from several sites on the main-stem of the Waikato River and analysed for a suite of 20 metals;[43] samples are also collected and analysed for a suite of 99 pesticides.[44]

The following broad conclusions can be drawn from the information on metals in river water:

- Concentrations of arsenic exceeded guideline values for ecological health, particularly at sites in the upper river (i.e. directly downstream of areas of geothermal activity)[45]

[42] See http://www.ew.govt.nz/enviroinfo/indicators/inlandwater/lakes/lake9/keypoints.htm

[43] Smith, P. 2006: Waikato River water quality monitoring programme: data report 2005. *Environment Waikato technical report 2006/34*. Environment Waikato, Hamilton.

[44] Smith, P. 2005: Waikato River water quality monitoring programme: data report 2004. *Environment Waikato technical report 2005/21*. Environment Waikato, Hamilton.

[45] Concentrations of arsenic in raw river water also exceeded drinking water standards, but conventional water treatment substantially reduces the concentrations in treated drinking water. As a result, all community water supplies sourced from the Waikato River meet the drinking water standards for arsenic.

- Concentrations of boron were occasionally close to guideline values at sites in the upper river
- Concentrations of other metals, including copper, lead, mercury, nickel and zinc, were generally below guideline values for ecological health.

The following broad conclusions can be drawn from the information on pesticides in river water:

- Even though sensitive, modern analytical methods were used, 89 of the 99 pesticides considered could not be detected in the water samples
- The most frequently detected pesticide was hexazinone, a herbicide used in forestry operations; however, there are no ecological guideline values for this chemical (but note that the concentrations observed in the river water were more than 100 times lower than the drinking water standard for it)
- The other pesticides detected were probably washed-off the land by floods (dieldrin and lindane), or were otherwise discounted as probably being unrepresentative.[46]

5.1.3 Water quality – trends

This section describes changes in water quality over time. Several of Environment Waikato's monitoring programmes have been designed to allow assessments to be made of whether water quality is improving or deteriorating over time, or whether there has been no overall change. Assessments have therefore been made of the changes in water quality in the following parts of the Waikato River system:

- Tributaries to Lake Taupo ("Taupo tribs"), 8 water quality monitoring sites
- Lake Taupo, 1 deepwater site
- Upland tributaries of the Waikato River ("Upland tribs"), 12 sites
- Lowland tributaries of the Waikato River (apart from the Waipa) ("Lowland tribs"), 26 sites
- The Waipa River—the major tributary—and its own tributaries ("Waipa"), 16 sites
- The shallow lakes in the Waikato River peatlands and flood-plain ("Shallow lakes"), 8 sites
- The main-stem of the Waikato River between the outflow of Lake Taupo and Karapiro dam ("Main-stem, Upper"), 5 sites, and
- The main-stem of the Waikato River between Karapiro dam and the sea ("Main-stem, Lower"), 5 sites

Trend assessments have been made each year for the ten sites on the main-stem of the Waikato River.[47] Assessments have been made at 5-yearly intervals for the 60 or so sites on tributaries,[48] with work on the latest update being underway at present (February 2008). An assessment was recently made for the deepwater site on Lake Taupo;[49] and several years ago an assessment was made of changes in several of the shallow lakes.[50]

5.1.3.1 Tributaries

The changes in water quality in the various tributaries to the Waikato River up to 2002 reflected the changes found for many rivers in the Waikato Region as a whole. The most notable changes in water quality at the 60 or so Waikato River tributaries included the following:

[46] See EW document #871285.

[47] Vant, B.; Smith, P. 2004: Trends in river water quality in the Waikato Region, 1987–2002. *Environment Waikato technical report 2004/02*. Environment Waikato, Hamilton. And subsequent annual updates of this have been summarised on the EW website, see http://www.ew.govt.nz/enviroinfo/water/healthyrivers/waikato/facts6c.htm

[48] Vant, B.; Smith, P. 2004: Trends in river water quality in the Waikato Region, 1987–2002. *Environment Waikato technical report 2004/02*. Environment Waikato, Hamilton.

[49] Vant, B. 2006: Assessment of results from Lake Taupo monitoring during 1974-to-2006. See EW document #1091457.

[50] Barnes, G. 2002: Water quality trends in selected shallow lakes in the Waikato Region, 1995–2001. *Environment Waikato technical report 2002/11*. Environment Waikato, Hamilton.

- Water clarity—improvement at 37 sites, deterioration at 2 sites, overall rate of change was an improvement of about 2 percent per year
- Ammonia—improvement at 20 sites, deterioration at 5 sites, overall rate of change was an improvement of about 5 percent per year
- Dissolved oxygen—improvement at 8 sites, deterioration at 21 sites, overall rate of change was a slight deterioration (of about 0.2 percent per year)
- Nitrate—improvement at 12 sites, deterioration at 19 sites, overall rate of change was a slight deterioration (of about 0.3 percent per year)
- Total phosphorus—improvement at 2 sites, deterioration at 26 sites, overall rate of change was a deterioration of about 2 percent per year
- Total nitrogen—improvement at 2 sites, deterioration at 26 sites, overall rate of change was a deterioration of about 1 percent per year.

The reasons for the improvements in water clarity were unclear, but reflected similar trends seen on many other rivers in New Zealand in the past decade or so. The improvement associated with reductions in concentrations of ammonia may reflect improved farm practice (e.g. smaller loads of ammonia reaching streams from oxidation ponds following a major shift to land disposal of dairy wastes in the past decade or so).

The deteriorations associated with the increases in concentrations of total nitrogen (and nitrate) and total phosphorus were significantly related to the area of catchment in pasture, and are likely to reflect the overall increase in farming intensity and stock numbers that has occurred in the Waikato catchment over recent decades.

Lake Taupo

During 1974-to-2006 there was a small, but statistically significant, increase in the concentrations of both nitrogen and algal chlorophyll in the waters of Lake Taupo. There was also a weak increase in the amount of nitrogen recycled from the bottom sediments of the lake during summer.

The overall conclusion was that, “while there have not been major changes in the water quality at a site in the middle of Lake Taupo over the past 30 years or so, and the water quality there is still high, there are clear signs of a gradual deterioration over this period”.

Shallow lakes

The analysis of the data available until 2001 showed that the water quality of three of the shallow lakes had deteriorated, while that of four others was unchanged. Since then, however, two lakes—Whangape and Waikare (see Table 4)—appear to have deteriorated markedly, and now contain substantially higher levels of blue-green algae than in the past.

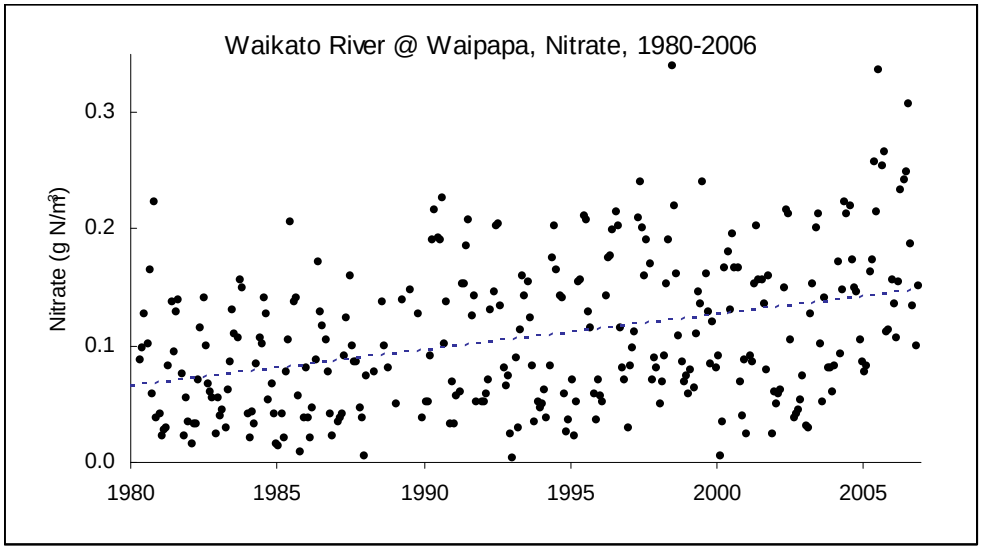
Waikato River main-stem

Environment Waikato’s most recent analysis of trends in water quality at the ten monitoring sites on the main-stem of the Waikato River separated the records into two periods as follows: (1) decade one, from 1987-to-1996, and (2) decade two, from 1998-to-2006. Contrasting results were obtained for the two periods.

