A RESOURCE INVENTORY FOR THE RUAMAHANGA CATCHMENT, WAIRARAPA, NEW ZEALAND

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Abstract

Currently, there is concern around various water management issues in the Ruamahanga Catchment, Wairarapa. This concern has prompted discussion among the stakeholders of the catchment about implementing an Integrated Catchment Management (ICM) Plan in the area. A prerequist of an ICM plan is to have a detailed resource inventory that documents the current state of the catchment, the level and areas of research already carried out in the catchment, and the specific problems occurring in the catchment. This report constitutes the Resource Inventory for the Ruamahanga Catchment and will serve as a discussion document that can be used by the stakeholders to implement an ICM plan.

This Inventory organises information under twelve topic headings that range from land and climate, water resources and land use, to freshwater ecology and public perceptions on the state of the water resources in the catchment.

Significant issues indentified in the catchment include; deteorating water quality in the Ruamahanga River as it flows southwards; a significant increase (~14,000 kg/year) in dissolved reactive phosphorus (DRP) loading in the Ruamahanga River segment between Te Ore Ore and Gladstone, which in most part, is a result of the Masterton Sewage Treatment Plant discharge; unsatisfactory bathing water quality at some sites on the Ruamahanga River; a lower diversity of freshwater species than the rest of the Wellington Region; current and future land use intensification which is leading to increasing demands for water; and fully allocated surface water zones and groundwater aquifers.

Recommendations are provided on how to improve the quality of data in this inventory, and also on how to proceed in the future with the findings of this report in mind. Faced with similar water quality issues as the Manawatu Catchment, stakeholders of the Ruamahanga Catchment should be aware of the outcomes of Horizon Regional Council's One Plan, and observe any success and failures of the One Plan when implementing an ICM Plan in the future.

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Abbreviations

ANOVA	Analysis of Variance
asl	Above sea level
BOD$_5$	Biochemical Oxygen Demand
CDC	Carterton District Council
CHI	Cultural Health Index
CINZAS	Central Index of New Zealand Archaeological Sites
CliDB	National Climate Database
CMS	Conservation Management Strategy
Cumecs	Cubic metres per second
DEV	Daily Effluent Volumes
DO	Dissolved Oxygen
DoC	Department of Conservation
DCDC	Digital Cadastral Database
DRP	Dissolved Reactive Phosphorus
DSIR	Department of Scientific and Industrial Research
E.Coli	*Escherichia coli*
ED	Ecological District
ENSO	El Nino – Southern Oscillation
ER	Ecological Regions
FC	Faecal Coliforms
FFNZ	Federated Farmers New Zealand
GWRC	Greater Wellington Regional Council
GWSOE	Groundwater State of Environment Monitoring
GV	Guideline Value
HCA	Hierarchical Cluster Analysis
IBI	Index of Biotic Integrity
IGNS	Institute of Geological and Nuclear Sciences
IPO	Interdecadal Pacific Oscillation
LCDB	Land Cover Database
LINZ	Land Information New Zealand
LRI	Land Resource Inventory
LUC	Land use capability
LWDS	Lower Wairarapa Development Scheme
LWW	Lake Wairarapa Wetlands
MAF	Ministry of Agriculture and Forestry
MALF	Mean Annual Low Flow
MAV	Maximum Acceptable Value
MCI	Macroinvertebrate Community Index
MDC	Masterton District Council
MfE	Ministry for the Environment
Mn	Manganese
MSRL	Maximum Species Richness Line
N	Nitrogen

NGMP	National Groundwater Monitoring Program
NH_4-N	Ammoniacal Nitrogen
NIWA	National Institute for Water and Atmospheric Research
NNN	Nitrate-Nitrite Nitrogen
NO_3-N	Nitrate Nitrogen
NO_2-N	Nitrite Nitrogen
NRWQN	National Rivers Water Quality Network
NSD	National Soils Database
NTU	Nephelometric Turbidity Unit
NZAA	New Zealand Archeological Association
NZBS	New Zealand Biodiversity Strategy
NZFFD	New Zealand Freshwater Fish Database
NZHPT	New Zealand Historic Places Trust
NZLRI	New Zealand Land Resource Inventory
NZSC	New Zealand Soil Classification
P	Phosphorus
RAP	Recommended Areas for Protection
REC	River Environment Classification
RMA	Resource Management Act (1991)
RPS	Regional Policy Statement
RSoE	River State of Environment
SO_4^{2-}	Sulphate
SQMCI	Semi-Quantitative Macroinvertebrate Community Index
SWDC	South Wairarapa District Council
TA	Territorial Authority
TDS	Total Dissolved Solids
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
WELA	Wairarapa Engineering Lifelines Association
WRIT	Wairarapa Regional Irrigation Trust
WWD	Wairarapa Wetlands Database
Zn	Zinc
%EPA	% Ephemeroptera, Plecoptera and Trichoptera Taxa

ha	Hectare
L/s	Litres per second
m^3/day	cubic metres per day
m^3/s	cumecs
L/s/km^2	litres per second per square kilometer
Ma	Million years ago
ka	Thousand years ago

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1. Introduction

1.1. PROBLEM STATEMENT

Recently there has been an increasing interest by the stakeholders in the Ruamahanga Catchment in the feasibility of implementing an Integrated Catchment Management (ICM) Plan. Stakeholder meetings have generated much discussion but also uncertainty about the current state of the catchment, the level and areas of research carried out in the catchment, and the specific problems occurring in the catchment.

1.2. AIM

The aim of this research is to compile a resource inventory for the Ruamahanga Catchment, Wairarapa. This resource inventory will reveal the *'status quo'* of the Ruamahanga Catchment, focusing mainly on the water resources in addition to other physical, economic, social and cultural assets. This inventory will highlight previous research carried out in catchment, and indicate areas which require further investigation. Ultimately this inventory will form a discussion document that could be used by the stakeholders to implement an ICM plan.

1.3. OBJECTIVES

1. To compile a resource inventory for the Ruamahanga Catchment based on the framework provided in the proposal.
2. Determine the 'status quo' of the catchment,
3. Outline previous research pertaining to this area, and also national databases and resources that can also contribute information.
4. To effectively display visual and spatial data using Geographic Information Systems (GIS).
5. Provide recommendations for actions that should be taken in the future, based on the conclusions of this inventory.

1.4. IMPORTANCE OF RESEARCH

This resource inventory will form a discussion document that could be used by the stakeholders in the Ruamahanga Catchment to implement an ICM plan.

1.5. LIMITATIONS OF RESEARCH

Limitations included: reliance on the quality of research that had already been done, since this inventory was effectively a compilation of other researchers work; outdated databases and publications (AgriBase, DoC CMS); and insufficient time to effectively review the relationship of the Tangata Whenua in Wairarapa to the water resources. Section 16.2 provides further details on the information gaps and limitations indentified in this research.

1.6. OUTLINE OF THESIS

This thesis is structured into 17 chapters; the coverage of these is outlined below.

1. Introduction

The introduction provides a brief background to the research. It outlines the problem statement, aim, objectives, importance and limitations of research.

2. Literature Review

The literature review in this report is an extension of the document entitled 'A proposal for a Resource Inventory for the Ruamahanga Catchment, Wairarapa, New Zealand' (Chrystall, 2006). However, in this report only five resource inventories are discussed, focusing on the topic categories that have been included in them, and using the trends established in these examples to provide the topic framework for the Ruamahanga Catchment Resource Inventory.

3. Methodology

The 'overall' methodology for the inventory is outlined in this section. This chapter is brief as many of the individual chapters contain their own methodologies.

4. Introduction to the Ruamahanga Catchment

This chapter introduces the Ruamahanga Catchment in terms of location and physical characteristics, the historical and development aspects, the socio-economic profile, statutory framework and land tenure.

5. Land

This chapter provides an in-depth review of the physical characteristics in the catchment, including physiography, geology, soils, erosion, vegetation, ecological districts, and infrastructure, and introduces the data sources which provide information on these topics.

6. Climate

The climate of the Ruamahanga Catchment is described according to three main elements: temperature, rainfall and wind. Impacts of these elements on the water resources in the catchment are reviewed.

7. Water Quantity

An assessment on the quantity of fresh water in the catchment's rivers and streams, lakes, water races and aquifers is carried out in this chapter. The majority of the chapter focuses on the flows in the main tributaries using raw data from Greater Wellington Regional Council (GWRC) and modelled data (River Environment Classification) from the National Institute of Water and Atmospheric Research (NIWA).

8. Water Quality

The quality of the surface water and groundwater in the catchment is reviewed in this chapter. An analysis has been undertaken for nutrient loads and suspended sediment concentrations several of the rivers and streams, while groundwater and lake water quality has been assessed by using previous studies carried out by GWRC.

9. Land Use

This chapter introduces several national databases and resources that can be utilised in revealing the land use patterns in the Ruamahanga Catchment. The chapter is broken down into sections according to land use type, and connections are made with the type of land use and the pressure each type exerts on the environment. Land use change and forecasts are covered in the last part of the chapter.

10. Freshwater Ecology

The data sources providing useful information on freshwater ecology are documented in this chapter. The presence and absence of freshwater fish species is analysed, coupled with a section on macroinvertebrates. The number of fish species and the Index of Biotic Integrity (IBI) in the Ruamahanga Catchment was then compared with other catchments in the Wellington Region.

11. Natural Hazards

Historical floods and droughts that have impacted on the Ruamahanga Catchment are listed in this chapter, and the link between El Nino phenomenon and meteorological hazards is briefly examined. References on flood and drought prediction have been given.

12. Māori Culture

This chapter introduces the Tangata Whenua of Wairarapa, and then provides a generic relationship of Māori and freshwater resources.

13. Heritage

New Zealand's main heritage preservation organisations are listed in this chapter. The cultural and natural heritage sites in the Ruamahanga Catchment are then commented on, and sites that are threatened by flooding are identified.

14. Recreation

Water based recreational activities that occur in the catchment are listed in this chapter in addition to an inventory of the popular recreational sites. Sources of information are provided at the beginning of the chapter.

15. Public Perceptions

This chapter provides the overview of the public perceptions survey carried out with participants from each of the main stakeholder groups in the catchment. The chapter reveals the range of views that individuals hold about the state of the Ruamahanga Catchment, and comments they have on other issues.

16. Conclusions and Recommendations

The findings of this inventory and the information gaps and limitaions are outlined in this chapter in addition to two sets of recommendations. One set outlines steps that can be carried out to improve the quality of data in this report, and the second set suggests what actions should be taken in the Ruamahanga Catchment in the future, based on findings in this inventory.

2. Literature Review

2.1. INTRODUCTION

This chapter is an extension of the 'Proposal for a Resource Inventory for the Ruamahanga Catchment, Wairarapa' (Chrystall, 2006). A further assessment is made into the topic categories that should be included in the Ruamahanga Catchment Resource Inventory. The fundamentals of Integrated Catchment Management (ICM) will not be included in this chapter as they were adequately addressed in the literature review of the proposal. Furthermore, due the nature of this thesis, literature on each sub-topic (e.g. climate, land water quality etc.) is reviewed within each chapter.

2.2. REVIEW OF RESOURCE INVENTORIES

Resource inventories typically contain the same underlying categories: physical features and landforms, climate, soils, infiltration and runoff, stream flow, water quality, plant and animal communities, land use, social and economic systems, and valued features and activities (Heathcote, 1998).

However, what is ultimately included depends on two underlying factors. Firstly, the purpose for which the inventory is created, and secondly, the nature of the catchment. In regards to the former, the focus for the inventory may be on a single environmental issue in the catchment (e.g. water quality, water quantity, biodiversity or pest management) and only categories relating to that impact will be included. In regards to the latter, each individual catchment is unique and will include categories specific to that catchment.

Examples of seven international and seven national resource inventories (including some state of environment reports and catchment board inventories, which are not technically resource inventories), were analysed in Chrystall (2006). For the purposes of this review only the inventories compiled with the intention of using them in an ICM process are outlined below. In each case, the ICM inventories are analysed to see how the purpose of the inventory and nature of the catchment relates to the final scope of the inventory.

Apparent trends can then be applied to create the inventory framework for the Ruamahanga Catchment.

2.2.1. International

2.2.1.1. Darby Creek Watershed Inventory (State of Ohio, USA)

Purpose of the Inventory

The purpose of this inventory was to assist in the "development of an implementable community-based watershed plan to maintain and enhance the socio-economic and ecological health of the Darby Creek Watershed" (Darby Watershed, 2006, para 1).

Nature of the Catchment

Agriculture is the predominant land use in the Darby Creek Watershed, a large proportion of the waterways are designated as scenic rivers, and the rivers contain a large number of fish species, and rare and endangered mussel species (Darby Creek Watershed Joint Board of Supervisors & Darby Creek Watershed Planning Group, 2005). Furthermore, the catchment is threatened by the increasing pressures of urbanisation.

Type of Inventory

This inventory includes the basic watershed characteristics e.g. location, geology, soils, topography, climate, and water resources. Due to its purpose of enhancing socio-economic health it has included an in-depth chapter on land use, which provides residential and urban statistics and for its purpose of enhancing ecological health it has a chapter on vegetation, wildlife and invasive species, and a chapter on water quality. The scenic river qualities are addressed within the land use chapter, and fish and mussel species are outlined in the wildlife section.

2.2.1.2. Little Swanport Catchment Water Resources Information Package (Tasmania, Australia)

Purpose of the Inventory

To assist stakeholders and the Department of Primary Industries, Water and Environment in developing a Draft Water Management Plan for the catchment, by providing brief summaries of key water assessment and management topics.

Nature of the Catchment

Sheep and beef and forestry are the main land uses in the catchment. The catchment is sparsely populated, but the population base increases in the holiday periods.

Type of Inventory

As the purpose of this inventory is to assist in developing a water management plan, the scope of the contents is water based. There is less emphasis on the basic watershed characteristics e.g. soil, topography, and geology, and more emphasis on pure hydrology, water quality, freshwater ecology and water management.

2.2.1.3. Roaring Fork Watershed Inventory (State of Colorado, USA)

Purpose of the Inventory

The inventory was carried out to provide vital statistics and information on the Roaring Fork Watershed. It has less of an issue focus than most of the other inventories.

Nature of the Catchment

Almost 60 percent of the catchment area is undeveloped forest land, 34 percent is range land, and only 3.7 percent is used for agriculture. Most of the population and economic activities (dominantly tourism) are located around Aspen and Glenwood Springs (O'Keefe & Hoffmann, 2005).

Type of Inventory

Due to the broad purpose of this inventory, there is a wide array of topics included. These range from the basic catchment characteristics (climate, geology, soil, topography), to water resources, vegetation, fish, wildlife, land and water use, demographics, history, and water quality and water quantity concerns.

2.2.1.3. Tweed River Catchment (United Kingdom)

Purpose of the Inventory

The Tweed Forum hosts an interactive version of a resource inventory[1] on their website. The Forum's main objective is "to promote the wise and sustainable use of the whole of the Tweed catchment through holistic and integrated management and planning" (Tweed Forum, n.d., para. 2), and this interactive resource inventory is formed to assist in this objective.

Nature of the Catchment

The Tweed River is the second longest river in Scotland, and it is one of the least polluted rivers in the country due to it large size, rural character and small population base. The Tweed River is world famous as a salmon river and it was managed as such until the 1990s when a more integrated approach, covering additional activities, was adopted with the creation of the Tweed Forum (Tweed Forum, n.d.).

Type of Inventory

Due to the way this inventory is presented, the volume of information is smaller than what is found in other inventories. It includes sections on 'the river', 'the land', 'habitat and species', 'fish and fisheries' and 'recreation'. Links providing further information on particular topics are included in these sections. For example, a 'fishtweed' link gives detailed information on Tweed salmon fishing.

2.2.2. New Zealand

2.2.2.1 Motueka and Riwaka River Catchments (New Zealand)

Purpose of the Inventory

The Motueka and Riwaka River catchments feature a range of management issues that are common in most catchments and the intention is that lessons learned in the Motueka ICM

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[1] http://www.tweedforum.com/explore/

project will be transferable elsewhere. Therefore this inventory is a focus study, which "summarises the present state of knowledge of the catchments" (Basher, 2003, p.1).

Nature of the Catchment

The catchment features a low population density. Land use in the catchment comprises native bush; commercial forestry; and dry land pasture, berry crops, hops and fruit trees. The catchment boasts a world famous brown trout fishery and offshore in the Tasman Bay, scallops and mussels are commercially harvested (Basher, 2003).

Type of Inventory

This inventory includes the basic catchment characterisitics, a section on erosion and sedimentation, land use and vegetation, terrestrial wildlife, freshwater hydrology and water quality and freshwater ecology. Unique topics include marine hydrology and water quality, and coastal and marine ecology. These topics are as a result of the aquaculture dimension in this catchment. The inventory varies from those mentioned above as it provides a detailed list of all the information and data (metadata)[2] that is available for the catchment, and has separate chapters for the statutory framework for ICM and lists six major resource management issues occurring in the catchment.

2.3. RUAMAHANGA CATCHMENT RESOURCE INVENTORY

Purpose of the Inventory

The purpose of the Ruamahanga Catchment Resource Inventory is to describe the *status quo* of the Ruamahanga River and its tributaries. Therefore the main focus is primarily on water quality with a secondary focus on water quantity. Other environmental issues in the Ruamahanga River valley e.g. biodiversity, are not within the scope of this inventory.

Nature of the Catchment

The Ruamahanga Catchment is largely rural, with five small urban centres located on the river valley. Rural runoff and municipal wastewater are the two major contributors to degraded water quality in the catchment. Two lakes are present at the lower end of the

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[2] Includes maps, aerial photos, electronic and paper databases, books and published and unpublished reports.

valley, which have recreational and aesthetic values. The water level of these lakes is now mostly mechanically controlled to prevent flooding on the surrounding farm land. The water resources in some parts of the catchment are fully allocated, which will limit the future rate of growth in this region. Initiatives to store water and evenly distribute throughout the year have been proposed. The Ruamahanga River and its tributaries host a wide variety of fish, and are important fisheries in the lower North Island. There is a strong Tangata Whenua presence in this catchment, signifying an important cultural dimension. There have been significant increases in subdivisions, and a large increase in the number of dwellings in the catchment; although this has not been paralleled by population increases, indicating that the number of people per household is decreasing, and that people from out of town are purchasing weekend homes.

Type of Inventory

The purpose of the inventory dictates that the categories to be included will relate to the water resources in the catchment. However, background information will be provided on the basic catchment characteristic (e.g. climate, topography, soil and geology), which are in fact interrelated with water resources in the wide sense. For example, climate relates to water quantity, geology and soils relate to water quality and flow and topography relates to water flow.

The statutory framework, Tangata Whenua interests, the history and development of the region, and socio-economic characteristics are some of the topics that are included to ensure completeness of the catchment background information. With the purpose of the inventory and the nature of the catchment in mind, the following topics have been included in the Ruamahanga Catchment Resource Inventory: land, climate, water quantity, water quality, land use, freshwater ecology, natural hazards, culture, natural heritage, recreation and public perceptions on the state of the Ruamahanga River.

3. Methodology

This Resource Inventory is comprised of twelve individual chapters, each focusing on a different charateristic of the Ruamahanga Catchment (previously outlined in Section 2.3). The first three chapters (Introduction to the Ruamahanga Catchment, Land and Climate) provide the foundation for the remaining chapters. The Water Quantity and Water Quality chapters build on the information provided in the three preliminary chapters. The next six chapters provide an overview of the Land Use, Freshwater Ecology, Culture and Natural Heritage, and Recreation in the catchment. The final chapter on 'Public Perceptions', documents what a small number of people of the Ruamahanga Catchment think about the state of their water resources.

Most of the chapters are descriptive, and have used a wide range of information sources (including previous publications, databases, and ArcGIS[3] files) to describe the current state of that aspect of the catchment. In most cases, the amount of information on each topic in the inventory was extensive. Therefore, a challenge in compiling this inventory was to keep the information concise while still conveying as much about the topic as possible. To allow this to happen, the discussion of each topic was restricted to include only those aspects that related to the water resources of the catchment. For example, recreation in the catchment included only water based activities, and natural hazards included only floods and droughts. The exception to this rule was when it was decided the information would need to be included to ensure completeness (e.g. Statutory framework, Tangata Whenua interests, history and development, socio-economic sub-topics).

The Water Quantity and Water Quality chapters are the two main analytical chapters in the inventory, and the Public Perceptions chapter utilised a survey. Therefore these chapters include more detailed methodologies than the other descriptive chapters.

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[3] Geographical Information System Software

The structure of the inventory is such that each individual chapter has its own literature review, methodology (ies), and a list of data sources that have been used to gather information to create the chapter. Several of the chapters (including Land Use, Freshwater Ecology, Natural Heritage, and Recreation) have sections that assessed how each of these characteristics would be affected with either degradation of water quality or a change in water quantity (including flooding).

4. Introduction to the Ruamahanga Catchment

4.1. PHYSICAL SETTING

The Ruamahanga Catchment is nestled between the axial (Tararua) ranges and the eastern Wairarapa hill country in the south east of the North Island, New Zealand. The entire catchment area is approximately 3,500 km^2 and extends from Mt Bruce in the north through to Lake Onoke in the south.

Elevations in the catchment range from sea level up to 1,571 m (Mitre Peak) in the Tararua Ranges in the west, and up to 575 m (Eringa) in the eastern Wairarapa hills and 979 m (Te Maunga) in the Aorangi Mountains in the southeast.

The Ruamahanga River is the main stem within the catchment and flows for a distance of 120 km. The headwaters of the river are located in the Tararua Ranges near Mt. Dundas (1,500 m), north of Mt Bruce. From here the river flows south until after Masterton, when it continues in a south westerly direction over the alluvial floodplain to eventually drain into Palliser Bay, in the Cook Strait. The general geomorphology of the Ruamahanga River alters on the southward journey from semi-braided in the northern region to a single channel in the lower reaches.

Historically, the Ruamahanga River flowed into Lake Wairarapa and on to Lake Onoke before discharging into the sea. However flood protection works that began in the 1960's resulted in a new diversion channel for the river, which bypasses Lake Wairarapa entirely. Lake Wairarapa is 78.5 km^2 in area, and together with its surrounding environs it makes up the largest wetland complex in the southern North Island (Cromarty & Scott, 1996). Lake Onoke is 6.5 km^2 in area and is a bar-dammed lagoon situated on the southern coast of the catchment (Cromarty & Scott, 1996).

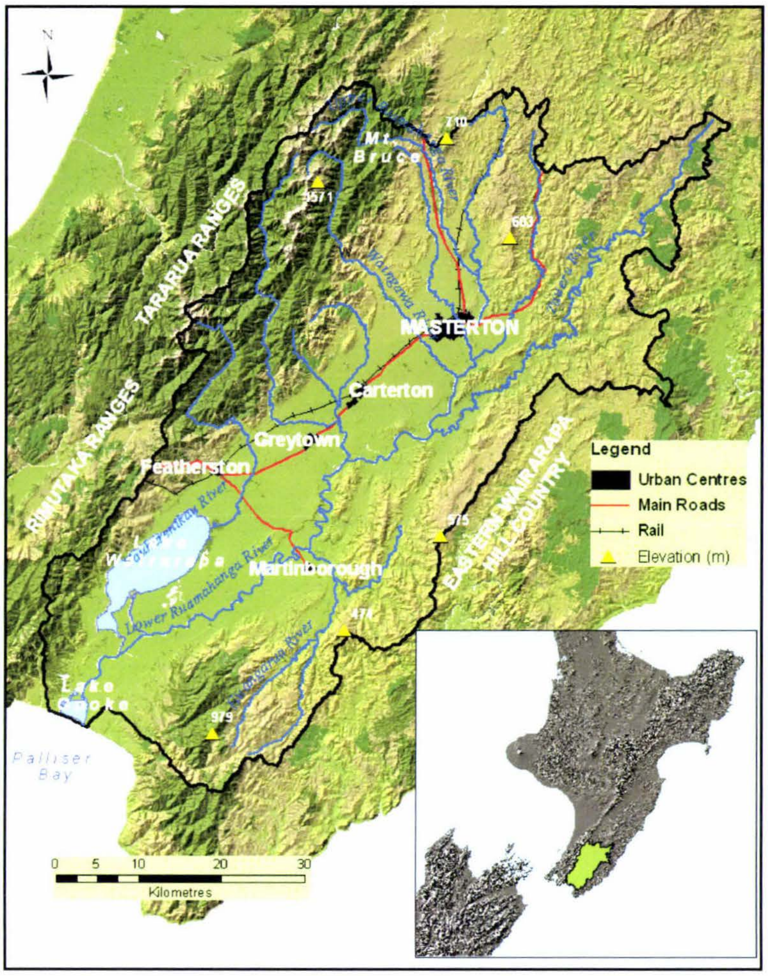

Figure 4-1: Ruamahanga Catchment. Insert: location of Ruamahanga Catchment in New Zealand

4.2. HISTORY AND DEVELOPMENT OF THE REGION

The history of Wairarapa is often associated with the legendary explorer and navigator, Kupe, who is said to have sailed into Palliser Bay in his canoe *Matahoroua*. One translation of the name Wairarapa is the "gift of Kupe" (Bagnall, 1976, p. 4). Several locations and landmarks around southern Wairarapa also carry this name, including the rock face Nga-ra-o-Kupe or "the sails of Kupe", and a landform Nga-waka-o-kupe "the canoes of Kupe" (Bagnall, 1976; McIntyre, 2002, p. 16).

According to the findings from various archaeological sites around Palliser Bay, which include extensive cultivation areas and stone walls, human occupation in Wairarapa has been estimated to date as far back as 1000 AD (McIntyre, 2002). It is thought that the Waitaha and Ngati Mamoe tribes were the first settlers of the area but after they migrated to the South Island, "the Ngati Ira tribe, led by Rakanui, took residence between Otaraia and Kawakawa in southern Wairarapa" (McIntyre, 2002, p. 21). The people of the Ngati Ira were soon accompanied by Te Tini-o-Awa and Rangitaane, originally from Heretaunga in the Hawke's Bay. After some time, the Te Tini-o-Awa tribe vacated the region as did some of the Ngati Ira tribe who relocated west to Wellington (McIntyre, 2002). Finally, around 1600 AD Rangitaane were joined by Ngati Kahungunu, also from Heretaunga and who acquired land from the Rangitaane by the exchange of canoes (Oxenham, 1993). These two tribes co-existed in Wairarapa with the Rangitaane occupying the northern Wairarapa and the Ngati Kahungunu the south.

Between the late Sixteenth and Nineteenth centuries Māori settlement was mostly in the Wairarapa valley and was fairly mobile. The period 1810-1840 was characterised by upheaval and insecurity with visits by war parties from both the north and west, thus the Māori population varied considerably around this time (Oxenham, 1993).

The New Zealand Company vessel *Tory* arrived in Port Nicholson (Wellington Harbour) in 1839, and it was after this date that Europeans first set eyes on the Wairarapa Valley from a view point in the Tararua Ranges. William Deans was the first European to travel into the Wairarapa Region via the coastal route in 1840, while Robert Stokes, a New Zealand Company surveyor, was thought to be the first to enter Wairarapa by crossing the Rimutaka Range in 1841 (Bagnall, 1976). By 1843, various other European settlers had traversed the Rimutakas and had "set up amicable verbal leasing agreements with the Māori Chiefs of the area" (Flack, 1998, para. 7). Sheep were driven into the area in 1844, making Wairarapa home to one of the first sheep stations in the country (Masterton District Library and Wairarapa Archive, 2006b; New Zealand Travel Infocus Ltd, 2006).

The leasing agreements worked reasonably well until 1853 when Colonel Grey legislated that it was illegal to 'squat' on native land. It was Grey's vision for the Government to purchase large blocks of the leased land to be further sold on as 'small farms', "giving an opportunity to the working class and newcomers to own their own land" (Bagnall, 1976, p. 100). Both the Māori landlords and the initial European 'squatters' resisted this decision, but bribing and other pressure tactics adopted by Grey soon wore down both parties (McIntyre, 2002).

The purchase of the Kuratawhiti block in the latter part of 1853 was the first notable purchase of land from the Māori by the Small Farms Association. This land was named 'Greytown' in 1854, and was the beginning of many large land purchases by the government and the impetus behind steady European settlement in Wairarapa (Bagnall, 1976). The Rimutaka Bullock Track from Wellington opened around this time, with a road link being established by 1859. Almost two decades later in 1877, the region was connected to Wellington and its shipping port, by the completion of one of the worlds steepest railways, the 1 in 15 gradient Rimutaka incline (New Zealand Travel Infocus Ltd, 2006). The incline and associated track closed in 1955, just prior to the opening of the new line running through the Rimutaka Tunnel (Te Ara - The Encyclopedia of New Zealand, 1966 updated 2006).

With most of their land sold, the Māori occupied small land areas like Papawai. Here the Government constructed a flour mill, and the Church of England constructed a school. However both failed to thrive, the former due to conflict between various Māori tribes and the latter due to poor Governmental support (Masterton District Library and Wairarapa Archive, 2006a). In contrast, the Papawai Marae became a well known site, becoming the home of the Māori Parliament in the late 1800's to early 1900's.

Wairarapa's economy has been inextricably linked to the land since European settlement. Flax gathering was one of the first industries to occupy Wairarapa; and once the land was cleared of some of its indigenous forest, which included "kahikatea stands in the valley and mixed podocarp and beech in the mountains" (Mills, 2002, p. 38), land use expanded to both cropping and pastoral practices. One of the first wheat crops was grown in 1868 and the fourth New Zealand co-operative dairy factory opened in Greytown in the early 1880's (Bagnall, 1976).

The first half of the twentieth century saw these farming practices intensify, accompanied by the advent of aerial top dressing which was encouraged by L.T. Daniell in 1949 (Tech History, 2006). Land use practices have diversified in recent times, so that in addition to sheep, dairy and crop farming, agricultural practices in Wairarapa include: horse studs, deer farming, forestry, viticulture, mushroom cultivation, organic farming, and hydroponics. Emu and ostrich farming, floriculture, and ulong tea growing are emerging activities in Wairarapa, which also contains New Zealand's first wind farm (New Zealand Travel Infocus Ltd, 2006).

4.3. SOCIO-ECONOMIC CHARACTERISTICS

4.3.1. Introduction

Socio-economic information including population numbers, urban and rural population ratios, population densities, and population growth or decline is fundamentally important for future planning within a catchment. Significant changes in population need to be provided for in future water allocation, sewage treatment and waste management services for example. Additional socio-economic characteristics include gender ratios, age and life expectancy, race/ethnicity, incomes, unemployment ratio, occupation and marital status. Although each of these characteristics are important for describing the social make up of the catchment, a detailed analysis is beyond the scope of this report.

4.3.2. Data Sources

Statistics New Zealand provides the main source of demographic data and socio-economic data nationally. Information gathered from the 2006 census has been utilised, and compared with figures gathered in the 2001 census for comparison.

4.3.3. Methodology

Population statistics for the Ruamahanga Catchment were calculated from the 2006 census data compiled by Statistics New Zealand. Statistics New Zealand has divided New Zealand up into small areas called meshblocks. Meshblocks are the "smallest geographical unit for which statistical data is collected" and they combine to make up larger geographical areas such as territorial authorities and electoral districts (Statistics New Zealand, 2007c, para 1).

The 2006 census data is in the form of GIS shape files that provide the location and identity number of the meshblocks, and Excel spreadsheets that relate all of the census data categories to each meshblock. A limitation of using census data at the meshblock level is that some of the fields (e.g. income), are listed as confidential - the reason being that at this level an individual in a meshblock may be able to be personally identified.

Before extracting any of the spreadsheet data, the meshblocks that fall within the Ruamahanga Catchment have to be defined. Many of the meshblocks were only partly within the Ruamahanga Catchment boundary. These were identified and given a proportional estimate (e.g. 90%, 50% and 20%) of their area falling within the boundary. These estimates were then used to multiply by the meshblock statistic (e.g. population count) to obtain the value for the area inside the catchment. This method, although quite simplistic, should give a reasonably accurate estimate of the actual catchment population.

To obtain the urban/rural population ratio, the urban/rural boundary had to first be defined. GWRC's GIS files showing the urban boundaries were used to select the meshblocks. All of the meshblocks that intersected, or were within the urban boundaries were selected and defined to be the urban area, all remaining meshblocks were designated as rural.

Additional socio-economic characteristics that are provided by the census were mentioned above. Although these are beyond the scope of this report, I will note that the above methodology may not be suitable for the analysis of other characteristics aside from population, due to the inability to calculate a median value from a set of median values (e.g. median incomes), and also because the number of fields listed as confidential will lead to incomplete data sets and underestimate the real value.

4.3.4. Socio economic data for the Ruamahanga Catchment

There are 36,983 people that usually reside in the Ruamahanga Catchment (Statistics New Zealand, 2006)(Statistics New Zealand, 2006). This equates to a population density of around 11 people per square kilometre. The Ruamahanaga Catchment is therefore less populated than the Manawatu Catchment which has around 21 people per square kilometre

(P Hodge, personal communication, 12 October 2007). The population base is made up of five settlements, Masterton (17,598), Carterton (4,134), Featherston (2,052), Greytown (1,998) and Martinborough (1,329)[4], making up a little over 70 percent of the total population, while the remaining 30 percent live rurally.

Since the 2001 census there has not been a significant change in population in the Ruamahanga Catchment. However there has been a change in dwelling conditions with many households moving to lifestyle blocks. Unlike other parts of New Zealand who have significant seasonal changes in population e.g. Queenstown, the Ruamahanga Catchment's population remains relatively steady throughout the year.

4.4. STATUTORY FRAMEWORK

4.4.1. Local Government

The Greater Wellington Regional Council (GWRC) is the regional authority that serves the entire Wellington and Wairarapa Regions. The Ruamahanga Catchment falls under their jurisdiction. Alongside GWRC and also within the catchment boundary are the three Territorial Authorities (TA) of Wairarapa: Masterton District Council, Carterton District Council and South Wairarapa District Council.

The roles and responsibilities differ between the regional and territorial authorities. Environmental planning, natural resource management and region-wide regulations are the responsibility of the regional authority (GWRC). A more localised role is required by the TA's, who have the responsibility of providing local services to the community including: water, sewage, rubbish collection, parks, libraries, street lighting and roads. In addition to these tasks, the TA's also approve building and other environmental consents (New Zealand Government, 2005).

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[4] Calculated from the 2006 usual resident population count. These numbers may be slightly under the true population due to confidential figures in the results returning zero values for some mesh blocks.

GWRC and the TA's both have responsibilities under the Resource Management Act 1991 (RMA). Under the RMA, a Regional Policy Statement (RPS) is prepared which "identifies the major resource management issues for the region and sets out objectives, policies and methods for tackling these issues" (Greater Wellington Regional Council, 2007b, para 1). Issues identified in the RPS must be taken into account by the TA's and regional councils in their district and regional plans.

GWRC has set out its role and responsibilities for the management of natural resources according to the RPS in five regional plans: coastal; soil; freshwater; air quality management; and discharges to land - all of which became operative between 1999 and 2000. All of these plans apart from the Regional Coastal Plan have since been modified. The current RPS which became operative in May 1995 is now under review, and a proposed version of the new RPS will be available for public notification in September 2007.

Several public documents have been produced by GWRC in regards to the RPS. 'Measuring up' (Greater Wellington Regional Council, 2005) provided findings from a review that assessed whether the objectives in the 1995 RPS had been met, and 'Our Region – Their Future' (Greater Wellington Regional Council, 2006c) went a step further and assessed the issues now and in the future as a discussion document.
A Combined District Plan has recently been prepared under the RMA by the three district councils in Wairarapa (Masterton, Carterton and South Wairarapa). The district plan is put in place to "manage the environmental effects of land use, development and subdivision in the Wairarapa" (Masterton District Council, 2007).

Various planning reports on a range of topics can be found on the Masterton District Council website (www.mstn.govt.nz). The planning reports include the submissions made on particular topics. Hearings on the combined plan will be completed by the end of August 2007. Submissions will then be discussed by Commissioners, and recommendations heard from consultants and planners. Adoption of the plan will commence after final approval by the commissioners (Masterton District Council, 2007).

Unlike Horizon's MW, GWRC does not have separate plans for individual catchments in their region. However, different water bodies in the region are managed for different purposes. The appendicies of the Freshwater Plan (1999) outlines the different management purposes and the water bodies that come under each category. The management purposes range from 'water to be managed in its natural state', 'water to be managed for aquatic ecosystem purposes', 'water bodies with nationally threatened indigenous fish and nationally threatened aquatic plants', 'water quality to be managed for fishery and fish spawning purposes', 'water quality to be managed for contact recreation purposes' and 'water bodies with water quality to be managed for water supply purposes' (Greater Wellington Regional Council, 1999, p. 197-269). In addition, the plan identifies water bodies in the catchment that need enhancement.

Some water bodies in the Ruamahanga Catchment included in these appendicies are the Waiohine River managed for its natural state, trout habitat, and recreation; Lake Wairarapa managed for its natural state, nationally threatened indigenous fish, and recreation; the Mangatarere River managed for its trout habitat; the Ruamahanga River managed for recreational values; and the Waingawa River managed for water supply, trout habitat and recreation. Some of the water bodies in the Ruamahanga Catchment indentified as needing enhancement include: the lower reaches of the Ruamahanga River and Waiohine River for contact recreation and the Mangatarere River for aquatic ecosystem purposes (Greater Wellington Regional Council, 1999).

4.4.2. Department of Conservation (DoC)

The legislative mandate that DoC works under is the Conservation Act 1987, in addition to other nationwide statutes including the National Parks Act 1980 and the Reserves Act 1977 (Department of Conservation, n.d.-d). The Department also provides for the protection of wildlife under the Wildlife Act 1953. Overall the Department "administers 25 Acts of Parliament and has functions under several others" (Department of Conservation, n.d.-c, para 4). A full list of the legislation that the Department administers, and a list of Acts that the Department has powers or duties under, can be obtained from www.doc.govt.nz.

Various blocks of land in the Ruamahanga Catchment are managed by the Department of Conservation (DoC) under the Conservation Act 1987 (Figure 4-2). These include the Tararua, Rimutaka, and Aorangi Forest Parks, Lake Wairarapa Wetland, Carters Reserve and Lowes Reserve, and part of the Mt Bruce Scenic Reserve.

4.4.2.1. Conservation Act 1987

The purpose of the Conservation Act 1987 is to "promote the conservation of New Zealand's natural and historic resources". After the passing of the Act, DoC was formed to achieve this purpose (Department of Conservation, n.d.-c).

"The main functions of the Act include:

- The management for conservation purposes of all land and natural and historic resources held under the Conservation Act;
- The preservation of indigenous freshwater fisheries (so far as is practicable);
- The protection of recreational freshwater fisheries and freshwater fish habitats;
- Conservation advocacy;
- Promotion of the benefits of international co-operation on conservation matters;
- Promotion of the benefits of the conservation of natural and historic resources in New Zealand, the subantartic islands, the Ross Dependency and Antarctica;
- The provision of educational and promotional conservation information;
- Fostering recreation and allowing tourism on conservation land, providing the use is consistent with the conservation of the resource;
- Provision of advice to the Minister"

(Department of Conservation, n.d.-c)

4.4.3. Lake Wairarapa Conservation Order 1989

National water conservation orders are national policy instruments enforced under the RMA and the Water and Soil Conservation Act 1967, and are used to preserve or protect water bodies with significant "nationally important habitats, fisheries, wild and scenic character, scientific or ecological values" (Basher, 2003, p. 91).

The Lake Wairarapa Conservation Order was put in place in March 1989, identifying the Lake's outstanding features (i.e. the wildlife habitat created in part as a consequence of the natural fluctuations of water levels), thus prohibiting diversion of any water from the lake ("National Water Conservation (Lake Wairarapa) Order," 1989). There is a clause in the Order that allows for the opening of the barrage gates from time to time (clause 5(4)).

4.4.4. Tangata Whenua Interests

There are two iwi present in the Ruamahanga Catchment, Ngati Kahungunu and Rangitaane, both of which have a strong connection with the Ruamahanga River and Catchment which is recognised through the Treaty of Waitangi. The relationship between these two tribes and the river is further elaborated on in Chapter 12 of this report.