During the first decade there were rather more improvements than deteriorations in water quality parameters. For example, concentrations of biochemical oxygen demand—a measure of the level of partly-treated organic wastewaters present in the river—declined at nine of the ten monitoring sites. This probably reflected improvements in the treatment of sewage and industrial wastewaters over the decade. Concentrations of ammonia and nitrate also declined at several sites.

During the second decade, however, there were more deteriorations than improvements, probably because increased loads from non-point sources in the catchment outweighed any further reductions in point source wastewater loads (see later). In particular, concentrations of total phosphorus and nitrate increased at 6-to-7 sites. At these sites, the concentrations increased at an average rate of about 3-to-4

percent per year. This is illustrated in the figure below, which shows the full record of monthly nitrate concentrations since 1980 at the Waipapa site, with the overall trend shown as a dashed line.



5.1.4 Summary – state of water quality, 2002-2006

1. Tributaries of the Waikato River system generally had satisfactory levels of dissolved oxygen and pH, and concentrations of the toxicant, ammonia, were low. The water in some of the tributaries was clear, but others such as the Waipa had water that was rather more turbid (i.e. murky). Water temperatures were sometimes warmer than is desirable, although the inflows to Lake Taupo were generally cooler. Concentrations of the plant nutrients nitrogen and phosphorus were often elevated.

2. As a result of this, the water which left Lake Taupo in generally excellent condition became progressively degraded as it flowed down the Waikato River, particularly as regards levels of turbidity, nitrogen and phosphorus. But dissolved oxygen, pH and ammonia levels were satisfactory or better throughout the length of the main-stem of the river. Some of the increase in nitrogen and phosphorus levels that occurs downstream of Lake Taupo is natural.

3. The nutrients enhanced the growth of the microscopic plants called algae in the impounded waters of the main-stem of the river downstream of Lake Taupo. As a result the clear, blue water that left the lake became murkier and greener as it flowed downstream. On two occasions, rapid growth of potentially toxic blue-green algae in the river led to public health and drinking water alerts.

4. Nutrient and algal levels in the shallow lakes were generally higher, or much higher, than those in the main-stem of the river, and the water appeared murky and green. High levels of blue-green algae were common. Nutrient and algal levels in Lake Taupo were low, and the water was clear and blue.

5. Some of the waterbodies were less suitable for swimming than others, with some tributaries having elevated levels of Ecoli bacteria, together with unsatisfactory water clarity. While Ecoli levels were mostly satisfactory or better throughout the main-stem of the river, water clarity was generally unsatisfactory in the lower section.

6. Arsenic concentrations in the main-stem of the river downstream of the Wairakei geothermal area often exceeded ecological guidelines. Levels of pesticides were generally low or very low, and currently provide little cause for concern.

7. Water quality in the tributaries has shown a mixture of improvements and deteriorations over the past decade or so. In many cases water clarity improved, as did ammonia levels. However, concentrations of both total nitrogen and total phosphorus increased (i.e. deteriorated) at just under half of the sites monitored.

8. In the main-stem of the river there was an overall improvement in water quality in the 10 years to 1996, but an overall deterioration in the following 10 years (to 2006). Concentrations of contaminants often associated with wastewaters, including biochemical oxygen demand and ammonia, declined during the first period, probably reflecting improvements in the management of wastewaters from municipal sewage and industries. But as in the tributaries, concentrations of nitrogen and phosphorus in the main-stem increased during the second period, probably reflecting the effects of intensified land use in the catchment as a whole.

9. Lake Taupo has not shown major changes in average water quality over the past 30 years or so, and water quality is still high, but there have been signs of gradual deterioration. Water quality in several of the shallow lakes has recently declined, and major blooms of blue-green algae have become more common in two of them.

5.2 Pressures

"Pressures" on water quality are regarded here as those human activities that affect water quality, either by the addition of contaminants to a waterbody, or by modifying the characteristics of a waterbody in such a way that water quality changes will occur. However, naturally-occurring factors, such as (1) the effects of varying flow (e.g. higher turbidity and lower conductivity at periods of high flow), and (2) seasonally-varying warming by the sun, are ignored.

1. Several human activities that affect the water quality of the Waikato River system can be identified, as follows:

2. The discharge of wastewaters containing a variety of contaminants from many different "point sources" including sewage treatment plants, dairy factories, meatworks, dairy shed treatment ponds, pulp and paper mill, quarries, geothermal and coal/gas power stations.

3. The impoundment of water in eight large hydroelectric reservoirs which markedly increases river travel times and thus provides an environment in which algae can flourish. Levels of faecal bacteria, however, are unusually low in this environment, presumably because of enhanced die-off and settling in the still, exposed waters.

4. Modification of riparian features, including the removal of shade that can result in increased heating of a waterbody by the sun, producing warmer water.

5. Land use practices that alter the rates at which contaminants are transported to the river system (i.e. "non-point sources"). These include (a) land clearance and soil removal, either temporarily or permanently, that markedly increase loads of particulate materials; (b) runoff of silt, metals and animal faecal matter from urban areas, particularly impervious areas; and (c) runoff and leaching of nitrogen and phosphorus from areas of pastoral farming.

The amount and the quality of the information available on these different pressures on the water quality of the Waikato River system varies. In a few cases a reasonably-comprehensive, quantitative catchment-wide assessment has been made; but in most cases the information available is rather more limited. The following material provides an overview of the information available.

5.2.1 Sources of nitrogen and phosphorus

The most comprehensive information on the relative importance of the different sources of contaminants to the Waikato River system is for loads of nitrogen and phosphorus.[51] These analyses show that point sources are relatively minor contributors of nutrients to the Waikato River system. The dominant source of nitrogen and phosphorus is runoff and leaching from areas of developed land, particularly land that has been developed for pastoral farming.

Nitrogen is supplied to pastoral areas in fertilizer and by fixation of atmospheric nitrogen. This is incorporated into plant tissue and eaten by grazing animals. In lightly-grazed areas, the nitrogen returned to the pasture in dung and urine is largely taken up again by plants, and there is little loss of nitrogen to groundwater. In intensively-grazed areas, however, urine is voided in concentrated patches, and the plants are unable to utilize all of the nitrogen before it is washed below the root zone occupied by plant roots. As a result, large quantities of nitrogen are leached to the groundwater, and thus to downstream surface waters. In addition, nitrogen in dung can enter surface waters directly in runoff from the pasture.

Phosphorus is strongly associated with sediment, and sediment generation is high from unprotected margins (i.e. where livestock have access to the beds and banks, or where annual crops are cultivated up to the water margin). Furthermore, animal wastes contain high levels of phosphorus, so deposition of wastes on the bed and banks of streams contributes to the phosphorus loads to streams, as does waste deposited up-slope, unless there is a vegetative buffer in the riparian margin to capture this runoff.

The analysis of the relative importance of the various sources of nutrients to the Waikato River during the 1990s showed that moderate-to-large point source discharges—sewage plus industrial wastewaters, not including the numerous dairy pond discharges—contributed about 15 percent of the nitrogen load to the river and about 30 percent of the phosphorus load. Areas of land developed for agricultural and urban uses were the dominant source of nutrients.

Since then, there have been substantial improvements in wastewater treatment that have reduced the nutrient loads discharged at several point sources. For example, Environment Waikato's records show that during summer, when nutrients are most likely to promote undesirable algal growths in the river, the nitrogen loads discharged by the two largest sources, namely Hamilton sewage and the Horotiu meatworks discharges (together accounting for 60 percent of the 1990s load of point source nitrogen, and 18 percent of the phosphorus), have fallen by between 75 and 90 percent. Large improvements like this cannot continue to be made, however. For several major point sources, the efficiency of wastewater treatment is approaching the current best practicable level.

At the same time, nitrogen and phosphorus loads have increased in many of the tributaries to the Waikato River that drain mainly pasture (and lack large point sources). As noted above, average concentrations of both total nitrogen and total phosphorus in the river's tributaries overall increased by about 1-to-2 percent per year during the period 1990–2002.

Over the past decade or so, the decrease in nutrient loads from point sources to the Waikato River appears to have been slightly out-weighed by the increase in loads from areas of developed land. That is, despite the reductions from point sources, over this time period the overall load to the river has probably increased slightly, leading to the

[51] Vant, B. 1999: Sources of the nitrogen and phosphorus in several major rivers in the Waikato Region. *Environment Waikato technical report 1999/10*. Environment Waikato, Hamilton. And.
Vant, W.N. 2001: New challenges for the management of plant nutrients and pathogens in the Waikato River, New Zealand. *Water science and technology 43*: 137–144.

increase in river concentrations of total phosphorus and nitrate that were described above.

5.2.2 Sources of heat

There are two major discharges of heat to the Waikato River, both of which involve the use of river water to cool generating equipment at thermal power stations. The Wairakei geothermal power station abstracts about 17 m^3/s of water from the upper Waikato River, uses it for cooling, then discharges it back to the river. This adds about 900 MW of heat to the river, while the associated discharge of geothermal water adds a further 80–90 MW of heat.[52] As a result, water temperatures in the zone up to 3 km from the discharge point frequently exceed those at which adverse effects on native fish are known to occur (25°C). Temperatures over a considerably larger distance frequently exceed the standards in the Waikato Regional Plan for the protection of trout spawning (although it appears that this section of the river is unsuitable for spawning). Temperature increases are greatest at low river flows.

The Huntly coal/gas power station also uses river water for cooling. In this case about 40 m^3/s of water is abstracted from the lower Waikato River, used for cooling and then discharged back to the river. This adds up to 1400 MW of heat to the river.[53]

5.2.3 Geothermal contaminants

The Wairakei power station discharges also contain appreciable concentrations of hydrogen sulphide, mercury and arsenic, all of which are toxic to organisms.[54]

The discharge of hydrogen sulphide causes concentrations of this toxicant in the river to markedly exceed guideline values for ecological health for several kilometres downstream of the discharge point. The high concentrations are believed to be the reason why certain native fish (common bullies) are uncommon in this area.

The discharge also contributes about 50 kg of mercury per year to the Waikato River. The resulting concentrations of mercury in the water downstream of the discharge point are lower than the guideline values for ecology and for drinking water, so the effects of the discharge on river water quality are small. However, the discharge is responsible for most of the mercury that accumulates in sediments, fish and freshwater mussels downstream from Wairakei. Mercury concentrations in the sediments of the river are up to six times higher than the relevant ecological guideline values. And concentrations exceed the NZ Food Standards in freshwater mussels from Lake Aratiatia, and in some trout in the upper hydrolakes, particularly in Lake Ohakuri.

Natural geothermal inputs mean that background concentrations of arsenic in the river are relatively high. Downstream of Wairakei, these concentrations increase still further as a result of the power station discharge. Since 1988, some of the geothermal fluid abstracted from the ground has been re-injected after use, which means it has not been discharged to the river. As a result, arsenic concentrations in the river downstream of the power station reduced for a period. Calculations show that about two-thirds of the arsenic found in the river sediments is likely to have come from the Wairakei discharge.

The Wairakei power station discharges have recently been re-consented. In due course this will result in substantial reductions in the loads of the various contaminants that are discharged to the Waikato River.

5.2.4 Dissolved colour

The Kinleith pulp and paper mill is a major source of wood-related chemicals similar to tannins, that cause a “pale tea-like” colouration of the downstream waters. In 1991 the

[52] See EW document #738124 for details.
[53] Based on a flow of 40 m^3/s and a temperature increase of up to 8.5°C.
[54] See EW document #738124 for details.

load of dissolved colour discharged from the mill was halved, causing levels in the river to fall also. For example, levels of dissolved colour in the river at Waipapa are now about half what they were in the 1980s.

5.2.5 Urban stormwater

A range of contaminants are present in urban stormwater, including silt, metals, synthetic organic chemicals and animal faecal matter. An assessment has shown that even the runoff from the largest urban area in the Waikato River system, namely Hamilton city, is likely to generally have only a small effect on river water quality.[55] Although it found the overall input of contaminants was small compared to the loads carried by the river, it did conclude that individual storm inputs had the potential to degrade the quality of the river water at the time of the storm and immediately after it.

5.2.6 Impoundment of river water in hydroelectric reservoirs

Between the outlet of Lake Taupo and Karapiro there are eight large hydroelectric reservoirs (or "hydrolakes") where river flows are controlled for electricity generation. One of the most striking physical effects of the cascade of hydrolakes is the way in which it slows the passage of water down the river. At the time of summer low flow, it now takes several weeks for a parcel of water to travel from the outlet of Lake Taupo to Karapiro dam, compared to just 2–3 days before the dams were built.

Because algae require time to grow, the impoundment of the river in the hydrolakes greatly increases the ability of the river water to support a flourishing algal community. Impoundment thus exacerbates the effects of nutrient enrichment that were described above. Calculations have shown that if the dams were not present, then at the time of summer low flow, the level of algae in the river at Karapiro would be likely to be less than one-third of that which we actually observe (i.e. 5 mg Chla/m^3 without the dams, compared to 17 Chla/m^3 with them).[56]

As noted above, however, levels of faecal bacteria are unusually low in the hydrolakes, presumably because increased die-off and settling in the still, sunlight-exposed waters provides additional "natural disinfection".

5.2.7 Summary – pressures on water quality

1. During the 1990s, sewage and industrial wastewaters contributed about 15 percent of the nitrogen loads and about 30 percent of the phosphorus loads entering the main-stem of the Waikato River. Areas of agricultural land were the dominant source of these nutrients.

2. Since then there have been substantial improvements in wastewater treatment that have reduced the nutrient loads at some of the point sources. At the same time, non-point source loads in a number of the tributaries that drain catchments mainly in pasture have increased. This increase appears to have out-weighed the decrease from point sources, leading to a slight increase in concentrations of nitrogen and phosphorus in the river.

3. Point source discharges contribute appreciable loads of other contaminants to the river. These include (a) the loads of heat added to the substantial flows of river water that are used for cooling at two thermal power stations, (b) the geothermal chemicals that are discharged to the upper section of the main-stem of the river at one of these power stations, and (c) chemicals derived from wood that are discharged from a pulp and paper mill, and that slightly change the colour of the water in the river.

[55] Williamson, B. 1999: Broad-scale assessment of urban stormwater issues in the Waikato Region. *NIWA Client Report EVW90213*. NIWA, Hamilton.

[56] Rutherford, J.C.; Williamson, R.B.; Davies-Colley, R.J.; Shankar, U. 2001: Waikato catchment water quality model. *NIWA Client Report ELE90229/3*. NIWA, Hamilton.

4. Urban stormwater from Hamilton city has only a relatively small effect on the overall water quality of the river. But there can be localised degradation of river water quality during and immediately after periods of heavy rainfall.