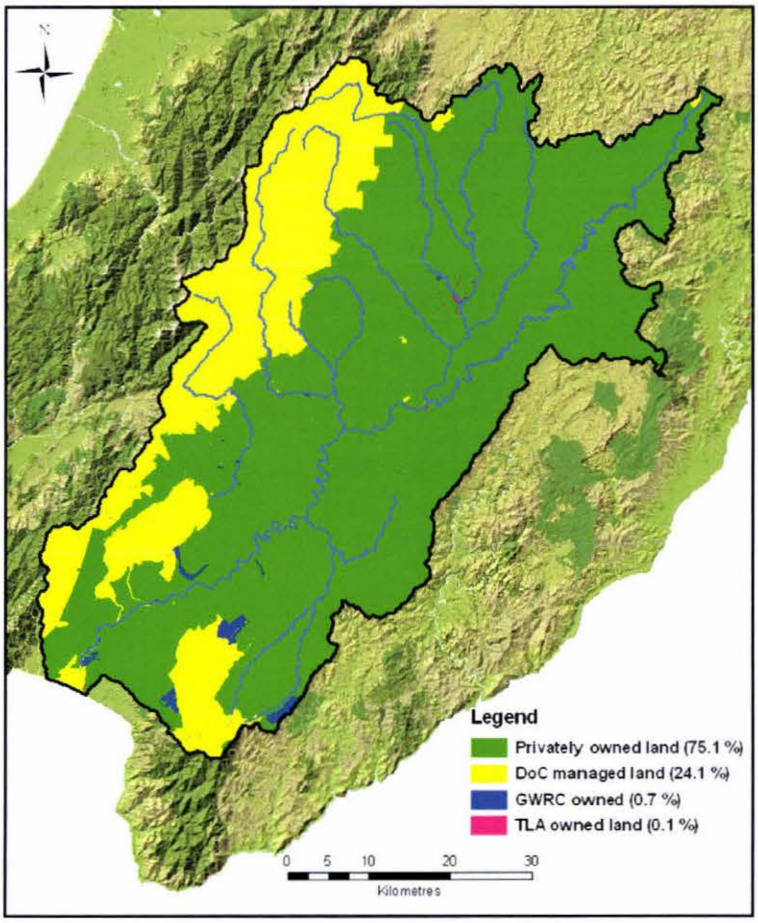

Figure 4-2: Land Management and Ownership in the Ruamahanga Catchment

Regional and district councils, and DoC have a "responsibility to work with Tangata Whenua on all matters concerning environment and heritage" (Basher, 2003, p. 95). The RMA (1991) includes many references to tangata whenua interests, and provides for tangata whenua participation in policy and plan preparation and resource consent decision making. The following sections of the Act are relevant to Māori interests:

In achieving the purpose of this Act -

– "*all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall recognise and provide for ... The relationship of Māori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga ... the protection of historic heritage from inappropriate subdivision, use, and development ... the protection of recognised customary activities*". (Section 6(e),(f),(g))

– "*all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall have particular regard to ... Kaitiakitanga (guardianship)*". (Section 7)

– "*all persons exercising functions and powers under it, in relation to managing the use, development, and protection of natural and physical resources, shall take into account the principles of the Treaty of Waitangi (Te Tiriti o Waitangi)*". (Section 8)

- Section 33 of the Act allows for the transfer of power to Tangata Whenua from local authorities
- Section 35A, requires that local authorities must keep and maintain, records for each iwi and hapu including *contact details... planning documents...* and areas ... *over which one or more iwi or hapu exercise kaitiakitanga*"
- Section 46A, requires that Iwi are consulted by the Minister for the Environment when preparing a National Policy Statement.

- Section 61(2A), 66(2A) and 74 (2A), requires regional councils and territorial authorities to take into account any relevant planning document recognized by an iwi authority and lodged with the council when preparing a regional policy statement, regional plan or district plan.

("Resource Management Act," 1991)

4.4.4.1. Treaty of Waitangi

The Treaty of Waitangi, signed in 1840, is an integral part of the RMA, which requires regional councils to:

- take into account the Treaty's principles
- recognise and provide for, as a matter of national importance, the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, wahi tapu, and other taonga (precious things)
- have particular regard to kaitiakitanga (the exercise of guardianship).

4.4.4.2. Claims made to the Waitangi Tribunal

Hearings for the Wairarapa Ki Tararua Inquiry District[5] were heard from March 2004 to March 2005. "A total of 17 claims were filed by members of the Ngati Kahunungu and Rangitaane hapu and other claimant groups" (Waitangi Tribunal, 2007, para. 2). The issues in the claims revolved around the relationship between the "Māori and the Crown from 1840-1865 and 1865-1900", "non-agrarian resources and the environment, with a particular emphasis on Wairarapa Moana (Lakes Wairarapa and Onoke/Ferry), rivers, foreshore and seabed, and environmental management and degradation", "the loss of land and resources", and "the management of heritage, sites of cultural significance, the environment, the coast, and the taking of land for public purposes, whether by central or local authorities" (Waitangi Tribunal, 2007, para. 3).

The inquiry is still in the report writing phase. The result of this inquiry may result in cultural or commercial redress. Cultural redress can include statutory acknowledgments and deeds of recognition, while commercial redress will involve monies paid for compensation.

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[5] This area includes all of Wairarapa, and also the Tararua District.

4.5. LAND TENURE

Land ownership information can be obtained from Land Information New Zealand (LINZ)[6].

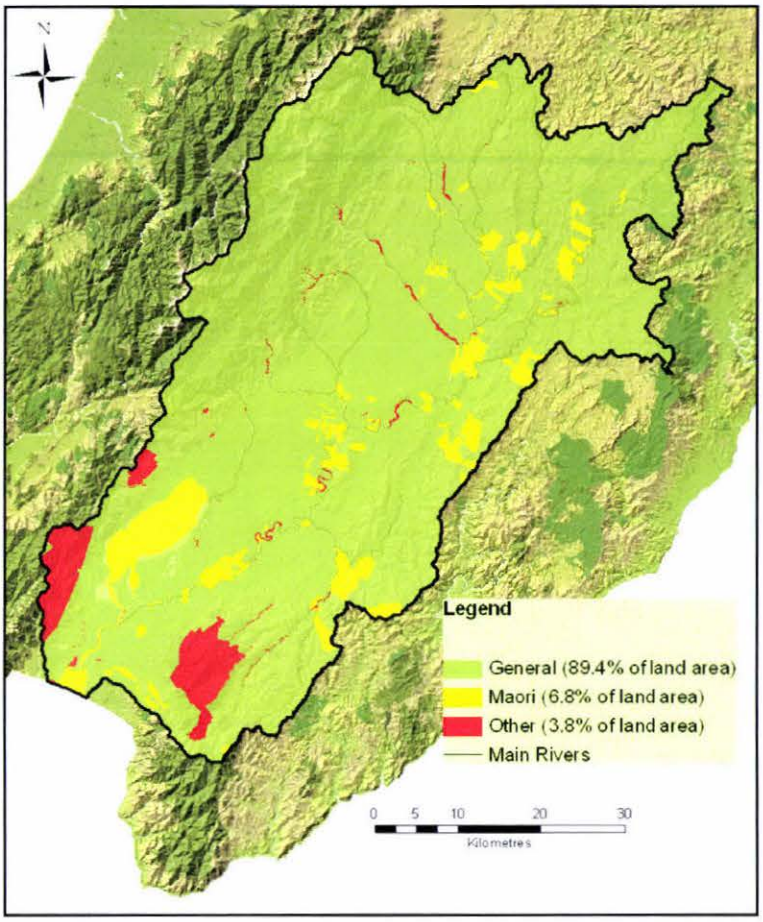

Figure 4-3: Land Tenure in the Ruamahanga Catchment. Source (LINZ, 2005)

Figure 4-3 displays the land holdings in the Ruamahanga Catchment as at December 2005. General land can be classed as land that has a legal title associated with it, while 'other' land can be defined as reserves and public land – land that does not have a legal title. The majority of land in the Ruamahanga Catchment is classified as 'general'. Māori land holdings include Lake Wairarapa and surrounding areas, including Lake Onoke, and patches of land mostly in the valley and to the east.

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[6] Using the National Bulk Data

5. Land

5.1. INTRODUCTION

An understanding of the physical characteristics of a catchment is an integral part of a resource inventory. This chapter aims to utilise the best possible resources to provide an overview of the physiography, geology, soils, erosion, vegetation, and infrastructure occurring in the Ruamahanga Catchment.

5.2. METHODOLOGY

The data sources used in this section are both New Zealand national sources, and Wairarapa regional sources. For each of the sections in this chapter, the relevant data sources used are listed, followed by an overview for the Ruamahanga Catchment. The New Zealand Land Resource Inventory (NZLRI) and the River Environment Classification (REC) are two national data sources which provide information for more than one section. These two sources are described initially under Section 5.3 to avoid repetition. Limitations of the data sources are given where appropriate. A core information source for this section was the 'Review of National Databases Relating to Land, Water and Biodiversity' (V. Froude, 1999).

5.3. GENERAL DATA SOURCES

5.3.1. New Zealand Land Resource Inventory (NZLRI)

The NZLRI was created in 1975 and is a nationwide database that has mapped New Zealand's land resources according to rock type, soil type, slope, erosion degree and type and vegetation. The inventory was formed from aerial photographs, field work and surveys obtained from other organisations (Ministry of Works and Development, 1979). First order boundaries making up the polygons in the NZLRI are based on slope, and soil and rock type. Second order boundaries are determined by vegetation and/or erosion. As it is an all encompassing database, it will be listed as a data source for most of the sections below. The Land Resources Information System Spatial Data Layers, Volume 1: 'Label Format' by (Newsome, Wilde, & Willoughby, 2000) provides the legend for the NZLRI.

Limitations of this database are that it is somewhat dated, especially in regards to vegetation and erosion, its scale of 1:50,000 can be also be limiting, and according to Froude (1999) up to 20 percent of any one polygon may be inaccurately described which can lead to further inaccuracies when the original map scale is increased.

5.3.2. River Environment Classification (REC)

The REC was compiled by NIWA as a "controlling factor approach that classifies and maps New Zealand's river environments at a range of spatial scales" (Snelder, Biggs, Weatherhead, & Niven, n.d, p. 1). The classified area "comprises 267,000 km^2 and 426,000 km of river network" (NIWA, 2007b, para. 2). It characterises river environments according to six hierarchical levels; climate, source of flow, geology, land cover, network position and valley landform, which in essence are the controlling environmental factors (Snelder, Biggs, & Weatherhead, 2004).

Some of the limitations of this database include the fact that it has "only been tested in small areas; it has used expert judgement for key variables rather than modelling; and that it is complex" (V. A. Froude & Beanland, 1999, section 5.1 'Limitations'). Further information on this database can be obtained from the publication released by the Ministry for the Environment and NIWA 'New Zealand River Environment Classification Guide' (Snelder et al., 2004).

5.4. PHYSIOGRAPHY

This section includes a physiographic overview of the catchment; an assessment of the slope classes and land use capability (LUC) groups; a description of the river system; and an insight into the lakes and wetlands in the catchment.

National Physiographic Sources

The NZLRI and the REC database provide information at a national scale. The NZLRI details slope data for all of New Zealand, while the REC can be used to describe any national river reach according to the hierarchical levels. These two data sources have been used in Sections 5.4.2 and 5.4.3 below. The information provided in Section 5.4.4 on lakes and wetlands has been derived from 'A Directory of Wetlands in New Zealand' complied by P Cromarty, and edited by Scott, D.A (Cromarty & Scott, 1996).

Regional Physiographic Sources

The physiography of the Ruamahanga Catchment has been described recently by Begg et al. (2005) in 'A review of Wairarapa geology - With a groundwater bias' and by the Wairarapa Engineering Lifelines Association (WELA) (2003) in the 'Wairarapa Engineering Lifelines Project - Risk to lifelines from natural hazards'. These two publications have contributed the majority of information for the following physiographic overview section. Various GWRC publications have also been used for additional data.

5.4.1. Physiographic Overview of the Ruamahanga Catchment

The catchment is characterised by a topographically diverse landscape that can be loosely divided into three physiographic units: mountain ranges; hill country; and a central lowland basin (Figure 5-1). Structurally the landscape is very complex resulting from the regional tectonic environment that it is situated in. The boundary between the Australian Plate and the Pacific Plate known as the Hikurangi Trough, is located off-shore, slightly north east of Wairarapa. This trough represents a convergence zone of the underlying tectonic plates which move towards one another at rates of about 40 mm/year (Begg et al, 2005). Due to the differing densities of the individual plates, the heavy basaltic-rich Pacific Plate submerges beneath the lighter silica-rich Australian Plate. This collision zone causes warping and tension to the crust above, which spatially underlies Wairarapa and Wellington regions, and thus is largely responsible for the broad geomorphic zones of the Tararua and Rimutaka ranges, the Wairarapa Valley and the eastern Wairarapa hill country (Begg et al, 2005).

The Tararua and Rimutaka Ranges, which comprise the catchment's western boundary, are the most dominating features in the catchment. Together they form part of the axial mountain system that cuts across New Zealand's landscape and have a strong influence on the weather regime of the catchment. The heights of these mountain ranges vary from 1,571 m above sea level down to 350 m above sea level in the foothills (Wairarapa

Engineering Lifelines Association, 2003). The ranges are comprised of heavily tilted and folded Triassic greywacke and argillite rocks with fault lines running from the south west to north east which influences the stability. "The steep slopes are mostly forested and punctuated with fast flowing streams and rivers which have become deeply carved into the hard underlying bedrock" (Begg et al, 2005, p. 5).

The eastern side of the catchment is bounded by the eastern Wairarapa hill country[7], with the steepest sections evident within the forest clad Aorangi range at the south eastern edge. Unlike the Tararua and Rimutaka Ranges, the eastern Wairarapa hill country is formed mostly from soft Tertiary mudstones, siltstones, sandstones and argillite. Limestone is also a common lithology in these hills, but it is the softer sediments, that are weakly structured that are highly susceptible to soil erosion. Most of the land has been modified to accommodate pastoral use which unfortunately accentuates the erosion problem (Wairarapa Engineering Lifelines Association, 2003).

The Wairarapa Valley occupies the area between the ranges in the west, and hill country in the east. The valley is a structural depression, up to 15 km wide and extends 110 km from Mt Bruce to Palliser Bay (Morgan, 2000). Slopes in the valley are mostly gentle, and the land has been largely deforested to make way for intensive pastoral use. Braided channel streams and rivers are bounded by terraces in the northern end of the valley which give way to extensive floodplains to the south.

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[7] Also referred to as Eastern Uplands

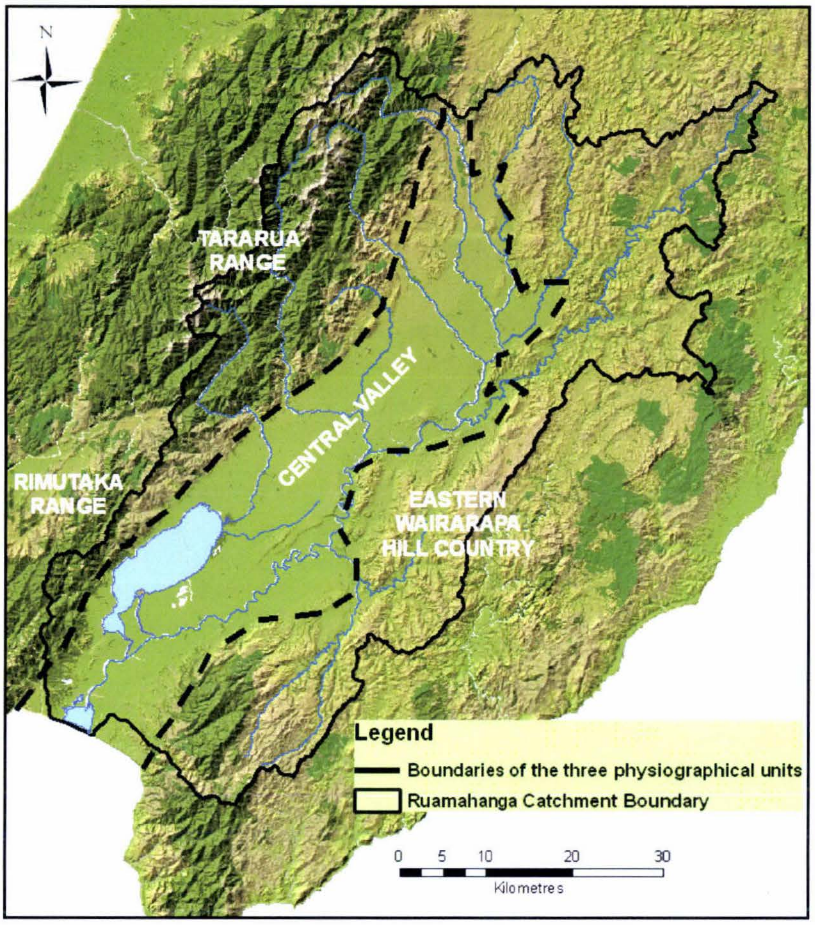

Figure 5-1: Location of the three physiographical units in the Ruamahanga Catchment. Source (Begg et al, 2005)

Hicks and Woodward (1978), interpreted gravity models of the Wairarapa Region and concluded that the basement greywacke under parts of the Wairarapa Valley had been covered by over 3,000 m of younger sediment . This younger sediment was derived from gravel material eroded from the Tararua and Rimutaka Ranges during the cold glacial periods. Coalescent alluvial fans were deposited on the eastern side of the ranges and pushed the Ruamahanga River over to its present day position on the eastern side of the valley (Morgan, 2000; Wairarapa Engineering Lifelines Association, 2003). The initial alluvial fans became reworked with the onset of alternating warm interglacial and cold glacial periods, consequently, the gravels nearest the ranges are poorly sorted and large in size, gravels adjacent to the river bed are well sorted, while in the lower valley, the gravels have been reduced greatly, and deep silts predominate.

Lake Wairarapa and Lake Onoke are the two largest lakes present in the valley. Both are situated in the southern portion of the catchment, in the remaining part of the structural depression which is still being infilled with sediment. These lakes are shallow, with an average depth of around one metre (Wairarapa Engineering Lifelines Association, 2003).

5.4.2. Slope Classes and Land Use Capability (LUC) Classification

Utilisation of the NZLRI revealed that the majority of the catchment (80.2 percent) features slopes of less than 15°, while a very minor portion contains very steep slopes of over 35° (Figure 5-2).

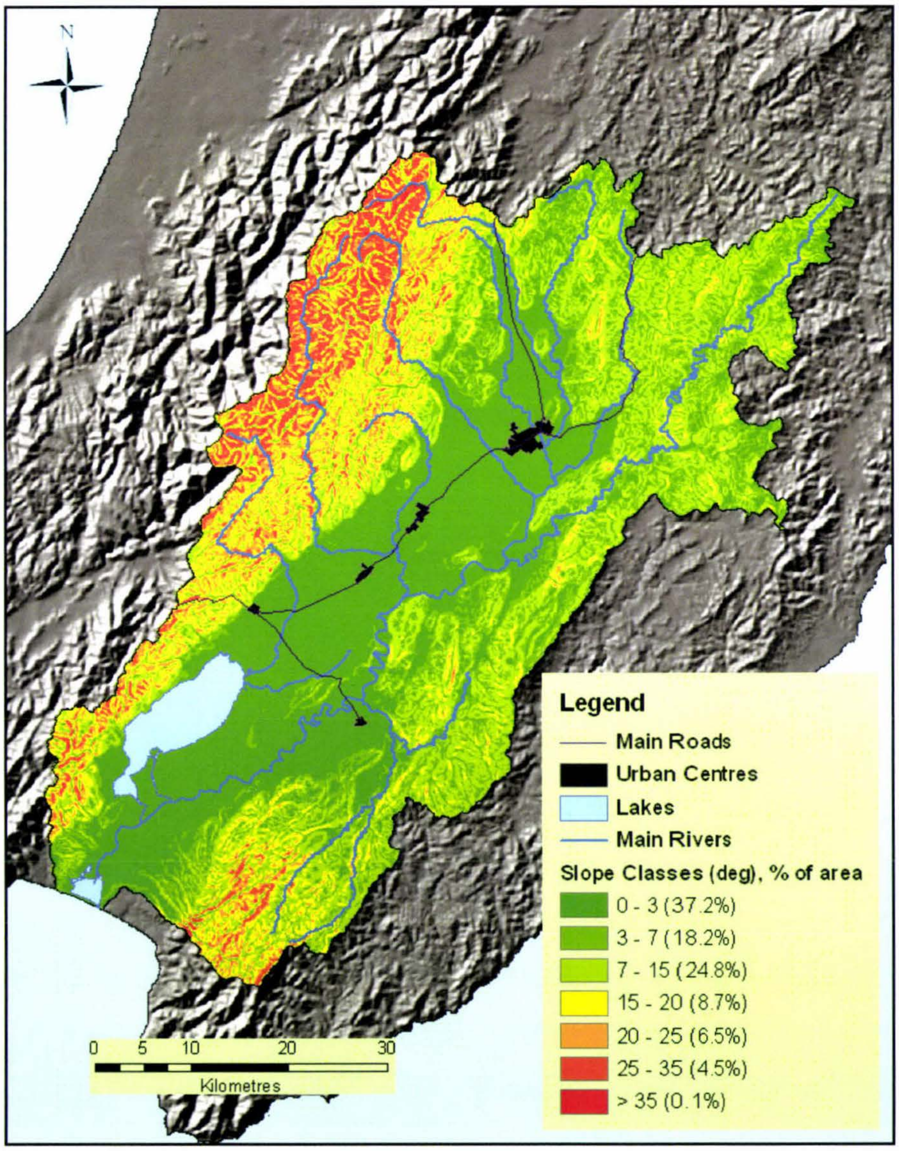

Figure 5-2: Slope classes in the Ruamahanga Catchment. Percentage of land area for each class is given in the legend

5.4.3. The Ruamahanga Catchment River System

The rivers in the Ruamahanga Catchment can be classified into the main stem and central tributaries; western; and eastern tributaries (Table 5-1).

Main Stem and Central Tributaries	Mid and Lower Ruamahanga River, Mangatarere River, Otakura Stream
Western Tributaries	Upper Ruamahanga River, Waipoua River, Waingawa River, Waiohine River, Tauherenikau River
Eastern Tributaries	Kopuaranga River, Whangaehu River, Taueru River, Huangarua River, Ruakokoputuna River

Table 5-1: Classification of the rivers in the Ruamahanga Catchment

The river system can be classified with the use of the REC database, which characterises river environments according to their climate, source of flow, geology, land cover, network position and valley landform (Snelder et al., 2004).

Main Stem and Central Tributaries

The central tributaries drain the central lowland valley; their river courses exhibit gentle gradients, and drain predominantly pastoral land. These rivers have their headwaters in the foothills and terraces of the catchment. In the case of the Ruamahanga River, flow is supplemented by both the western and eastern tributaries. These rivers traverse mostly soft sedimentary rocks, in the foothills and terraces, and alluvial sediments on the plains.

Western Tributaries

The western tributaries are subject to the cool-wet, to cool-extremely wet climatic conditions that occur in the Tararua Ranges, where all of these tributaries have their headwaters - apart from the Waipoua River whose headwaters are in the lower elevated foothills of the ranges. In the upper reaches, these rivers feature steep gradients and incise the hard greywacke sandstone before traversing over the younger alluvial gravels that dominate on the valley floor. The majority of these western tributaries drain catchments clad with indigenous forest, with some scrub and tussock land in the highest reaches.

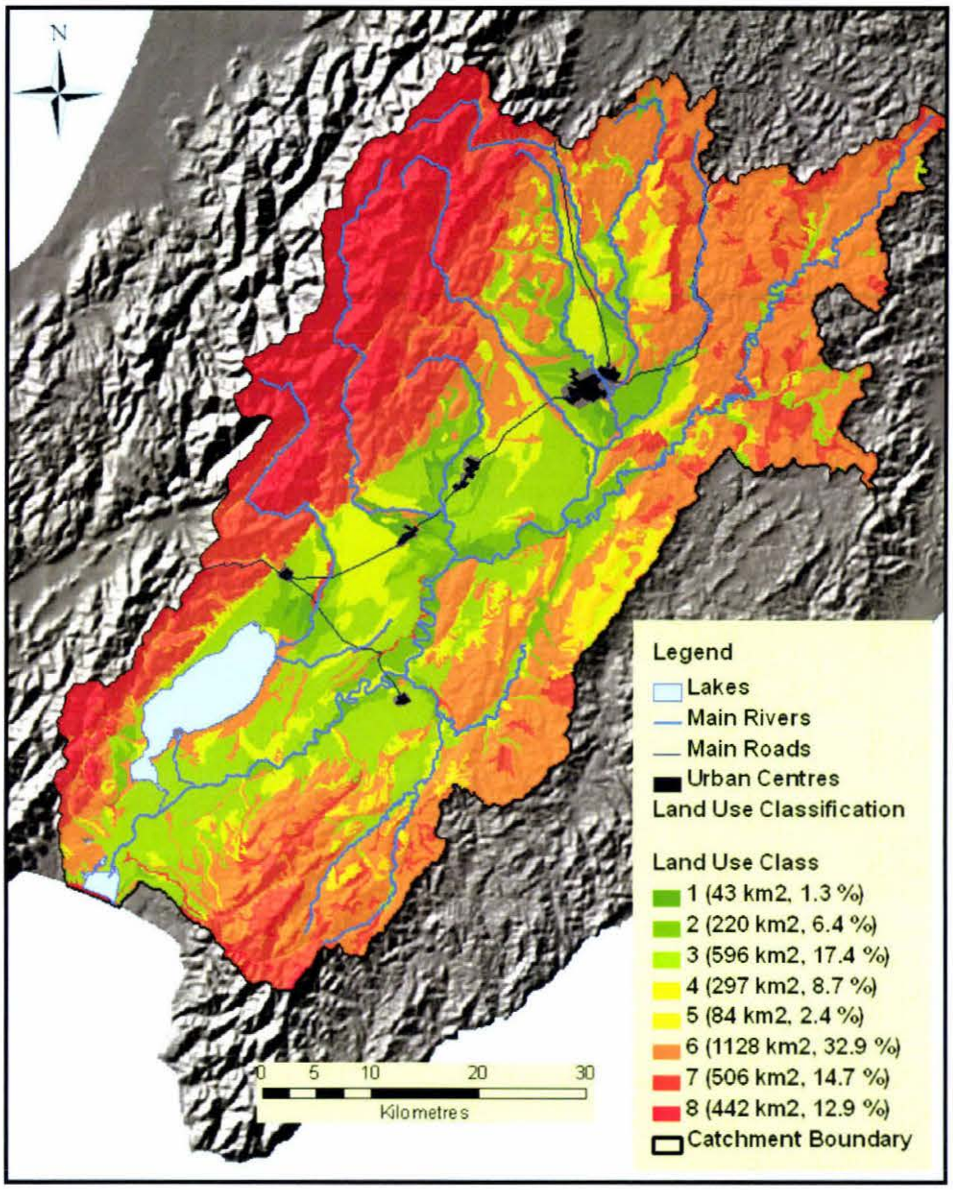

Figure 5-3: Land area and percentage of land area in the Ruamahanga Catchment classified into specific LUC classes

As a group these western tributaries have the highest median flow rates and specific discharges and mean annual low flows (MALF) values are considerably larger than any of the eastern tributaries (Chapter 7 details further water quantity information).

Eastern Tributaries

The eastern tributaries differ greatly from the western tributaries. They are subject to drier climatic conditions, drain predominantly pastoral land, and have their headwaters in lower elevated catchments - apart from the Makara Stream and Ruakokoputuna River that are sourced from higher elevated hill country in the south east corner of the catchment. These two rivers also feature steep river gradients in their upper reaches, but become gentle like the rest of the eastern tributaries closer to the valley floor. The majority of these tributaries drain soft sedimentary rocks including mudstones, limestones (and coquina[8]), however there is some older greywacke that features in the top end of the Huangarua Catchment. As a group the eastern tributaries have the lowest median flow rates, specific discharges and MALF's. The major sub catchments and their areas are listed in Table 5-2 and shown in Figure 5-5. A 3-dimensional image of the Ruamahanga Catchment looking northwards is presented in Figure 5-4.

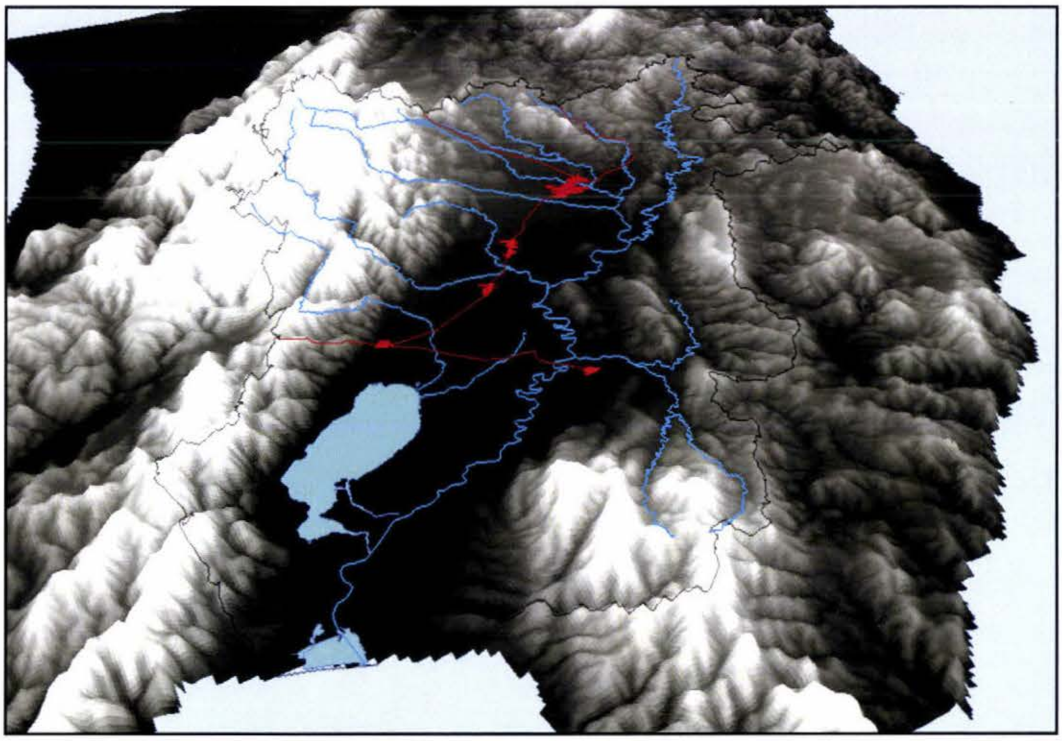

Figure 5-4: 3 dimensional image of the Ruamahanga Catchment looking northwards. Rivers are shown in blue, and town centres and roads are shown in red.

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[8] A type of limestone composed of an aggregate of shells and shell fragments.

Sub Catchment	Area (km^2)	% Land area
Taueru	498.90	14.54
Whangaehu	144.90	4.22
Kopuaranga	166.20	4.84
Upper Ruamahanga	115.30	3.36
Waipoua	173.80	5.06
Waingawa	151.20	4.41
Waiohine upstream of Mangatarere	203.40	5.93
Mangatarere	150.90	4.40
Parkvale	72.96	2.13
Tauherenikau	146.80	4.28
Wairongomai	28.64	0.83
Whangaehu Huangarua	131.20	3.82
Huangarua	158.50	4.62
Turanganui	70.68	2.06
Tauanui	54.10	1.58
Mid and Lower Ruamahanga	1164.10	33.92
Total Catchment	**3431.58**	**100.00**

Table 5-2: Areas and percentage of areas of the sub catchments of the Ruamahanga Catchment

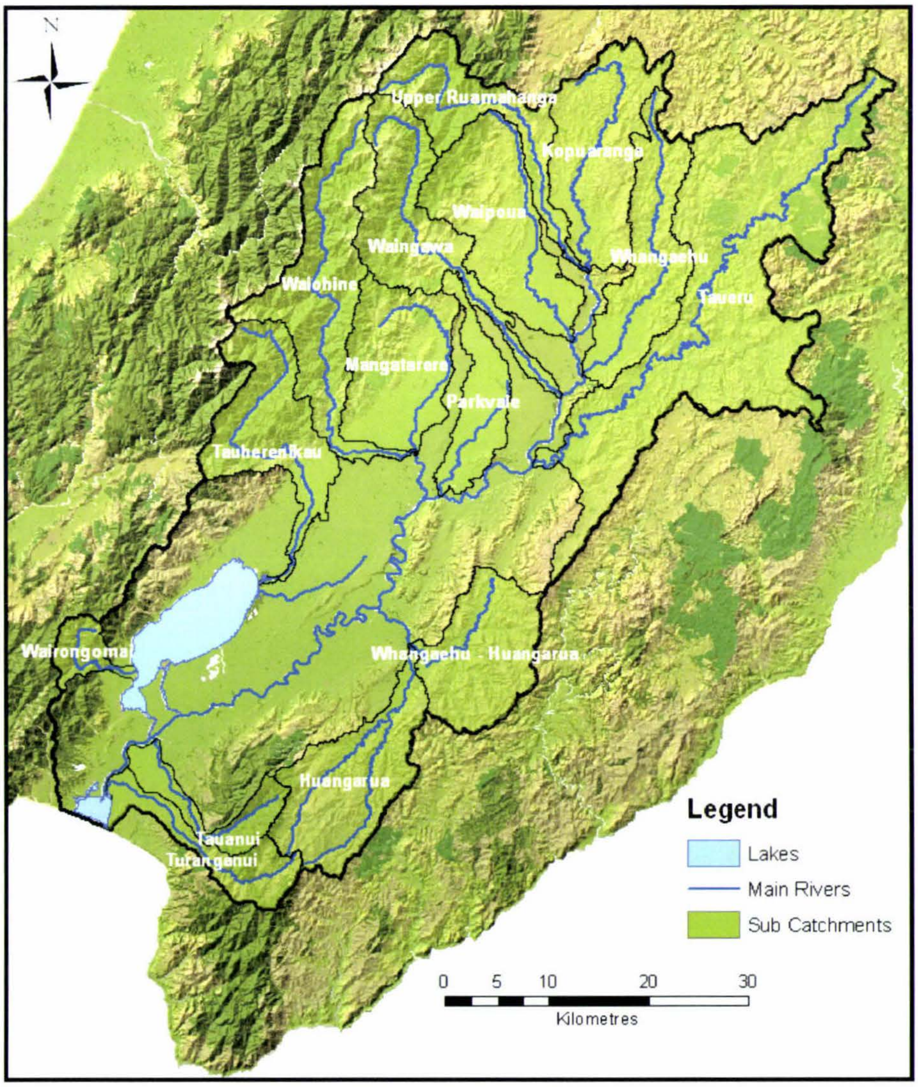

Figure 5-5: Sub catchments within the Ruamahanga Catchment

5.4.3.1. Modifications to the River System

Since the completion of the Lower Wairarapa Valley Development Scheme (LWVDS) in the early 1980's the course of the lower Ruamahanga River has changed significantly. Figure 5-6 and Figure 5-7 feature two aerial photos taken in 1961 and 2001 which indicate the extensive modifications to the system. The main flow of the Ruamahanga River was diverted so that it bypassed Lake Wairarapa entirely and flowed directly into Lake Onoke, thus avoiding the bottleneck between the two lakes and consequent flooding (Poole, 1983).

In addition to this major river diversion, the scheme introduced to the Lower Wairarapa[9], a floodway system for high flows to spill into Lake Wairarapa, 200 kilometres of stopbank, 130 drainage outfall culverts with floodgates to drain farmland, a flood detention dam and the Blundell Barrage (Wairarapa Engineering Lifelines Association, 2003). The scheme is worth an estimated $42 million and protects around 40,000 ha of farm land in the southern Wairarapa.

Refer to Section 5.10.6 for further information on the flood protection infrastructure in the catchment.

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[9] Lower Wairarapa includes the Ruamahanga River downstream from the Waiohine Confluence, the Tauherenikau River, all of the eastern and western tributaries draining into the lower Ruamahanga River and Lake Wairarapa (Greater Wellington Regional Council, 2006a).

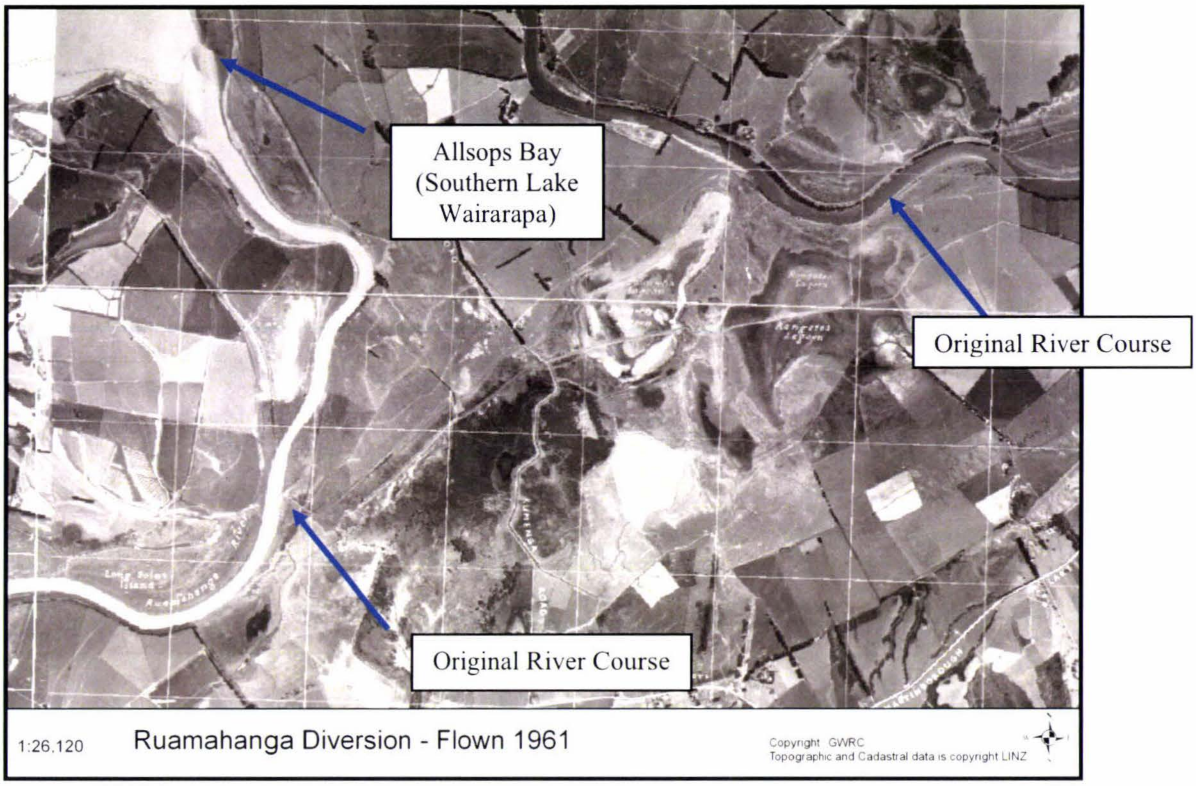

Figure 5-6: Lower Ruamahanga River course 1961

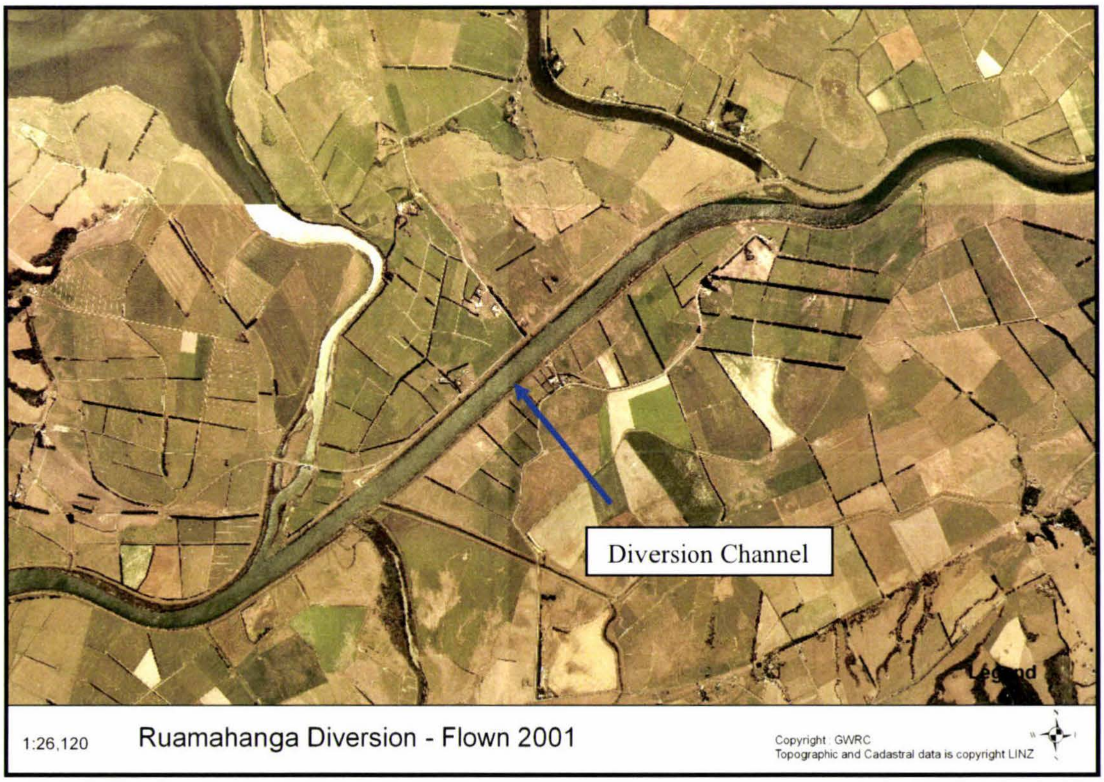

Figure 5-7: Lower Ruamahanga River course 2001

5.4.4. Lakes and Wetlands

There are two major lakes, Lake Wairarapa and Lake Onoke, and numerous other smaller lakes within the Ruamahanga Catchment, and there are approximately 98 wetlands covering about 9,320 ha in area (F. Forsyth & Dixon, 2004).

The Lake Wairarapa Wetlands (LWW) spread over an area of approximately 9,350 ha at the southern end of the Ruamahanga Catchment, which includes Lake Wairarapa (7,850 ha) and Lake Onoke (650 ha)[10] and represent most of the wetland area in the catchment. The LWW are the largest wetland complex in the southern North Island. Additional wetlands and smaller lakes make up the remaining area of wetlands of about 900 ha (Cromarty & Scott, 1996).

Lake Wairarapa is a shallow lake (<2.5 m deep), and stretches 18 km in length and six km in width. Various rivers and streams discharge into the lake from the north and western margins, including the Tauherenikau River. Water exits from the lake via the barrage gates situated at the southern end past Allsops Bay. The introduction of the LWVDS has meant that lake levels are mostly manually controlled (Cromarty & Scott, 1996). Further details on water levels in the lakes are provided in Chapter 7.

There is a large variability in Lake Wairarapa's western and eastern shorelines. The former has a thin margin which almost abuts against the nearby foothills of the Rimutaka Range, while the latter has a more extensive margin, as the lake bed has is more gently sloped on the eastern side (Cromarty & Scott, 1996).

Lake Onoke, the smaller of the two main lakes, is a bar-dammed lagoon containing brackish water with a three kilometre long shingle spit often separating it from Palliser Bay depending on oceanic conditions and flow volumes occurring in the Ruamahanga River (Cromarty & Scott, 1996). North west of Lake Onoke, back into the foothills of the ranges lies a small but deep water body, Lake Pounui. Battery Stream flows from the ranges, via

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[10] Lake Wairarapa and Lake Onoke represent 78 percent of the entire wetland area in the catchment (F. Forsyth & Dixon, 2004).

Lake Pounui to feed the Pounui Lagoons, which until recently were connected to Lake Onoke (Cromarty & Scott, 1996).

The LWW are of significant importance ecologically. They provide habitats for various species of fish, and other rare and endangered species. There are large numbers of waterfowl resident at the wetlands, including ducks, geese and swans, and also many rare plant species (Cromarty & Scott, 1996). These wetlands are also of social and cultural importance, valued highly for recreation and tourism purposes, and also provide important hydrological and biophysical values particularly in regard to recharge and discharge of groundwater, flood protection and sediment trapping (Cromarty & Scott, 1996).

The area of wetlands in the Ruamahanga Catchment was once considerably larger than it is today. The demand for fertile agricultural land from the mid-1800's onwards led to the substantial clearing and draining of the original wetland area. It has been estimated that only 13 percent of the original area remains (F. Forsyth & Dixon, 2004). In order to preserve the state of remaining wetlands, a wetland inventory was developed by GWRC in 2003 which focused on the current state of the wetlands to serve as a baseline as to measure change in the future.

One hundred and thirty three wetlands were individually identified and classified according to land tenure and wetland health indicators before being entered onto the Wairarapa Wetlands Database (WWD) (98 of these wetlands are within the Ruamahanga Catchment boundary) (Figure 5-8). The identified wetlands were found to be between 0.2 – 411 ha (excluding Lake Wairarapa and Lake Onoke), with the majority falling within the range 1-10 ha (F. Forsyth & Dixon, 2004). One fifth of the wetlands are very small - less than one hectare.

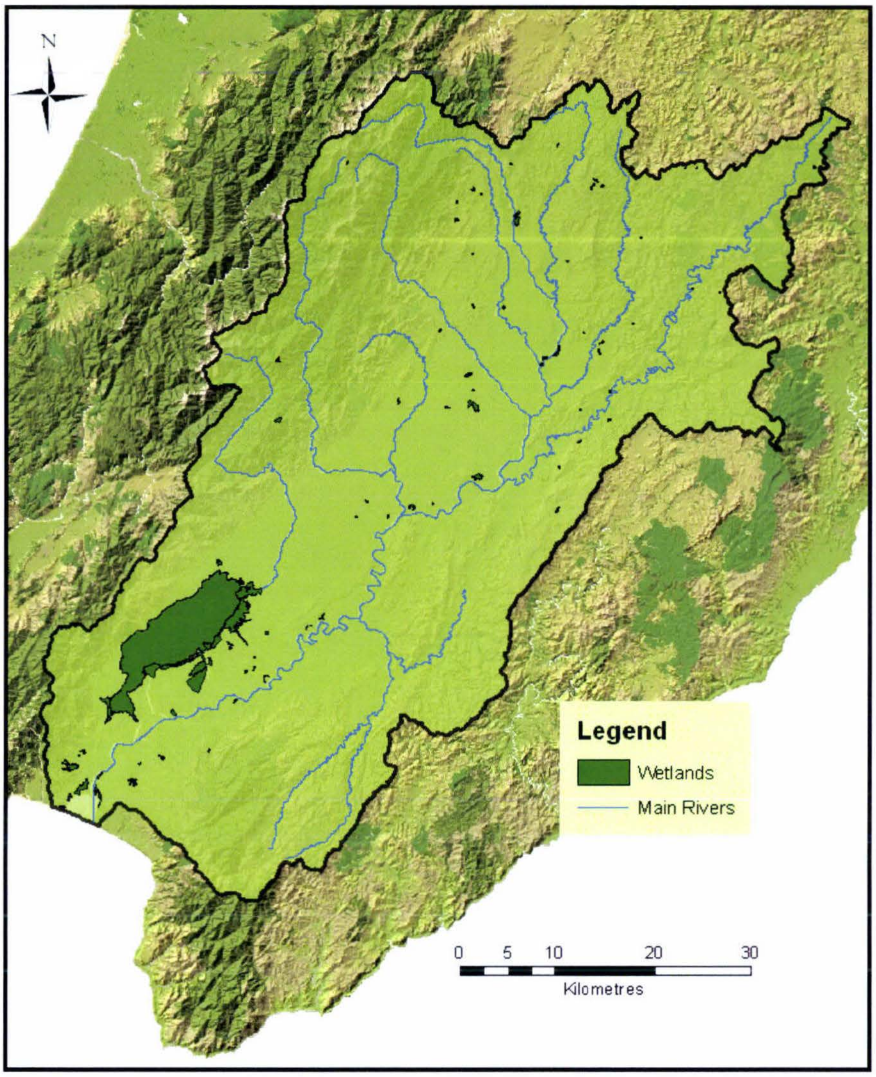

Figure 5-8: Wetlands in the Ruamahanga Catchment

The monitoring of the wetlands found that "80 percent of the wetlands by area have suffered changes to their hydrology regime", that "less than 10 percent have adequate buffer zones", and that "only eight percent of all wetlands in Wairarapa are in good condition" (F. Forsyth & Dixon, 2004, p. 23). Findings from this monitoring survey have prompted an increase in restoration and protection activities by GWRC.

Further information on the LWW, and the WWD can be found from 'A Directory of New Zealand Wetlands' (Cromarty & Scott, 1996), that provides an in-depth inventory of the LWW, inclusive of a comprehensive listing of flora and fauna, and 'Wairarapa Wetlands – an overview' (F. Forsyth & Dixon, 2004).

5.5. GEOLOGY

This section includes a description of the geological units occurring within the Ruamahanga Catchment and comments on the catchment's structural geology.

5.5.1. Data Sources

5.5.1.1. National Geological Maps

National geological information is listed in the NZLRI. There are two lithological editions of the NZLRI, both of which have been derived from "aerial photograph interpretation, field verification and measurement" (Newsome et al., 2000, p. 11 & 16). The REC database also provides some indication of geology, but is rather simplistic, classifying areas into only three categories: 'soft sedimentary'; 'hard sedimentary'; and 'volcanic'.

5.5.1.2. Regional Geological Maps and Publications

Many geological maps have been generated for the Wairarapa and Wellington Regions. These include:

- Kingma J.T. 1967. Sheet 12 Wellington. Geological Map of New Zealand. (1:250 000). DSIR. Wellington - (Kingma, 1967)
- Begg, J.G.; Mazengarb, C. 1996: Geology of the Wellington Area, *Institute of Geological and Nuclear Sciences, Geological Map* 22 (1:50,000). - (J G Begg & Mazengarb, 1996)
- Begg, J.G.; Johnston, M.R. 2000: Geology of the Wellington area, New Zealand: *Institute of Geological and Nuclear Sciences, Geological Map* 64 (1:250,000). - (J.G. Begg & Johnston, 2000)
- Begg, J.G.; Legg, J.G. 2002: Geology of the Wairarapa area, New Zealand *Institute of Geological and Nuclear Sciences, Geological Map* 11 (1:250,000). - (J.G. Begg & Legg, 2002)
- QMAP: 1:250 000 digital geological maps of New Zealand. - (Institute of Geological and Nuclear Sciences, n.d.)

The Ruamahanga Catchment land area falls on the join of the Wellington and Wairarapa IGNS maps. Therefore to obtain the geology for the full extent of the Ruamahanga Catchment, these two maps must be merged.

Most recently, Begg et al., (2005) prepared a document entitled – 'A review of Wairarapa Geology – with a groundwater bias' for GWRC. In this publication, Begg and others classified the geology into five separate units based on rock relationships (and hence geological history) and properties. These units can be loosely correlated to the three physiographic units described in Section 2.1: mountain ranges; hill country; and a central lowland basin. The distribution of these rock units can be seen in Figure 5-9 (note that Unit 2[11] is not evident at the surface level within the Ruamahanga Catchment). The data for Figure 5-9 was obtained by merging the QMap data[12] for the Wairarapa and Wellington IGNS maps. The lithological units (1-5) were distinguished using information from Begg et al. (2005), and described in Section 5.5.2.

5.5.2. Lithological Units

Unit 1 is comprised of mostly hard quartzofeldspathic sandstone, and interbedded mudstone, commonly known as greywacke. Unit 1 sediments are the oldest in the catchment being deposited over the time frame of 230 – 120 Ma ago (Permian to Cretaceous)[13], and are generally referred to as basement. Begg et al., (2005) gave this unit the name of Torlesse composite terrane and Pahaoa Group, these rocks make up the Tararua and Rimutaka Ranges, as well as the Aorangi Range in the south east. These rocks have been highly deformed over geological time due to the tectonic uplift associated with the underlying plate boundary. "Bedding planes within this unit are usually steeply dipping" (Begg et al, 2005, p. 6). Fault planes are common, especially those trending north west up the axial ranges, which are part of Wellington fault system.

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[11] Unit 2 is comprised of the Mangapurupuru Group, Glenburn Formation, Tinui Group,and the Mangatu Group. It is found in Eastern Wairarapa.

[12] QMap is the digital geological mapping data, created by IGNS.

[13] A geological time scale and correlated units have been included in Appendix 1.

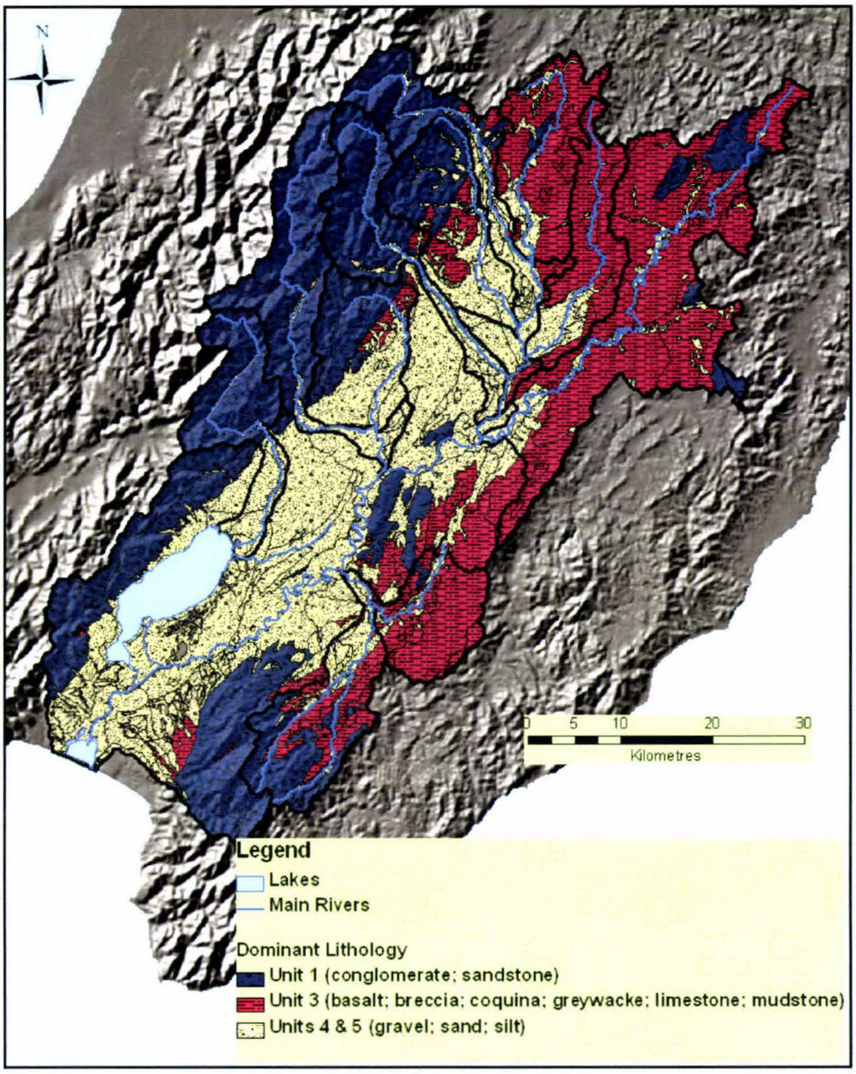

Figure 5-9: Geological Map of the Ruamahanga Catchment, divided into units after Begg et al., (2005). Nb. Unit 2 is not evident at the surface level within the Ruamahanga Catchment.

The eastern Wairarapa hill country consists mostly of Unit 3, the Palliser Group and Onoke Group. Rocks in these groups are entirely sedimentary and include conglomerate, sandstone, siltstone, mudstone and limestone. It is thought that these rocks were deposited in a marine environment in the period 25 – 2.3 Ma (Late Oligocene – Late Pliocene) (Begg et al, 2005). Unit 3 sediments are also found in the terraces north of Masterton, and are those that form the rise of Mt Bruce.

The lithologies of Units 4 and 5 make up the Wairarapa Valley. Sediments in Unit 4 were deposited in the period between early to middle Quaternary (2.3 Ma – 128 ka) and Unit 5 sediments were deposited later in the late Quaternary (<128 ka). Unit 4 sediments consist mainly of "alluvial gravel and sand with minor silt and swamp deposits, they were deposited in response to tectonic uplift of the eastern Wairarapa hill country and the Tararua Range during a period of fluctuating climatic conditions" (Begg et al, 2005, p. 8). Unit 5 sediments are "dominated by alluvial gravel deposited by the major rivers draining the Tararua Range" (Begg et al, 2005, p. 10). These late Quaternary gravels are featured more extensively in the Wairarapa Valley, with the Early to middle Quaternary deposits only outcropping in several locations of the eastern edge of the valley (east of Gladstone and south west of Martinborough), and also at some isolated areas west of Martinborough and on the western edge of Lake Onoke.

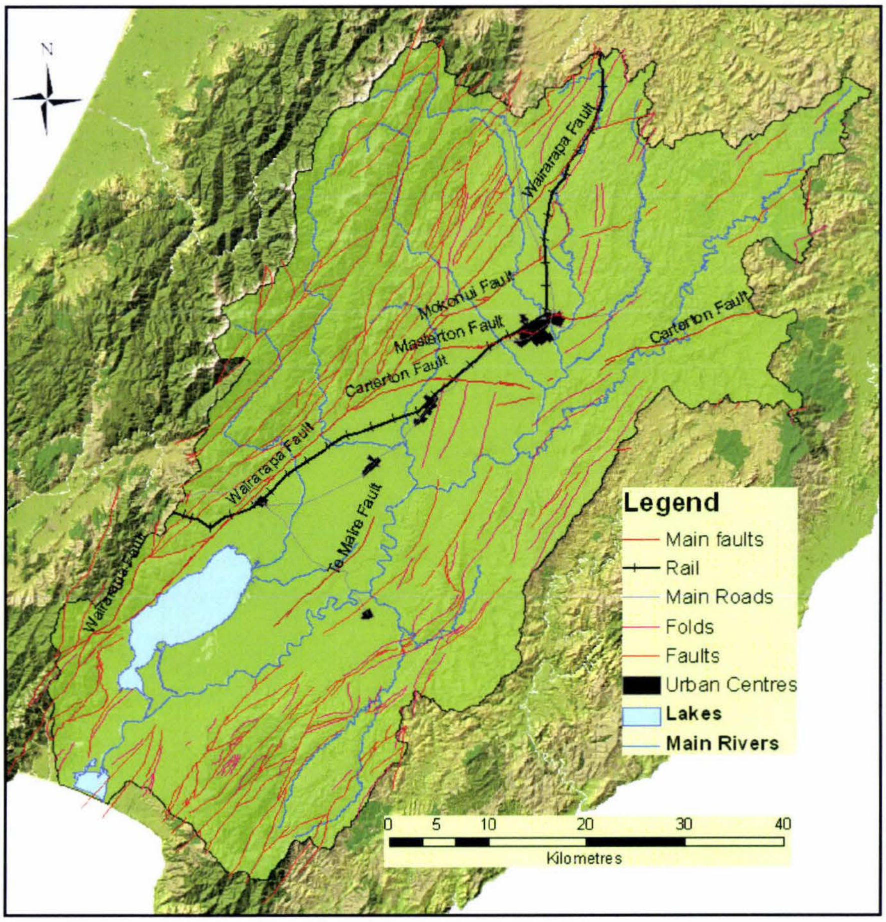

Figure 5-10: Map showing the geological structure of the Ruamahanga Catchment (QMap)

Appendix 2, sourced from Begg et al, (2005) provides further subdivision of Units 4 and 5, and relates the deposited material to the depositional environment and relative time of deposition.

5.5.3. Structural Geology

The most recent structural geology data for the Ruamahanga Catchment can be obtained from the merged QMap data sets and from Begg et al (2005) (Figure 5-10). Fault line hazard areas have also been mapped on the Wairarapa Combined District Plan.

The Wairarapa Fault is the dominant structural feature in the Ruamahanga Catchment. It is an active dextral[14] strike slip fault that extends throughout the entire catchment dividing the up-thrown greywacke rocks of the ranges (Unit 1) and the younger Quaternary sediments that form the majority of the Wairarapa Valley (Units 4 and 5). The Wairarapa Fault, along with others in the southern North Island, carry most of the shear associated with the Hikurangi Trough (Begg et al, 2005). The Wairarapa Fault splits into two splays at the southern end of Lake Wairarapa, one of these splays enters into the Rimutaka Range, while the other (known as the Wharekauhau Thrust) continues down the eastern margin of the ranges.

Three active faults (Mokonui, Masterton and Carterton Faults) branch off the Wairarapa Fault in the northern portion of the catchment and cut across the valley in an eastward direction. Slip on these faults include a dip slip[15] vector that has resulted in uplift and northwest tilting of terrace gravels on the northwest side of each fault (Begg et al, 2005).

The lower Wairarapa Valley is thought to be absent of cross-cutting active faults, and is characterised by long-valley faults. The Huangarua Fault is located in the Aorangi Range and is aligned in a north easterly direction, parallel with the Wairarapa Fault on the opposing side of the valley. "The Huangarua fault is thought to be associated with the anticlinal fold that makes up the Harris Ridge" (Collen & Vella in prep, Nicol et al. 2002 as

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[14] Right - lateral

[15] Dip-slip faults include both *normal* and *reverse* faults. The other type of faults are Strike-slip, where most of the movement is horizontal.

cited in (Begg et al, 2005, p. 17)). The Te Maire, Turanganui and Martinborough Faults are some of the other long-valley faults present in the catchment.

It has been postulated that uplift is currently occurring in the lower section of the Ruamahanga River across the mouth of the Wairarapa Valley while concurrently there is subsidence in the Lake Wairarapa area. Such movements can cause a "plug" in the lower Wairarapa valley which can have ramifications for subsurface water flow (Begg et al, 2005). This has been discussed further in Chapter 7 of this report.

5.6. SOILS

5.6.1. Data Sources

5.6.1.1. National Soils Databases

Nationwide soils information can be obtained from the NZLRI as well as the National Soils Database (NSD), the Soils of New Zealand Database, the New Zealand Soils Spatial Database, S Map, the 500 soils project, and the soils portal on the Landcare Research website.

The NZLRI was previously introduced in Section 5.3.1. Soil units are one of the parameters that the inventory provides along with soil chemical and physical attributes, soil drainage parameters, soil environmental parameters, and soil moisture properties. Parts of the information in the NZLRI were obtained from the 1:250,000 scale DSIR soil bureau maps and expanded to higher resolutions of 1:63,000 and 1:50,000, this scaling has been the cause of many inaccuracies in the database (V. Froude, 1999, section 12.6).

The NSD includes characteristics for approximately 3000 New Zealand soils that were collected and mapped from 1938 to 1992 largely by the DSIR Soil Bureau. Characteristics include soil profiles, site descriptions, and chemical, physical and mineralogical data (V. Froude, 1999).

Soils mapped from the 1930's to 1960's at 1:1,000,000 scale and published by the New Zealand Soil Bureau have been digitised to create the Soils of New Zealand Database. Included in this database are "soil type distributions and subdivision of soil groups" (V. Froude, 1999, section 13.3).

The New Zealand Soils Spatial Database was derived from the NZLRI, the New Zealand Soils Classification, and the NSD, to provide national soils identification and distribution and information on soil characteristics and chemical and physical properties. Creation of the database began in 1994 and continued until 2000 (V. Froude, 1999).

S Map, currently being created by Landcare Research is a digital soils database which "builds on previous mapping by filling gaps with new mapping and upgrading the information content and associated database to meet a new national standard" (Landcare Research, 2007, para. 2).

The *500 Soils Project*, is a joint initiative by Landcare Research, Crop and Food and the Ministry for the Environment which ran from 1999 to 2001 (Denton, 2006). Organic matter characteristics, chemical characteristics, physical properties, and biological activity were measured at all of the sites over the period in an effort to create a baseline against which to measure future trends of soil quality. Soil quality at these sites was strongly linked to land use.

5.6.1.2. Soil Classification

Several different soil classifications have been used in New Zealand. The New Zealand Soil Classification (NZSC) (Hewitt, 1998) is the most recent classification system, which overtook the New Zealand Genetic Soil Classification which was done in 1968. The NZSC "groups soils on the basis of properties that can be precisely measured or observed" while the genetic soil classification "classifies soils largely on their origin" (Hawke, Watts, & McConchie, 2000, p. 3).

5.6.1.3. Regional Soil Maps and Soil Monitoring

The New Zealand Soil Bureau mapped the soils of the Wairarapa Valley in 1975 (Heine, 1975, #40), since this time only small localised soil studies have been carried out within Wairarapa, e.g. on the Riverside Farm north of Masterton (Pollok, Neall, & De Rose, 1994). In 2000, Victoria University published a series of reports in the Wairarapa Irrigation Study, one report gives soils classification and characterisation for the area (Hawke, Watts et al., 2000).

In addition to these studies GWRC monitors soil quality throughout the Wellington Region and have compiled a report 'Soils and Minerals – Background Report' (Denton, 2006), a soil monitoring technical report (Croucher, 2005), and also participated in the *500 Soils Project*. Of the 116 soil sites for the project in the Wellington Region, only 35 percent met all of the targets. Soil compaction was the main reason for this (Croucher, 2005; Denton, 2006).

At the time of writing the S Map for Wairarapa was not completed. Further information on this can be obtained from Linda Lilburne from Landcare Research.

5.6.2. Soils of the Ruamahanga Catchment

Soil types and their characteristics are strongly related to geology, landforms, elevation, rainfall and vegetation cover, and are commonly classified according to their location e.g. soils of the low terraces. In the Ruamahanga Catchment soils have been classified by Heine (1975) into the following categories: soils of the floodplains and swamps (recent, gley and organic); soils of the sand dunes (yellow-brown sands); soils of the river terraces and fans (yellow grey – yellow brown earths and loams); soils of the undulating, rolling and hilly land (yellow grey – yellow brown earths, rendzinas); and soils of the steepland (steepland soils and subalpine gley soils)[16].

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[16] Soils in brackets are the Genetic Soil Group Classification.

The soils in Figure 5-11 have been derived from the soil groups in the NZLRI, and the New Zealand Genetic Soil Group Classification. The square brackets in the legend dictate the updated New Zealand Soil Classification soil. These conversions were made using Molloy (1998, p. 234) and the New Zealand Soils Database. Hawke et al (2000, p. 4), similarly utilised the NZLRI to generalise the soils on the Wairarapa plains. Figure 5-11 has utilised the recent soils classification used in Hawke et al (2000), separating poorly from well drained recent soils.

Recent, well drained soils parallel most of the major tributaries in the catchment, as well most of the length of the Ruamahanga River. Poorly drained recent soils (Gley Soils)[17] are located around Lake Wairarapa, in addition to yellow brown sands (Recent and/or Brown) and saline recent soils (Gley and/or Recent) (Figure 5-11). Both types of recent soils are prone to flooding (Hawke, Watts et al., 2000). Yellow grey earth soils (Pallic Soils) dominate the eastern side of the Ruamahanga River, in particular around Martinborough. On the western side of the river, soils are predominately yellow brown stony and shallow (Brown and/or Pallic). These alluvial soils are free draining and are suitable for sheep and cattle production (Hawke, Watts et al., 2000; Molloy, 1993, p. 120).

Yellow brown earth soils (Brown Soils) feature extensively on the higher elevated, high rainfall areas of the catchment, including the Tararua and Rimutaka Ranges, the Aorangi Ranges, and in the north of the eastern Wairarapa hill country. Organic soils are found in peaty areas that were once raupo swamps. Rendzinas (Melanic Soils) form on the limestone of the eastern hills, and the sands found at the southern end of the catchment have been developed by wind blown sand from Lake Wairarapa's foreshore (Hawke, Watts et al., 2000). "There are only relatively small pockets of good soils, some of which are used for pip fruit and berry fruit (Greytown) and viticulture (Martinborough)" (Molloy, 1993, p. 120).

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[17] The soils in brackets are the New Zealand Soil Classification soil

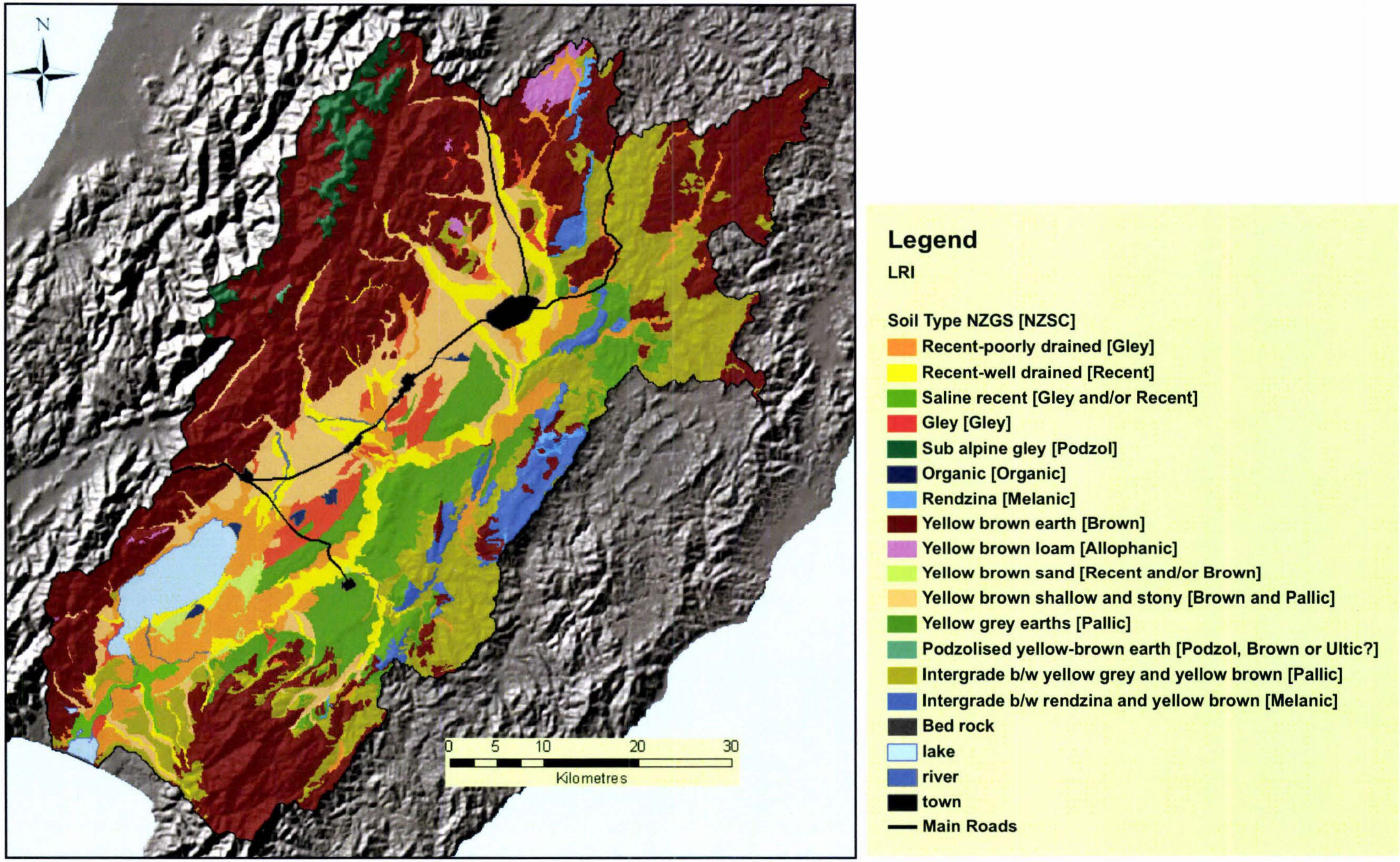

Figure 5-11: Genetic soil map of the Ruamahanga Catchment derived from the NZLRI

5.7. EROSION

5.7.1. Data Sources

5.7.1.1. National Databases pertaining to Erosion

Surface erosion, mass movement erosion, fluvial erosion, and stream bank erosion are the main types of erosion occurring in New Zealand (Ministry for the Environment, 1997). Mass movement erosion is closely linked with land use capability maps (Figure 5-2 Figure 5-3) that are derived from the NZLRI. "Most hill slopes steeper than 15 degrees are susceptible to mass movement, and those steeper than 28 degrees generally have a severe potential" (Fransen and Brownlie, 1995 as cited in Ministry for the Environment (1997, p. 52).

The other types of erosion in New Zealand are identified on the national susceptibility to erosion map that has been created by Clough and Hicks (1992) at 1:3,000,000 scale, and in the NZLRI which distinguishes between 17 different types of erosion, including earthflow, scree, wind, slump and streambank (Newsome et al., 2000).

5.7.1.2. Regional Erosion Mapping and Additional Publications

The Wairarapa Combined District Plan provides erosion hazard zones. Erosion occurring within the Ruamahanga Catchment is also described by Denton (2006) in GWRC's 'Soils and Minerals – background report' and by Tait et al. (2002) in the NIWA report 'Meteorological Hazards and the Potential Impacts of Climate Change in Wellington Region – A scoping study'.

5.7.2. Present Assessment of Erosion in the Ruamahanga Catchment

Erosion severity in the Ruamahanga Catchment is featured in Figure 5-12. This map, derived from the NZLRI, shows erosion at the time of mapping, not potential erosion. Therefore at the time the NZLRI was created in the 1970's there was severe to very severe erosion occurring on 2.3 percent of the Ruamahanga Catchment. Potential erosion can be obtained from the NZLRI by using the LUC units. However this information can be difficult to extract as it requires in depth indexing between the extended legend of the NZLRI and the database (P. Newsome, personal communication, 5 June, 2007).

Wind erosion (a type of surface erosion) can be severe on the Wairarapa Plains. "Cultivation and grazing pressure in time of drought can lead to exposed topsoil which can blow away in the wind, depleting essential nutrients and hinder plant growth" (Denton, 2006, p. 24). A survey carried out in the mid seventies found a large area was susceptible to surface erosion which instigated the establishment of over 200 km of shelter belts to minimise soil loss over 15,000 ha of land (Denton, 2006).

Hicks (1995), identified erosion susceptible land in New Zealand. For the Wellington Region he stated that 454,300 ha were at risk to erosion, of this area 279,000 ha is being farmed. He also divided the farmland into percentages of stable and erodible land, which for Wellington equated to 42 percent and 58 percent respectively. At this time, a further subdivision of these statistics for the Ruamahanga Catchment is not available.

Another Wellington wide erosion map was completed by GWRC in 1994, detailing earthquake and rainfall induced slope failures. Tait et al (2002, p. 18) commented that "to date this is the best method GWRC has to determine the rainfall induced landslide hazard for a particular area". Further information on landslides in the Ruamahanga Catchment can be sourced from these publications.

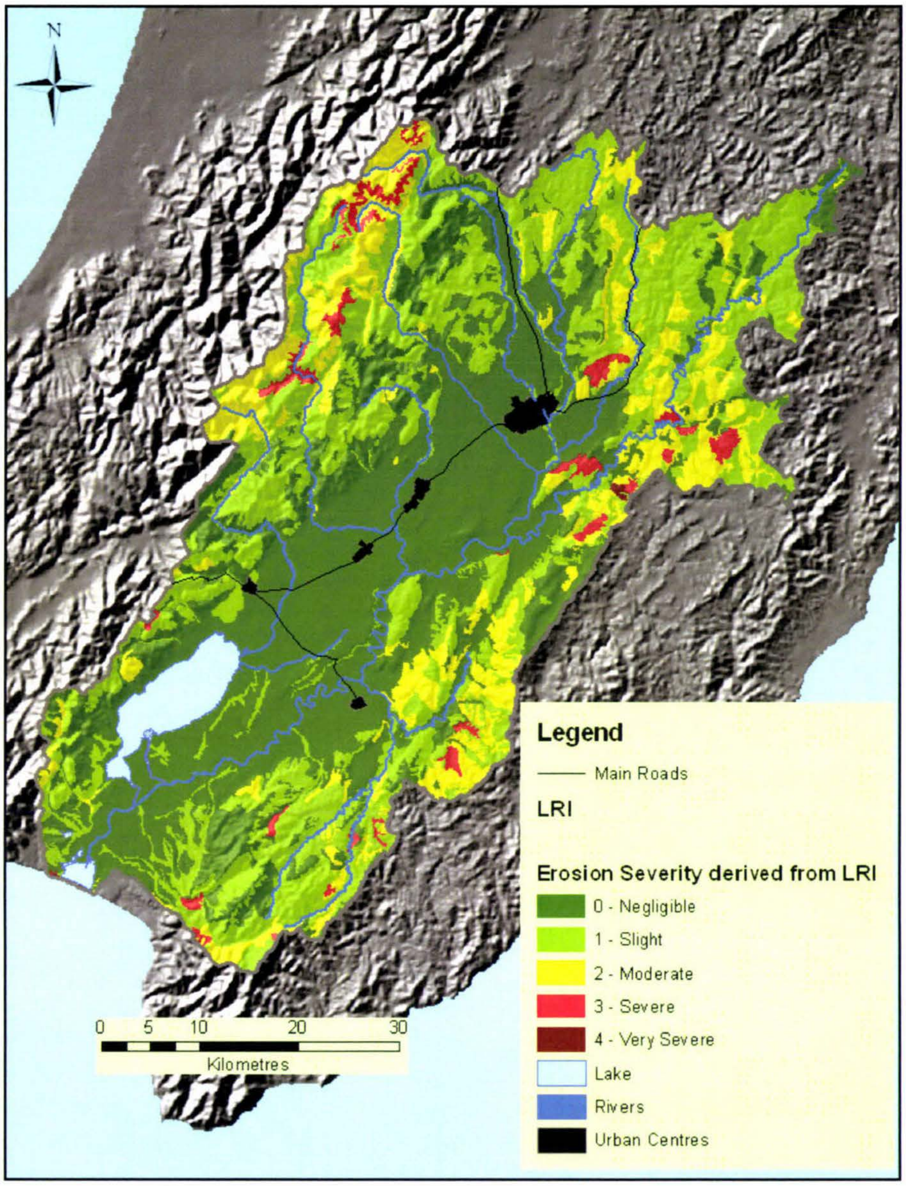

Figure 5-12: Erosion occurring within the Ruamahanga Catchment, derived from the NZLRI

5.7.3. Factors Influencing Erosion

The various factors that influence erosion in the Ruamahanga Catchment include slope instability which is directly related to topography and vegetation (Tararua and Rimutaka Ranges and eastern Wairarapa hill country); high winds (Wairarapa Plains); high rainfall (Tararua and Rimutaka Ranges); erosion prone soils and sediments (eastern Wairarapa hill country); and seismic activity (widespread due to extensive splaying of fault lines in the catchment).

5.8. VEGETATION

5.8.1. Data Sources

5.8.1.1. National Vegetation Maps

Spatial data pertaining to the vegetation coverage in New Zealand include the Land Cover Database (LCDB), the vegetation inventory in the NZLRI, and the Vegetation Cover Map of New Zealand. The REC also covers vegetation to some extent. A 1:1,000,000 vegetation map was also compiled by Newsome et al. in 1986.

New Zealand's land cover has been represented in the LCDB. The original LCDB1, used Spot II satellite imagery from 1996/97, and was completed in 2000. This database has since been superseded by the LCDB2, which utilised Landsat 7 imagery from 2001/02. The LCDB indicates artificial, cultural and natural landscapes, with a minimum mapping area of one hectare (V. Froude, 1999). There are some limitations with this database. These include the exclusion of vegetation patches that are less than 1 hectare in area; classification of wetland vegetation can be inconsistent; and there can also be confusion with the classification system, as some units can belong to more than one category (V. Froude, 1999, section 12.5).

The vegetation inventory in the NZLRI distinguishes between five types of vegetation (crops, grass, scrub, forest and herbaceous) and then includes some further subdivision within each of these categories. Shortcomings of using the NZLRI for vegetation coverage according to Froude (1999, section 12.6) is that the description of the vegetation units in a polygon "can result in descriptions of entities that do not actually occur in nature" because the polygons in the NZLRI are based on rock type, soil unit and slope, and "do not provide any understanding of the different ecological associations occurring within a polygon and the relationships between those associations".

The Vegetation Cover Map of New Zealand was completed in the 1980's, and includes parameters such as vegetation cover group, class, and element. This map was primarily created from the NZLRI which can be perceived as being somewhat outdated, and hence is one of the major downfalls of this map.

5.8.1.2. Regional Vegetation Mapping and Publications

Information on the vegetation occurring within the Ruamahanga Catchment came from publications that were not solely focussed on vegetation. These publications included the 'Wairarapa Engineering Lifelines Project - Risk to lifelines from natural hazards', 'Wairarapa Wetlands' by (F. Forsyth & Dixon, 2004), and Lake Wairarapa Wetlands (Cromarty & Scott, 1996).

5.8.2. Historic Vegetation of the Ruamahanga Catchment

In the lower portion of the Ruamahanga Catchment, surrounding the lake systems, remnant tree species indicate the vegetation that was likely to have existed in pre-human times. Ogle, Moss and Druce (1990) as cited in Forsyth & Dixon (2004) and Cromarty (1996) identified these species to include kahikatea, cabbage tree, totara, ribbonwood, kowhai and lacebark. Black beech is remnant on the western side of Lake Wairarapa, along with Titoki and Karaka, and Cromarty (1996, p. 151) suggests that these species were "probably typical of the original forest between the Rimutaka Range and Lake Wairarapa", on the other side of the lake, in the floodplains, "tall podocarp or podocarp beech swamp forest once stood" (Fuller (1993) as cited in (F. Forsyth & Dixon, 2004, p. 10). Interestingly, according to Hill (1965 as cited in (Hawke, Watts et al., 2000), "prior to European settlement much of the valley was grassland" and only some of the valley had to be cleared for pastoral use.

5.8.3. Present Vegetation of the Ruamahanga Catchment

Wairarapa Engineering Lifelines Association (2003, p. 42) described the current vegetation of the Ruamahanga Catchment according to the landforms; the "foothills are grassed or scrub covered, while the ranges are largely forested with podocarp inhabiting the lower valleys and the more resilient beech forest occupying the higher more exposed slopes". At higher elevations above "1,200 m the scrubby, leatherwood zone gives way to tussock grassland". Flax plantations, originally used by the Māori people and commercially harvested have all but disappeared (Cromarty & Scott, 1996).

The map in Figure 5-13 provides the spatial distribution of the vegetation coverage in the Ruamahanga Catchment, derived from the Land Cover Database (LCDB) (1st order class). The largest two types of vegetation in the catchment are high producing exotic grassland (60 percent of area, 2081 km^2), and indigenous forest (16 percent of the area, 586 km^2). Further sub classifications of the LCDB groups used in the LCBD2 are given in Appendix 3. Additional land use information will be covered in Chapter 9.