5. The cascade of hydrolakes between the outlet of Lake Taupo and Karapiro markedly slows the downstream passage of river water, so algae in the river are able to make good use of the available plant nutrients and grow to reach moderately-high densities. Calculations suggest that if the hydrolakes were not present, algal levels at Karapiro would be likely to be less than one-third of those currently observed. At the same time, however, the removal of faecal bacteria appears to be enhanced in the hydrolakes.

6 Wetlands

6.1 State of, and pressures on, the ecology and biodiversity of wetlands within the Waikato River catchment

Wetlands associated with the Waikato River and greater catchment range from low nutrient peat areas, moderately fertile wetlands dominated by sedges (also with kahikatea and manuka), highly fertile raupo and flax swamps, through to riparian turf communities and tidally influenced brackish wetlands in the lower Waikato River and estuary. Wetlands exist along the margins of, and on islands within, the Waikato River and hydro lakes, and form part of the network of many waterways and lakes within the Waikato River catchment.

Collectively, these wetlands contain a diverse range of flora and fauna, and offer significant habitat for many rare and threatened species. Wetland ecology, and the types of plants and animals that occur in them, is closely linked to the source of their water (i.e., ground-, surface- or rain-water supplies), along with water depth, permanence, temperature and chemical characteristics. As an interface between terrestrial and freshwater ecosystems wetlands play an important role in enhancing waterways by filtering nutrients, chemicals, and suspended sediment before they reach streams, lakes and rivers. Wetlands are highly valued by local communities and tangata whenua for their recreational, educational, scientific, aesthetic and cultural values. They are also important storage areas for floodwaters.

6.1.1 State of wetland ecosystems within the Waikato River catchment

Current extent

Freshwater wetlands are often located in areas that are highly desirable for farmland or other activities such as sand-mining. As such, many of those within the Waikato River and catchment, particularly throughout the lower Waikato river area, have been drained and converted to pasture or otherwise irreversibly altered. Analyses of the Land Cover Database by Landcare Research (LCDB 1996, and Leathwick et al., 1995 respectively) show that wetlands in the Waikato Region (excluding areas of open water but including freshwater and saline wetlands) have reduced in extent by more than 75% over the last 160 years. There were also fewer, larger wetlands 160 years ago. Most of these have now been lost or split into small fragments, and those which remain are scattered and mostly smaller than 50 hectares. Analysis of Landcover data suggests a current figure of about 13,610[1] hectares of wetland within the boundaries of the seven territorial authorities through which the Waikato River flows (excluding areas of open water but including freshwater and saline wetlands). All these remaining wetland areas are highly vulnerable to drainage, damage by pest plants and animals, sedimentation and nutrient runoff.

Changes in wetland extent

Wetland losses are still occurring within the Waikato River catchment. Some are driven by changing land-use (for example, recent pine-pasture conversions in the South Waikato District) and others occur as wetland quality slowly degrades as a result of plant invaders (particularly willows), along with hydrological changes brought about by drainage of surrounding land. Some losses are being offset by small-scale wetland restoration projects, but generally wetlands in the Waikato region remain under-protected.

Waikato wetland species

Reduction in habitat size, fragmentation and isolation of wetlands has led to a decline in the populations of wetland species. A relatively high number of these are under threat, with 13 threatened plant species and 11 threatened animal species present in lower Waikato Region wetlands alone (Champion, 1998, Hitchmough *et. al* 2007). Rare birds, incuding the Australasian Bittern, North Island Fernbird and Spotless Crake frequent many of the Waikato wetlands. Notable plants in these areas include the swamp helmet orchid (found only in the Whangamarino wetland), and a threatened clubmoss and bladderwort species. Waikato wetlands are also important habitats for indigenous fish including the chronically threatened black mudfish (although the extent of suitable habitat for this species has declined considerably as a result of drainage). Waikato wetlands also support large numbers of common species, including mallard ducks (which provide important recreation for hunters), and inanga (whose juveniles make up the bulk of whitebait catches).

Significant wetlands

Among the many wetlands located within the Waikato River catchment, the following four are of particularly highly significance:

The South Taupo wetland located near Turangi covers an area of approximately 1540 hectares and is one of the largest in the upper Waikato catchment. It plays an important role in trapping sediment washed off the Kaimanawa ranges and central mountains, ensuring high water quality in the shallow bays of adjacent Lake Taupo. It supports a high diversity of plant and bird species, several of which rank as acutely or chronically threatened (Cromarty and Scott ,1995).

The 7100 hectare Whangamarino Wetland, located east of State Highway 1 between Mercer and Te Kauwhata, is the second largest bog and swamp complex in New Zealand and is one of the largest wetlands connected with the Waikato River (Cromarty and Scott 1995). Its size, combination of wetland types and diverse range of species are the basis for 5690 hectares being accorded international status as a Ramsar[1] site, signifying its importance to conservation world-wide. The Whangamarino wetland supports over 20,000 waterfowl and populations of rare and endemic species of plants and animals including an estimated 25% of the total Australasian bittern population in New Zealand and one of the largest populations of North-Island fernbird. It is the only known New Zealand location of the swamp helmet orchid. The Whangamarino wetland also plays an important role in the Lower Waikato/Waipa Flood Protection Scheme.

The Opuatia peat bog is one of five large restiad peat bogs remaining within the Waikato Region and is the only one in private ownership. It is situated north of Lake Whangape in the lower Waikato River catchment and covers approximately 950 hectares of low-lying land. The wetland contains many rare and endangered plants and is habitat for several threatened fauna. It is one of only four recorded locations of the endemic giant cane rush (*Sporodanthus ferrugineus*) – a species that occurs only in the Waikato Region. The Opuatia catchment is predominantly used for agriculture and livestock have access to parts of the wetland margins. Environment Waikato has undertaken wetland enhancement measures in an area of degraded wetland at Opuatia wetland as a conditional requirement of a resource consent granted to extend the existing Lower Waikato Flood Control Scheme. The work involved the construction of bunds along the boundaries of an area of willow and pasture in order to increase the residence time of flood waters in the ecosystem and increase the position of the water table (Browne and Campbell 2005). Status of the wetland is monitored on a yearly basis by Environment Waikato.

The lower Waikato River from Rangiriri downstream about 56km to Port Waikato at the mouth of the river is tidally influenced. Here the river passes through a network of mineralised swamp areas and swampy islands (some of which are vegetated with native Kahikatea, Totara, flax, raupo, sedges and rushes, and some of which are almost exclusively vegetated with exotic species), before it finally discharges through

widely diverse delta habitats into the sea. Estuarine habitat near Port Waikato is used by a wide variety of bird species (including migratory shorebirds) and supports both estuarine and freshwater plant and animal species. Collectively, the islands and estuarine areas within the Lower Waikato river form an internationally significant wetland complex (Cromarty and Scott ,1995).

Pressures on Wetland Ecosystems

Wetland habitats are particularly vulnerable to impacts arising from human activities. Within the Waikato River catchment these activities continue to fragment and isolate wetlands and are driving a general decline not only in wetland extent and quality, but also in abundance and diversity of many wetland plant and animal species. Pressures include:

- Reclamation of lake, river and estuarine margins and draining of farm and forestry swamps, reducing the area, connectivity and quality of wetlands.

- Invasion by plant and animal pests. Tall invasive species such as willow can overtop and shade lower native wetland plant communities, ultimately forcing detrimental changes to wetland habitat and native fauna.