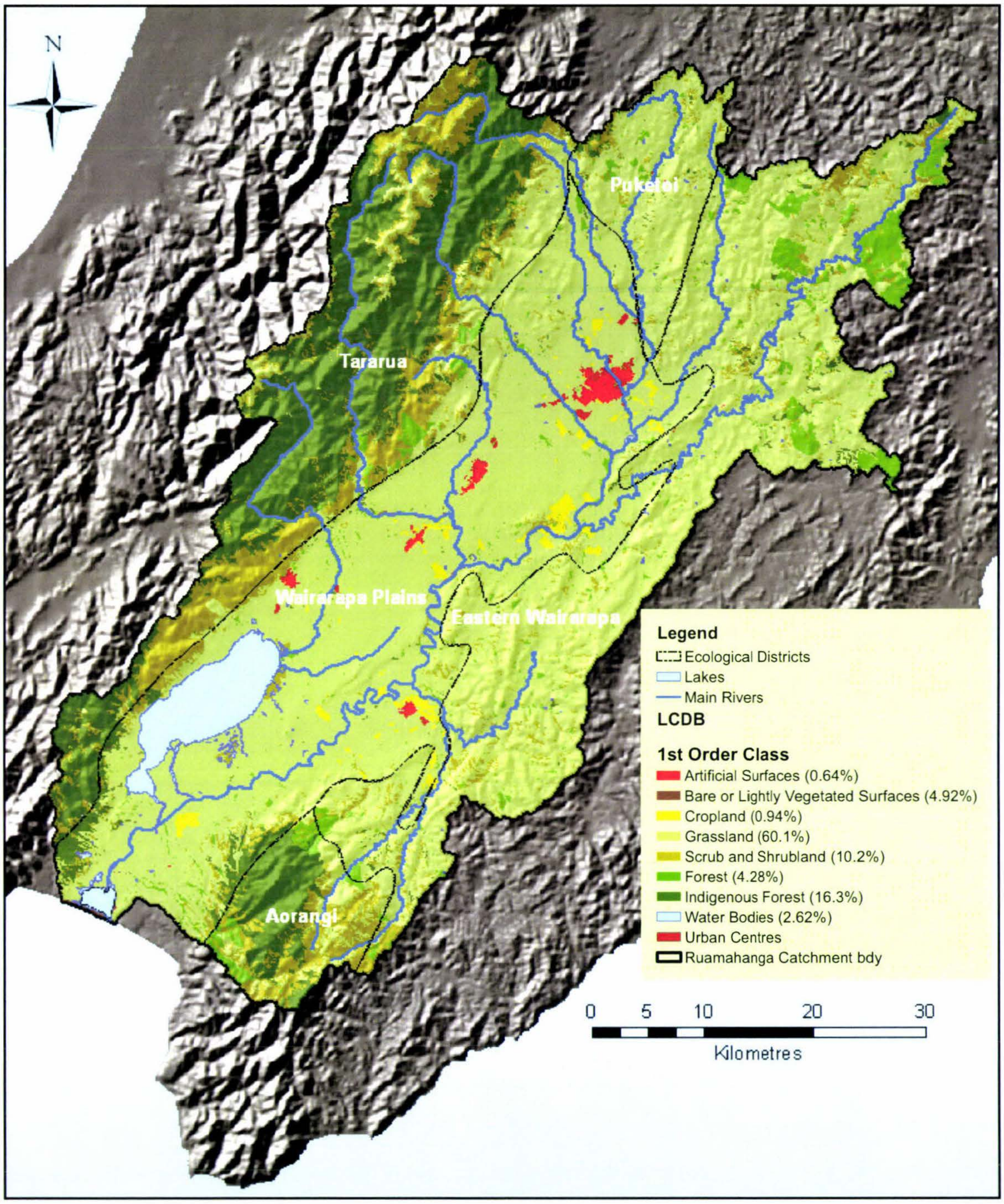

Figure 5-13: Vegetation Classes in the Ruamahanga River derived from the LCDB, and the Ecological District boundaries

5.9. ECOLOGICAL DISTRICTS

Although the previous sections on physiography, geology, soils, erosion, vegetation, and climate have been presented separately thus far, they are all inextricably linked. These linkages have been recognised throughout New Zealand and were described as 'Ecological Districts[18]' (EDs) by a DSIR working party in 1983.

ED	Physiography	Geology	Climate	Soils	Vegetation	Erosion	Land Use
Puketoi (Pahiatua ER)	Low ranges and dissected hills	Unit 3	Cool, wet hill climate	Fertile, less leached soils in areas of lower rainfall closer to the plains	Native forest cleared	Moderate to severe	Mostly semi-extensive sheep and beef
Eastern Wairarapa	Hill country	Unit 1, 3 and 4	Dryand warm	Hill and steepland soils, areas of loess derived soils with impeded drainage	Small area of indigenous forest remain, extensive secondary forest	Moderate to severe	Semi-extensive pastoral farming, areas of exotic forest
Wairarapa Plains	Terraces and Plains with a large lake	Units 4 and 5	Dry and warm	East - stony, shallow droughty soils. West - silter, friable soils. Fertile soils on the river flats	Most indigenous forest cleared. Kahikatea patches and scrub and wetland around L Wairarapa	Unstated	S and W have been modified for semi-extensive sheep and beef, rest of district for more intensive farming, cropping
Tararua	Steep, high dissected hills and mountains	Unit 1	High rainfall, strong westerly winds, snow	Diverse soils: steepland, alpine, fertile less leached soils on lower foothills	Alpline vegetation and tussock in higher elevations giving way to beech, kamahi, rimu, totara and miro forests below	Severe Erosion	Gorse covers a large amount of the Rimutaka Range as a result of fires and land clearing.
Aorangi	Steeply dissected range	Unit 1	Stong winds, rainfall similar to Puketoi	Steepland soils, leaching depends on elevation and rainfall	Podocarp hardwood beech and silver beech	Slipping and gullying	Modified by fire and introduced mammals, small areas of exotic forest

Table 5-3: A summary of the Ecological Districts in the Ruamahanga Catchment. Source (McEwen, 1987)

The Ruamahanga Catchment includes segments of five different Ecological Districts (EDs). Each ED represents part of the ecological character of the Ruamahanga Catchment (Figure 5-13, Table 5-3). They have been described by McEwen (1987) in the 'Ecological Regions and Districts of New Zealand' (Parts 2 and 3). The data in Table 5-3 excludes information on flora, mammals, birds, reptiles, frogs, fish, insects and snails.

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[18] "A local part of New Zealand where geological, topographical, climatic, soil and biological features and processes, including the broad cultural pattern, inter-relate to produce a characteristic landscape and range of biological communities" (Park, 1983). An 'Ecological Region' is an aggradation of ecological districts.

Refer to (McEwen, 1987) for more details. It is important to note that this resource is somewhat dated, and may not give an entirely accurate depiction of the catchment today.

5.10. INFRASTRUCTURE

Infrastructure commented on in this section includes roads, bridges, railway, community services, water races, water supply systems, sewerage systems, and flood protection infrastructure. The majority of this information has been acquired from the WELA publication and GIS data has come from GWRC.

5.10.1. Roads and Bridges

State Highway No.2 is the major road connecting Wairarapa to Hawke's Bay and Wellington. The road enters the Ruamahanga Catchment near Mt Bruce (at a height of 333 m above sea level (asl)), and cuts down the middle of the catchment passing through most major townships (at a general height of 40 m asl) before ascending over the Rimutaka Hill (maximum height of 555 m asl) (Wairarapa Engineering Lifelines Association, 2003).

The other major road found in the Ruamahanga Catchment is State Highway 53 which connects Featherston to Martinborough. This road is approximately 18 km long crossing a typically flat landscape as well as two major rivers, the Tauherenikau River at the Lower Tauherenikau Bridge, and the Ruamahanga River at the Waihenga Bridge.

5.10.2 Railway

Wairarapa's railway network is operated by Tranz Rail Ltd. Services run from Wellington through the Wairarapa Valley and on to Woodville, where the line merges with the Palmerston North - Gisborne Line. A passenger commuter service runs between Wellington and Wairarapa. Initially the railway crossed over the Rimutaka Hill on its journey into Wairarapa from the capital. This part of the track closed in 1955, and now uses the 8.8 km tunnel that extends from Upper Hutt through to the eastern side of the ranges. The line crosses numerous rivers and fault lines on its path through the Ruamahanga Catchment (Figure 5-14).

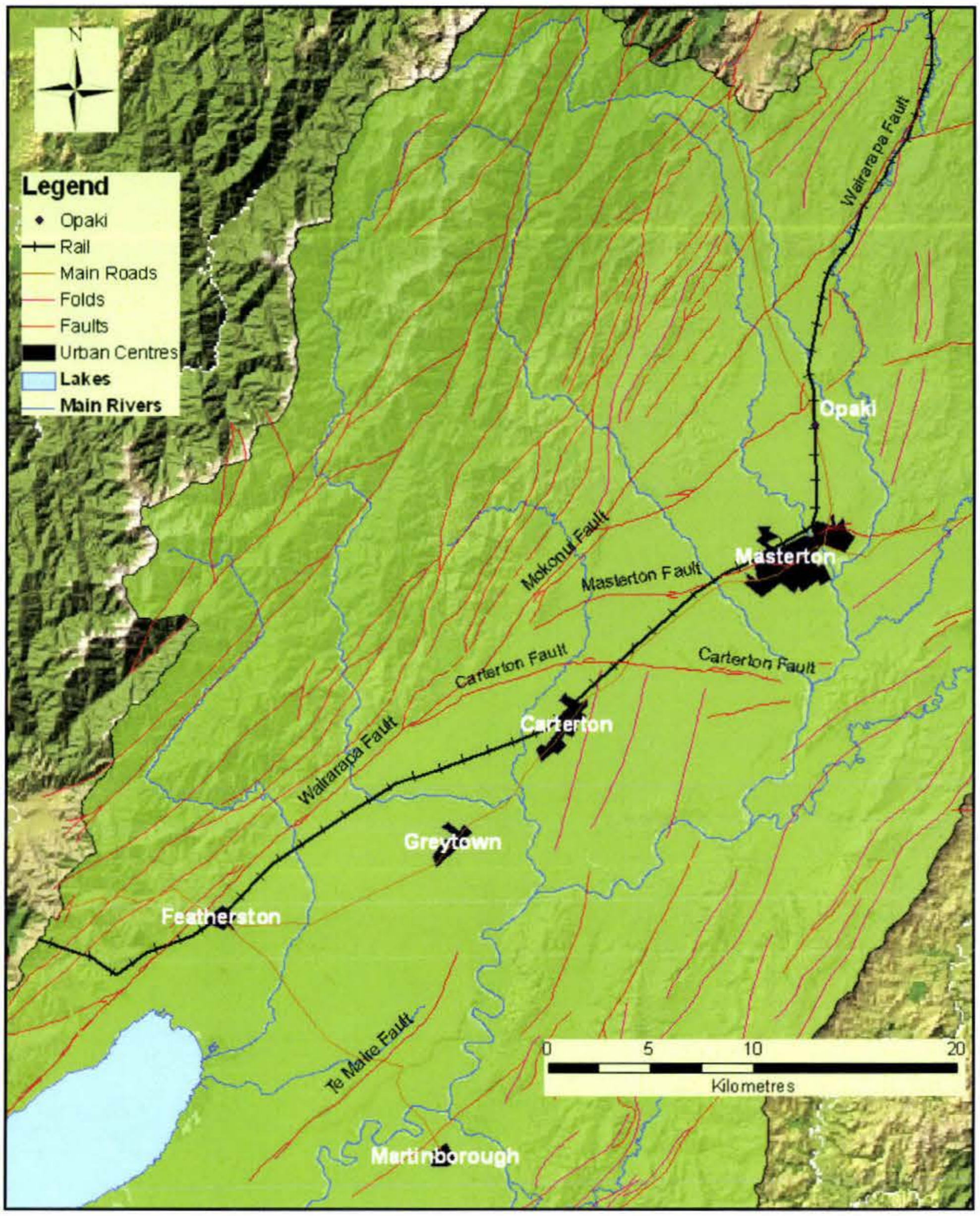


Figure 5-14: Wairarapa Railway route including physical features it crosses

In addition to these physical features, the line crosses areas of liquefiable sediment in the floodplain of the Mangatarere River, and at Opaki and north of Mauriceville (Wairarapa Engineering Lifelines Association, 2003). Generally the line traverses flat topography; however steeper gradients can be experienced near some of the major bridges.

5.10.3. Services

The main hospital servicing the area is located in Masterton, which has facilities for helicopter landings. Light fixed wing aircraft use the Hood Aerodrome, also in Masterton, which offers the only sealed runway in the Wairarapa District (Wairarapa Engineering Lifelines Association, 2003). In addition to the aerodrome, around 60 currently used rural airstrips have been identified throughout Wairarapa. Further information on telecommunications, electrical networks, and other services can be obtained from WELA.

5.10.4. Water Races

Water races have been used in the Ruamahanga Catchment for over 100 years. Their purpose is to "supply water across the plains by gravity" (Bevin, 1998, p. 5). Six open water systems are currently in use today (Table 5-4, Figure 5-15).

In addition to providing stock and irrigation water to numerous properties on the Ruamahanga Catchment valley floor, these water races "provide farm drainage systems for properties, water supply for fire fighting, support natural wetlands and swamps which have an influential impact on the flora and fauna in the district" (Stronge, 2000, p. 71).

5.10.5. Water Supply and Sewage Systems

The water supply and sewage management for each of the five townships in Wairarapa are detailed in Table 5-5 and Table 5-6. The map code column relates to the map in Figure 5-16, and identifies specific locations mentioned in the tables. Further information can be obtained from WELA, however the size of the water takes and discharge volumes are provided in Section 9.4.5 of this report.

Water Race	River	Allowable Take L/s*	Use
Opaki*	Ruamahanga River	170	▪ Stock water – Opaki Plains and vineyard irrigation
Te Ore Ore*	Ruamahanga River	250	▪ Stock and irrigation water – Te Ore Ore Plains
Taratahi	Waingawa River	482	▪ Stock water and irrigation?
Moroa*	Waiohine River	450	▪ Stock and irrigation water – Te Ore Ore Plains
Carrington	Mangatarere River	113	▪ Stock water – Mangatarere Valley
Longwood*	Tauherenikau	180	▪ Stock water

Table 5-4: The water races in the Ruamahanga Catchment. Source (Bevin, 1998)

* Resource consent for these four water races have been renewed in 2007. The Taratahi and Carrngton water races consents are due to be renewed in the near future. Currently these two water races are operating under the previous consent conditions.

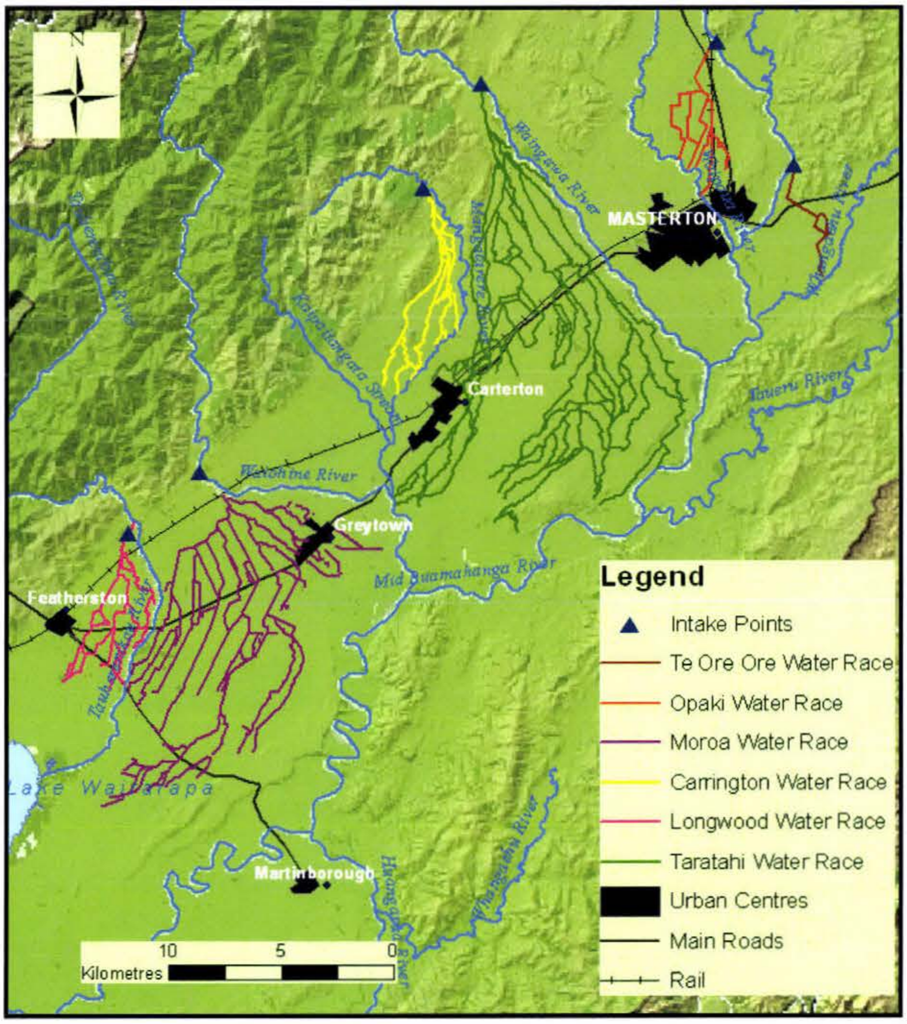
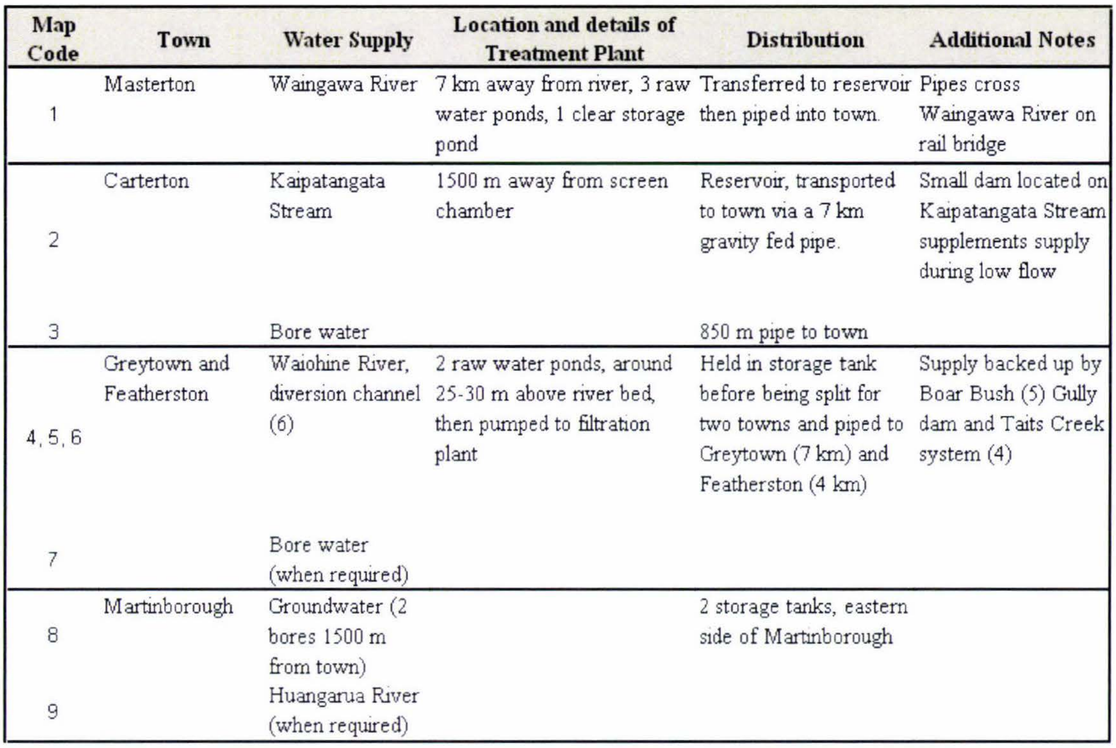
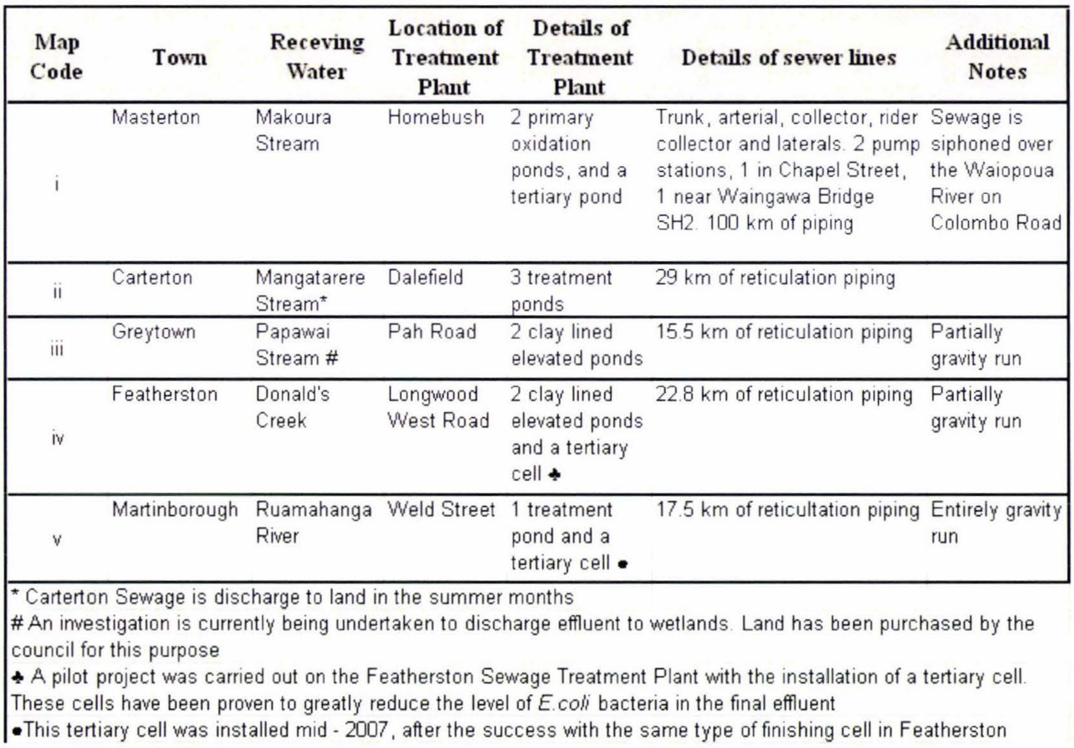


Figure 5-15: Location of the water races, and their intake points in the Ruamahanga Catchment



Map Code	Town	Water Supply	Location and details of Treatment Plant	Distribution	Additional Notes
1	Masterton	Waingawa River	7 km away from river, 3 raw water ponds, 1 clear storage pond	Transferred to reservoir then piped into town.	Pipes cross Waingawa River on rail bridge
2	Carterton	Kaipatangata Stream	1500 m away from screen chamber	Reservoir, transported to town via a 7 km gravity fed pipe.	Small dam located on Kaipatangata Stream supplements supply during low flow
3		Bore water		850 m pipe to town	
4, 5, 6	Greytown and Featherston	Waiohine River, diversion channel (6)	2 raw water ponds, around 25-30 m above river bed, then pumped to filtration plant	Held in storage tank before being split for two towns and piped to Greytown (7 km) and Featherston (4 km)	Supply backed up by Boar Bush (5) Gully dam and Taits Creek system (4)
7		Bore water (when required)			
8	Martinborough	Groundwater (2 bores 1500 m from town)		2 storage tanks, eastern side of Martinborough	
9		Huangarua River (when required)			

Table 5-5: Water Supply information for the five main townships in the Ruamahanga Catchment. Source (Wairarapa Engineering Lifelines Association, (2003). Nb. Map Codes relate to Figure 5-16.



Map Code	Town	Receving Water	Location of Treatment Plant	Details of Treatment Plant	Details of sewer lines	Additional Notes
i	Masterton	Makoura Stream	Homebush	2 primary oxidation ponds, and a tertiary pond	Trunk, arterial, collector, rider collector and laterals. 2 pump stations, 1 in Chapel Street, 1 near Waingawa Bridge SH2. 100 km of piping	Sewage is siphoned over the Waiopoua River on Colombo Road
ii	Carterton	Mangatarere Stream*	Dalefield	3 treatment ponds	29 km of reticulation piping	
iii	Greytown	Papawai Stream #	Pah Road	2 clay lined elevated ponds	15.5 km of reticulation piping	Partially gravity run
iv	Featherston	Donald's Creek	Longwood West Road	2 clay lined elevated ponds and a tertiary cell ♣	22.8 km of reticulation piping	Partially gravity run
v	Martinborough	Ruamahanga River	Weld Street	1 treatment pond and a tertiary cell ●	17.5 km of reticultation piping	Entirely gravity run

* Carterton Sewage is discharge to land in the summer months

\# An investigation is currently being undertaken to discharge effluent to wetlands. Land has been purchased by the council for this purpose

♣ A pilot project was carried out on the Featherston Sewage Treatment Plant with the installation of a tertiary cell. These cells have been proven to greatly reduce the level of *E.coli* bacteria in the final effluent

●This tertiary cell was installed mid - 2007, after the success with the same type of finishing cell in Featherston

Table 5-6: Sewage system information for the five main townships in the Ruamahanga Catchment. Source (Wairarapa Engineering Lifelines Association (2003) and (B.Johnson (SWDC), personal communication, 14 August 2007) Nb. Map Codes relate to Figure 5-16.

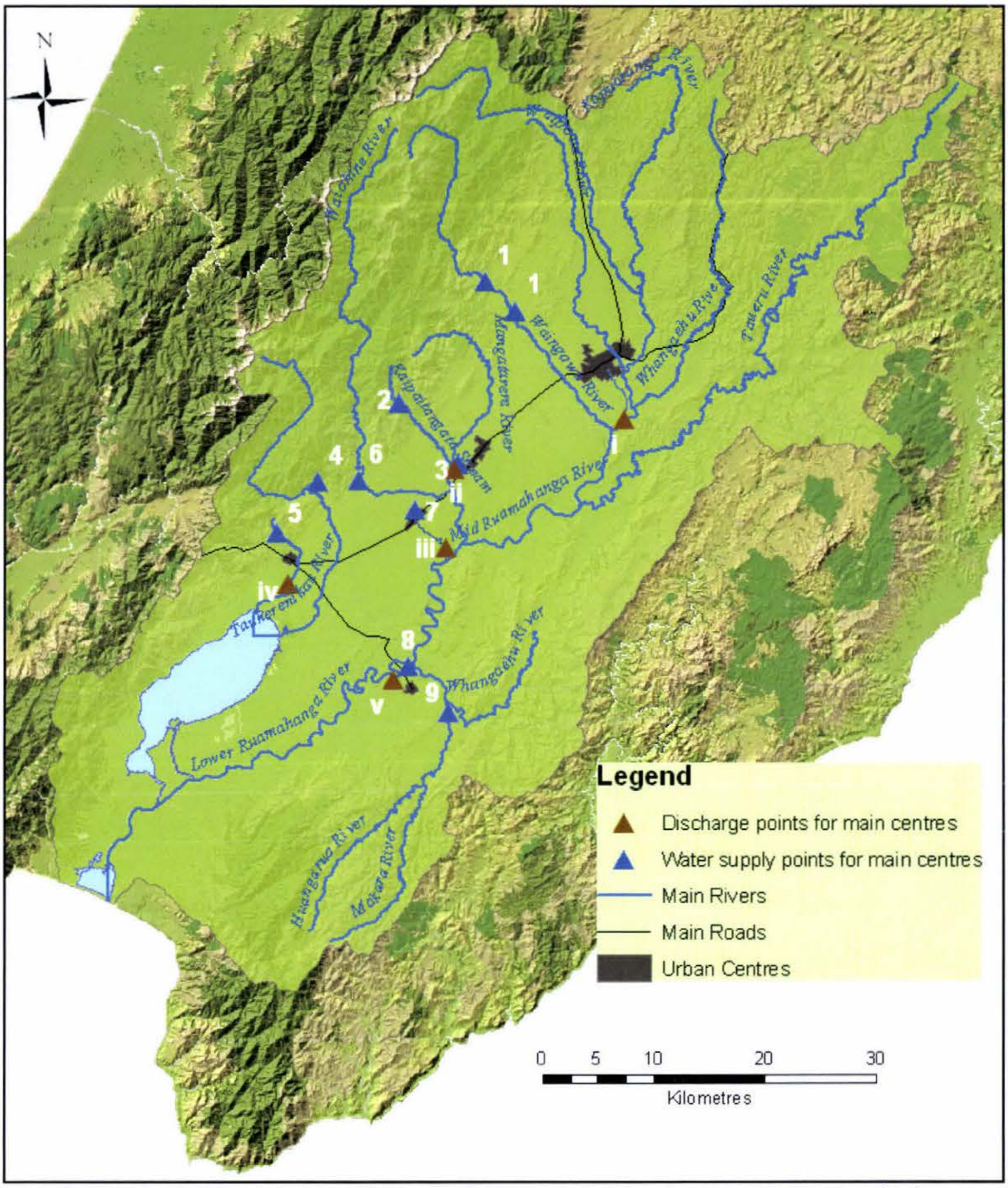


Figure 5-16: Water supply and sewage discharge points for the main town centres in the Ruamahanga Catchment. Numbers and Roman Numerals relate to the items in Tables 5-5 and 5-6.

5.10.6. Flood Protection Infrastructure

The map featured in Figure 5-17 indicates the location of the components of the flood protection infrastructure in the lower Wairarapa Valley. The LWVDS, as previously mentioned in Section 5.4.3.1 of this report, is made up of a combination of stopbanks, floodways, drainage outfall culverts, a flood detention dam and a barrage gate (Blundell Barrage).

The stopbank network provides protection from flooding for the following severity levels: "a 20 year flood level plus freeboard (a safety margin of approx 600 mm) from Martinborough to Tuhitarata and a 100 year flood level plus freeboard downstream of Tuhitarata" (Greater Wellington Regional Council, 2006a, p. 1).

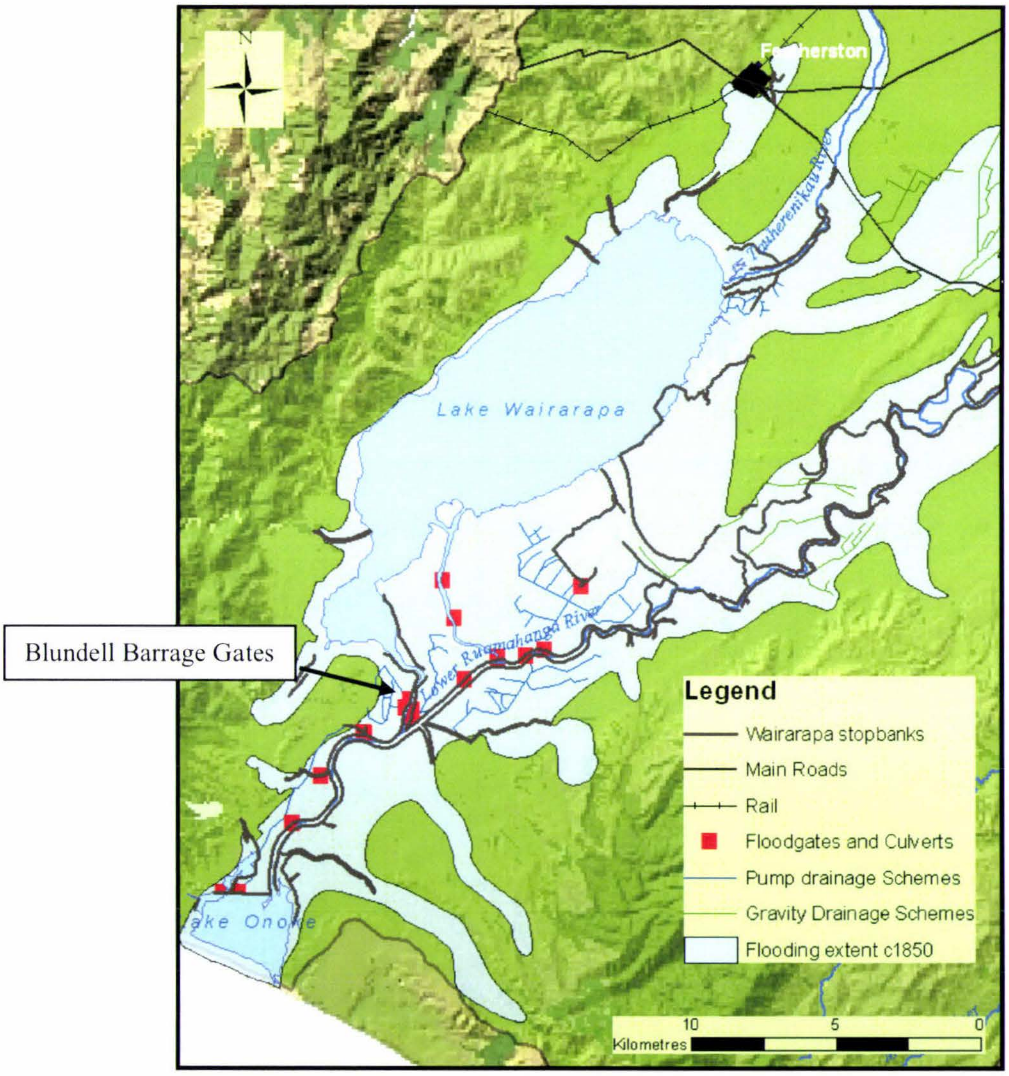


Figure 5-17: Flood Protection Infrastructure in the Lower Ruamahanga Catchment

The Blundell Barrage control gates are situated at the southern end of Lake Wairarapa. They are used control the water level in both Lake Wairarapa and Lake Onoke. They can prevent water flowing into Lake Wairarapa during a flood and reduce the water level in Lake Wairarapa after a flood has occurred (Greater Wellington Regional Council, 2006a).

Although the scheme does not protect urban areas, it assists in the protection of roads such as State Highway 2 and 53, Western Lake Road, the East-West Access Road, Kahutara Road and the Martinborough to Lake Ferry Road (Wairarapa Engineering Lifelines Association, 2003). GWRC is currently exploring the option of upgrading this flood control system. This will include increasing annual maintenance to make improvements especially to the previously identified risk areas.

The upper portion of the Wairarapa Valley contains flood protection measures on a smaller scale than that featured with the LWVDS. The Waiohine River, Waingawa River, Waipoua River and upper Ruamahanga River have stopbanks that endeavour to protect rural farmland, the townships of Masterton and Carterton, and many important roads in the area (Wairarapa Engineering Lifelines Association, 2003). Further information on the flood protection infrastructure in Wairarapa can be obtained from GWRC and WELA.

5.11. CONCLUSION

The purpose of this chapter was to provide an overview of the physical characteristics of the Ruamahanga Catchment. The landforms, geology, soils, level of erosion, vegetation and infrastructure are all described. A knowledge and understanding of these characteristics will serve as the foundation for many of the following chapters of this inventory.

6. Climate

6.1. INTRODUCTION

An appreciation of the climatic regime of the Ruamahanga Catchment is a fundamental aspect of this resource inventory as it strongly relates to water quantity, subsequent quality; and floods and droughts. This chapter will provide an insight into the main climatic elements (temperature, rainfall and wind) occurring within the Ruamahanga Catchment and relationships between rainfall and river flows will be established.

6.2. METHODOLOGY

The climate of the Ruamahanga Catchment will be described utilising the most relevant data sources. The description will be split into three sections pertaining to temperature, rain and wind and is based to a certain extent on information obtained from the publications presented in Section 6.3 but is also supplemented by various Greater Wellington Regional Council (GWRC) reports.

6.3. DATA SOURCES

The weather and climatic conditions of Wairarapa have been previously described in:

1. 'The Weather and Climate of the Wairarapa Region' by Thompson (1982) in a New Zealand Meteorological Service publication;
2. 'Wairarapa Engineering Lifelines Project - Risk to lifelines from natural hazards' (Wairarapa Engineering Lifelines Association, 2003); and
3. 'Meteorological Hazards and Potential Impacts of Climate Change in the Wellington Region' (Tait et al, 2002) – NIWA.

Additional information for this chapter was obtained from GWRC hilltop[19] records.

New Zealand's National Climate Database (CliDB) provides nationwide rainfall, wind, and temperature data among other parameters collected from NIWA and Met Service

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[19] Computer software for storing, plotting, retrieving and analysing time dependent data.

stations dating back to 1852. Information from CliDB can be accessed by registering with the Cliflo web system. From July 2007, this data will be freely available on the internet.

6.3.1. Climate Monitoring within Wairarapa

Official rainfall monitoring began in Wairarapa in June 1880, however comprehensive climatological records did not begin until 1905 where measurements were recorded in Masterton (Thompson, 1982). Today, there are numerous recording sites that make up the climate and rainfall monitoring network in Wairarapa. Appendix 1 of a GWRC publication by Morgan (2000) lists the automatic climate sites, manual climate sites, automatic rain gauges and manual daily read rain gauges that are found within Wairarapa. GWRC is responsible for the majority of the sites, while the Met Service, NIWA and private owners manage the remainder (Appendix 4 includes a list of selected rainfall and climate monitoring sites).

Currently GWRC records rainfall at Bannister Basin, Mt Bruce, Castlehill, Angle Knob, Carkeek, Waingawa, Waihi, Bull Mound, Valley Hill (Mangatarere), Te Weraiti, Phelps, and Iraia. A full set of climatic parameters are monitored at Wairarapa College (Masterton) and at Alloa. NIWA currently records rainfall in the Ruamahanga Catchment at 21 sites (Appendix 5) and holds historical rainfall records for 52 sites (Appendix 6).

Climatic data, in addition to rain, is currently recorded by NIWA at Masterton Te Ore Ore (air temperature, sunhours, windrun), Martinborough EWS[20] (air temperature, sunhours, windrun, radiation), East Taratahi AWS[21] (air temperature, windrun, radiation), Masterton (air temperature), and Masterton Intermediate School (air temperature) for CliDB.

NIWA holds historical climatic data, in addition to rain, at the following sites: Waingawa (air temperature, sunhours, windrun, up until 1991); Tauherenikau (air temperature,

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[20] Electronic Weather Station
[21] Automatic Weather Station

sunhours, windrun, up until 1994); Martinborough (air temperature, sunhours, up until 2000); East Taratahi (air temperature, windrun, until 1978); Pakaraka (air temperature, until 1980); Gladstone-Arahura (air temperature, windrun, until 1982); Waiorongomai (air temperature, windrun until 1993); and Martinborough-Dublin Street (air temperature, until 2000).

6.4. CLIMATE OF THE RUAMAHANGA CATCHMENT

Thompson (1982, p. 58) described Wairarapa as a "windy, sunny region with large temperature variations" and because the "orographic influences on the climate are strong, it hosts variable wind related rainfall, resulting in drought like conditions in the summer and flooding in the winter". High temperatures and dry weather in the Wairarapa Valley are generally associated with westerly winds, while southerly and easterly weather systems bring rain. Further analyses of three main climatic elements, temperature, rainfall and wind have been carried out below.

6.4.1. Temperature

Temperatures throughout the catchment range both spatially, as they decrease closer to the coast and decrease with elevation, and temporally as they exhibit large seasonal and diurnal fluctuations. The daily range in temperature (the difference between the daily maximum and minimum record) is around 7°C at the coast and 11°C inland (Thompson, 1982). On a generalised basis, the Ruamahanga Catchment experiences warm afternoon temperatures in the summer (20 – 23°C) and cold night time minimum temperatures (1-3°C) in the winter (Tait et al, 2002; Thompson, 1982).

Table 6-1 shows the monthly means, monthly maxima and monthly minima, for the period 2000-2006 at Masterton and Tauherenikau (east of Featherston)[22]. The monthly means are similar at both sites throughout the year; however Masterton reaches overall

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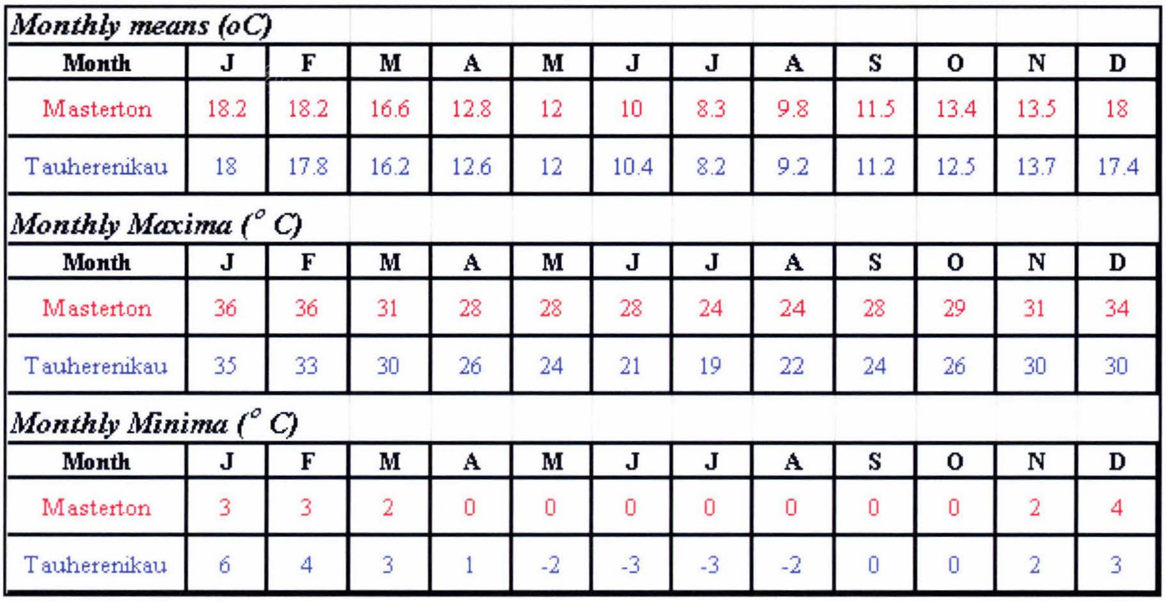
[22] Based on records obtained by the Greater Wellington Regional Council (GWRC) for the period 2 August 2000 – 1 March 2006.

warmer temperatures in the summer, while Featherston, located farther to the south and closer to the ranges, can drop to freezing temperatures in the winter months.



Monthly means (oC)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Masterton	18.2	18.2	16.6	12.8	12	10	8.3	9.8	11.5	13.4	13.5	18
Tauherenikau	18	17.8	16.2	12.6	12	10.4	8.2	9.2	11.2	12.5	13.7	17.4

Monthly Maxima (° C)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Masterton	36	36	31	28	28	28	24	24	28	29	31	34
Tauherenikau	35	33	30	26	24	21	19	22	24	26	30	30

Monthly Minima (° C)

Month	J	F	M	A	M	J	J	A	S	O	N	D
Masterton	3	3	2	0	0	0	0	0	0	0	2	4
Tauherenikau	6	4	3	1	-2	-3	-3	-2	0	0	2	3

Table 6-1: Monthly mean, maximum, and minimum temperature for Masterton and Tauherenikau for the period 2000-2006

Extreme temperatures recorded in Wairarapa have been listed in both Thompson (1982, p. 37) and Tait et al. (2002, p. 99). For the former data set, the maximum temperature recorded at Tauherenikau, Alloa was 36.3°C in the period 1965-1981, while the lowest temperature recorded was -9.3°C at East Taratahi in the period 1972-1978. The latter data set featured a maximum temperature ever recorded of 35.1°C at Waingawa from 74 years of records; this data set did not measure the coldest temperatures.

Frosts in Wairarapa occur mostly in the winter months (May through to September), and the sun shines over 2000 hours on average throughout the year (Thompson, 1982).

6.4.2. Rainfall

There are large spatial variations in rainfall volumes across the catchment, primarily related to topography. The Tararua and Rimutaka Range receive volumes between 3000 and 7000 mm per annum while the Tararua foothills and the eastern Wairarapa hill country receive between 1500 – 3000 mm per annum and 1000 – 1500 mm per annum respectively (Morgan, 2000). The Wairarapa Valley occupies an area described as a "rain shadow" zone (Watts, 2005, p. 20), as it is sheltered by the Tararua and Rimutaka Ranges from the prevailing westerly winds that lose their moisture before reaching the zone. Rainfall on the valley varies from 1500 mm per annum on the western side to 800 mm per annum to the east, with the majority of these rains being brought in by southerly winds (Begg et al, 2005).

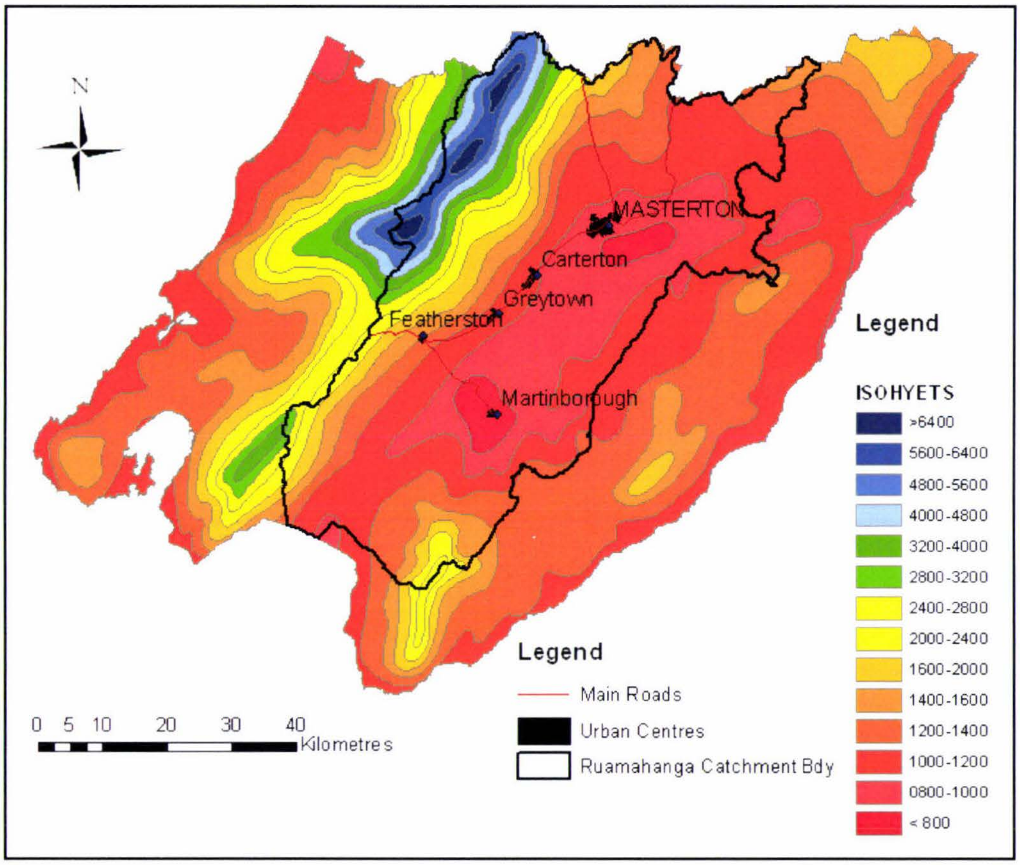


Figure 6-1: Rainfall Isohyets for the lower North Island, showing the Ruamahanga Catchment Boundary. Source (Greater Wellington Regional Council, n.d.)

Area	ANNUAL RAINFALL (mm/yr)
Tararua & Rimutaka	3000-7000
Tararua foothills	1500-3000
Eastern Wairarapa hills	1000-1500
Plains	800 (E) -1500 (W)

Table 6-2: Summary of spatial rainfall volumes in the Ruamahanga Catchment. Source (Begg et al, 2005; Morgan, 2000)

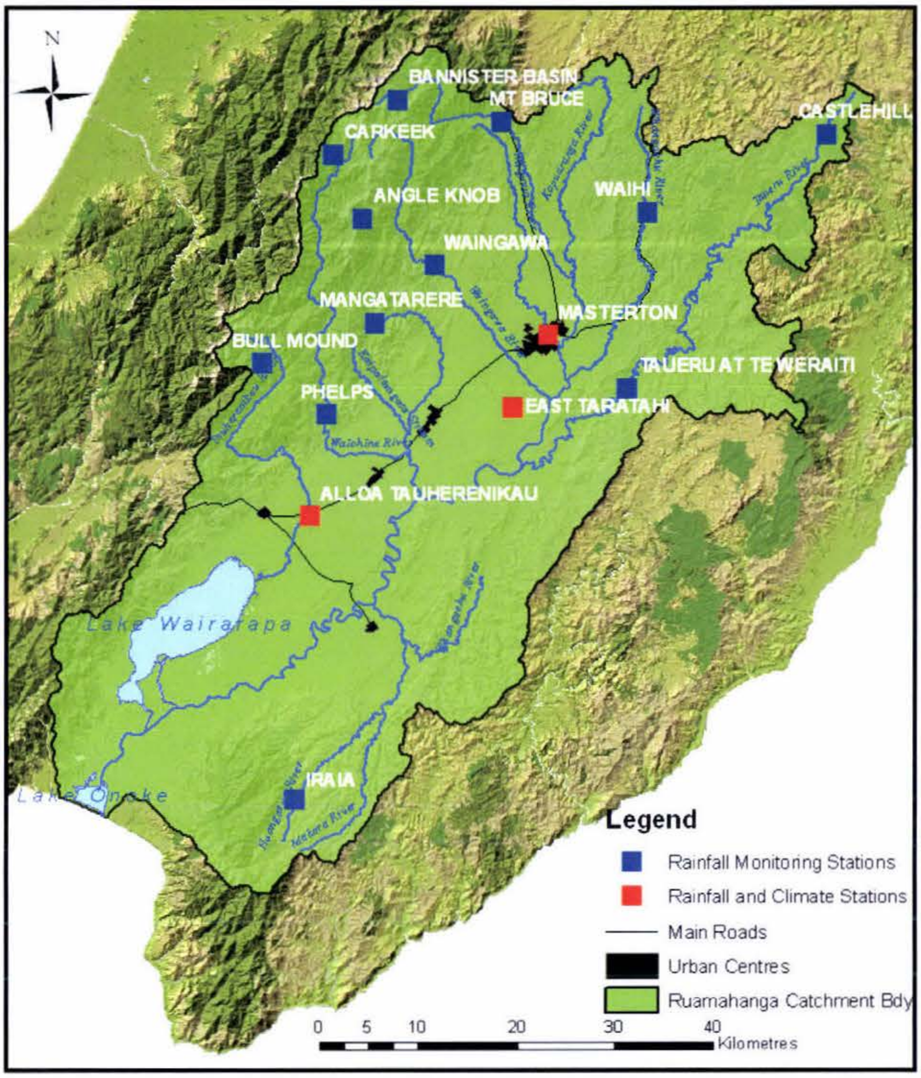


Figure 6-2: Rainfall and Climate stations in the Ruamahanga Catchment

Martinborough and areas to the east of Carterton and Masterton are the driest parts of the catchment, and the driest months are usually January to March. During these times, rainfall volumes can be as low as 150 mm in Martinborough (Watts, 2005). Understandably, the wettest parts of the catchment are the Tararua and Rimutaka Ranges, however it is not the peaks of the ranges that receive the highest rainfall volumes it is the zone between 800 to 1,100 m (Thompson, 1982).

Selected rainfall monitoring sites have been included in Table 6-3 to represent certain areas within the Ruamahanga Catchment. Those sites situated in the Tararua Range have measured annual rainfalls of up to nine metres (Angle Knob in 2004). The lowest annual rainfalls were recorded at Taueru and at the two sites on the Wairarapa Plains.

Location	Rainfall Station	Station Number	1999	2000	2001	2002	2003	2004	2005	2006*	Range	Difference
Tararua Range	Bannister Basin	57511	5928	3354?	4539?	7610	6123	4867?	3883?	845?	5928-7610	1682
	Carkeek	58411	4124	2743?	3396?	4747	2020?	5606	3365?	560?	4124-5606	1482
	Angle Knob	58403	7008	7787	5995	8011	6776	9309	5879	948?	5879-9309	3430
	Bull Mound	59310	4320	3667?	3875	5029	4455	6074	3598	479?	3598-6074	2476
Tararua Foothills	Waingawa at Kaituna	58582	1471?	1635?	1690	1974	1977	2507	654?	345?	1690-1977	287
	Mangatarere	59445	2618	3091	1879?	2921	2487	3918	2285	541?	2487-3918	1431
	Phelps	150303	1992	2065	1635	2067	1667	2683	1481	184?	1481-2683	1202
Wairarapa Plains	Masterton	?	-	392?	836	755	848	1064?	841	336?	755-848?	93
	Alloa	1513501	1025	865	773	992	973	1457	964	741?	773-1457	684
NE Wairarapa	Castlehill	57958	863?	1101	974	999	1091	1588	998	501?	974-1588	614
	Taueru	?	783	765	826	711	738	1146	813	204?	711-1146	435
SE Wairarapa	Iraia	153387	747?	1497?	1350?	1805	1530	2498	&	&	1530-2498	968

? - Incomplete data set for the year

Table 6-3: Annual rainfall volumes for the period 1999-2006 for selected monitoring stations within the Ruamahanga Catchment. Source (Greater Wellington Regional Council, 2006b)

6.4.2.1. Rainfall Variability

Annual rainfall totals presented in Table 6-3 show that rainfall at one point in the catchment can vary considerably from year to year. This is especially evident at Angle Knob and Bull Mound, two sites in the Tararua Ranges. Although these two sites feature particularly variable rainfalls, the amount of rain falling is still high (over three metres). Rain variability can have more of an impact on water management in areas of the catchment where rainfall totals are lower, e.g. on the plains and on the eastern side of the catchment. Thompson (1982, p. 21) confirmed that "rainfall in the Wairarapa is more variable in summer than winter, and rainfall becomes more variable the further away the location is from the western ranges".

The seasonal rainfall pattern and seasonal evaporation rates directly influence river flows. Rivers draining the western sub catchments are subject to less rainfall variability than those draining the eastern sub catchments and therefore have more consistent flows throughout the year. The eastern catchments receive two to three times more rain in the winter than summer (Watts, 2005, p.22). This can lead to flooding in the winter and minimal low flows in the summer. For example at Kopuaranga at Palmers, the minimum flow in February for the period 1985-2005 was 211 L/s while in July the minimum flow was 2,320 L/s, thus the February flow represents approximately nine percent of the winter flow. A similar situation exists at the Whangaehu River with the February flow representing four percent of the flow in July[23].

Hawke, McConchie, & Trueman (2000), studied the summer rainfall patterns in Wairarapa and concluded that the western ranges still received rainfalls between 800-1500 mm in the summer months. The consistent rainfall on the western side of the catchment throughout the year results in the western tributaries featuring low flows that are considerably larger and less seasonal than those in the eastern tributaries. Low flows in February for the western tributaries are at least one quarter to one third of the low flow recorded in July[24].

Summer rainfalls on the Wairarapa Plains are lowest in January (Table 6-4). Such low rainfall volumes impact on agricultural and horticultural production and it is at these times when demand for irrigation is high. Further details on irrigation in the catchment can be found in Chapter 9 of this report.

Site	J	F	M	A	M	J	J	A	S	O	N	D
Masterton	63	69	66	48	70	102	86	92	76	89	74	84
Alloa	64	67	82	79	97	112	119	104	88	97	89	82

Table 6-4: Annual Rainfalls for two sites on the Wairarapa Plains. Masterton recording period 2000-2006. Tauherenikau Alloa recording period 1963-2006.
Source (Greater Wellington Regional Council, 2006b)

Storms and high rainfall events are not exclusive to winter months, as is evident in the extremely high river flows recorded in both eastern and western tributaries in February 2004. During this storm, flows of 11,739 L/sec were recorded on the Kopuaranga Stream

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[23] For the period 1967 to 2005.

[24] Mt Bruce 25 percent, Waiohine River 35 percent, Waingawa River 36 percent

at Palmers, and flows of 79,588 L/sec were recorded at the Waiohine River at Gorge. The February 2004 storm event had widespread impacts on the Ruamahanga Catchment, and is discussed in further detail in Chapter 11 of this report. Many storm events however only impact on certain areas of the catchment. For example, in a common north westerly scenario, rainfall is measured at sites adjacent to the ranges but most of the remaining catchment remains dry, while in an easterly situation, heavy rain can fall over the eastern hills, the Aorangi Mountains and the Wairarapa plains (Thompson, 1982).

When examining rainfall in any region, it is important to realise that storm events are not the same, and each individual one can cause high rainfall and perhaps flooding to any part of the catchment.

6.4.2.2. Rainfall Frequency and Persistence

Rain falls on average between 130 and 180 days a year, with over 200 rain days at higher elevations in parts of the Tararua Ranges. More than 50 mm of rain falls at Mt Holdsworth 12 days a year, while the same volume falls at Masterton and Martinborough one day a year, and one day in every second year at Gladstone (Thompson, 1982).

High intensity rainfalls in the catchment are usually associated with east to southeast weather systems, but can still occur in westerly airstreams (Wairarapa Engineering Lifelines Association, 2003). The intensity of the rainfall and its duration can determine the effect on the land. Flooding generally occurs from high intensity rainfall events, while events which produce larger volumes of rainfall, perhaps over a longer period can cause landslides (Wairarapa Engineering Lifelines Association, 2003). Chapter 11 of this report covers further details on floods and droughts in the Ruamahanga Catchment.

6.4.2.3. El Nino – Southern Oscillation (ENSO) and Interdecadal Pacific Oscillation (IPO)

The El Nino – Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) are two of the natural phenomena occurring largely in the Pacific Ocean that influence New Zealand's and the Wairarapa's weather regime.

ENSO, operates over a time scale of years and it is a "tropical Pacific-wide oscillation that affects pressure, winds, sea-surface temperature and precipitation" (Salinger, 2004, p.1). IPO, by contrast, is an "oscillation in the ocean-atmosphere system that affects decadal climate variability" (Watts, 2005, p.4). ENSO is caused by cyclical warming and cooling of the surface of the central and eastern Pacific Ocean resulting in El Nino periods (when the eastern Pacific warms), and La Nina periods (when the eastern Pacific cools).

ENSO impacts on Wairarapa with "droughts east of the Tararua Ranges becoming more prevalent during El Nino, while during La Nina's, areas west of the Tararua Ranges (e.g. Kapiti Coast) can experience prolonged periods of drought" (Tait et al, 2002, p. 17). Both La Nina and El Nino events can cause low seasonal rainfall, however an El Nino and its associated westerly conditions will exert a stronger influence on the climate than La Nina. Dry periods in Wairarapa can still be expected in a La Nina summer (Harkness, 2000), but these can be interrupted by heavy rain events from tropical cyclones that may be passing by.

Harkness (2000), summarised the influence of ENSO on Wairarapa as being: El Nino events will decrease the amount of summer rainfall, La Nina events will decrease the amount of autumn rainfall.

The phase of the IPO is considered important as it modulates the frequency of El Nino and La Nina phases of the ENSO (McKerchar & Henderson, 2003 as cited in (Watts, 2005). It is thought that the IPO phase has recently shifted from a positive phase into a negative phase, if this is the case, weaker westerly flows are thought to occur, in addition to a weakening in the west-east rainfall gradient that is evident across New Zealand. More La Nina and less El Nino events are also expected along with higher temperatures for New Zealand (Tait et al, 2002). For Wairarapa, entering this negative IPO phase could lead to a lesser chance of drought in summer, but a larger chance of low flows in autumn, and a larger likelihood of ex-tropical cyclones influencing the area from the east (Watts, 2005).

6.4.3. Wind

Wind speeds and direction in Wairarapa are dominated largely by its orography. The predominant wind crossing New Zealand is a westerly, but Wairarapa's proximity to Cook Strait and the Manawatu Gorge means that local winds within the catchment tend to blow as northeasterlies east of the gorge and southwesterlies east of the ranges (Coulter, 1969 as cited in Thompson (1982) and Hawke, McConchie et al., (2000)). The most frequent wind type in Wairarapa are light north easterlies (Tait et al, Hawke, McConchie et al., 2000; 2002).

Although there are some sheltered parts of the catchment (the inland northern plains for example), the catchment has been defined as being windy (Thompson, 1982, p. 11). Gusty föhn surface winds are common in the Wairarapa Plains, which are a result of strong westerly winds descending off the ranges (Tait et al, 2002; Thompson, 1982). High winds are also prevalent in the elevated sections of the catchment, on the ranges, the Aorangi Mountains and the eastern Wairarapa hill Country (Thompson, 1982). The Featherston area is also renowned for its windiness, the result of winds gusting over the Tararuas and the town's location near a river gorge (NIWA, 1999-2000 as cited in (Wairarapa Engineering Lifelines Association, 2003).

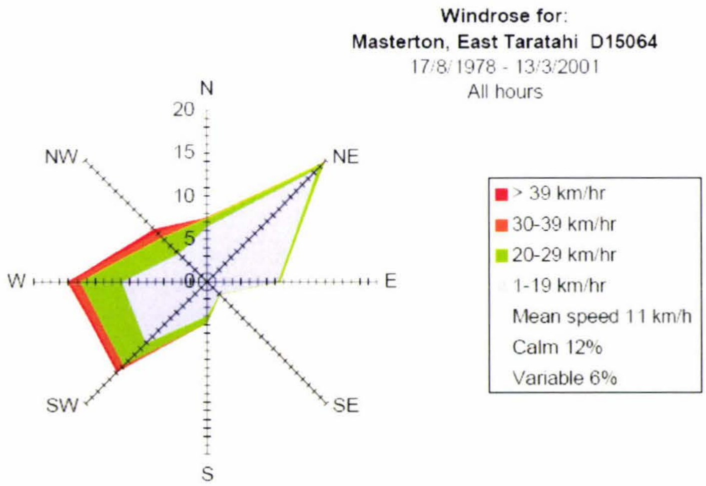

Figure 6-3: Windrose for Masterton, East Taratahi. Source (Tait et al, 2002, p. 14).

Maps of extreme winds in Wairarapa have been previously produced by Porteous et al (1999) and Reid, Turner, & Wratt (2000) also compiled a publication on Wairarapa windstorms.

Spring and summer tend to be windier than autumn and winter, and there is a strong diurnal variation which is especially evident on the lowland plains when maximum wind speeds occur in the afternoon and minimum wind speeds occur at night time (Thompson, 1982).

6.5. CONCLUSION

The climatic regime of the Ruamahanga Catchment is strongly influenced by the catchments' topography. The western ranges shelter the Wairarapa Valley from a considerable amount of rain. Rain falling on the western ranges is fairly consistent throughout the year and results in the tributaries draining the ranges having reliable flows. The flows in the tributaries draining the eastern catchments by contrast, are more unreliable as a direct result of the rainfall variability on this side of the catchment. ENSO and IPO phenomena are predicted to alter the catchments rainfall regime which could have significant impacts on river flows.

The western ranges also influence the spatial temperature pattern and wind regime occurring in the catchment. Highest temperatures are recorded in the sheltered areas of the catchment and the temperature gradient decreases at higher elevations and towards the coast. Local wind patterns parallel the ranges, blowing either north east from Cook Strait, or south west from the Manawatu Gorge.

7. Water Quantity

7.1. INTRODUCTION

Knowledge of how much water there is today in the Ruamahanga Catchment, and accurate predictions of how much water there will be in the future is critical to the sustainable management of water resources.

As such, the purpose of this section is to estimate the current volume of surface water and groundwater within the catchment, and to establish any temporal and spatial trends that may be apparent. River flows are first assessed with the use of measured data and an estimated national database. Secondly, a quantitative analysis to determine sub catchment contribution of flow is undertaken, which is then followed by comments on trends in river stages and water levels in the region's lakes and water races. Lastly the quantity of groundwater is reviewed with the use of various Institute of Geological and Nuclear Science (IGNS) and Greater Wellington Regional Council (GWRC) publications.

7.2. SURFACE WATER

7.2.1. Background

As previously described in Section 5.4.3 of this report, rivers in the Ruamahanga Catchment can be subdivided into those draining the western catchments of the Tararua and Rimutaka Ranges, those draining the eastern catchments of the eastern Wairarapa Hill Country and those draining the central low-lying valley. In addition, surface water is contained in two large lakes, Lake Wairarapa and Lake Onoke, at the southern end of the Wairarapa Valley; in several water race systems; and in numerous wetland areas throughout the catchment. Water quantity monitoring is not currently carried out in the region's wetlands; further information on wetlands in the area can be found in Section 5.4.4.

7.2.2. River Flow Statistics

River flow varies over the entire Ruamahanga Catchment. Flows are dependent on rainfall and also on the characteristics of the catchment that they drain e.g. size, slope, altitude, lithology etc. River flow statistics are compiled and analysed in New Zealand by regional councils, however additional national studies have also been done. In this section, two different river flow data sets are presented and compared, concluding with an estimate of the current quantity of surface water found in the major tributaries.

7.2.2.1. Methodology

GWRC carries out comprehensive monitoring of the river and stream flows in the catchment (referred to in this report as 'actual flows' or 'actual flow data set'). In addition, NIWA has created the 'River Environment Classification' (REC), which is a national database that may possibly be adapted to provide flow data for any particular river reach[25] in the country.

The actual flows monitored by GWRC are the most accurate and should be used wherever possible in water quantity analyses. However, in cases where there may be missing data in the flow records, or where monitoring sites only monitor high flows, or where there is not a monitoring site at an appropriate position, the REC data set may be used as a substitute.

The actual flow data set for the Ruamahanga Catchment is incomplete as four of the monitoring sites measure only high flows and floods, and are not calibrated to reliably monitor mean, median and mean annual low flows (MALF). After presenting a background on each of the two data sets and the variables that can be derived from each, the REC data set will be assessed as to its suitability to act as a proxy for the actual data set. If the REC data parallels the actual monitored flows, it will enable a more complete and thorough analysis of water quantity throughout the Ruamahanga Catchment.

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[25] 426,000 km of New Zealand's river network been split into individual river reaches by NIWA.

Measurement of actual flows

Fifteen river level monitoring stations are located within the Ruamahanga Catchment (Figure 7-1). The majority of these sites are operated by GWRC except for two that are owned and operated by NIWA[26].

Flow is monitored on the Ruamahanga River at four sites. From north to south these sites are: Mt Bruce, Wardells, Gladstone, and Waihenga. In addition, flow is monitored on the following tributaries: the Waipoua, Waingawa, Mangatarere, Waiohine and Tauherenikau Rivers on the western side of the catchment and the Whangaehu, Taueru and Huangarua (at Hautotara and Iraia) Rivers and the Kopuaranga Stream on the eastern side of the catchment. A representative 'central valley' stream site the 'Otakura Stream at Weir' completes the set of monitoring stations in the catchment.

Of these 15 sites, four are used only for monitoring of high flows and for flood warning. Data collected from these sites is unsuitable for any type of low flow analysis and for the calculation of mean and median flows, and therefore limits the ability to calculate contaminant loads at these sites[27]. These sites are Ruamahanga at Gladstone, Waipoua at Mikimiki, Taueru at Te Weraiti, and Huangarua at Hautotara.

The flow monitoring sites on the rivers are located part way up each of the tributaries (Figure 7-1), which complicates the estimation of the flow contribution from each of the various catchments to the Ruamahanga River. Accurate calculation of flow contributions requires a flow measurement immediately prior to the confluence with the Ruamahanga River. Fortunately this is a measurement that the REC database can provide.

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[26] The sites operated by NIWA are Whangaehu at Waihi and Ruakokoputuna at Iraia

[27] Contaminant loads will be calculated in Chapter 8 of this report.

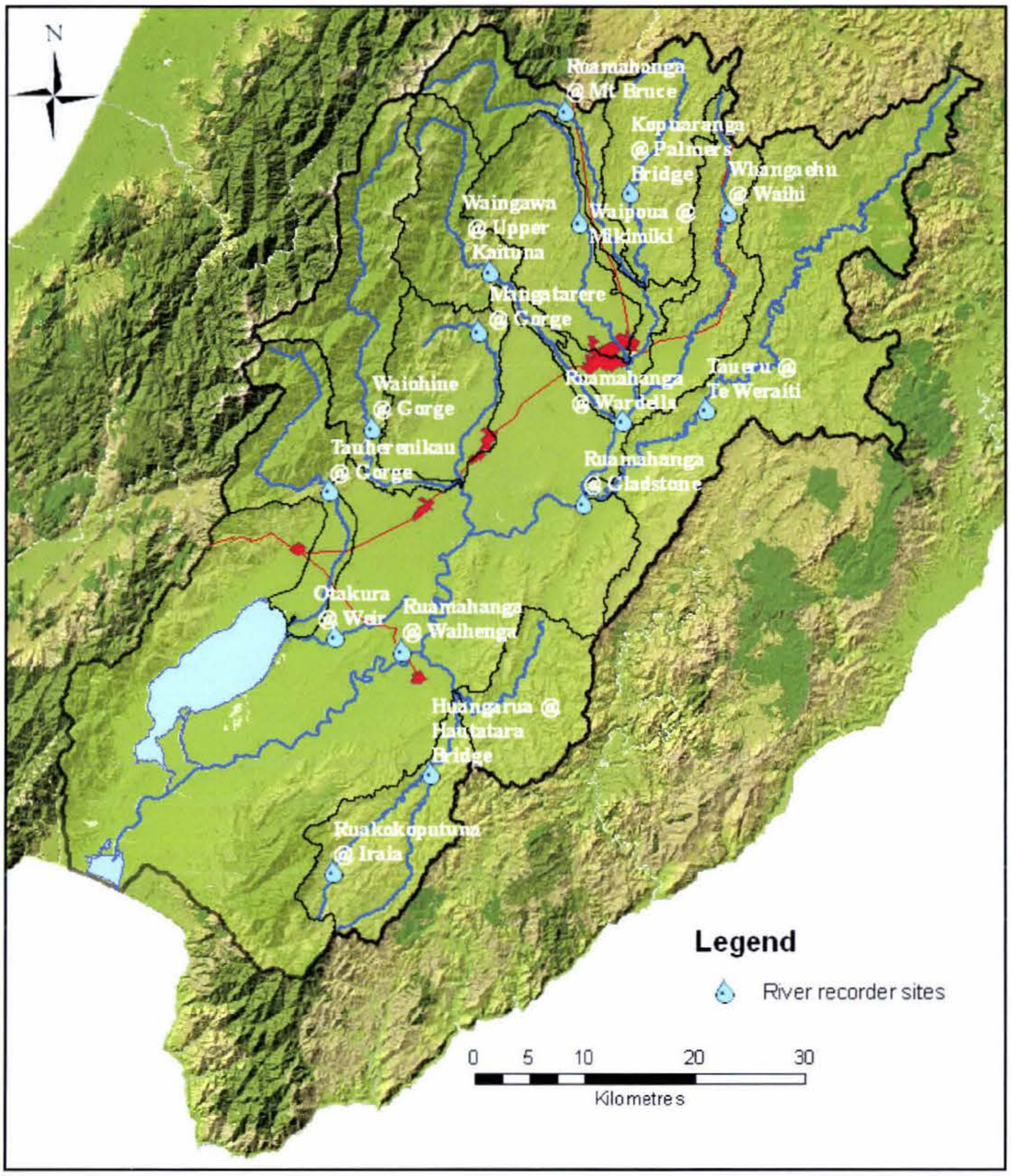

Figure 7-1: Location of river level monitoring sites

Reports summarising the data collected from the water monitoring sites and others in the Wellington Region include the 'Annual Hydrology Report' (Gordon, 2005) and the 'Hydrological Monitoring Technical Report' (Watts, 2005). Four primary flow variables, including the mean, median, MALF and return periods for the MALF, have been extracted from the Annual Hydrology Report for 11 of the 15 monitoring sites, to be used in the analysis below.

River Environment Classification (REC)

The REC database was previously introduced in Chapter 5. It characterises river environments according to six hierarchical levels: climate, source of flow, geology, land cover, network position and valley landform. These have been identified as the controlling environmental factors (Snelder et al., 2004).

The raw data used to create the REC database can be utilised in estimating mean flows in the Ruamahanga Catchment's rivers providing some assumptions are made about evaporation. The raw data provides information on any national river reach (defined by a unique NZREACH identification number). Each reach begins and ends with a node[28], and these nodes dictate the order between each reach. For each reach elevation, upstream catchment area, and precipitation data can be extracted with the use of ArcGIS.

Initially ArcGIS was utilised to find the NZREACH identification numbers for each of the 15 water quantity sites. The required data for each of the sites was then extracted to be used in the following calculations.

Mean river flows could potentially be estimated from the REC data by applying the following formula:

$$\text{Mean Flow } (m^3/sec) = \text{Accumulated Runoff}^{29}\ (m^3/yr)\ /(365 \text{ days} \times 24 \text{ hours} \times 60 \text{ minutes} \times 60 \text{ seconds})$$

Eqn. 7.1

where;

$$\text{Accumulated Runoff } (m^3/yr) = \text{Accumulated Rain } (m^3) - \text{Actual Evaporation } (m^3)$$

Eqn. 7.2

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[28] A node is a point located at either end of a defined reach of a waterway.

[29] Accumulated Runoff is defined to include all runoff occurring upstream or up-catchment from the monitoring site on the stream or river. These values will be used further in Chapter 8 to calculate nutrient loads (Section 8.2.3, Equation 8.1).

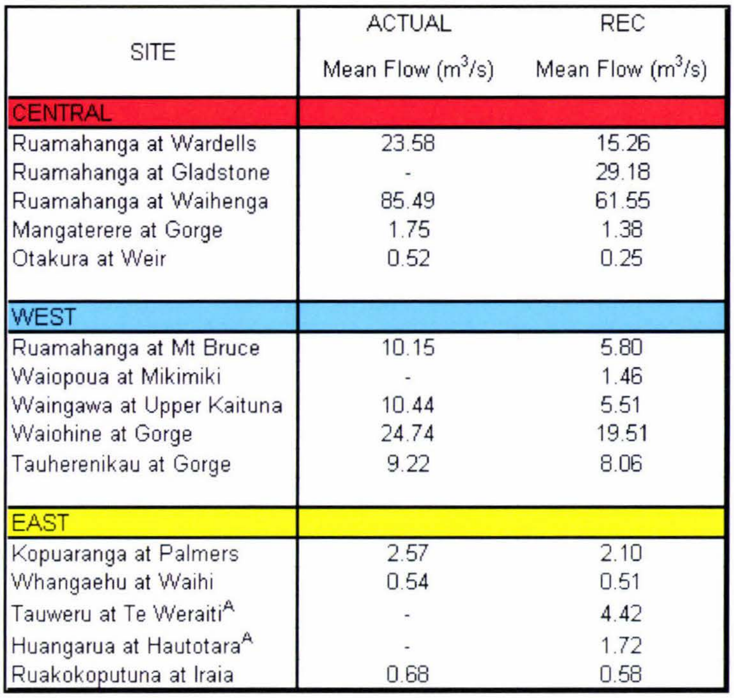
These equations assume that all precipitation that is not evaporated enters a river or stream channel.

In order to solve Equations 7.1 and 7.2, the accumulated rain and actual evaporation volumes must first be calculated. Accumulated rain volumes (mm rainfall multiplied by m^2 area) were given in the REC's raw data as eighteen individual fields for land ranging in elevation from 50 m to above 1,500 m. Not all possible elevations occurred in all reaches. For example, lowland reaches may not have land at high elevation. The rainfall volumes from each of the elevation classes within a particular reach were added together to obtain the total precipitation volume within the catchment upstream of the downstream node.

The annual evaporation volume was established by a trial and error approach explained below. The catchment areas for Equation 7.3 were taken from the REC database.

$$\textit{Accumulated Evaporation } (m^3/yr) = 500 \textit{ mm/yr } /(1000) \times \textit{ Catchment Area } (m^2) \qquad \text{Eqn. 7.3}$$

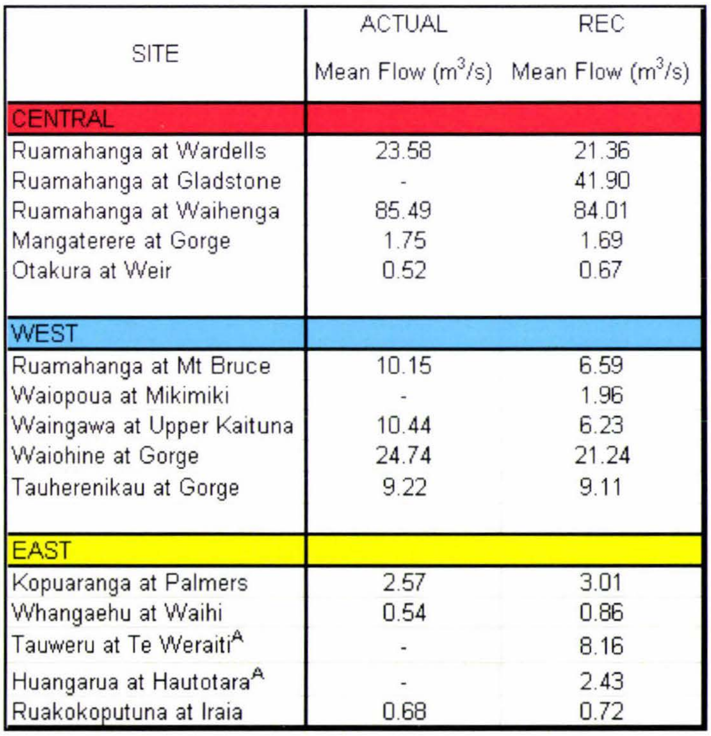
Initially a volume of 800 mm/year was used for the annual evaporation volume, a value which roughly equals New Zealand's average potential annual evaporation volume. The mean flow calculations were worked out with this value and compared to the mean flows in the actual data set. Comparison showed that several of the central and western sites had considerably smaller REC mean values than actual mean values (Table 7-1).



SITE	ACTUAL Mean Flow (m^3/s)	REC Mean Flow (m^3/s)
CENTRAL		
Ruamahanga at Wardells	23.58	15.26
Ruamahanga at Gladstone	-	29.18
Ruamahanga at Waihenga	85.49	61.55
Mangaterere at Gorge	1.75	1.38
Otakura at Weir	0.52	0.25
WEST		
Ruamahanga at Mt Bruce	10.15	5.80
Waiopoua at Mikimiki	-	1.46
Waingawa at Upper Kaituna	10.44	5.51
Waiohine at Gorge	24.74	19.51
Tauherenikau at Gorge	9.22	8.06
EAST		
Kopuaranga at Palmers	2.57	2.10
Whangaehu at Waihi	0.54	0.51
Tauweru at Te Weraiti[A]	-	4.42
Huangarua at Hautotara[A]	-	1.72
Ruakokoputuna at Iraia	0.68	0.58

Table 7-1: Comparison of Actual and REC data sets for mean flow (800 mm/yr evaporation)

The same analysis was carried out with a lowered evaporation rate of 500 mm/year to determine whether it would generate a better fit between the two data sets (Table 7-2).



SITE	ACTUAL Mean Flow (m^3/s)	REC Mean Flow (m^3/s)
CENTRAL		
Ruamahanga at Wardells	23.58	21.36
Ruamahanga at Gladstone	-	41.90
Ruamahanga at Waihenga	85.49	84.01
Mangaterere at Gorge	1.75	1.69
Otakura at Weir	0.52	0.67
WEST		
Ruamahanga at Mt Bruce	10.15	6.59
Waiopoua at Mikimiki	-	1.96
Waingawa at Upper Kaituna	10.44	6.23
Waiohine at Gorge	24.74	21.24
Tauherenikau at Gorge	9.22	9.11
EAST		
Kopuaranga at Palmers	2.57	3.01
Whangaehu at Waihi	0.54	0.86
Tauweru at Te Weraiti[A]	-	8.16
Huangarua at Hautotara[A]	-	2.43
Ruakokoputuna at Iraia	0.68	0.72

Table 7-2: Comparison of Actual and REC data sets for mean flow (500 mm/yr evaporation)

With an evaporation rate of 500 mm/year, the REC mean flow values for the central sites were much closer to the actual mean flows than with the 800 mm/year evaporation rate. The difference between the two data sets reduced for the western sites also, but not significantly, highlighting the simplicity in using a single evaporation rate for the entire catchment.

A fitted linear regression line added to the scatter plot of the two data sets (Figure 7-2) gives a slope of 0.9795. This slope is close to one and infers that the REC values approximate the actual values well. The r squared (R^2) value of 0.9951 also indicates that there is a good fit between the REC values and the actual values. Table 7-3 provides variation in the evaporation value that can be used in the calculation of the REC mean values (See Eqn 7.3) and associated slope and R^2 values. This data shows that the closest fit of the two data sets would be when the evaporation value used is between 450 and 500 mm/yr.

Although the mean value from the two data sets are not completely exact (which cannot reasonably be expected from a modelled estimate), the mean values derived from the REC database can be used as an approximation for the measured flow values. Drawing conclusions from the REC's absolute mean flow values should be avoided, and used only for inter-site comparison.

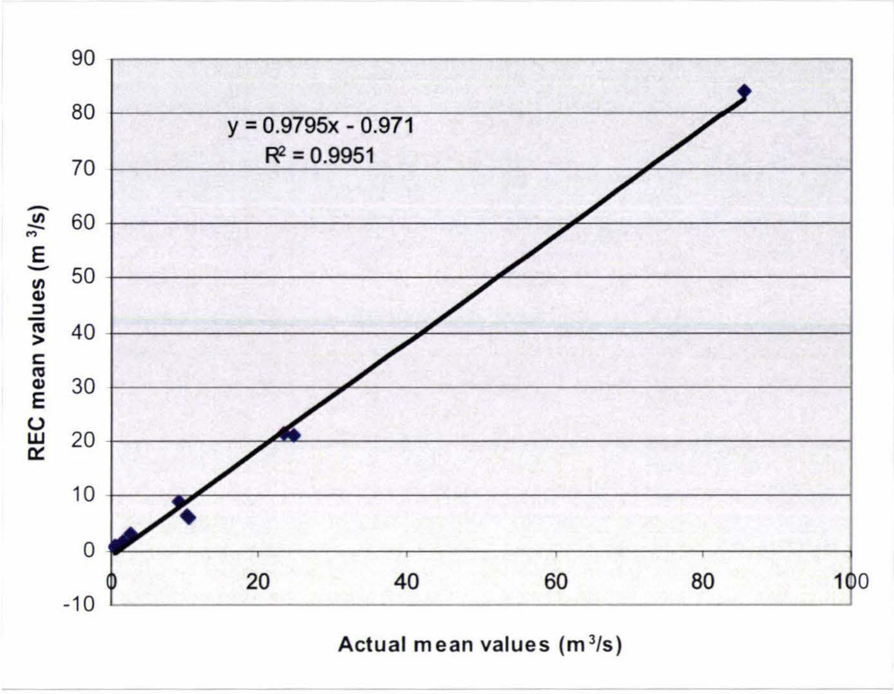


Figure 7-2: Scatter Plot of Actual versus REC mean flow values and the fitted regression line

Evaporation (mm/yr)	R^2	Slope
800	0.9957	0.7207
750	0.9964	0.7639
700	0.9966	0.807
650	0.9965	0.8501
600	0.9962	0.8932
550	0.9957	0.9364
500	0.9951	0.9795
450	0.9944	1.0226

Table 7-3: Evaporation values and associated R^2 values

As mentioned earlier, the REC mean values for the three western sites (Ruamahanga at Mt Bruce, Waingawa at Upper Kaituna, and Waiohine at Gorge) have the worst fit with actual data set. These three sites have the highest specific discharges i.e. rainfall. This probably indicates that in this model evaporation is being overestimated. Evaporation is highest at low altitudes (Weingartner & Pearson, 2001) and low rainfalls. An average across a catchment therefore will tend to underestimate evaporation at low altitudes and overestimate at high altitudes. This is consistent with the differences seen in the three western sites. This process could be enhanced by using specific evaporation rates for different areas in the catchment, thus achieving a better fit of the two data sets, and increasing the suitability of using the REC data set in analyses.

Flow Variables

Outlined in Table 7-4 below are the different levels of flow variables that each data set provides. Primary flow variables can be defined as variables that can be retrieved directly from the source; secondary flow variables have been derived from a primary flow variable and a tertiary flow variable derived from a secondary flow variable. The table also includes limitations associated with each type of data set.

Data Set	Primary Flow Variables	Secondary Variables	Tertiary Variables	Limitations
1. Actual (GWRC & NIWA) (Gordon, 2005)	• Mean Flow • Median Flow • MALF • Return periods for 7 day MALF	• Specific Discharge • Annual Discharge • Specific MALF	• Annual Flow	• Full range of variables complete for only 11 of 15 sites. • Four sites without primary flow variables. • Period of record differs for each site (See Table 7-2)
2. REC	• Mean Flow • Accumulated Runoff	• Specific Discharge • Annual Discharge • Runoff per hectare	• Annual Flow	• Modelled data set • Based on estimations and assumptions e.g. constant evaporation volume. • No allowance for water infiltration.