- Drainage of wetlands for urban or rural developments / drainage schemes and alteration of water levels due to and sand or gravel extraction processes or electricity generation may alter habitat conditions which lead to species losses and weed invasion (particularly by willows). Lowering of the water table can have serious implications for a wetland including loss of plant species that depend on a high water table. A lower water table also leads to degradation and shrinkage of peat, and further habitat changes following the establishment of dryland species such as blackberry and bracken. Loss of standing water also may also reduce the number of nesting sites for water birds and allow terrestrial predators easier access to the wetland. Connections to associated rivers and streams may also cease, inhibiting fish migration. However, alteration of water levels does not necessarily result in adverse effects on wetland areas. Recent research by NIWA on the effects of drawdown levels in Lake Waipapa for the purposes of electricity generation indicated that a larger variation in water level may have positive effects on species composition and abundance in riparian wetlands (Reeves and Wells 2008).
- Stock access and grazing around and within wetlands causing pollution, damage to vegetation and deterioration in soil stability.
- Decline in habitat and water quality due to excess run-off of sediment and nutrients. This can occur through inappropriate use of surrounding land in a catchment (e.g. pine forest drawing water away from ground water systems leaving depleted water supply, or poorly managed farming practices causing sediment and/or fertiliser run-off), or by loss of vegetation in the surrounding catchment (including harvesting of plantation forest close to wetlands) causing erosion and subsequent runoff of excess sediment directly into wetlands. Sedimentation threatens not only plant communities but also breeding areas for native fish (e.g. black mudfish).
- Loss of natural character (i.e. the natural appearance of wetlands in the landscape) due to habitat alteration.

- Fires. Wetlands are much smaller than they used to be, and a single uncontrolled fire has the potential to burn either a significant proportion, or an entire wetland. Although fires may ensure the survival of species that depend on them (e.g. the swamp helmet orchid), they may also promote the establishment of exotic plant species. In high fertility areas these can dominate the native plants and prevent the regeneration process.

- Careless recreation practices (including hunting, kayaking etc) which disturb plant and animal life and which may destroy parts of the physical wetland environment.

Weed invasion and human pressures arising from land-use changes and intensification are arguably the greatest threats to wetland ecosystems in the Waikato region. Management practices that improve surrounding land management, protect wetland areas and enhance linkages between other wetlands, lakes and rivers, are vital to ensuring these ecosystems do not deteriorate further.

6.1.2 References

Barnes, G. (2003); **Opuatia Wetland Monitoring Plan**. EWDOCS#814676

Browne, K and Campbell, D. (2005) **Ecohydrological Characterisation of Opuatia Wetland and Recommendations for Future Management**. Environment Waikato Technical Report TR05/17.

Champion, P. (1998); **An overview of the Lower Waikato/Hauraki Plains Wetlands Issues Relating to their Management.** National Institute of Water and Atmospheric Research (NIWA) Consultancy Report DOC80216

Cromarty. P and D.A. Scott (eds.) (1995); **A Directoy of Wetlands in New Zealand.** Department of Conservation, Wellington. 395 pp.

Denyer, K (2007); **Area of Vegetation Type in each Territorial Authority and protected in QEII Covenants in the Waikato Region**. EWDOCS# 1147154

Hitchmough, R., Bull, L., and Cromarty, P. (compilers) (2007); **New Zealand Threat Classification System Lists.** Science & Technical Publications, Department of Conservation. 194 pp.

Leathwick, J., Clarkson, B.D., and Whaley, P.T. (1995); **Vegetation of the Waikato Region: Current and Historical Perspectives.** Landcare Research Contract Report LC9596/022.

Reeves, P and Wells, R. (2008).; **Pulling the plug to create wetland habitat.** Presentation at “Wai Wetlands”. The National Wetlands Trust Symposium 2008.

7 Shallow lakes

7.1 Introduction

This report outlines the health of lakes in the Waikato River catchment below the outfall of Lake Taupo. Many of the lakes have direct (albeit artificially managed) hydrological connections with the main stem of the Waikato and Waipa Rivers whereas a small number are more isolated. The lakes have been greatly impacted by historical land clearance and past and current land uses, with significant impacts on water quality and ecology in all the lakes. This report outlines the state of the lakes as assessed using biological indicators and identifies the main pressures on the lakes.

7.2 State

In the Waikato River catchment below the outflow of Lake Taupo there are 46 lakes listed in the Environment Waikato database (Table 7). This excludes artificial lakes such as hydro lakes and Lake Weavers in Huntly.

Of these, 28 lakes (19 peat lakes and 9 riverine lakes) have been surveyed using a lake health indicator called LakeSPI (Lake Submerged Plant Indicator) developed by NIWA as a means of detecting changes in lake condition by assessing the health, extent and composition of submerged plant communities. Three lakes (Rotopiko North, South and East) are classed as excellent or close to pristine, 3 are classed as satisfactory but with impacted vegetation or weed invasion (Kainui, Mangakaware and Rotoroa), and 22 are classed as unsatisfactory being totally or predominately devegetated. All nine riverine lakes are considered unsatisfactory (Edwards *et al*, 2007).

Environment Waikato has set minimum lake levels for 15 vulnerable shallow lakes within the catchment through the Waikato Regional Plan. A further 10 lakes are listed as priorities for setting minimum levels and timeframes have been set for installing structures to protect these.

7.3 Pressures

Water quality pressures on surface waters in the catchment are referred to more fully in the water quality report. Generally it is poor water clarity due to high concentrations of algae (resulting from high nutrient loads), and the presence of exotic fish species that has led to the decline and collapse of submerged plant communities in lakes. These same factors hinder attempts to re-establish plants in lakes where they have disappeared. The inability to return aquatic plants to many lakes is a major impediment to lake restoration activities.

We have records of exotic fish species from 23 of the 46 lakes identified. Species recorded are catfish (21 lakes), goldfish (20 lakes), gambusia (14 lakes), rudd (9 lakes), koi carp (9 lakes), and tench (1 lake). However, these records are incomplete and underestimate the magnitude of the problem of exotic fish species in Waikato lakes. Ecological impacts of exotic fish have also been discussed in the paper on Ecology and Biodiversity of the Waikato River and its Tributaries.

In summary, key issues for the health of regional lakes are:

- intensive land use in lake catchments and ongoing nutrient and sediment inputs,
- loss of depth due to the impacts of drainage activities,
- lack of fencing of some lakes and their tributaries to exclude stock,
- impacts of pest fish - particularly koi carp,
- invasive weed species - terrestrial and aquatic

Table 7: Biological health of lakes within the Waikato River catchment and Waipa River catchment (south of Puniu). Empty fields indicate that survey work has not been carried out at the site

Lake name	LakeSPI	Pest fish recorded
Henderson Pond		
Lake Areare	Unsatisfactory	Y
Lake Cameron		
Lake Hakanoa	Unsatisfactory	Y
Lake Hotoananga	Unsatisfactory	Y
Lake Kainui	Satisfactory	Y
Lake Kaituna	Unsatisfactory	Y
Lake Kimihia	Unsatisfactory	Y
Lake Komakorau		Y
Lake Kopuera		Y
Lake Koromatua	Unsatisfactory	
Lake Mangakaware	Satisfactory	
Lake Mangahia	Unsatisfactory	
Lake Maratoto		
Lake Milicich		
Lake Ngaroto	Unsatisfactory	Y
Lake Ngarotoiti		
Lake Ohinewai	Unsatisfactory	
Lake Okowhao	Unsatisfactory	Y
Lake Pataka	Unsatisfactory	
Lake Pikopiko		Y
Lake Posa	Unsatisfactory	
Lake Rotokaeo (Forest lake)		
Lake Rotokaraka		
Lake Rotokauri	Unsatisfactory	Y
Lake Rotokawau	Unsatisfactory	Y
Lake Rotomanuka North	Unsatisfactory	Y
Lake Rotomanuka South		Y
Lake Rotongaro	Unsatisfactory	Y
Lake Rotongaroiti	Unsatisfactory	
Lake Rotongata		
Lake Rotopiko East	Excellent	Y
Lake Rotopiko North	Excellent	Y
Lake Rotopiko South	Excellent	Y
Lake Rotopataka		
Lake Rotoroa	Satisfactory	Y
Lake Ruatuna	Unsatisfactory	
Lake Te Kapa		
Lake Te Koutu		
Lake Tunawhakapeka	Unsatisfactory	
Lake Waahi	Unsatisfactory	Y
Lake Waikare	Unsatisfactory	Y
Lake Waiwhakareke (Horseshoe lake)		
Lake Waiwhata		
Lake Whakatangi		
Lake Whangape	Unsatisfactory	Y

7.4 References

Edwards, T., Clayton, J. and de Winton, M. 2007. The condition of 41 lakes in the Waikato Region using LakeSPI. Environment Waikato Technical Report 2007/35.