Table 7-4: Available data sources, their provided flow data and limitations

A description of each of the variables and the information they can provide for water quantity analysis follows:

Primary Flow Variables

The mean and median flow values provide an indication of the normal flow of each river. The frequency distribution of flows in rivers, however, is not usually normally distributed. Rivers generally have low to medium flows most of the time, but during floods the flow in the river can increase many fold. Because of this 'skewed' frequency distribution of river flows the mean flow is often considerably higher than the median flow. Median flow measurements are thought to provide better information when comparing flows between rivers as they give a better picture of what the river is like most of the time. Mean flows however have to be used when computing annual loads of contaminants carried by the river[30].

The MALF has been calculated by GWRC from the 7-day rolling average for the lowest flow sustained for seven days over a given period. The 7-day low flow was also calculated at 5, 10, 20 and 100 year return periods. These calculations were carried out using the Hilltop/Tideda software event analysis tool (M Gordon, personal communication, May 28, 2007).

Secondary and Tertiary Flow Variables

Specific discharge and annual discharge values are secondary flow variables as they are both derived from the mean flow. Calculating the specific discharge of each river enables more precise comparison between tributaries as it divides the mean flow rate by the area of the catchment upstream from the flow monitoring site.

$$\textit{Mean Specific Discharge } (L/s/km^2) = \textit{Mean Flow } (m^3/s) \times 1000 / \textit{Catchment Area } (km^2)$$

Eqn. 7.4

Annual discharge (m^3/yr) was derived from the mean flow (m^3/s) by converting the mean flow from cubic metres per second (cumecs) to cubic metres per year.

$$\textit{Annual Discharge } (m^3/yr) = \textit{Mean Flow } (m^3/s) \times (60 \textit{ seconds} \times 60 \textit{ minutes} \times 24 \textit{ hours} \times 365 \textit{ days})$$

Eqn. 7.5

Annual discharge may also be represented as "annual flow", which is the "total volume of water carried on an annual basis" (Basher, 2003, p. 46) measured in millimetres. This allows for direct comparison with the contributing catchment's rainfall. This approach was used by Basher (2003) in the Motueka and Riwaka Catchment's resource inventory.

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[30] Contaminant loads will be calculated in Chapter 8 of this report.

$$Annual\ Flow\ (mm/yr) = (Annual\ Discharge\ (m^3/yr)\ /\ Catchment\ Area\ (m^2))*1000^{(31)}$$

Eqn. 7.6

The Specific MALF was calculated by dividing the MALF by the catchment area. Watts (2005, p. 21) states that the specific MALF is "an indicator of water availability across the region, with the effect of 'freshes' removed" and by allowing for different catchment sizes by dividing the MALF by the area, the "low flows from different rivers can be directly compared".

$$Specific\ Mean\ Annual\ Low\ Flow\ (L/s/km^2) = Mean\ Annual\ Low\ Flow\ (L/s)\ /Catchment\ Area\ (km^2)$$

Eqn. 7.7

7.2.2.2. Results

Flow Variables

The data provided in Table 7-5 gives the primary flow variables, directly retrieved from Gordon (2005) and the calculated secondary and tertiary flow variables. The data in **Error! Reference source not found.** provides flow variables derived from the REC database.

7.2.2.3. Discussion

Concluding that mean flow values calculated from the REC may cautiously be used as a replacement for the actual mean flow, allows for a complete analysis at all water level monitoring sites in the Ruamahanga Catchment. This discussion draws on results from both data sets. The actual data set is used to illustrate median flows, MALF and the return periods for MALF for 11 of the 15 sites, while the REC data set is used to provide mean flows, and all of the secondary variables derived from mean flows for all 15 sites.

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[31] For converting catchment area: 1 $km^2 = 1{,}000{,}000\ m^2$

SITE	Area (km^2)	Mean Flow (m^3/s)	Median Flow (m^3/s)	Specific Dis. ($L/s/Km^2$)	Annual Discharge (m^3/yr)	Annual Flow (mm/yr)	MALF (L/s)[C]	7-day low flow (L/s)[B]				Specific MALF (L/s/Km2)	Records Began	Recording Authority
								5 yrs	10 yrs	20 yrs	100 yrs			
CENTRAL														
Ruamahanga at Wardells	637	23.58	12.37	37	743618880	1167.4	3232	2306	1996	1768	1396	5.07	20/09/1977	GWRC
Ruamahanga at Gladstone[A]	1315	-	-	-	-	-	-	-	-	-	-		6/06/1992	GWRC
Ruamahanga at Waihenga	2340	85.49	51.01	36.5	2696012640	1152.1	10775	7884	7090	6507	5550	4.60	31/12/1975	GWRC
Mangaterere at Gorge[C]	33.30	1.75	0.87	52.6	55188000	1657.3	168[D]	127	108	94	70	5.05	9/02/1999	GWRC
Otakura at Weir	43.50	0.25	0.37	5.8	8020179	184.4	87	23	2	0	0	2	17/12/1997	GWRC
WEST														
Ruamahanga at Mt Bruce	76.5	10.15	4.57	132.7	320090400	4184.2	1319	1049	959	893	786	17.24	1/01/1975	GWRC
Waiopoua at Mikimiki[A]	80.3	-	-	-	-	-	-	-	-	-	-	-	21/12/1995	GWRC
Waingawa at Upper Kaituna	79	10.44	5.15	132.2	329235840	4167.5	1444	1124	1016	936	807	18.28	14/05/1976	GWRC
Waiohine at Gorge	180	24.74	13.15	137.4	780200640	4334.4	3593	2926	2731	2587	2352	19.96	27/12/1954	GWRC
Tauherenikau at Gorge	112	9.22	4.99	82.3	290761920	2596.1	1308	1028	933	863	750	11.68	30/03/1976	GWRC
EAST														
Kopuaranga at Palmers	100.3	2.57	1.21	25.6	81047520	808.1	314	214	185	163	127	3.13	15/03/1985	GWRC
Whangaehu at Waihi	36.6	0.54	0.16	14.8	17060976	466.1	21	14	12	10	8	0.57	10/05/1967	NIWA
Tauweru at Te Weraiti[A]	373	-	-	-	-	-	-	-	-	-	-	-	10/12/1969	GWRC
Huangarua at Hautotara[A]	140	-	-	-	-	-	-	-	-	-	-	-	1/01/1968	GWRC
Ruakokoputuna at Iraia	15.54	0.68	0.24	43.4	21286800	1369.8	36	25	22	20	16	2.32	29/05/1969	NIWA

[A] These monitoring sites are used for flood warning only

[B] 7-day low flow (L/s) figures are based on predictions only

[C] Mean annual low flow (MALF) calculated from the 7-day MALF as done by Basher (2005)

[D] Mean Annual Low Flow (MALF) has been derived from correlated data from the Atiwhakatu site by Gordon (2005, p. 55). This value is the 1-day MALF, used as no 7-day low flow was provided.

Table 7-5: Primary flow variables obtained from Gordon (2005) and secondary and tertiary derived flow variables

Site No.	Site Description	Area (km^2)	Av. Elev. (m)	Accum. Rain (m^3)	Accum. Evap. (m^3)	Accum. Runoff (m^3)	Mean Runoff (m^3/ha)	Mean Flow (m^3/s)	Specific Discharge $L/s/km^2$	Annual Discharge m^3/yr	Annual Flow (mm/yr)
CENTRAL											
29201	Ruamahanga River at Wardells	641.4	321.7	9.9E+08	3.2E+08	6.7E+08	1.1E+04	21.36	33.3	6.7E+08	1050
29206	Ruamahanga River at Gladstone Bridge	1337.4	321.2	2.0E+09	6.7E+08	1.3E+09	9.9E+03	41.90	31.3	1.3E+09	988
29202	Ruamahanga River at Waihenga Bridge	2361.2	310.8	3.8E+09	1.2E+09	2.6E+09	1.1E+04	84.01	35.6	2.6E+09	1122
292243	Mangaterere at Gorge	32.8	422.8	7.0E+07	1.6E+07	5.3E+07	1.6E+04	1.69	51.7	5.3E+07	1631
292069	Otakura at Weir	43.5	44.6	4.3E+07	2.2E+07	2.1E+07	4.8E+03	0.67	15.4	2.1E+07	484
WEST											
29254	Ruamahanga River at Mt Bruce	82.4	731	2.5E+08	4.1E+07	2.1E+08	2.5E+04	6.59	79.9	2.1E+08	2520
29257	Waipoua at Mikimiki	52.4	417.2	8.8E+07	2.6E+07	6.2E+07	1.2E+04	1.96	37.4	6.2E+07	1179
29246	Waingawa at Upper Kaituna	75.6	789	2.3E+08	3.8E+07	2.0E+08	2.6E+04	6.23	82.4	2.0E+08	2599
29224	Waiohine River at gorge gauge	182.4	752.4	7.6E+08	9.1E+07	6.7E+08	3.7E+04	21.24	116.5	6.7E+08	3673
29251	Tauherenikau at Gorge	110.5	587.7	3.4E+08	5.5E+07	2.9E+08	2.6E+04	9.11	82.4	2.9E+08	2600
EAST											
29230	Kopuaranga at Palmers	96	320	1.4E+08	4.8E+07	9.5E+07	9.9E+03	3.01	31.3	9.5E+07	989
29244	Whangaehu at Waihi	37.2	285	4.6E+07	1.9E+07	2.7E+07	7.3E+03	0.86	23.2	2.7E+07	731
29231	Tauweru at Te Weraiti	392.5	250.9	4.5E+08	2.0E+08	2.6E+08	6.6E+03	8.16	20.8	2.6E+08	655
29222	Huangarua at Hautotara	74.6	380.9	1.1E+08	3.7E+07	7.7E+07	1.0E+04	2.43	32.6	7.7E+07	1028
29250	Ruakokoputuna at Iraia	15.6	507.1	3.1E+07	7.8E+06	2.3E+07	1.5E+04	0.72	46.3	2.3E+07	1461

Table 7-6: Results from REC data set providing flow variables for the 15 monitoring sites

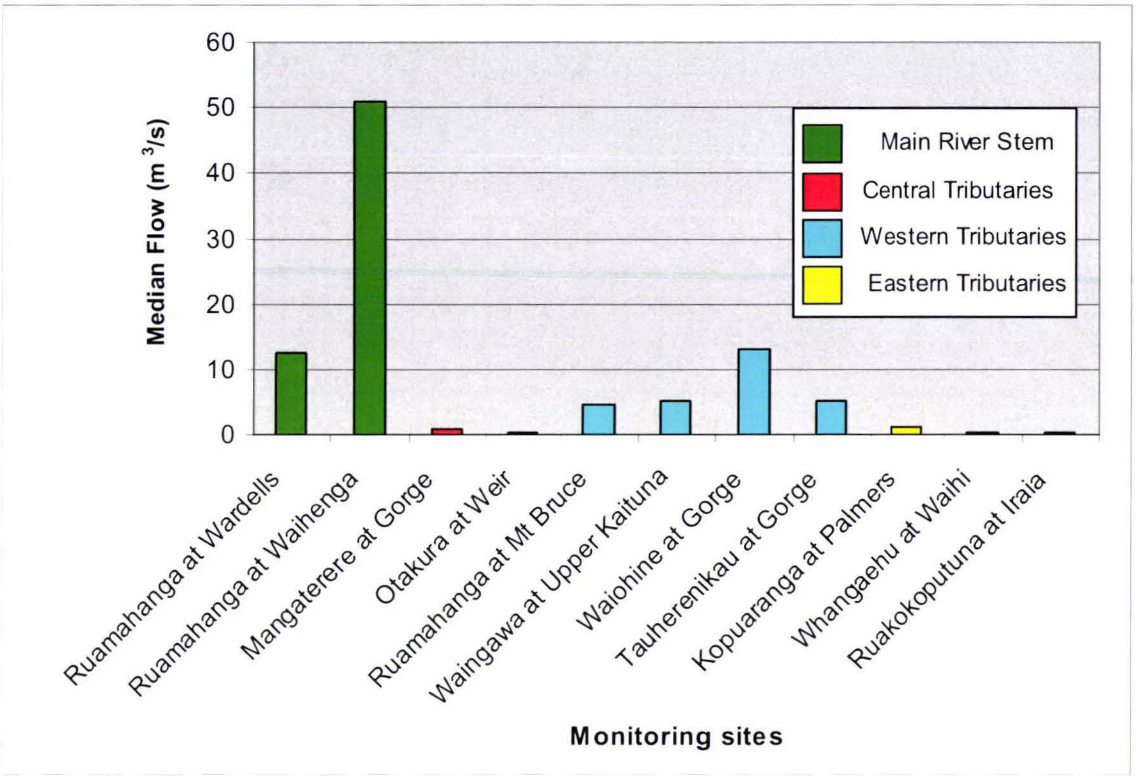


Figure 7-3: Median Flow (m^3/s) derived from Actual data set for 11 of the monitoring sites, which have been grouped according to their location in the catchment

The median flow rates shown in Figure 7-3 give a visual representation of the flow which is exceeded 50 percent of the time. The western tributaries; the Ruamahanga River at Mt Bruce; the Waingawa River at Upper Kaituna; the Waiohine River at Gorge and the Tauherenikau River at Gorge (shown in blue) all have greater median flows than those tributaries on the eastern side of the catchment (shown in yellow). However this judgement is based on data excluding values for the four high flow monitoring sites.

Utilising the REC data set, the mean flows for all of the 15 sites are displayed in the graph in Figure 7-4. The highest mean flow occurring within the Ruamahanga Catchment is in the Ruamahanga River at Waihenga Bridge. Mean flows increase steadily along the Ruamahanga River from the site at Mt Bruce (6.59 m^3/sec) to Wardells (21.36 m^3/sec) to Gladstone (41.90 m^3/sec) and Waihenga Bridge (84.01 m^3/sec). The lowest average flows of less than 1 m^3/sec occurred in two eastern tributaries, the Whangaehu River and Ruakokoputuna River, and one central tributary, the Otakura Stream.

Overall the trends in the mean data match those found with the median data, with the western tributaries having larger mean flows than the eastern tributaries. One eastern tributary however, the Taueru River, had a mean flow similar to the Waingawa River and larger than the Waipoua River. This relatively larger mean value is attributable to the large catchment area of the Taueru River.

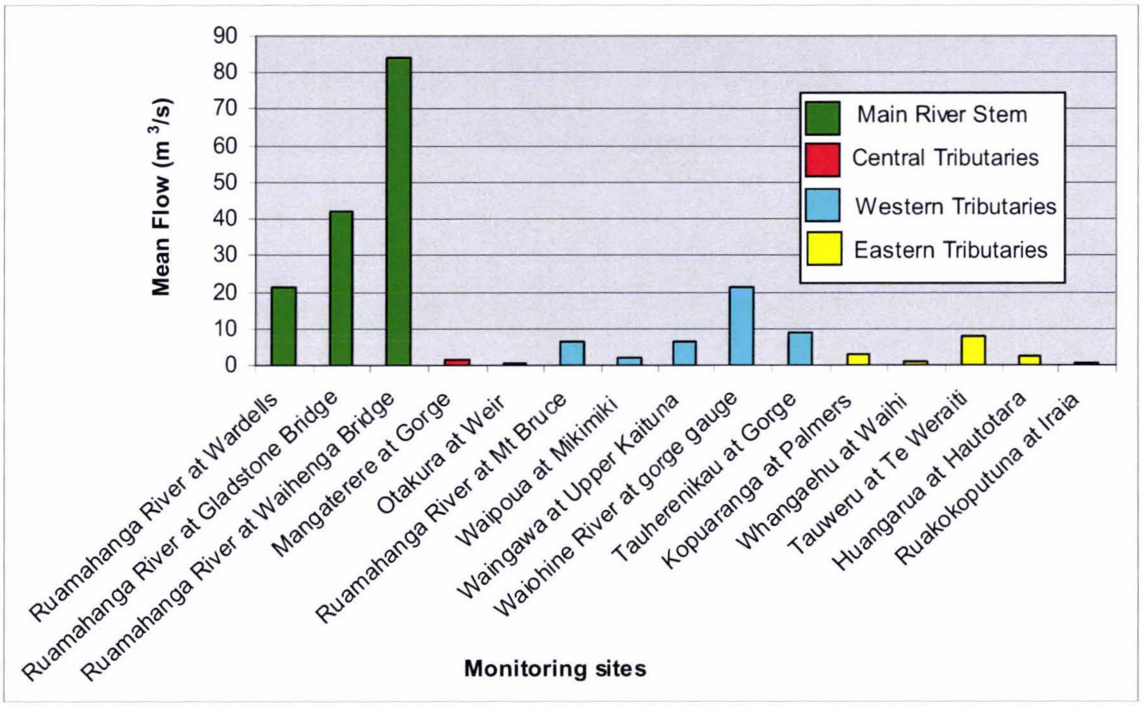
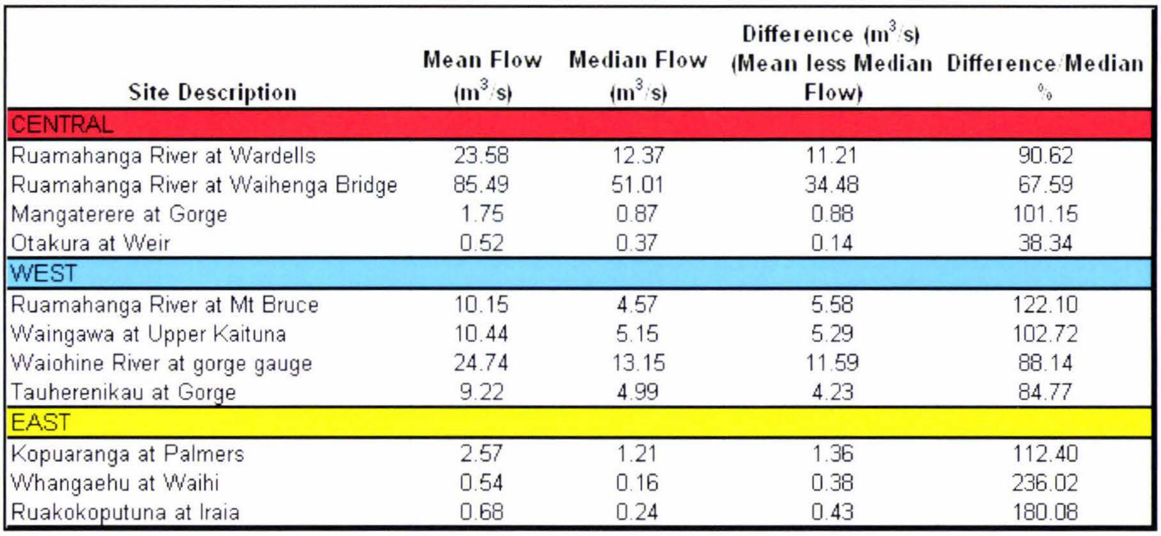


Figure 7-4: Mean Flow (m^3/s) derived from the REC data set for all 15 of the monitoring sites, which have been grouped according to their location in the catchment

As noted earlier, if river flows were normally distributed it would be expected that the mean and median flow values would be similar. The mean value however is often skewed upwards by the occasional occurrences of very high flows, and the distribution of flows becomes positively skewed. The difference between mean flows and median flows has been calculated in Table 7-7. This value was then divided by the median flow to give a relative indication of the extent to which the total annual flow was dominated by occasional flood events.

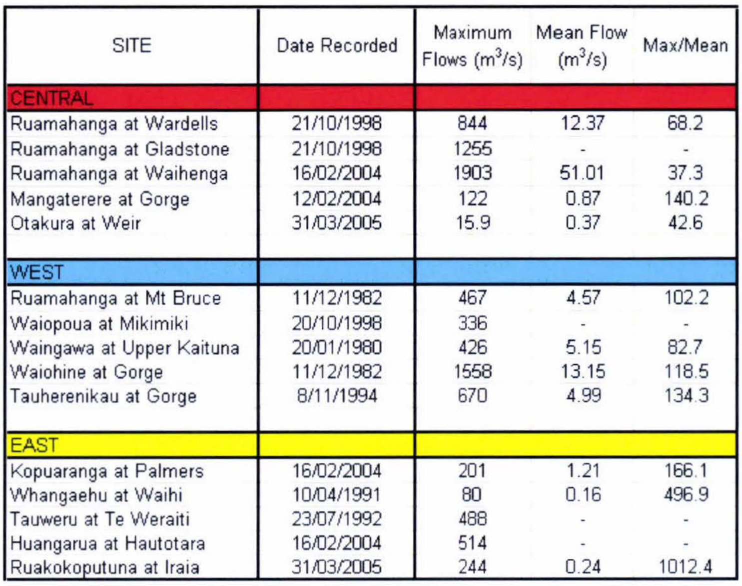
Those sites where the mean was much higher than the median (in percentage terms), like the Whangaehu River at Waihi, had a large proportion of their overall flow coming from high flow or flood events, while alternately the smaller percentages featured in the central and western rivers indicate that most of the flow is generated from normal flow periods, and flood events do not generally have a significant impact on total flow. This possibly reflects more consistent rainfall on the western side of the catchment compared to the eastern side, which is dry most of the time but also is subject to occasional large storms.



Site Description	Mean Flow (m^3/s)	Median Flow (m^3/s)	Difference (m^3/s) (Mean less Median Flow)	Difference/Median %
CENTRAL				
Ruamahanga River at Wardells	23.58	12.37	11.21	90.62
Ruamahanga River at Waihenga Bridge	85.49	51.01	34.48	67.59
Mangaterere at Gorge	1.75	0.87	0.88	101.15
Otakura at Weir	0.52	0.37	0.14	38.34
WEST				
Ruamahanga River at Mt Bruce	10.15	4.57	5.58	122.10
Waingawa at Upper Kaituna	10.44	5.15	5.29	102.72
Waiohine River at gorge gauge	24.74	13.15	11.59	88.14
Tauherenikau at Gorge	9.22	4.99	4.23	84.77
EAST				
Kopuaranga at Palmers	2.57	1.21	1.36	112.40
Whangaehu at Waihi	0.54	0.16	0.38	236.02
Ruakokoputuna at Iraia	0.68	0.24	0.43	180.08

Table 7-7: Relationships between mean and median values and a measure of skewness. Nb. Values shown are primary flow variables from Table 7-5.

Also of note is the fact that the difference between the mean and the median (in percentage terms) decreased on the Ruamahanga River in a downstream direction, from 122 percent at Mt Bruce to 91 percent at Wardells. This indicates that in the lower reaches of the Ruamahanga River, flow is more consistent and less influenced by high flow events as in the headwaters. Similarly this is seen in the Manawatu River, where the difference between the mean and the median (in percentage terms) in the headwaters is 105 percent, decreasing to around 70 percent in the lower reaches of the river[32].



SITE	Date Recorded	Maximum Flows (m^3/s)	Mean Flow (m^3/s)	Max/Mean
CENTRAL				
Ruamahanga at Wardells	21/10/1998	844	12.37	68.2
Ruamahanga at Gladstone	21/10/1998	1255	-	-
Ruamahanga at Waihenga	16/02/2004	1903	51.01	37.3
Mangaterere at Gorge	12/02/2004	122	0.87	140.2
Otakura at Weir	31/03/2005	15.9	0.37	42.6
WEST				
Ruamahanga at Mt Bruce	11/12/1982	467	4.57	102.2
Waiopoua at Mikimiki	20/10/1998	336	-	-
Waingawa at Upper Kaituna	20/01/1980	426	5.15	82.7
Waiohine at Gorge	11/12/1982	1558	13.15	118.5
Tauherenikau at Gorge	8/11/1994	670	4.99	134.3
EAST				
Kopuaranga at Palmers	16/02/2004	201	1.21	166.1
Whangaehu at Waihi	10/04/1991	80	0.16	496.9
Tauweru at Te Weraiti	23/07/1992	488	-	-
Huangarua at Hautotara	16/02/2004	514	-	-
Ruakokoputuna at Iraia	31/03/2005	244	0.24	1012.4

Table 7-8: Maximum Flows for all sites from GWRC. Source (Gordon, 2005)

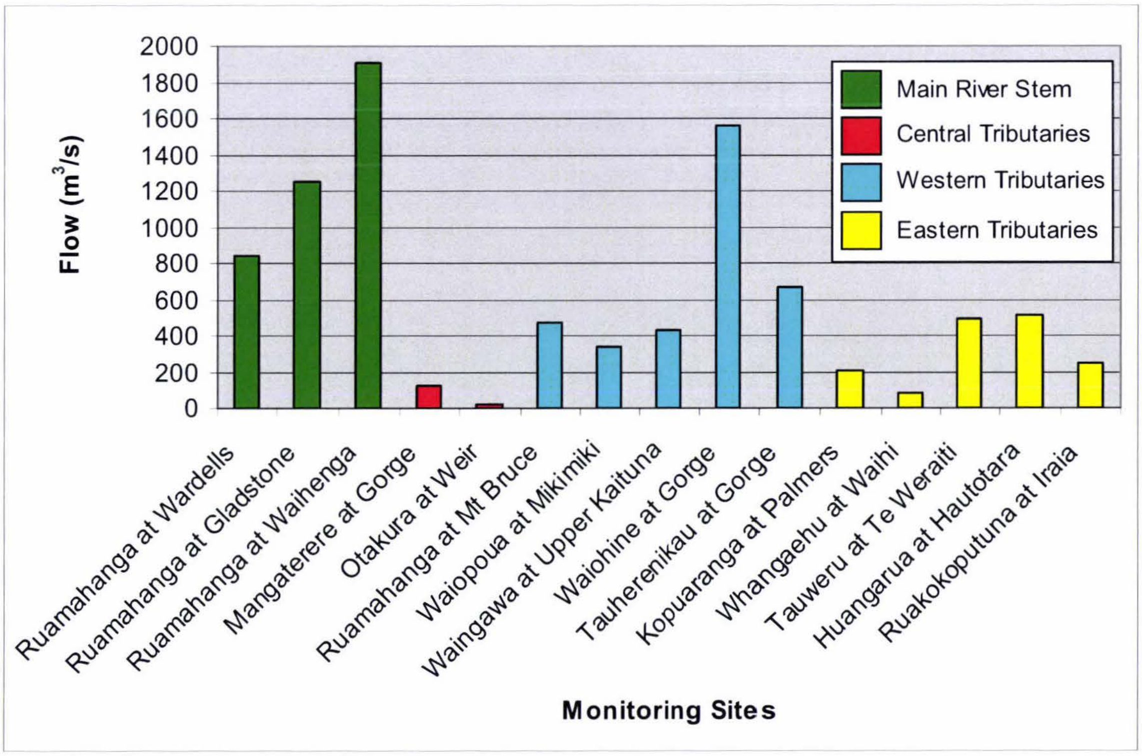


Figure 7-5: Maximum Flows recorded on all sites by GWRC. Source (Gordon, 2005)

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[32] Data for these calculations on the Manawatu River were sourced from Henderson & Diettrich (2007).

The data provided in Table 7-8 and Figure 7-5, show the maximum flows recorded for each site since monitoring began. Note that the monitoring periods are not the same for each site; these periods are listed above in Table 7-5. The highest recorded flows were recorded on the main river stem and in the western tributaries, which receive considerably more rainfall as their headwaters are in the ranges. As previously mentioned, the eastern catchments also receive occasional heavy rainfall events; these situations are shown in the relatively high flows measured on the Taueru and Huangarua tributaries. The ratio of maximum flow to mean flow (Table 7-8) again highlights the difference between the eastern and western tributaries. The large ratios (Max/Mean) in the eastern tributaries reinforce the fact that the flow in these rivers is relatively low most of the time but can have large flows in occasional events.

Many of the high flows in the catchment occurred in October 1998, and February 2004. Further discussion on flood frequencies in the Ruamahanga Catchment will be included in Chapter 11 of this report.

A calculation of the specific discharge at each monitoring point allows for a better comparison between catchments than the mean or median flow provides as it takes into account the size of the contributing catchment. As shown in Equation 7.4, the specific discharge is the mean flow value divided by the catchment area. The resultant data provided in Figure 7-6 has been calculated from the REC data set.

Figure 7-6 indicates that it is the western tributaries (excluding the Waipoua River), that discharge the highest volume of water per area (>70 $L/s/km^2$). These high specific discharges are due to the high rates of precipitation received in these sub catchments that reach back into the high rainfall zone in the Tararua Ranges. The Waipoua River at Mikimiki differs from the other western tributaries as its headwaters do not extend as far westward into the ranges.

The lower specific discharges calculated in the main river stem sites are a result of the high intensity rain occurring in the west being levelled out by the lower rainfall occurring on the plains and the eastern catchments.

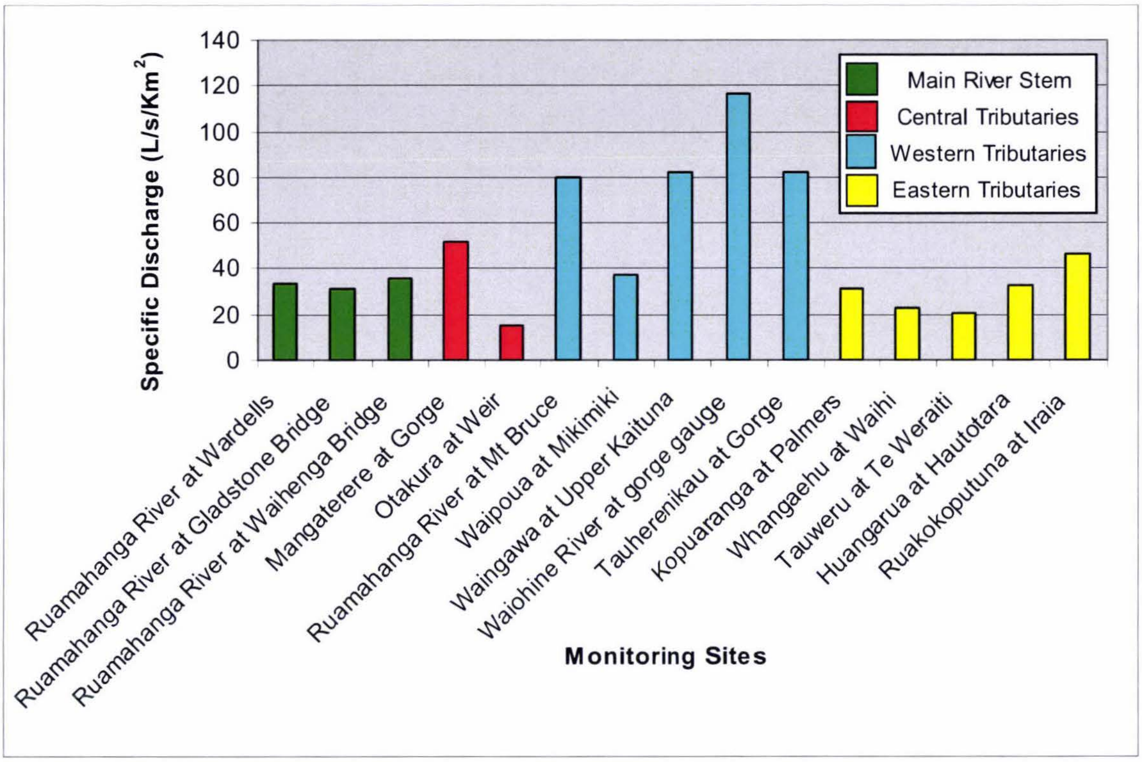


Figure 7-6: Specific Discharge (L/s/km^2) calculated from the REC data set

MALF's vary significantly throughout the catchment, values as low as 21 L/s were calculated for the Whangaehu River at Waihi, while MALF values between 1,300 L/s and 4,000 L/s were found in the western tributaries. The Ruamahanga River at Waihenga had the highest MALF value, which is not unexpected considering its position within the river system, receiving waters from all of the major tributaries within the catchment. The 7-day low flows were calculated by GWRC using the event analysis tool in the Tideda/Hilltop software, with return periods of 5, 10, 20 and 100 years.

The low flow return periods in the Ruamahanga River at Waihenga showed that the 100 year MALF is very low at 5,550 L/s (Table 7-9). The potential for the river to have sustained periods of such low flow has implications for water management e.g. future water allocation plans.

Low flows in water ways occur by natural processes (low rainfall in summer), as well as human influenced processes. Water abstraction can amplify the effects of low flows that are already occurring due to lack of rain. The low flow values for the Ruamahanga River at both Wardells and at Waihenga are likely to be due to the seasonal nature of the river in combination with the large water abstractions that occur in the vicinity of these two sites. Unfortunately "there is little information available to quantify this impact" by anthropogenic influences since "inadequate abstraction data restricts estimating the natural flow records" (Watts, 2005, p. 34 & p.36).

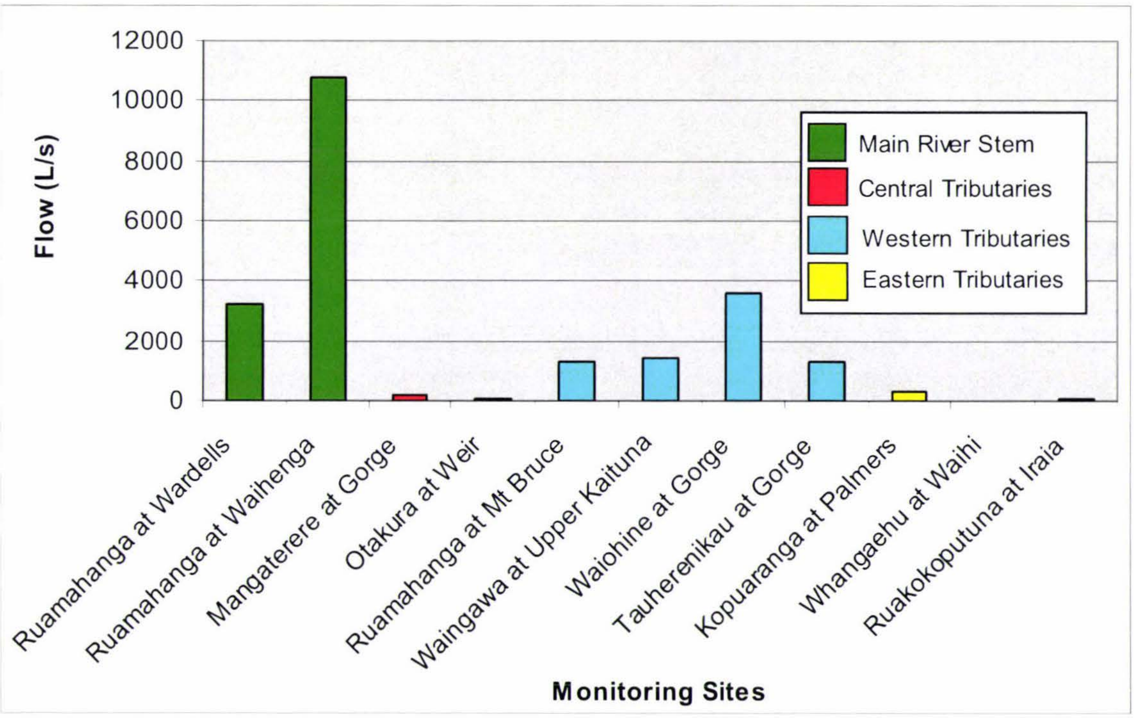
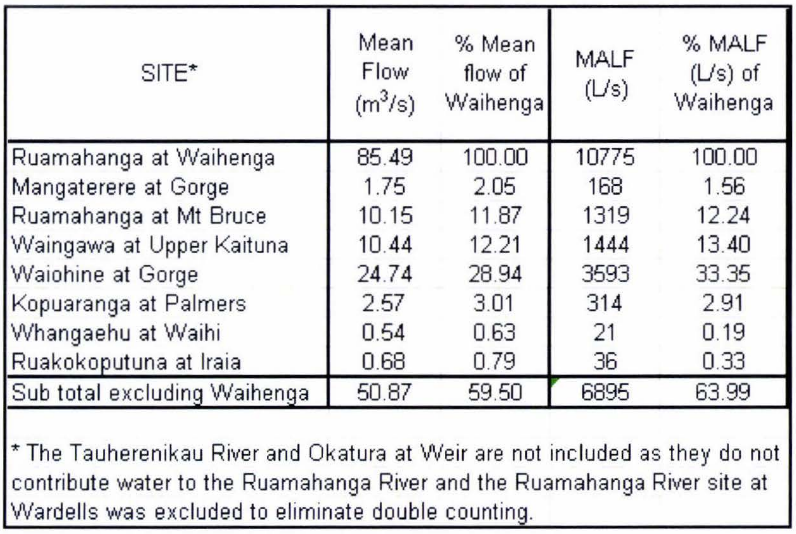


Figure 7-7: 7-day Mean Annual Low Flow (L/s) from Actual data set

Return Period	Low flow (L/s)
MALF	10775
5	7884
10	7090
20	6507
100	5550

Table 7-9: Low Flow Return Periods for 5, 10, 20 and 100 years for the Ruamahanga River at Waihenga

The Ruamahanga River monitoring site at Waihenga is the last water quantity monitoring site in the river system before the ocean. Mean flows and MALF's for the contributing tributaries to this point can be proportioned as a percentage of the mean flow and MALF measured at Waihenga which will allow judgements to be made on whether the relative contributions of tributaries to mean flows and MALF's vary within the river system. The data are presented in Table 7-10 and Figure 7-8. Note that only the tributaries with monitoring sites that measured mean flows and MALF's were able to be included in this analysis. Furthermore, the Tauherenikau River and Otakura Stream are excluded from the analysis as they do not flow into the Ruamahanga River.



SITE*	Mean Flow (m^3/s)	% Mean flow of Waihenga	MALF (L/s)	% MALF (L/s) of Waihenga
Ruamahanga at Waihenga	85.49	100.00	10775	100.00
Mangaterere at Gorge	1.75	2.05	168	1.56
Ruamahanga at Mt Bruce	10.15	11.87	1319	12.24
Waingawa at Upper Kaituna	10.44	12.21	1444	13.40
Waiohine at Gorge	24.74	28.94	3593	33.35
Kopuaranga at Palmers	2.57	3.01	314	2.91
Whangaehu at Waihi	0.54	0.63	21	0.19
Ruakokoputuna at Iraia	0.68	0.79	36	0.33
Sub total excluding Waihenga	50.87	59.50	6895	63.99

* The Tauherenikau River and Okatura at Weir are not included as they do not contribute water to the Ruamahanga River and the Ruamahanga River site at Wardells was excluded to eliminate double counting.

Table 7-10: Actual Mean Flows and % of Mean flow at Waihenga, and MALF and % of MALF at Waihenga

The analysis showed that 59.5 percent of the mean flow at Waihenga is represented by flows from the seven tributaries. While around 64 percent of the MALF at Waihenga is represented by the same tributaries. At low flows the contributions of these tributaries do not significantly change. This has important implications for determining the source of water and contaminants at low flows when the river is at most risk.

The approximate 40 percent that is missing from the calculations comes from those tributaries that have monitoring sites that cannot measure mean flows and MALF's (e.g. Taueru, Waipoua and Huangarua Rivers), and other smaller tributaries that have not been mentioned in this chapter.

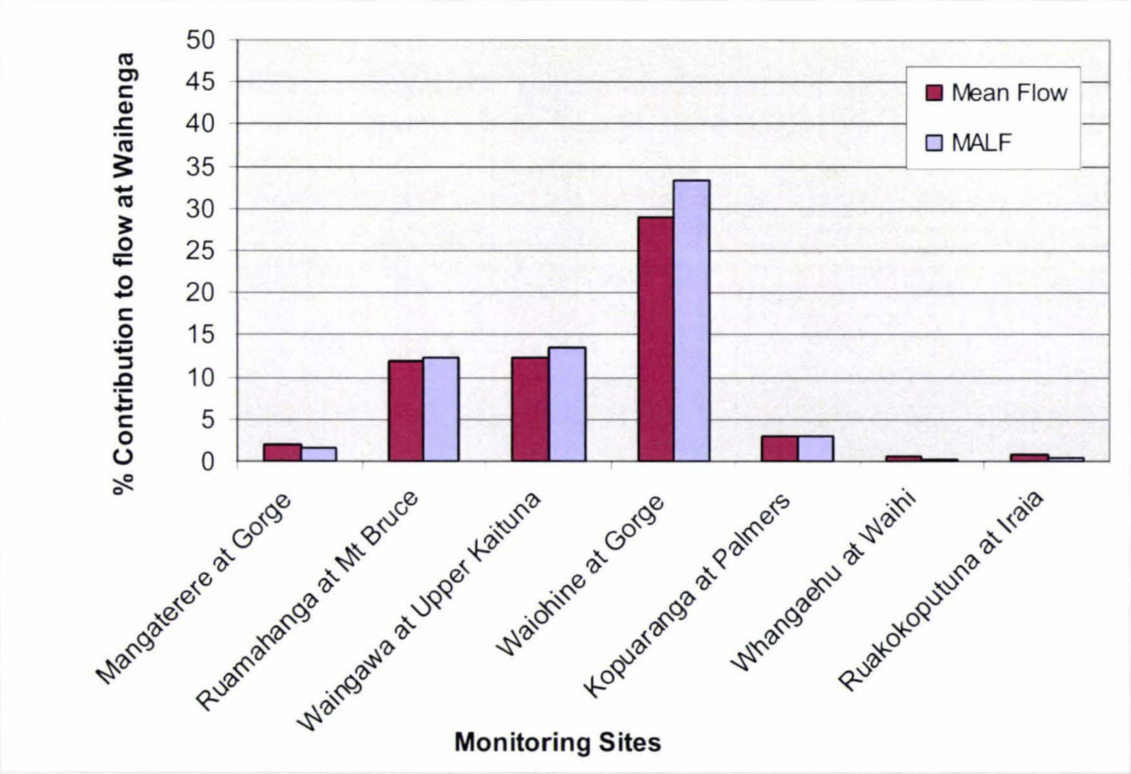


Figure 7-8: Percentage contribution of Actual Mean flow and MALF flow at the Ruamahanga River at Waihenga

Although 100 percent of the mean or MALF cannot be attributed to different tributaries, judgments can still be made on the relative contributions of those tributaries that are monitored. The above graph shows that the three western tributaries (Ruamahanga River at Mt Bruce, Waingawa River at Upper Kaituna, and Waiohine River at Gorge) make the largest contributions to flow at Waihenga in both normal and low flow periods. In the summer time, when low flow periods are common, flows at Waihenga are reliant on these western tributaries, as the three eastern tributaries exhibit much smaller low flows and corresponding contributions to the MALF at Waihenga. The specific MALF values are shown in the graph in Figure 7-9. Watts (2005, p. 21), found that the specific MALF "ranged from less than 1 L/s/km^2 in the eastern Wairarapa hills to 10 – 20 L/s/km^2 in catchments with headwaters in the Tararua Range" which is in alignment with the data below.

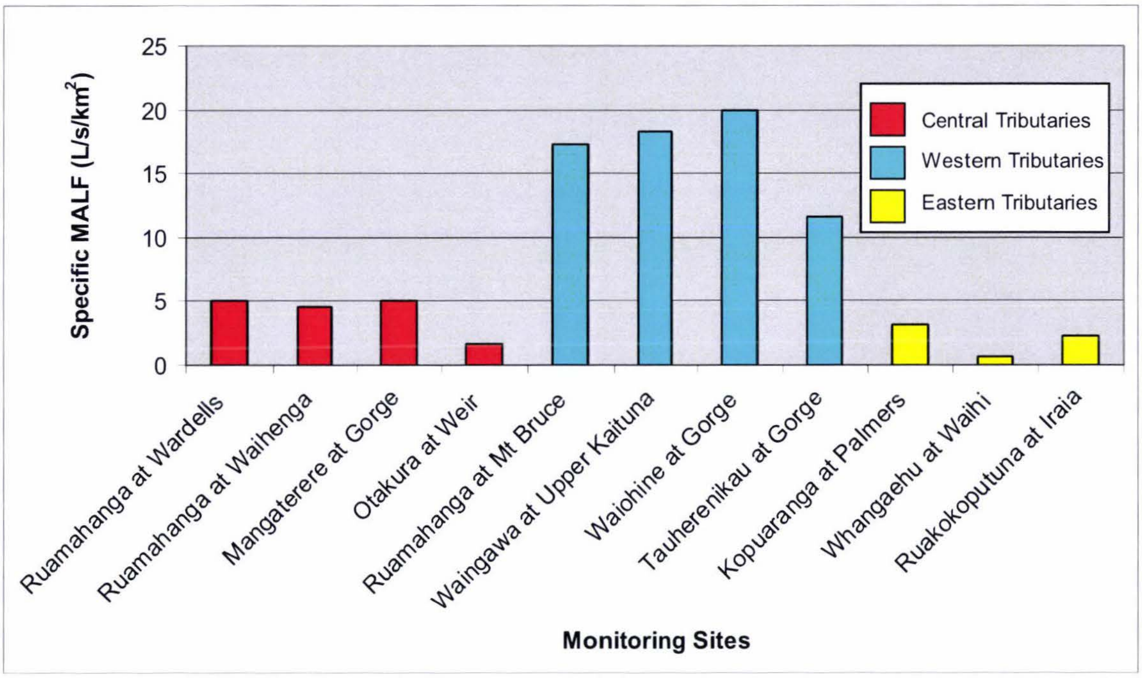


Figure 7-9: Specific Mean Annual Low Flow (L/s/km^2) from the Actual data Set

7.2.2.4. Conclusion

In this section, an actual monitored data set and the REC modelled data set were presented and utilised to draw conclusions regarding the quantity of water found in the catchment. The REC data set was found to be suitable to act as a surrogate for the actual data set which was incomplete with four of its sites being unable to reliably measure mean, median and low flow.

The largest mean and median flows occurred in the central Ruamahanga River, with mean flows increasing downstream. The western tributaries, with their headwaters in much higher rainfall zones had larger flows than the eastern tributaries, and also discharged much larger volumes of water per area. The smallest low flows occurred in the eastern tributaries, and in the summer months when flow from the east reduces, flow in the lower Ruamahanga River is reliant on the western tributaries, which have larger specific MALFs and contribute a greater percentage of water to the lower Ruamahanga River.

7.2.3. Quantitative analysis of Contributors to Flow

7.2.3.1. Methodology

In order to calculate which catchment contributes the highest proportion of flow to the lower Ruamahanga River, the REC data was used to obtain the annual discharge (m^3/yr) for each catchment, measured from the confluence of each tributary with either the Ruamahanga River or another secondary river. The annual discharge in the REC data set is equal to accumulated runoff. The contribution of flow was analysed at three points down the Ruamahanga River (located on the map in Figure 7-10). Point 1 is downstream of the confluence with the Taueru River, point 2 is downstream of the confluence with the Waiohine River, and point 3 is downstream of the confluence with the Huangarua River.

This analysis differs from that carried out in Section 7.2.2.3 (Table 7-10 and Figure 7-8), as it makes use of the REC data set so that more tributaries can be included to obtain a more complete result (the former analysis accounted for around 60 percent of the water while this latter analysis using the REC data set can account for nearly 90 percent of the water). It also differs by monitoring water contribution at the confluence of each tributary, which can only be done with the REC data set.

7.2.3.2. Results and Discussion

In the upper Ruamahanga Catchment at point 1, the Taueru River, the Waingawa River, and the Upper Ruamahanga River are the largest contributors to flow. Moving further south at point 2, the Waiohine River (excluding the Mangatarere River) is the largest contributor of flow, supplying the Ruamahanga River at this point with 29 percent of its flow. The Waiohine River remains the largest contributor below the confluence of the Ruamahanga River and the Huangarua River (point 3), providing over a quarter of the flow (Table 7-11).

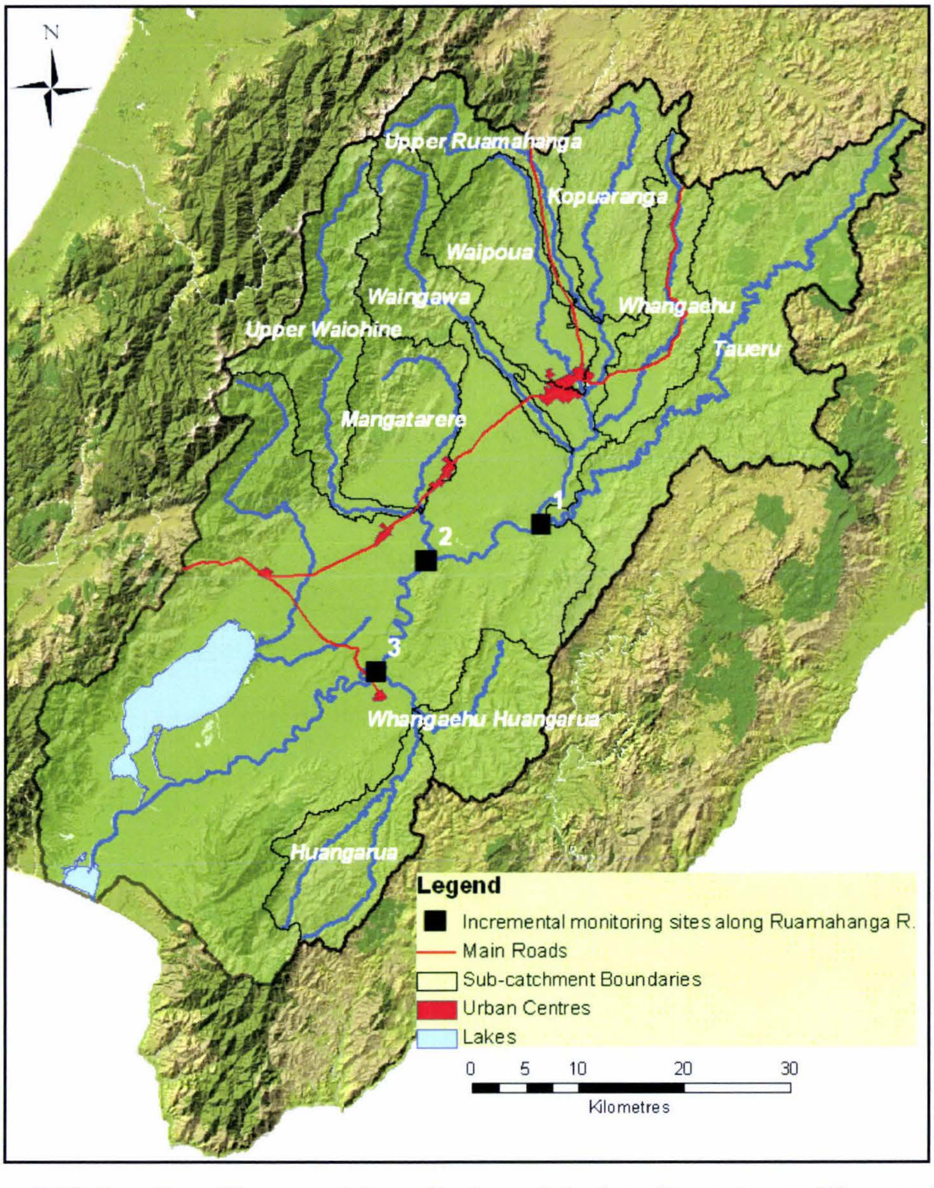
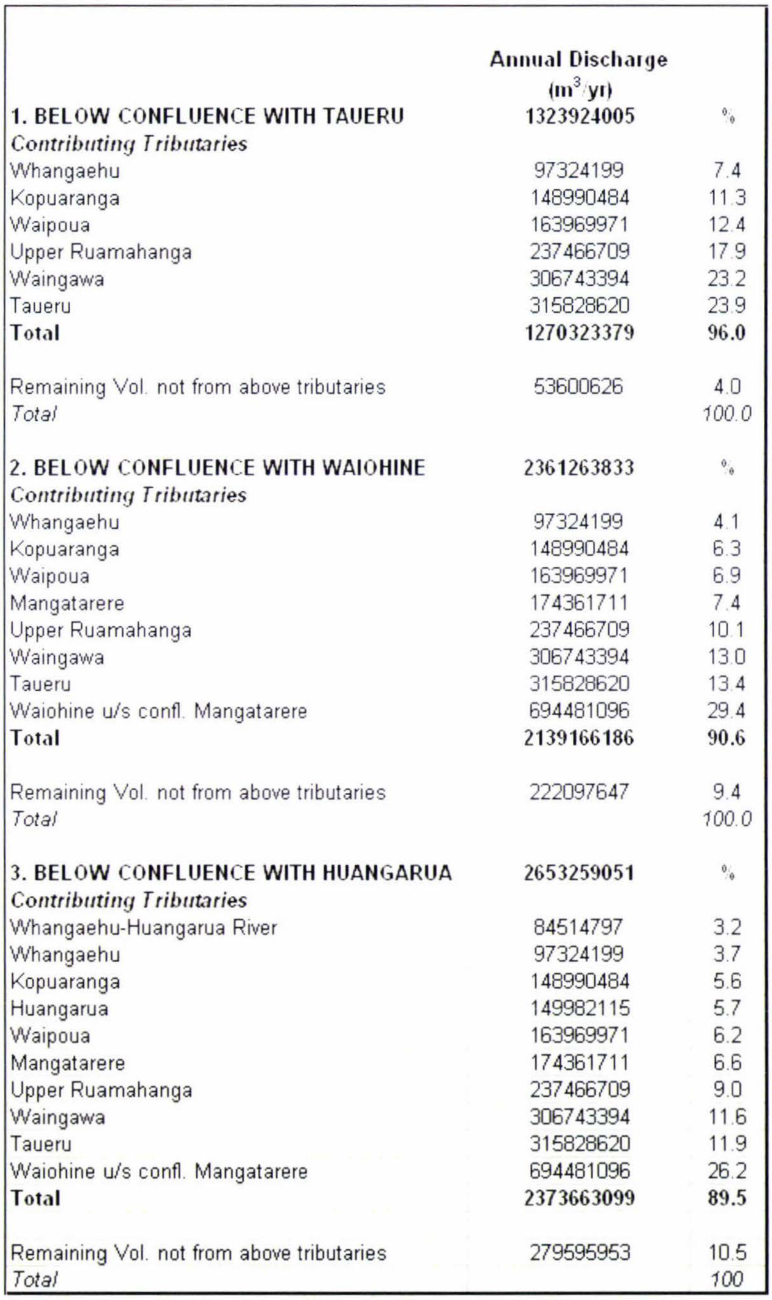


Figure 7-10: Location of incremental monitoring points along Ruamahanga River, and sub catchment boundaries

The top three contributors to flow at point 3 (the upper Ruamahanga River, the Waingawa River and the Waiohine River), supply 56 percent of the water to the Ruamahanga River, but comprise just under 20 percent of the catchment area (Table 7-11). The maps provided in Figure 7-11 show the catchments contributing the highest volumes of water. Darker blue colours represent greater volumes of water.



	Annual Discharge (m^3/yr)	
1. BELOW CONFLUENCE WITH TAUERU	**1323924005**	%
Contributing Tributaries		
Whangaehu	97324199	7.4
Kopuaranga	148990484	11.3
Waipoua	163969971	12.4
Upper Ruamahanga	237466709	17.9
Waingawa	306743394	23.2
Taueru	315828620	23.9
Total	**1270323379**	**96.0**
Remaining Vol. not from above tributaries	53600626	4.0
Total		*100.0*
2. BELOW CONFLUENCE WITH WAIOHINE	**2361263833**	%
Contributing Tributaries		
Whangaehu	97324199	4.1
Kopuaranga	148990484	6.3
Waipoua	163969971	6.9
Mangatarere	174361711	7.4
Upper Ruamahanga	237466709	10.1
Waingawa	306743394	13.0
Taueru	315828620	13.4
Waiohine u/s confl. Mangatarere	694481096	29.4
Total	**2139166186**	**90.6**
Remaining Vol. not from above tributaries	222097647	9.4
Total		*100.0*
3. BELOW CONFLUENCE WITH HUANGARUA	**2653259051**	%
Contributing Tributaries		
Whangaehu-Huangarua River	84514797	3.2
Whangaehu	97324199	3.7
Kopuaranga	148990484	5.6
Huangarua	149982115	5.7
Waipoua	163969971	6.2
Mangatarere	174361711	6.6
Upper Ruamahanga	237466709	9.0
Waingawa	306743394	11.6
Taueru	315828620	11.9
Waiohine u/s confl. Mangatarere	694481096	26.2
Total	**2373663099**	**89.5**
Remaining Vol. not from above tributaries	279595953	10.5
Total		*100*

Table 7-11: Annual Discharge and Percentage Contribution from each catchment at the 3 monitoring points

The Waiohine and Waingawa Catchments retain their rankings in both maps; however the most obvious difference between the maps is the Taueru Catchment. Although the catchment contributes 8.5 percent of the total volume of water, it contributes the least on a per hectare basis, providing only 3,331 m^3/ha compared to the Upper Ruamahanga Catchment, which contributes slightly more (10.4 percent), but has a per hectare discharge of 17,596 m^3/ha.

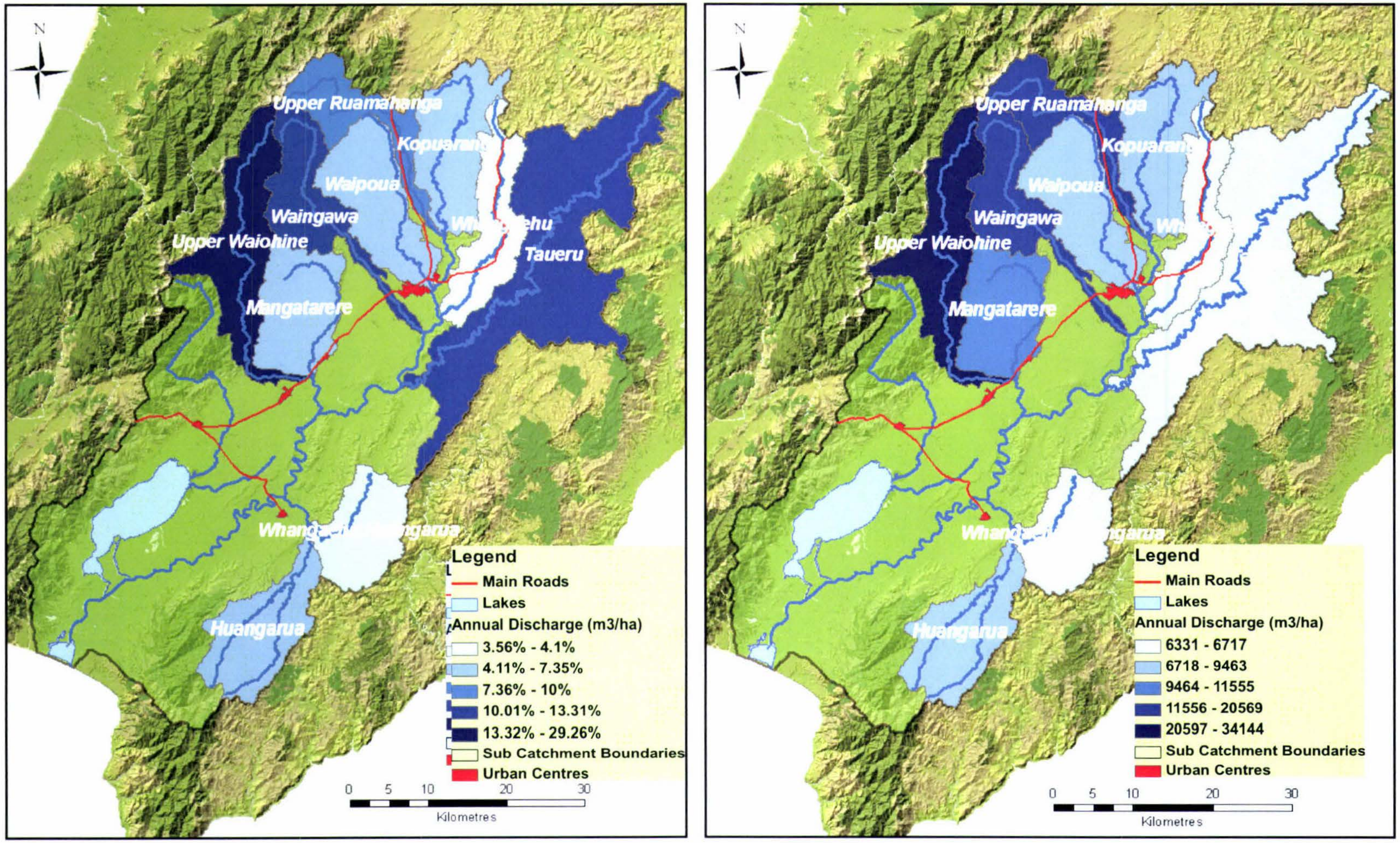


Figure 7-11: Annual Discharge from sub catchments as a) percentage of total and b) per hectare (m^3 per hectare).

7.2.3.3. Conclusion

Annual discharge volumes were calculated using the REC data set, at points on the tributaries just prior to their confluence with the Ruamahanga River or another secondary river. The volume that each tributary was contributing was determined at three points down the Ruamahanga River. The Waiohine River was found to contribute over a quarter of the water to the lower Ruamahanga River, while the Taueru River and the Waingawa River contributed just less than twelve percent each at the same point.

7.2.4. Trends in Surface Water Levels

The Hydrological Monitoring Report compiled by Watts (2005), gives an overview of the trends in surface water levels from 1999-2004. These trends are strongly correlated to rainfall events. All of the rivers in the Ruamahanga Catchment experienced below average flows from January 2001 to May 2001, and above average flows in the early months of 2004, which coincided with the extreme storm events in February of that year (Watts, 2005). Low flows for some rivers were also experienced in early 2003.

Minimum flow compliance levels are set within GWRC's Regional Freshwater Plan. The Ruamahanga River at Wardells, the Ruamahanga at Waihenga and the Kopuaranga River have target levels of 2,400, 8,500 and 270 L/s respectively, and all three sites fell below this level in four of the six years in the monitoring period. The Tauherenikau River at Gorge and the Waingawa River at Kaituna also on occasion dropped below their specified levels of 1,100 L/s in the period 1999-2004 (Watts, 2005, p. 38).

7.2.5. Lake Water Levels

Lake Wairarapa and Lake Onoke are the two largest lakes present in the Ruamahanga Catchment. As previously stated in Section 5.4.3.1 of this document, the Ruamahanga River was diverted to bypass Lake Wairarapa in the 1960's as part of the Lower Wairarapa Development Scheme (LWDS); the river now flows directly into Lake Onoke before discharging into Palliser Bay.

In addition to altering the course of the Ruamahanga River, the LWDS introduced Barrage Gates (see Section 5.4.3.1 and 5.10.6), thus artificially controlling the water level in Lake Wairarapa and Lake Onoke. These control gates, known as the Blundell Barrage control gates are located at the southern end of Lake Wairarapa. Floodways adjacent to the river are used to divert excess water into Lake Wairarapa in time of flood. The water is then held within the lake until after the river levels have receded and then re-released back into the river via the Barrage Gates. Flooding can thus alter the lake levels considerably, although the levels are strongly influenced by the use of the control gates.

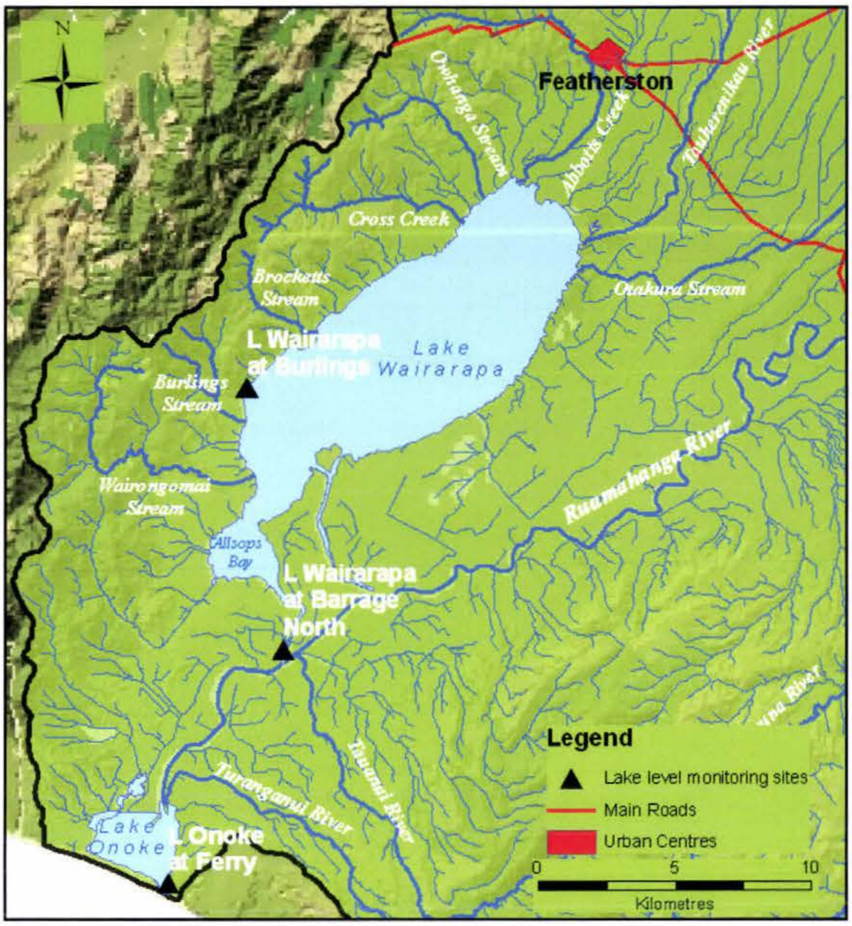


Figure 7-12: Lake Wairarapa and Lake Onoke, contributing tributaries, and locations of water level monitoring sites

Additional variability in the water level in Lake Wairarapa can be attributed to the inflows of the Tauherenikau River as well as other streams entering the Lake along its western and northern edges (Watts, 2005).

Figure 7-13 indicates that levels in Lake Wairarapa are highest in July. This is reflective of higher winter rainfalls and subsequent inflows from the Tauherenikau and other adjacent catchments. The peak shown in October can be attributed to the predominant north westerly frontal system common around late spring which results in wetter weather in the surrounding catchments of the Lake (Watts, 2005).

The water level in Lake Onoke is influenced by the flow of the Ruamahanga River, the use of the Barrage Gates, and oceanic conditions prevailing in Palliser Bay. The volume of flow in the river competes against the strength of the sea in determining whether there will be an outlet in the shingle bar that separates Lake Onoke from the beach. Rougher seas that are common in March and April, combined with lower flows in the Ruamahanga River result in the bar being closed and the lake level rising (Watts, 2005). By contrast, in winter, when the volume of water being carried by the Ruamahanga River is large, the outlet is open leading to lower lake levels. According to Watts (2005), the slight peak in the graph in spring, is a result of the water flow in the Ruamahanga River lessening, making it unable to maintain the opening in the shingle bar.

GWRC's Regional Freshwater Plan stipulates the minimum water levels for Lake Wairarapa, which are consistent with those outlined in the National Water Conservation (Lake Wairarapa) Order (Granted 6 March 1989). In their latest State of the Environment report 'Measuring up', GWRC stated that in the past five years, lake levels were mostly above those stipulated levels except for a few occasions in the summer period (Greater Wellington Regional Council, 2005).

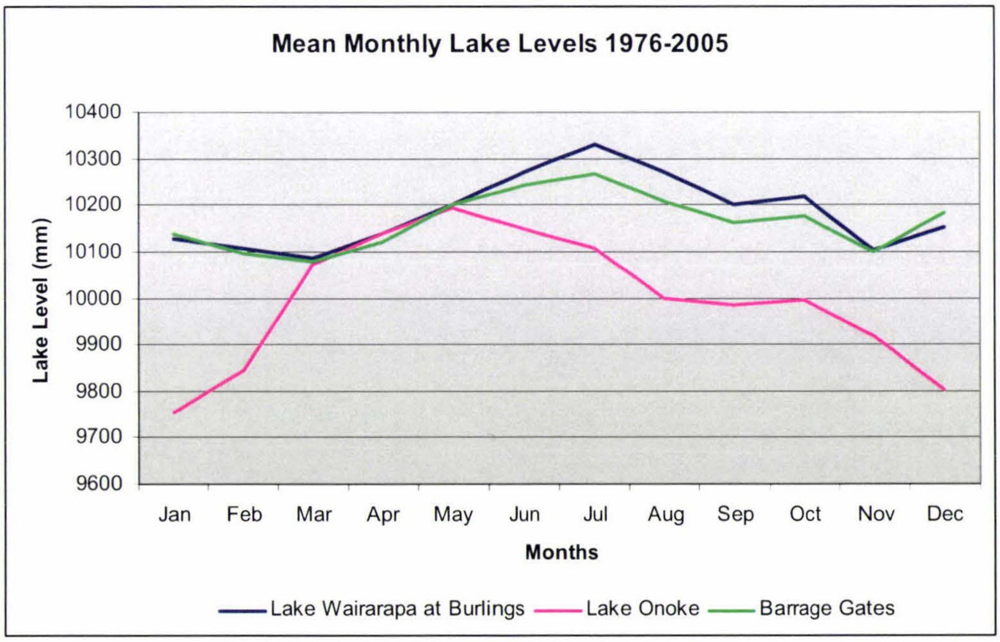
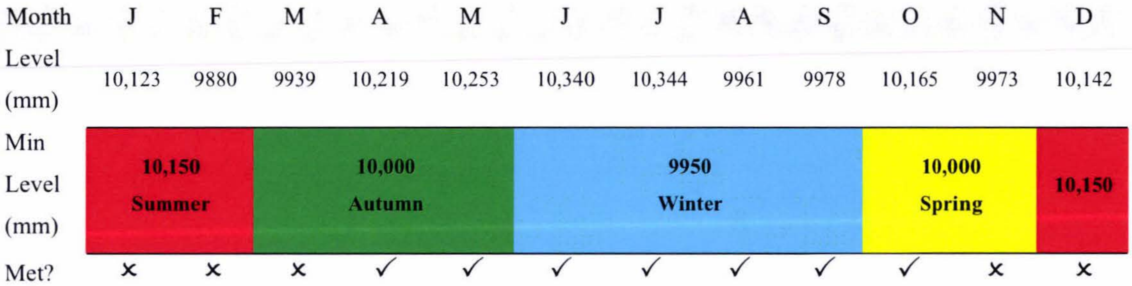


Figure 7-13: Mean Monthly Lake Levels at Lake Wairarapa, Lake Onoke and Barrage Gates (Source (Gordon, 2005; Watts, 2005, p.24)



Month	J	F	M	A	M	J	J	A	S	O	N	D
Level (mm)	10,123	9880	9939	10,219	10,253	10,340	10,344	9961	9978	10,165	9973	10,142
Min Level (mm)	**10,150** **Summer**		**10,000** **Autumn**			**9950** **Winter**				**10,000** **Spring**		**10,150**
Met?	✗	✗	✗	✓	✓	✓	✓	✓	✓	✓	✗	✗

Figure 7-14: Wairarapa Lake Level Compliance in 2005 at Burlings

Figure 7-14 shows the monthly lake level at Burlings at Lake Wairarapa for 2005 (Gordon, 2005, p. 109) and the minimum guidelines stipulated by the conservation order. It can be seen from this figure that five of the months fell below the minimum level. Staff at GWRC commented that it has always been difficult to meet these guideline lake levels. In the summer it is especially hard with a combination of low flows, low rainfall, high evapotranspiration and water loss from the fish pass. It was also noted that water levels in the lake can vary from east to west depending on wind direction and strength (M. Gordon, personal communication, 1 October, 2007).

7.2.6. Water Races

The six open water races in the Ruamahanga Catchment were introduced in Section 5.10.4. Each of these races has resource consent to abstract a certain volume of water from the supplying river. Flow in the races is manually periodically monitored. In times of low flow in the supplying rivers, the consented abstraction amount is reduced. Resource consents for four of the six water races had been renewed in 2007. Only two of the consents (for Moroa and Longwood both in the South Wairarapa District Council) require automatic flow monitoring in the water races. This information can be obtained from GWRC. The core takes and median flows for some of the water races are supplied in Table 7-12. The median flow values are somewhat dated; however these were the only values freely available at the time of writing.

Stronge (2000), undertook an investigation into the efficiency of the Taratahi and Carrington Water Races, both of which are in the vicinity of Carterton. It was found by way of surveys that estimated total consumption was 4.2 percent of the total Carrington inflow and 3.8 percent for the Taratahi inflow. It was also concluded that there were large rates of water loss due to seepage, however this loss can be assumed to be functioning as aquifer recharge.

Water Race	Supplying River	Core Take L/s	Median Flow L/s	Monitoring Period
Opaki*	Ruamahanga	170	?	?
Te Ore Ore*	Ruamahanga	250	190	1976 - 1978
Taratahi	Waingawa	482	533.5	1969 - 1997
Moroa*	Waiohine	450	688	1969 - 1973
Carrington	Mangatarere	113	?	?
Longwood*	Tauherenikau	180	152	1976 - 1978

* Resource consent for these water races were renewed in 2007. Consents for Carrington and Taratahi are yet to be renewed.

Table 7-12: Flow data for the Water Races in the Ruamahanga Catchment. Source (Bevin, 1998)

Water Race	Supplying River	Core Take	Flow in supplying rivers			% of supplying rivers flow	
		L/s	Site	Median (L/s)	MALF (L/s)	% of Median	% of MALF*
Opaki	Ruamahanga	170	Mt Bruce	4,570	1,319	3.7	12.9
Te Ore Ore	Ruamahanga	250	Mt Bruce	4,570	1,319	5.5	19
Taratahi	Waingawa	482	Upper Kaituna	5,150	1,444	9.4	33.4
Moroa	Waiohine	450	Gorge	13,150	3,593	3.4	12.5
Carrington	Mangatarere	113	Gorge	870	168	13	67.3
Longwood	Tauherenikau	180	Gorge	4,990	1,308	3.6	13.8

* At times of low flow core take for the water races is reduced by around 30 percent.

Table 7-13: Percentages of core water take for the Water Races of the median flows and MALF's of the supplying rivers.

When comparing the core water takes with the median flow and MALF of the supplying rivers (Table 7-13), it can be noted that the two water races that take the highest percentage of the median flow and MALF are the two whose consents are yet to be renewed (Taratahi and Carrington). The Carrington water race could potentially take nearly 70 percent of the Mangatarere River's water in times of low flow. However, in such times, the volume of water for the water races is reduced by around 30 percent from the core take (S. Thawley, personal communication, 9 October 2007).

7.3. GROUNDWATER

7.3.1. Background

Groundwater is seen as a fundamental resource for the Wairarapa Region. Its use has expanded from domestic and stock drinking water to extensive irrigation enabling the growth of the agricultural sector in the area. Since the 1970's consented groundwater abstraction has increased considerably, from 25 million m^3 per annum in 1989, to 48 million m^3 per annum in 1999 and 80 million m^3 per annum in 2006 (Morgan, 2000). Several of the aquifers are currently highly allocated, in some cases more than 80 percent. Furthermore, in three of Wairarapa's groundwater zones (Parkvale, Kahutara and Martinborough), additional water abstraction is currently being discouraged in order to restrict long term declines in the groundwater level (Jones & Gyopari, 2005).

One of the first major investigations into Wairarapa's groundwater resource was the 'Wairarapa Ground Water Study' carried out by the Wairarapa Catchment Board and Regional Water Board between 1981 and 1986. The impetus for this study was the Wairarapa Resource Survey[33] completed a few years previously that suggested a lack of water for irrigation would limit the growth of the agricultural sector (Annear, Butcher, Gunn, Montgomery, & Wright, 1989).

Further research into Wairarapa's groundwater resource has been extensive. GWRC has produced numerous reports detailing smaller localised groundwater zones within the Wairarapa Valley and safe yield estimates. Some of these include (Butcher, 1996a, 1996b, 1996c, 1997, 2000, 2001a, 2001b, 2001c, 2004) who has reported on the Te Ore Ore Plains; Martinborough Terraces; Huangarua, Battersea, Rathkeale and Parkvale Ground Water Zones.

More recent publications include: the 'Groundwater Monitoring Technical Report' by Jones & Baker (2005) of GWRC; 'A review of Wairarapa geology - With a groundwater

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[33] Wairarapa: Resources of a Region. A Wairarapa Regional Development Council Publication, April 1978

bias' by Begg et. al (2005) of IGNS; 'Wairarapa Valley Groundwater - Residence time, flow pattern, and hydrochemistry trends' by Morgenstern (2005), also of IGNS; and 'Regional conceptual and numerical modelling of the Wairarapa groundwater basin' by Jones & Gyopari (2005), which was a joint effort by GWRC and Pheytos Consulting.

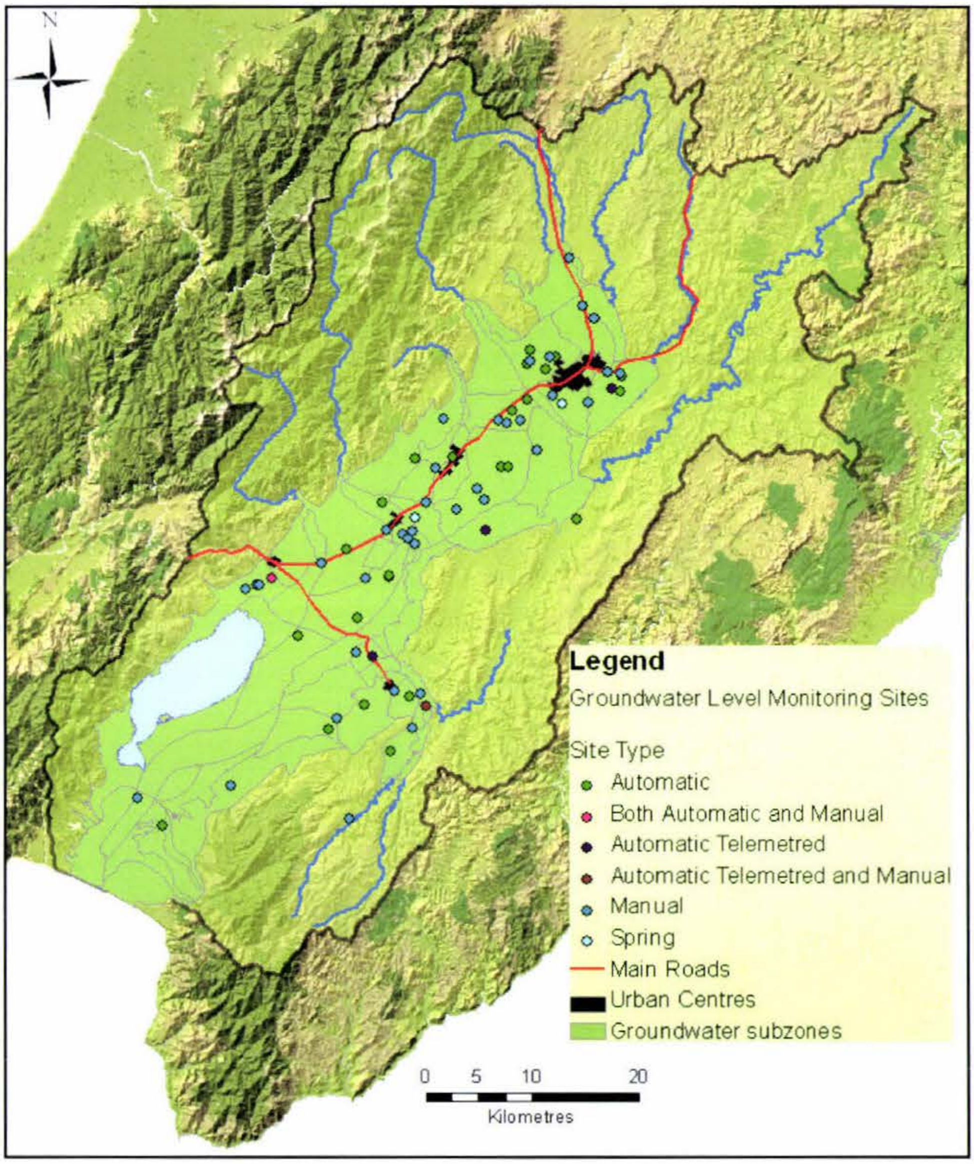

Figure 7-15: Location of groundwater level monitoring sites, and groundwater sub zone boundaries.

Groundwater levels are measured at 66 sites (excluding the two springs) within the Ruamahanga Catchment. Of these sites, 29 record the water level automatically (five of these are fitted with telemetry equipment), while at the remaining 37 sites manual monthly dipping is carried out. The location of these monitoring sites is shown on the map in Figure 7-15. The Groundwater Management Zones that GWRC has divided the Wairarapa Valley into are also displayed. The zones that are highly allocated are presented in Figure 7-16. High use aquifers are subjected to a higher level of monitoring than the low use aquifers (Morgan, 2000).

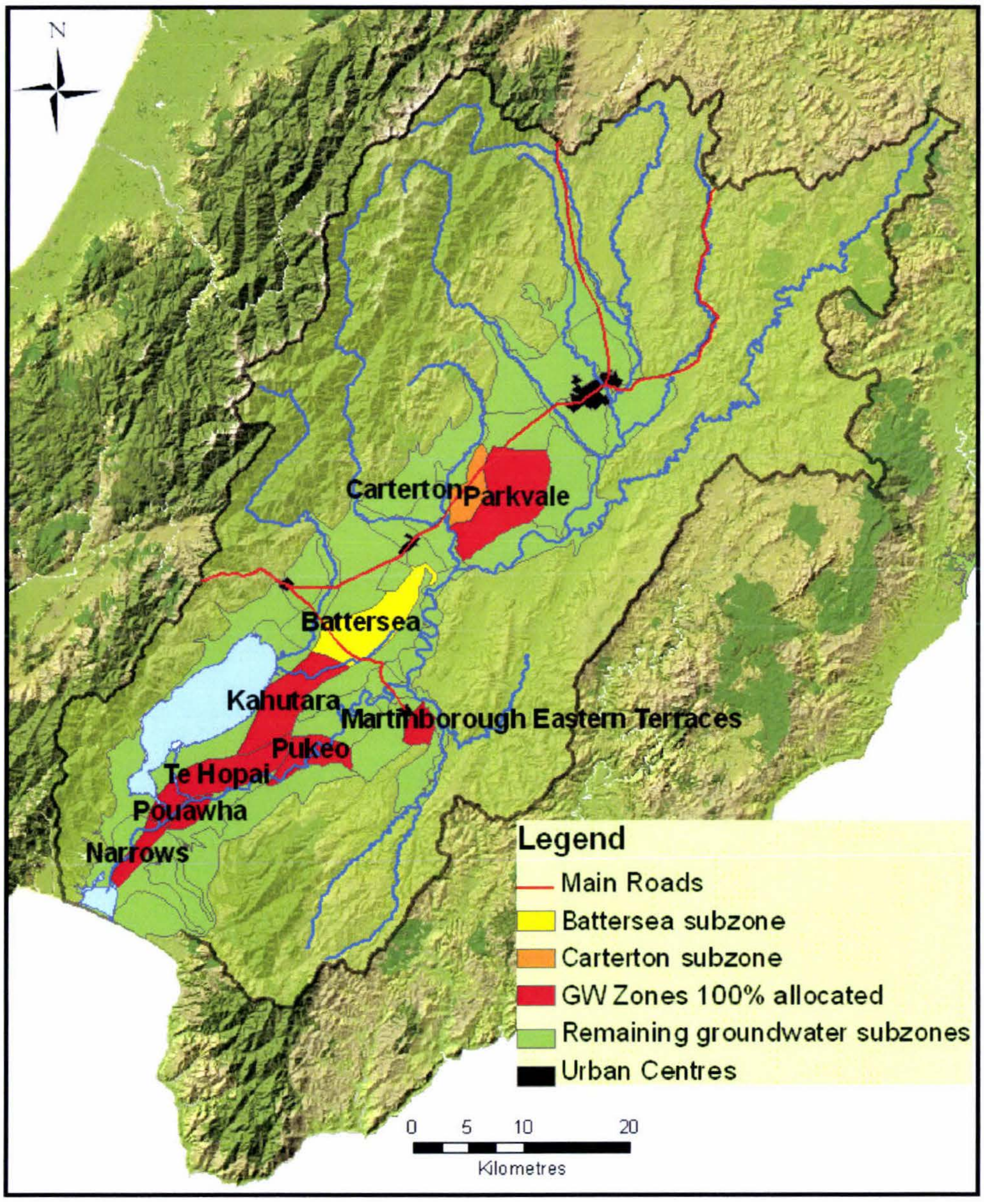

Figure 7-16: Location of Battersea and Carterton sub zones and other groundwater sub zones that are 100% allocated.