8 Operational river and catchment management

8.1 Background

The Waikato River system, like many of our region's rivers, has changed dramatically since European settlement due to human modification of the river system. The Waikato River system has been dammed, had water extracted and diverted, and has had extensive land use changes and impacts. In the upper reaches of the system, many catchment areas have been greatly modified. Much of the native vegetation that once slowed the flow of water from hillsides and helped to hold hillsides together has been cleared for agriculture, forestry and urban development. In the lower reaches, river modification has had significant adverse effects on the Waikato River system by altering the way in which the river and its flood plains naturally operate.

Whilst river and catchment modification has led to increased use of land for rural and urban economic development and a reduction in local flood hazard risks, it has also contributed to increased flooding and erosion. Flooding and erosion threatens people and property, infrastructure and limits land productivity. River modification has not eliminated flood risks, and in some cases has encouraged intensification of urban development within flood prone areas.

The hydrology of the Waikato River System could be best described as a complex, modified system due human use – especially the existence of hydroelectric dams and changes to land use.

8.2 Environment Waikato activities

Environment Waikato undertakes a range of river and catchment activities in the Waikato River system to meet statutory responsibilities for erosion control, river management and flood protection and management. Much of this activity is associated with ongoing commitments made to communities regarding levels of flood protection and standards of service.

Many of the activities are associated with the ongoing management and maintenance of existing schemes and assets. However, commitments have been made to continue to carry out new protection measures where this has been sought by communities.

8.3 River and catchment management assets

Table 8 shows and overview of the approximate number of river and catchment assets in the area of interest to the Guardians Establishment Committee.

Table 8: Outline of River and Catchment Assets managed by Environment Waikato

Asset Type	Total length/ number
Floodgates	200
Pump stations	80
Stopbanks	400km
Drains	1,500 km
Main Channel	458 km
Tributaries	600 km

Land retired for soil conservation under Land Improvement Agreements	8,200 ha
Soil Conservation Planting Compartments	4,327
Soil Conservation Fencing	2000 km

The replacement value of river and catchment assets managed by Environment Waikato over this part of the Waikato River system is approximately $300 million. This value is distributed over 16,000 individual assets including pump stations, stopbanks and flood gates.

Annual expenditure for 2007/2008 for this section of the Waikato River system is $6.1 million. Most of this expenditure relates to the management and maintenance of existing protection measures. In some areas, there is a demand for new or additional work programmes. Separate capital expenditure is allocated to the construction of new work.

8.4 Core activities

The activities undertaken in the delivery of river and catchment services include the following:

8.4.1 Information and advice

Involves response to enquiries and provision of advice and information on river and catchment issues across the catchment. Also includes monitoring programmes to assess environmental impacts of the works being undertaken.

8.4.2 Catchment works

Land throughout the region is susceptible to soil erosion. Typical soil erosion control measures (soil conservation) promoted by Environment Waikato with landowners include:

- retirement of erosion prone land by fencing and planting
- riparian protection
- sediment and debris detention
- installation of erosion control structures
- promotion of sustainable land use practices.

For most historic catchment works, Land Improvement Agreements are in place and registered against the property title. These are agreement between Environment Waikato and the property owner. Currently 1000 such agreements are in place across the region.

8.4.3 River management

Typical river management works managed by Environment Waikato include:

- controlling bank erosion (by planting and fencing off river banks, construction of rock or other bank revetment works or construction of groynes)
- removing blockages
- river training works (ensuring the flow paths of rivers are stable and optimum channel widths are maintained)
- gravel and sand management.

Flood protection

Environment Waikato is responsible for maintaining major flood protection schemes throughout the Waikato region. Some of these areas are managed with district councils. Typical flood protection works managed by Environment Waikato:

- stopbanks and floodways
- pump stations
- floodgates
- detention dams.

A large scale flood protection scheme known as the Lower Waikato-Waipa Scheme is in place for the Waikato River. In the lower Waikato, 17,200ha of land is directly protected from flooding by the scheme with a further 16,500ha receiving benefit from the improvements made. Such areas are dependent on the effective ongoing management of both the scheme and river systems and on the management of the wider catchment.

8.4.4 Land drainage

Environment Waikato is responsible for maintaining nine land drainage schemes in the region. These works are aimed at ensuring efficient and stable drainage systems, which function to effectively maintain optimum groundwater levels and drain surface runoff. Rural land drainage services are provided in the following areas:

- Aka Aka/Otaua
- Waikato North
  - Eureka
  - Taupiri
  - Te Rapa
- Waikato South
  - Fencourt
  - Hautapu
  - Rotomanuka
  - Ohaupo/Ngaroto

8.4.5 Clean Streams

Environment Waikato also implements a water quality protection project known as Clean Streams. It is a 10-year project introduced in 2002 that grants funds to farmers to fence waterways to restrict stock access to natural water bodies.

8.5 Pressures

River systems across the region, including the Waikato River system, are subject to a wide range of pressures. The primary pressures are outlined as follows:

8.5.1 Increased frequency and intensity of rainfall

The frequency and intensity of severe weather events are likely to increase owing to climate change. This not only intensifies the direct impacts of flooding by raising flood flows and levels, but alters the nature of natural river systems by increasing erosion and sedimentation. The impacts of intense storm events will also be exacerbated by land use changes in the catchments – particularly by large scale land clearance such as that occurring in the Upper Waikato. Predicted rises in sea level will also have an impact on river flooding in coastal areas through increased flood levels and changes to the functioning of natural systems in their lower reaches.

8.5.2 Land use change

Rivers and catchments change naturally over time, but these changes can be accelerated greatly by human intervention. Land use changes in the Waikato River system are primarily a result of two pressures.

1. Deforestation in the Upper Waikato river system: this is likely to increase the quantity and speed of flood flows, and these changes are likely to accelerate over time. The combination of ongoing deforestation and increased river flows have impacts throughout the river system in terms of managing high flow levels and

increasing flood levels in the lower river system, which crosses several district council areas and many communities.

2. Development pressure in river flood hazard areas: there is increasing demand for development of flood-prone land in the lower reaches of the Waikato River system, driven by a combination of increasing population and a management framework that does not always consider broad system effects.

8.5.3 Increased flood management expectations from communities

An increase in population, coupled with changing economic uses of land, will exacerbate the risk to communities from flood hazards. It is recognised that there are significant costs involved in preventing floods from affecting properties and that there are significant economic and social costs after floods have impacted on communities. However, there is an ongoing expectation and demand for better protection. In some instances, the community expectations for flood protection will not be able to be met at a practical or affordable level. Communities and individuals do not always understand the risk from river flood hazards they are subject to, nor do they necessarily understand the residual risks associated with flood protection or mitigation activities.

8.5.4 Management of the impacts of increased flooding and erosion

There is an increased need to manage specific issues arising from increased flooding and erosion across the Waikato River system. These issues include:

- High flow management of the hydro lakes in the middle reaches
- River stability below the Karapiro hydro dam
- Flood hazard identification, assessment and long-term planning provisions for the Lower Waikato.

8.6 Central Government review of flood risk management

In 2005, Central Government reviewed flood risk management following floods in 2004 in the Manawatu-Wanganui and Bay of Plenty regions. Local government supported the review by developing a draft New Zealand Standard for flood risk management. The directions of the Central Government review and New Zealand Standard will influence river and catchment management, particularly:

- recognition of natural river and catchment processes as non-negotiable constraints on river modifications
- the interaction of natural and social systems, under the emerging umbrella of sustainability – floodplain management
- context-based decision-making
- continuing community engagement
- recognition of the need to consider all appropriate forms and levels of protection
- the recognition and treatment of residual risks
- the need for adaptive management principles, including cumulative effects.

Appendices

Appendix 1 – Plant and animal pests

Biological pests in the Waikato River catchment

Pest species, be they aquatic or terrestrial, or weed, fish or animal, occur throughout the Waikato River catchment. Current and future pests endanger ecosystem functions, cultural values, human health and economic productivity. This report summarises the general state of both plant and animal pests in the Waikato River catchment, with an emphasis on environmental pests. The general issues of pests in the catchment and their potential impacts on river health are outlined here, with examples of several existing pests that are of considerable concern for the Waikato River catchment (summarised from Environment Waikato's Regional Pest Management Strategy). The pressures affecting pest distribution and impacts are also noted.

State

Key issues affected by introduced pest species are:

- biodiversity, and natural and cultural heritage
- soil stability and river management
- public health and amenity.

Biodiversity

Biological diversity (biodiversity) refers to the myriad of living organisms and their natural systems that are indigenous to New Zealand. Biodiversity is also important for natural ecosystem functioning. These values are celebrated as taonga and important elements of cultural heritage in the Waikato River catchment.

Exotic organisms have invaded the Waikato catchment and displaced or interfered with indigenous species or ecosystems. The result is disturbed and depleted ecosystems or possibly even local extinction of individual species. Habitat loss and destruction by introduced pests are the two main reasons for the continuing loss of native biodiversity in New Zealand.

Specific issues in the Waikato region are:

- introduced pests have become established in all of our mainland forests
- wetland systems continue to be modified by invading pests
- the spawning of native fish in river mouths and estuaries is compromised by pest fish and weed invasion (as well as other land use pressures referred to in other reports)
- access to the region's waterways, wetlands and lakes is under threat due to invasion of plant pests (e.g. gorse and blackberry) along their boundaries
- many lakes have lost their indigenous submerged plant communities to aggressive invasive species. In most of the region's shallow lakes the exotic species have collapsed, contributing to a decline in water quality
- land cultivation adjacent to geothermal features has allowed invasion by pines, blackberry and other weeds to the detriment of the natural geothermal vegetation.

Health and amenity

The effects of pests on health and the amenity of the natural environment can include:

- the spread of disease
- effects on outdoor recreational pursuits
- physical impediments to access caused by species such as blackberry or gorse
- interference with the enjoyment of water bodies, caused by aquatic weeds preventing swimming, boating or fishing.
- detrimental impacts on landscape values by pest infestations and invasions

Important pests affecting the Waikato River catchment

The Regional Pest Management Strategy identifies the priority pests in the Waikato Region. Some of the important pests that are relevant to the Waikato River catchment are:

Pest plants

Alligator weed (*Alternanthera philoxeroides*) which is present in the lower Waikato River, Waipa District and Hamilton City environs. Alligator weed forms extensive floating mats that extend out from the banks of rivers or drains and effectively cover the water surface. This restricts water flow, increases sedimentation, aggravates flooding and has the potential to spread to high value conservation areas. The weed can also affect recreational access (boating/fishing) and affect whitebait breeding areas.

Yellow flag iris *(Iris pseudacorus*) is most prolific in the lower reaches of the Waikato River catchment (particularly downstream of Ngaruawahia) where it inhabits the margins of lakes, rivers or drains. Yellow flag iris forms dense stands that can displace native species and restrict access for recreational activities.

Grey and crack willow (*Salix cinerea and Salix fragilis*) occur throughout the Waikato River catchment. The species propagate readily and can replace native species in wetlands and form vast dense stands and thickets. They also cause blockages, flooding and structural change in waterways, which leads to erosion and increased sedimentation.

Woolly nightshade (*Solanum mauritianum*) is most prevalent in the lower Waikato River catchment. It is a terrestrial plant species that threatens biodiversity on land by completely excluding native vegetation.

Cathedral bells (*Cobaea scandens*) occurs in several sites in the middle reaches of the Waikato River catchment, mainly around Hamilton City and Karapiro. It is a terrestrial plant species that threatens biodiversity on land.

California bullrush (*Schoenoplectus californicus*) is a tall riparian sedge that is confined currently to the Waikato River delta area and threatens to displace other riparian vegetation.

Pest fish

There are several pest fish species that directly threaten the ecology and biodiversity of the Waikato River and other water bodies in the catchment by directly affecting other fish, animal and vegetation, or through their adverse effects on water quality.

Brown bullhead catfish (*A. nebulous*) is widespread throughout the Waikato River system, including Lake Taupo. It is a predator and scavenger and eats many native species of fish and invertebrates. It could also affect trout in New Zealand. It can survive for long periods out of water and so can be transferred to new areas easily, both intentionally and accidentally (on boat trailers, for example).

Koi carp (*Cyprinus carpio*) were introduced to New Zealand as ornamental fish, but they now breed in natural waterways. Koi carp pose a significant threat to water bodies in the Waikato River catchment by uprooting water plants, lowering water quality and eating insects and young indigenous fish and eels. There are currently no adequate methods for controlling koi carp in rivers, though their numbers may be controlled in small, closed water bodies. Koi carp are found throughout the Waikato River downstream from Karapiro Dam and in lower reaches of the Waipa River.

Gambusia (*Gambusia affinis*) are small fish introduced to New Zealand in the 1930s to control mosquito larvae. However, they have proved to be ineffective in the control of mosquito and instead have become pests. Gambusia are aggressive predators that attack native fish by nipping at their fins and eyes and prey on their eggs. Whitebait and mudfish species are especially vulnerable to gambusia as they share similar habitats. This pest is widespread in the Waikato River catchment in the shallow margins of slow flowing ponds, wetlands and streams, especially around aquatic plants. Gambusia habitat overlaps with several native fish species: inanga (*Galaxias maculatus*), smelt (*Retropinna retropinna*) and the common bully (*Gobiomorphus cotidianus*). Of particular concern is a reduction of inanga populations as this impacts whitebait fisheries.

Wild goldfish (*Carassius auratus*) are numerous and widespread in natural water bodies in the Waikato River catchment and in many cases much more numerous than koi carp. The fish are omnivorous, feeding on plant material, organic detritus and small insects and crustaceans. Wild goldfish are prolific breeders and have the capacity to out-compete native fish species and other aquatic life such as water snails and aquatic plants, leading to highly degraded freshwater environments. Recent research has shown that growth of cyanobacteria (blue-green algae) is stimulated by passage through goldfish intestines, thereby potentially contributing to algal blooms.

Pest animals

Terrestrial pest animals threaten the health of waterways in the Waikato River catchment through their effects on land vegetation cover, which in turn affects erosion and runoff and the amount of faecal contaminants entering the water system. The main pest species are possums, feral goats, rats, mustelids (ferrets, stoats and weasels), wild deer and feral pigs.

Some of the animals referred to above are valued for recreational hunting or as food supplies. In most cases, these animals only become an environmental threat at high densities or when very vulnerable resources are endangered.

Pressures

Many pests directly affect the health of the Waikato River and its catchment. It is difficult to rank the seriousness of individual pests because they all contribute to overlapping problems. For example, water quality is diminished both by pest fish stirring up river sediments and feral goats increasing sediment loads to the river.

One of the greatest threats to the health of waterways comes from pest fish, which directly compete with or feed on native species. The risk of pest fish spreading through illegal introductions or accidental transfers is considerable. For example, koi carp do not appear to be established above Lake Karaprio Dam – they would threaten water quality upstream considerably if they did so.

Aquatic weeds are also of considerable concern. They out compete native species which can undermine the entire aquatic community and reduce water quality. These weeds are often spread inadvertently, a risk enhanced by the large numbers of recreational boats in the region.

Terrestrial weeds impact on terrestrial biodiversity by crowding out native plants and reducing native food sources for native animals. Many weeds spread from home gardens and inappropriate disposal of waste and clippings. Earthmoving machinery and land subdivision also presents a major risk.

Animal pests indirectly affect health of waterways through impact on land cover and subsequent erosion. They also damage some native species (invertebrates, birds,

reptiles) through direct predation. For example, ship rats can reduce tui nest success to less than 25 percent. High numbers of animals such as possums and goats can also increase faecal contamination in water. For example, 1300 possums were trapped in one 167ha water supply area.

One critical issue for the future is the progressive decline in Animal Health Board funding for possum control in the region. This funding, primarily directed at eliminating bovine Tb, has had significant side benefits for biodiversity. In line with the success of the programme, large areas currently funded in this manner will no longer be a priority for the Animal Health Board. It is important that the positive gains made through these works (including those to biodiversity) are maintained. Over the next five years Animal Health Board Tb vector control is expected to cease on 502,300 hectares of land, most of which is in the Waikato River catchment.

Appendix 2 – Recreational use of the Waikato River

Introduction

The Waikato River and tributaries are popular recreation areas in the Waikato. There are a few locations under significant pressure that require management. For example, Lake Karapario throughout the year, Lake Arapuni, Waikato River through Hamilton City and Mercer to the Mouth through some of the summer period.

To that end, these high use areas require rules to separate incompatible and personnel to ensure public safety in high use areas. The use of the river and tributaries is discussed in the following sections from a navigational safety perspective.

Huka Falls to Aratiatia

This short stretch of river is attractive to recreational users because the water is clear and clean. Commercial use includes Huka jets operating a tourist venture and a floating restaurant paddle boat on Aratiatia. Few private vessels use this area of the river. It is also a popular area for canoeists year round.

Aratiatia to Lake Ohakuri

Lake Ohakuri has become more popular with the public, especially over the summer period. It is used for skiing, wake boarding, trout fishing and canoeing. A commercial camp at Orakei korako caters to people using the waterway. A commercial ferry takes people across the river to the geothermal area. A company, River Jet, operates tours from its base at Mihi Bridge. Two new boat ramps have been opened recently, increasing access to the lake.

Lakes Atiamuri, Whakamaru, Maraetai and Waipapa

These lakes are small and unable to cater for many users at any one time. Greatest use is made by locals during summer weekends. Canoeing and fishing occur year round. At Whakamaru members of the ski club use the lake most weekends. Lake Maraetai is becoming more popular as Mangakino develops. Lake Maraetai is now recognised as an alternate venue to Karapiro for national events such as the North Island wake boarding championships and the Grand Prix boat racing. Commercial ski and wake boarding operations are proposed at the lake. Lake Waipapa is mostly used for fishing and canoeing.

Lake Arapuni

Lake Arapuni is used for skiing, fishing and canoeing. It is relatively close to Hamilton, Cambridge and Tokoroa and is well used at weekends. Use of Arapuni is increasing as Karapiro becomes busier or is closed due to organised sporting events. Lake Arapuni is popular for skiing, wake boarding, canoeing and trout fishing. During summer weekends Arapuni reaches capacity for recreational use.

Lake Karapiro

Lake Karapiro is the busiest stretch of the Waikato River. Many rowing, skiing and sailing clubs are located at Karapiro. The lake is used for international events including the World Rowing championships (2010), and for high performance training for rowing, skiing, wakeboarding and waka ama. Parts of the lake are closed most weeks and weekends for organised sports events. About 36 applications for temporary events are received each year. There are two Christian Camps located at the head of the lake that host groups throughout the year and make full use of the lake. Several commercial activities are based on the lake including the Karapiro Cruiser and two house boats. Recently jet skis and wake board vessels have become a problem for other users on the lake.

Karapiro to Hamilton City

The stretch of river through Hamilton City is heavily used by rowing clubs in the morning and after work or school. During summer there are ski boats on the river at weekends and after work. More canoeists are using this section for training. School trips are becoming more common as part of student confidence courses. During the summer weekends people often float along the river on inner tubes. The Waipa Delta is a nationally recognised commercial paddle steamer that caters for locals and tourists throughout the year. Illegal skiing through the city part of the river is endangering other users.

Hamilton City to Huntly

Use at the northern end of Hamilton City (Pukete ramp) is increasing for skiing, wakeboarding and jet skiing. The Bridge to Bridge Classic ski race also uses this section of the river. Tainui make extensive use of the river at Ngaruawahia. A ski club is also located at Ngaruawahia.

Huntly to Mercer

Light use is made of this reach of river, mainly skiing and canoeing. More use is made of the river during the duck shooting season. There is also some commercial eeling through this stretch.

Mercer to the river mouth

The rowing clubs based at Mercer use this area for summer rowing camps, weekend training and regattas. Skiing is also popular on this reach (Tuakau Bridge ramp and Elbow ramp) during the weekends. Use is increasing as more people from South Auckland travel south for water sports and recreations. Areas have been set aside for skiing, rowing and jet skis. A significant increase in use is obvious during the duck shooting and white baiting seasons. Near the river mouth fishing, windsurfing, kite boarding and canoeing are popular. The Port Waikato Yacht Club and the Port Waikato Fishing Club launch their boats in the river estuary.

Waipa River

The Waipa River is mostly used for canoeing because boat access is limited. Skiing occurs in its lower reaches with boats launched from Ngaruawahia.

Lakes Waikare, Whangape, Waahi and Weavers

These lakes have some fishing for mullet, carp and eels. There is limited water skiing and windsurfing. Recreational use is mainly by locals during the weekend. Access to Lake Weavers for water skiing is controlled by a key system.

Appendix 3 – Consents and permitted activities in the Waikato River

Consents

The following table identifies the number of consents (includes current authorisations and applications but excludes expired consents) in the area of interest to the Guardians Establishment Committee.

Consent type	Number
Surface water takes	279
Ground water takes	263
Discharges direct to waterways	605
Discharges to land	345
Dams/Diversions	252
Total	**1,745***

*Note 1: This number excludes bore permits which are granted on a short term basis (the duration of most of these consents is less than three months).
*Note 2: Excludes all other subtypes of consents within the database, such as consents for structures.

Consents for taking surface water authorise volumes in the range of 22 to 155,000 cubic metres per day. Consents for taking ground water range from 17 to 35,000 cubic metres per day. Discharges to water range from 4 up to 310,000 cubic metres per day and comprise a wide range of activities. In these consents, Environment Waikato is more likely to specify daily, seasonal and annual requirements than maximum daily volumes. Maximum volumes are specified for some consents based on projected growth (e.g. municipal infrastructure) or seasonal use (e.g. irrigators).

There are many dams in the Waikato catchment ranging in size from small storage dams on private land up to the large hydro dams.

Several consents to take water from the Waikato River are 'non-consumptive or partially consumptive'. Huntly Power Station is one example, discharging directly back into the Waikato River 98.5% of the water it takes to cool the plant.

Permitted activities

As well as consented activities, the Waikato Regional Plan permits a number of activities in the catchment that do not require resource consent from the regional council. An example of these are discharges to land from farm dairies, fertiliser use, vegetation clearance or whitebait stands, provided they meet the relevant conditions.

Other permitted activities include the rights to take surface and ground water for an individual's reasonable domestic needs or the reasonable needs of an individual's animals for drinking water (under s14(3)(b) of the Resource Management Act). We have no information on the amount of water used under these provisions.