7.3.2. Groundwater Quantity Overview

The volume of groundwater found beneath the surface is strongly related to the underlying geology. Aquifers are generally composed of coarse-grained sediments such as gravels and coarse sand that allow the movement and storage of water between pores. Fine sand and silt layers are impermeable and form aquitards or aquicludes which transmit water very slowly if at all. These fine layers often cap underlying aquifers, forming confined aquifers, which can result in artesian pressure. The way in which different layers relate to each other below the surface dictates groundwater flow velocity and directions. Often flow is horizontal, but vertical leakage is also common between aquifers at differing depths.

Recharge and discharge mechanisms also play an integral part when determining groundwater quantity and are often referred to as 'the groundwater balance'. Recharge of aquifers can be by rainfall or by infiltration of surface waters (rivers, streams or lakes) or by a mix of both. Aquifers can also discharge to the surface forming a free flowing spring, or supplementing the base flow in rivers or streams. Discharge also occurs into lakes and commonly into the sea.

This Groundwater Quantity Overview section will include information on the hydrogeological units occurring within the catchment, the groundwater balance and also flow directions and velocities. The section will conclude with a discussion on the temporal trends of groundwater levels within the catchment.

7.3.2.1. Methodology

As previously mentioned in Section 7.3.1, research into the hydrogeology of the Wairarapa Basin has been extensive and recent, with four reports produced in 2005. Information from these reports has been utilised in this section to give an overview of the current state of the groundwater resource in the Ruamahanga Catchment. The reader is referred back to these reports for further information on this topic - in particular Jones &

Gyopari (2005) as it draws on information supplied in the other three publications mentioned above.

7.3.2.2. Hydrogeological Units

Jones and Baker (2005, p.10), grouped the aquifers in the Wairarapa Valley into three broad categories: "alluvial fan deposits, reworked river gravels and stratified lower valley deposits". In the successive publication, Jones and Gyopari (2005, p. 29) elaborated on the above categories and distinguished six hydrostratigraphic units that occur in the Wairarapa Valley based on "formation lithology, well yields and measured aquifer properties" these are shown below in Table 7-14 and Figure 7-17.

Unit	Name	Hydraulic Properties	Distribution
1	Alluvial Fans Outwash Gravels	Low hydraulic conductivity poor yields	Western side of catchment, alluvial fans of Tauherenikau, Waiohine, Waingawa and Waipoua
2	Recent Gravels	High hydraulic conductivity	Main River Channels
3	Reworked Gravels	Medium to high hydraulic conductivity	Lower Valley and east of the valley
4	Lower Valley Transition Zone	High hydraulic conductivity in gravels, low hydraulic conductivity in silts	Lower Valley
5	Uplifted Blocks	Very low or low hydraulic conductivity Form barriers to flow	Lansdowne, Tiffen, Fernhill. Te Maire ridge, Martinborough Terraces
6	Lower Valley Sub-basin estuarine and lacustrine deposits	Very low hydraulic conductivity, high hydraulic conductivity in thin gravel bands	Lower Valley, Lake Wairarapa

Table 7-14: The hydrostratigraphic units identified in the Ruamahanga Catchment. Source (Jones & Gyopari, 2005, p. 29)

Unit one, alluvial fans and outwash gravels, that were deposited during the cold glacial periods occur on the western side of the Wairarapa valley. These sediments are poorly sorted and matrix supported[34] and such have low hydraulic conductivities[35] and low transmissivities[36].

Unit two, recent gravels, are much more important economically, with high hydraulic conductivities and high transmissivities. The majority of the large irrigation bores are therefore located in these gravel aquifers. They are generally located around the present-day river channels and floodplains (Jones & Gyopari, 2005). Unit three comprises of reworked gravels. Hydraulic conductivities and transmissivities in these sediments are moderate, due to the fact that they have been better sorted than the original matrix supported alluvial fans and contain less fine silt and sand.

Sediments found in Unit four, the Lower Valley transition zone (Lake Wairarapa), exhibit variable hydraulic conductivities. "The transition zone occupies the area between lower Tauherenikau fan and the Lower Valley Sub-basin" (Jones & Gyopari, 2005, p. 31). Sediments occurring here include a combination of reworked alluvial gravels generated from the Tauherenikau fan, and thick fine-grained postglacial estuarine and lacustrine sediments, deposited at the height of the seaward transgression[37]. As a result of the high rates of subsidence around this area, some of the gravel aquifers have sunken into Lake Wairarapa and have become confined by the finer grained sediments which have been deposited over top (Jones & Gyopari, 2005).

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[34] Sedimentary rock texture where larger clasts are supported by a finer grained material.

[35] Describes how easily groundwater flows through a particular type of rock or soil.

[36] The rate at which groundwater is transmitted through a unit of aquifer.

[37] The advance of the sea inland, due to sea level rise or land subsidence

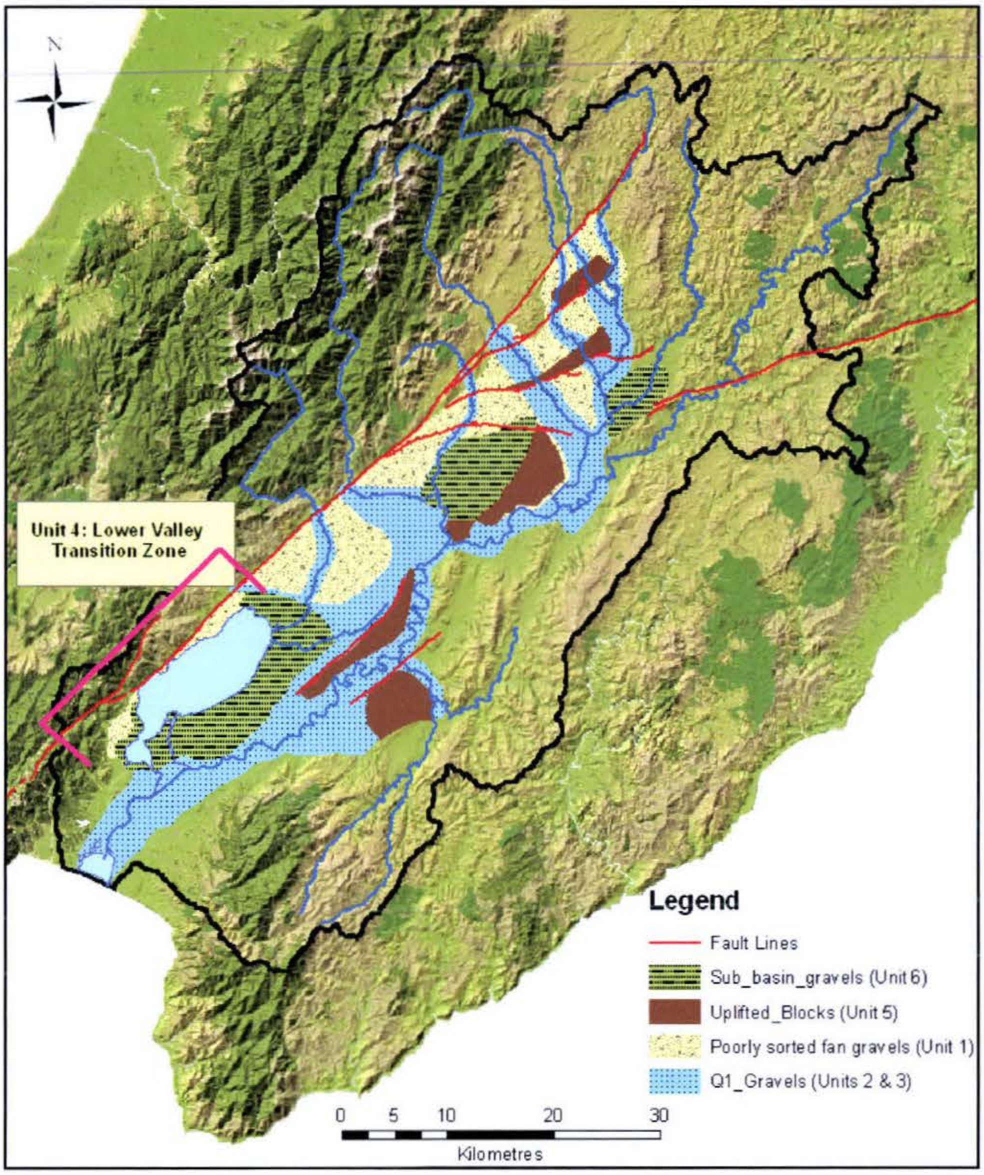

Figure 7-17: Locations of the six hydrostratigraphical units in the Wairarapa Valley Source (Jones & Gyopari, 2005, p. 14)

Tectonic processes played a role in the creation of Wairarapa's complex groundwater system. Unit five refers to the uplifted blocks comprised of less permeable sediments which can restrict the regional groundwater flow in places. The final hydrostratigraphic unit identified by Jones & Gyopari (2005), is the low permeability lacustrine and estuarine deposits. Hydraulic conductivity is very low in these fine-grained sediments; however it is thought that some gravel layers may be present within them. Unit five is very thick, probably greater than 200 metres.

7.3.2.3. The Groundwater Balance: Recharge and Discharge Zones

The data provided in Table 7-15 below has been taken from (Jones & Gyopari, 2005, p. 63) and gives the recharge and discharge components of the groundwater balance for the Wairarapa groundwater basin.

	Recharge (M m^3/day)	**Discharge (M m^3/day)**
Rainfall	0.55	
River Infiltration	1	
Discharge to Rivers		1.3
Discharge to Ocean		0.0045
Discharge to Lake		0.1
Discharge to Springs		0.2
TOTAL	**1.6**	**1.6**

Table 7-15: Groundwater Balance: Source (Jones & Gyopari, 2005, p.63)

Recharge to the groundwater system comes from rainfall and direct river infiltration. The alluvial fan aquifers (Unit 1) that extend from the base of the Tararua Ranges are thought to be predominantly recharged by rainfall. The Holocene gravel aquifers (Unit 2) located in close proximity to the main river courses are recharged by direct infiltration from the rivers. The aquifers located in the reworked gravels in the east and the lower valley (Units 3 and 4) are thought to be recharged by a mixture of rainfall and river losses from both the eastern and western sides of the valley (Jones & Baker, 2005), however this is not yet fully understood. Further quantitative analysis on recharge volumes can be found in Jones & Gyopari (2005, p. 39-44 & 63-65), and also in Morgenstern (2005, p. 12), it is interesting to note that these individual studies show some disagreement with the types of recharge occurring spatially over the valley.

As shown in Table 7-15, groundwater in Wairarapa discharges into rivers, lakes, the ocean and springs, all at differing rates. In the upper valley, groundwater is thought to discharge into the "Ruamahanga River and surrounding alluvium behind the Fernhill Block and Te Maire Ridge" (Jones & Gyopari, 2005, p. 33). Discharge also occurs in the northern section of the valley where active faults cutting the landscape have formed springs, which provide flow in several small streams in the area (Jones & Baker, 2005). Down valley are the Tauherenikau, Papawai and Otakura springs which have been described as "surface expressions of the shallow groundwater flowing through the permeable gravels" (Jones & Gyopari, 2005, p. 50).

Previous assessments of the groundwater system have confirmed that the discharge mechanism of the lower valley is unclear. Jones & Gyopari (2005) have suggested with the assistance of groundwater chemistry data, that discharge from the lower valley occurs by slow upward leakage[38] between the deeper gravel aquifers and the shallow aquifers or to the ground surface. They also propose that only the shallow gravel aquifers within the Lower Valley are actually continuous out to the coast, postulating that horizontal flow from the deeper gravel aquifers out towards the sea has been 'blocked' by the uplift of older Quaternary sediments and the subsidence of the Lake Wairarapa area.

7.3.2.4. Regional Groundwater Flow Directions

Included in the recent publication by Jones and Gyopari (2005), are the 1985 piezometric survey contours. The data for these contours are given in Appendix 2 of that report. The general trend of groundwater flow is in a southerly direction. However, around the Lake Wairarapa area, flow vectors are not easily identified. Jones & Gyopari (2005) identified eight sub-regional flow systems within the Wairarapa Groundwater Basin. More information can be obtained on these systems from the above-mentioned publication.

7.3.2.5. Trends in Groundwater levels

As discussed Section 7.3.2.3, groundwater levels are dependant on the balance between aquifer recharge and discharge. Aquifer recharge is strongly correlated to seasonal periods and associated rainfall events. In times of above average rainfall, groundwater levels rise and similarly, decline in dry periods. The wet 2006 winter resulted in "shallow groundwater levels reaching record highs in Wairarapa" (Baker, 2006, para.2).

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[38] Via a vertical hydraulic mechanism.

Aquifer discharge, contrastingly, can be defined as both a natural process and an anthropogenic process, which refers to the millions of litres of water abstracted for human consumption. As mentioned in the preceding sections, groundwater abstraction in Wairarapa has increased substantially in the last few decades. Baker (2006) stated that the total allocated volume of water is over 400,000 m^3/day, and this value has doubled since 1996. Obviously such high levels of abstraction will lead to lower groundwater levels unless there is an increase in recharge to counterbalance the decline. Groundwater abstractions are covered in more detail in Section 9.5 of this report.

The groundwater balance data shown in Table 7-15 has not accounted for water abstraction as a type of discharge. However in their analysis, Jones & Gyopari (2005, p. 65) found that the "total allocated groundwater volume is likely to be close to the estimated rainfall recharge on a regional basis". On a first assessment this statement seems alarming, in that groundwater abstraction alone would be causing a deficit in the groundwater balance of 0.55 M m^3/day (equal to the estimated rainfall recharge). However, it has been suggested that "less than 30 percent of the allocated groundwater volume" is actually used, and this is true for drier periods also (Jones & Gyopari, 2005, p. 65), and therefore the strain placed on the groundwater resources would be less than previously thought. The lack of metering on groundwater abstractions hinders the ability to accurately ascertain the volume of water that remains in the region's aquifers. This, in turn affects the long term sustainability of the resource.

Groundwater level declines due to pumping have been identified in some areas within the Ruamahanga Catchment. These include Battersea (noticed seasonally), Kahutara, and Parkvale (noted in the deeper wells) (Jones & Baker, 2005). Such groundwater level declines may also be noticed in the future in the Carterton and Lower Valley areas, as these are the zones supplying the largest volumes of water (consented allocations of 50,000 m^3/day) (Jones & Gyopari, 2005) (Figure 7-16). It is likely that decline in groundwater levels will impact negatively on the quantity of water in the rivers, since around 80 percent of discharge from aquifers goes to river infiltration alone.

GWRC has designated indicator wells to assess movements in groundwater levels. The deep well is Baring. Baring is located in the Parkvale groundwater basin and is recharged by rainfall. The shallow indicator well is Oliver Shallow, which is located farther north in the Te Ore Ore Basin. Oliver is thought to be recharged by a mix of river and rain (T Baker, personal communication, 11 May, 2007).

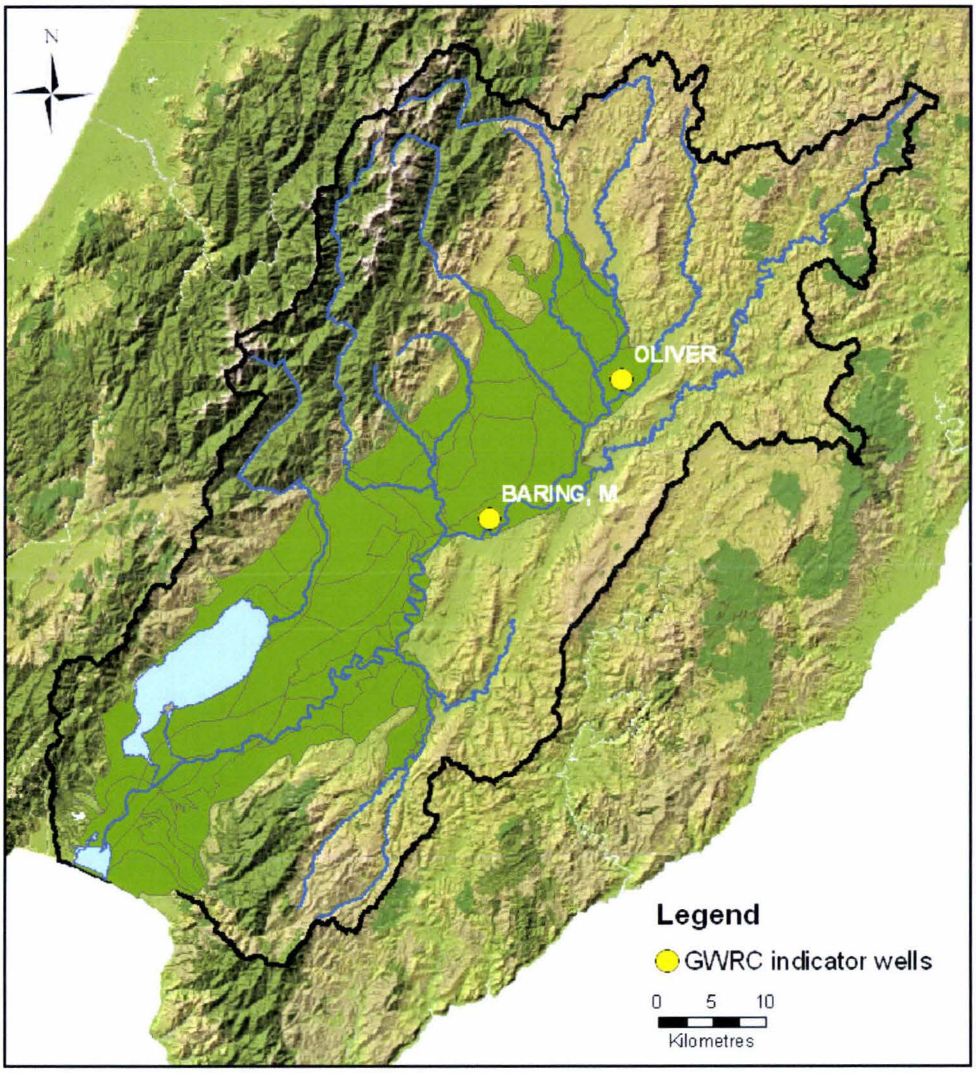


Figure 7-18: Greater Wellington Regional Council indicator wells

7.3.2.6. Conclusion

The Ruamahanga Catchment features a widespread aquifer system on the Wairarapa Valley floor. The complex geological history of the area has resulted in the formation of six distinct hydrogeological units with varying abilities to store and transmit water. The most productive hydrogeological unit in terms of water abstraction are the recent gravel aquifers which are located near the present day river channels and floodplains.

The aquifers in the Ruamahanga Catchment are recharged from rainfall and river infiltration. The predominant recharge mechanism usually depends on the geographical location of the aquifer. Groundwater exits the aquifers to infiltrate rivers, lakes, springs and the ocean depending on the characteristics and location of the particular aquifer. In the Wairarapa Valley, discharge of groundwater to rivers amounts to around 80 percent of total discharge, compared to discharge to the ocean which comprises only 0.3 percent.

The level of groundwater in the aquifers depends on the volume of inputs (natural recharge) and the volume of outputs (natural discharge and human abstraction). Researchers in the Ruamahanga Catchment established that the allocated groundwater volume was almost equal to the rainfall component of recharge (0.55 M m^3/day, around 35 percent of total recharge), however it is likely that less than 30 percent of the allocated volume is actually used. Nevertheless the increase in groundwater abstraction that has occurred in the Wairarapa valley in the past forty years has resulted in an overall decline in groundwater level in some aquifers. Such decline can have implications for future groundwater use and can also have an impact on water quantity in the rivers that receive groundwater discharge from neighbouring aquifers.

7.4. CONCLUSION

In the Ruamahanga Catchment, surface water is found in various rivers and streams, lakes, water races, and wetlands. In terms of rivers and streams, the largest quantity occurs in the central Ruamahanga River, which has the highest mean and median flow rates. The eastern tributaries have the lowest mean and median flow rates, although some of the eastern tributaries are subject to large occasional storm events which result in large maximum flows. Annually, the lower Ruamahanga River receives most of its water from the western tributaries due to more consistent rainfall in the headwaters of these rivers and streams. River water levels in some of the tributaries have occasionally breached minimum flow compliance levels since 1999. These times of lower flows are strongly related to rainfall events. In terms of managing the freshwater in the rivers in the future, accurate climate forecasts are necessary along with the ability to reduce non-critical water abstractions from the river in low flows.

The level of water in Lake Wairarapa is controlled manually, while the water level in Lake Onoke depends on the seasonal nature of the Ruamahanga River, oceanic conditions and some human influence. The water level in Lake Wairarapa is usually highest in July, while in Lake Onoke it is highest in May. There are six water races servicing the Wairarapa Valley. Resource consents for all of the water races apart from the Carrington and the Taratahi have recently been renewed. When compared to the median flow and MALF of the river supplying each water race, only the Carrington and the Taratahi represent any significant proportion of the flow. It is expected that the resource consents for both of these water races will be renewed in the near future.

Groundwater is located in many aquifers throughout the Wairarapa Valley. The aquifers most conducive to groundwater abstraction are recent gravel aquifers located near the present day river channels and floodplains. Over the past several decades demand in groundwater use has increased significantly. Due to this several of the sub zones are now fully allocated and some are experiencing long term water level decline.

8. Water Quality

8.1. INTRODUCTION

Water is one of the most important resources in any catchment. Poor water quality can adversely impact on human health, ecosystem health, biodiversity, agriculture, horticulture, recreation, and cultural needs. Good water quality is the essential to the well being of a catchment: socially, environmentally and economically.

The aim of this chapter is to describe the state of surface water and groundwater quality in the Ruamahanga Catchment. This will be carried out by drawing on previous research in these areas and then expanding this research to include nutrient loading and suspended sediment concentration. Conclusions pertaining to lake water quality and groundwater quality have been established from previous studies undertaken by Greater Wellington Regional Council (GWRC) and Institute of Geological and Nuclear Science (IGNS).

8.2. SURFACE WATER

8.2.1. Background

Surface water includes water in rivers, streams, lakes and wetlands, the quantity of which has been described previously in Chapter 7. The quality and quantity of water in the region's wetlands has not been monitored and therefore has not been included in this report. The water quality of Lake Wairarapa has been condensed into its own section (Section 8.2.5), thus the main focus of this chapter is on the water quality in the catchment's rivers and streams. Some of the rivers and streams in the Ruamahanga Catchment have been subject to water quality monitoring at both a national and regional level.

National Monitoring Programs

In 1987, the national "100 Rivers Survey" was conducted from late summer to autumn, sampling 96 rivers at baseflow to determine and characterise each river's water quality in low flows conditions (Close & Davies-Colley, 1990a, 1990b). The Ruamahanga River was the only Wairarapa river to be included in this survey and was grouped into 'cluster one' with 35 other rivers including the Rangitikei River, the Motueka River, and the Waimakariri River. 'Cluster one' rivers represented rivers with "low concentrations of most chemical species", including phosphorus (P) and nitrogen (N) (Close & Davies-Colley, 1990b, p.350).

The New Zealand National Rivers Water Quality Network (NRWQN) was carried out from 1989 through to 1996. Three sites on the Ruamahanga River were included as part of the 77 sites around New Zealand. In their first paper Smith and Maasdam (1994) commented on the physico-chemical variables that they had monitored at each site on a monthly basis for the first two years of the program. In their second paper, the physico-chemical data was related back to environmental variables and then a cluster analysis was performed, classifying each river site into one of nine clusters (Maasdam & Smith, 1994).

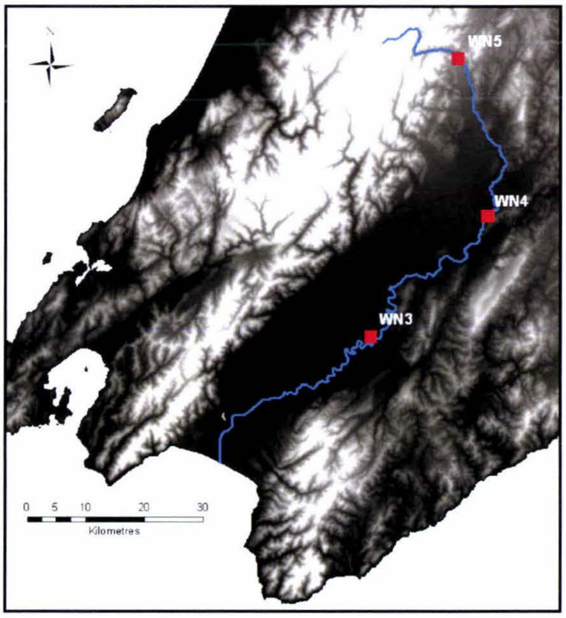


Figure 8-1: Ruamahanga River sites included in NRWQN. Source (Maasdam & Smith, 1994)

The Ruamahanga River site at SH2 (WN5) was grouped as part of Cluster 1, which are described as "the clearest and most pristine waters" (Maasdam & Smith, 1994, p. 46).

The other two downstream Ruamahanga River sites at Wardells (WN4) and Waihenga (WN3) contain waters that are less pristine. These sites were both grouped into Cluster 4. "Clusters 1-3 have relatively low conductivity and BOD_5, low concentrations of major ions and P and N species" (Maasdam & Smith, 1994, p. 46), and the next group of clusters (4-6) have "relatively higher" concentrations of P and NO_3^- species than clusters 1-3 (Maasdam & Smith, 1994, p. 46).

A publication by Smith, McBride, Bryers, Wisse, & Mink (1996), looked at the same sampling points over a five year period (1989-1993), and reported on trends in the measured water quality variables. Both the sites at Wardells and Waihenga featured an upward trend in flow over the five year period. The site at SH2 (WN5) and the lowest downstream site at Waihenga (WN3) both had a reduced level of visual clarity after the five years. Furthermore, after the sampling period, the site at SH2 had an increase in the dissolved oxygen (DO) percentage saturation, and a decrease in the total phosphorus (TP). The site situated at Wardells (WN4), half way down the Ruamahanga River, featured an increasing level of dissolved reactive phosphorus (DRP) after the time period (Smith et al., 1996, p. 492-494). Scarsbrook et al. (unpublished) as cited in Milne and Perrie (2006), also found significant increases in DRP at Wardells and Waihenga in the period 1989 – 2003.

Based on the two above-mentioned national water quality studies, the Ruamahanga River, when taken as whole, is considered to be one of the top 35 cleanest rivers in New Zealand (of 96 studied). However when broken down into three segments, the view changes. The furthest upstream point (WN5) retains its pristine status, but the two points downstream (WN3 and WN4) are not as clean as perhaps they could be. The Ruamahanga River near these points is draining predominately pastoral land, and is subject to urban influences such as municipal waste discharge. At these points the Ruamahanga River has already absorbed loadings from both the eastern and western tributaries which can strongly alter the quality of its water.

A final national survey of river water quality is the 'Nationwide and regional state and trends in river water quality 1996-2002' (Larned, Scarsbrook, Snelder, & Norton, 2005). This report was compiled by NIWA for the Ministry of the Environment. Unfortunately this report fails to distinguish between the Wairarapa and Wellington Regions, and therefore is unsuitable for making assessments on water quality in the rivers in the Ruamahanga Catchment.

Regional Monitoring Programs

Surface water quality has been monitored in Wairarapa by GWRC since 1991. Several changes have occurred in the monitoring program over this time, including a change in the location of the monitoring sites to "better reflect the natural diversity of rivers, streams, major land uses and human activities in the region", a change in water quality variables measured, and adjustments to the procedures used for water quality analysis (Milne & Perrie, 2006, p. 5).

Currently, water quality is measured in the Ruamahanga Catchment at 20 sites under the Rivers State of Environment (RSoE) Monitoring Programme and reported on annually. Seven sites were introduced into the catchment in September 2003, and at this time, four historical sites were relocated or removed from the programme. These include: Ruamahanga River at Mt Bruce which was relocated; and the Ruamahanga River at Double Bridges and at Waihenga Bridge and the Whangaehu River at Waihi which were all removed. At these 20 sites, physico-chemical and microbiological variables (water quality variables) are measured monthly, while macroinvertebrate and periphyton analysis (biological monitoring) is done on a yearly basis.

Publications relevant to this section include the Recreational Water Quality Monitoring Technical Report (Milne, 2005), the Lake Wairarapa Water Quality Monitoring Technical Report (Perrie, 2005), the Freshwater Quality Monitoring Report (Milne & Perrie, 2006) and the Lower Ruamahanga Instream Flow Assessment (Watts & Perrie, 2007).

8.2.2. Surface Water Quality Overview

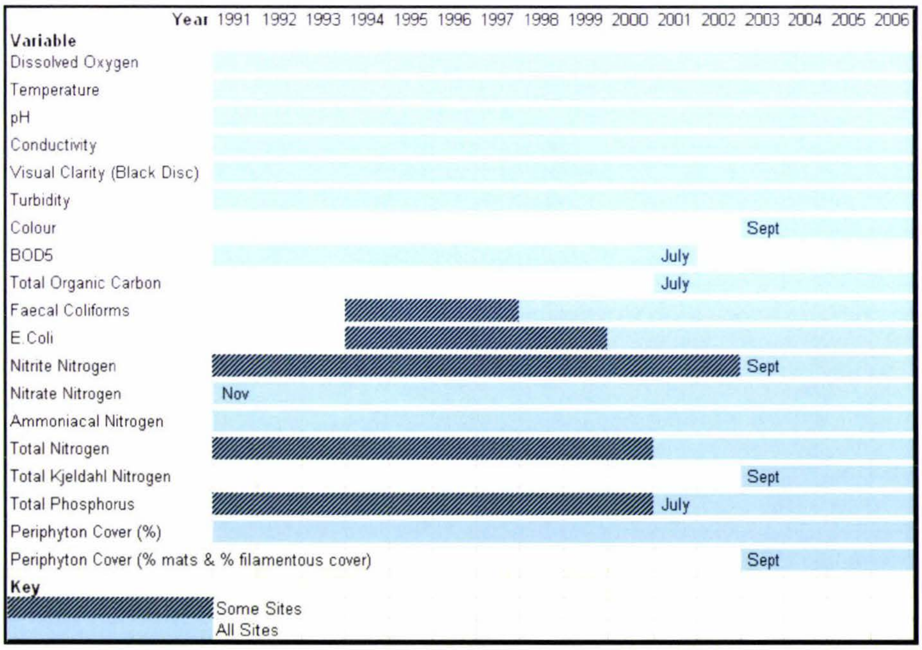
This section will give an overview of the current state of the Ruamahanga Catchment's rivers as monitored by GWRC.

8.2.2.1. Methodology

As noted in Section 8.2.1 GWRC has produced a series of reports pertaining to water quality within the Wellington Region. In this section, information from these reports has been extracted to provide a brief review of the quality of water in the Ruamahanga Catchment. The reader is referred back to these reports for further information that may be required.

8.2.2.2. Water Quality Variables

The suite of variables that surface water has been tested for in Wairarapa has expanded since monitoring began in 1991 (Table 8-1). Definitions and uses of these variables can be found in Appendix 7.



Variable / **Year**	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Dissolved Oxygen	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Temperature	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
pH	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Conductivity	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Visual Clarity (Black Disc)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Turbidity	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Colour													🟦 Sept	🟦	🟦	🟦
BOD5	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦 July					
Total Organic Carbon											🟦 July	🟦	🟦	🟦	🟦	🟦
Faecal Coliforms				▨	▨	▨	▨	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
E.Coli				▨	▨	▨	▨	▨	▨	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Nitrite Nitrogen	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟦 Sept	🟦	🟦	🟦
Nitrate Nitrogen	🟦 Nov	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Ammoniacal Nitrogen	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Total Nitrogen	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟦	🟦	🟦	🟦	🟦	🟦
Total Kjeldahl Nitrogen													🟦 Sept	🟦	🟦	🟦
Total Phosphorus	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	🟦 July	🟦	🟦	🟦	🟦	🟦
Periphyton Cover (%)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Periphyton Cover (% mats & % filamentous cover)													🟦 Sept	🟦	🟦	🟦

Key

▨	Some Sites
🟦	All Sites

Table 8-1: Variables monitored in the Ruamahanga Catchment over time

Table 8-2 outlines the guideline values (GV's) for several of the water quality variables, and summarises the water monitoring sites in the Ruamahanga Catchment that have often breached particular GV's, or in the case of conductivity and total organic carbon (TOC) exhibited the highest values of all monitoring sites over the monitoring period 1997-2003. A full list featuring data for all variables at all of the sites can be found on pages 29-30 of the Freshwater Quality Monitoring Report (Milne & Perrie, 2006). The sources of each GV can be found in Appendix 8.

It appears from the data in Table 8-2 that the water flowing in the eastern tributaries of the Ruamahanga Catchment is of lesser quality than the central and western tributaries. The eastern tributaries frequently breached the GV's for a number of the variables on a large proportion of the monitoring occasions e.g. DO, visual clarity, NNN, TN, DRP and Faecal Coliforms (FC). The measured conductivity values in the eastern tributaries were all above 250 μS/cm, and in addition, clarity measurements in these same tributaries were almost always less than the GV of 1.6 m. The Taueru River at Gladstone, and the Huangarua River at Ponatahi Bridge, both had a relatively alkaline pH level, which possibly could be due to the presence of limestone in these catchments.

Breaching of the DRP GV was not exclusive to the eastern tributaries. Three of the central sites, and one of the western sites were found to be almost always above 0.010 mg/L. Of the three central rivers the Mangatarere River, which flows into the Waiohine River near Carterton, features the most degraded water. The western tributaries were mostly of better quality, although high levels of NNN and TN were common in the Waipoua River.

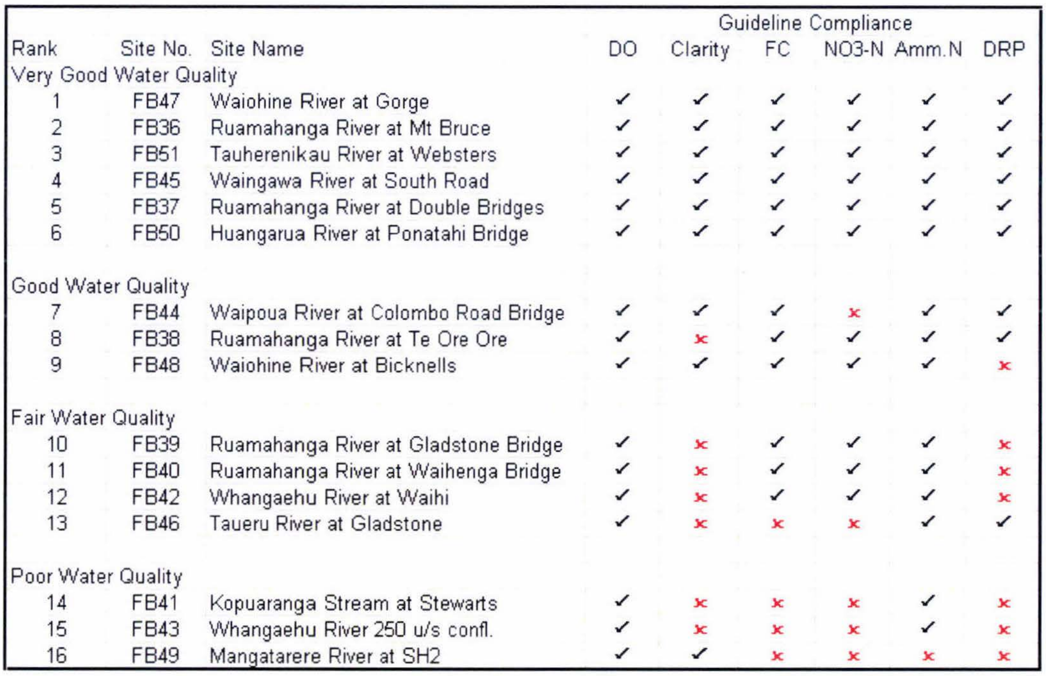
High occurrences of FC (>100 cfu/100 mL) were found only to occur within the Whangaehu River, Kopuaranga Stream, and Mangatarere River. This guideline was set by the ANZECC (2000) for livestock drinking water. GWRC also compared the FC counts to the contact recreation guideline of 1,000 cfu/100 mL given by ANZECC (1992). Over the period from July 1997 to July 2003, none of the sites within the Ruamahanga Catchment had a median FC count that exceeded this level and only two sites, on the Kopuaranga Stream and on the Whangaehu River had a moderate number of counts that were over 1,000 cfu/100 mL. Six of the sites, all in the western tributaries, never exceeded this threshold during the monitoring period.

Variable	Water Temperature	DO	pH	Conductivity	Visual Clarity	TOC	NNN	NH4-N	TN	DRP	TP	FC
Guideline Value (GV)	*<20°C*	*≥80 % Sat*	*7.2-7.8*	*> 250 µS/cm*	*<1.6 m*	*>7 mg/L*	*≤0.444 mg/L*	*≤0.021 mg/L*	*≥0.614 mg/L*	*≤0.010 mg/L*	*≤0.033*	*>100cfu/100ml*
	% of times that sites did not comply with the GV	*% of times that sites did not comply with the GV*	*median pH results not betweeen 7.2 - 7.8*	*median conductivity values (µS/cm)*	*% of times that sites did not comply with the GV*	*median TOC values (mg/L)*	*% of times that sites did not comply with the GV*	*% of times that sites did not comply with the GV*	*% of times that sites did not comply with the GV*	*% of times that sites did not comply with the GV*	*% of times that sites did not comply with the GV*	*% of times that sites did not comply with the GV*
CENTRAL												
Ruamahanga River at Gladstone Bridge	**12.2**	0	7.5	108	58.1	1.9	45.9	24.3	28	**98.6**	68	17.8
Ruamahanga River at Waihenga Bridge	4.1	0	7.6	130	**71.6**	2.3	47.3	9.5	36	**94.6**	44	22.2
Mangatarere River at SH2	0	0	6.9	115	52.7	1.8	**97.3**	**89.2**	**96**	**98.6**	**96**	**70.3**
WEST												
Waipoua River at Colombo Road Bridge	2.7	0	7.4	103	31.5	1.7	**94.6**	0	**92**	21.6	8	17.8
Waiohine River at Bicknells	0	0	7.1	76	47.3	1.2	41.9	12.2	36	**97.3**	24	13.5
Tauherenikau River at Websters	**11.1**	0	7.3	74	38.4	1.3	0	0	0	5.5	4.2	6.8
EAST												
Whangaehu at Waihi	0	**20.8**	7.6	303	**98.2**	7.9	5.5	16.4	36	**100**	**92**	49
Whangaehu River 250m u/s confl	1.4	**15.1**	7.4	262	**78.4**	5.4	**91.9**	24.3	**100**	**94.6**	84	**72.6**
Taueru River at Gladstone	4.1	**5.5**	8	405	**75**	7.2	77	**45.9**	88	81.1	64	50
Huangarua River at Ponatahi Bridge	8.1	0	8.2	395	33.8	2.9	12.2	1.4	28	33.8	20	18.9
Kopuaranga Stream at Stewarts	0	0	7.8	265	**72.2**	4.2	**98.6**	16.4	**100**	**97.3**	79	**87.5**

Table 8-2: Water monitoring sites in the Ruamahanga Catchment that have a median water quality variable breaching the Guideline Value (GV) (underlined) and sites that have frequently breached the GV (red bold).

Water Quality Index (WQI)

As part of the RSoE monitoring program, GWRC compiled the results for six of the above-mentioned physico-chemical and microbiological variables to obtain a water quality index (WQI). These variables included: visual clarity (black disc), DO (% saturation); DRP; NH_4-N; NNN; and FC bacteria. Depending on whether the site met the given criteria for each of the variables, it would be ranked from very good, good, fair to poor (Milne & Perrie, 2006). It should be noted that the "WQI should be used only for comparative purposes rather than an absolute measure of water quality" (Milne & Perrie, 2006, p. 37). The sites have been ranked to differentiate between the best and the worst within each grade.



			Guideline Compliance					
Rank	Site No.	Site Name	DO	Clarity	FC	NO3-N	Amm.N	DRP
Very Good Water Quality								
1	FB47	Waiohine River at Gorge	✓	✓	✓	✓	✓	✓
2	FB36	Ruamahanga River at Mt Bruce	✓	✓	✓	✓	✓	✓
3	FB51	Tauherenikau River at Websters	✓	✓	✓	✓	✓	✓
4	FB45	Waingawa River at South Road	✓	✓	✓	✓	✓	✓
5	FB37	Ruamahanga River at Double Bridges	✓	✓	✓	✓	✓	✓
6	FB50	Huangarua River at Ponatahi Bridge	✓	✓	✓	✓	✓	✓
Good Water Quality								
7	FB44	Waipoua River at Colombo Road Bridge	✓	✓	✓	✗	✓	✓
8	FB38	Ruamahanga River at Te Ore Ore	✓	✗	✓	✓	✓	✓
9	FB48	Waiohine River at Bicknells	✓	✓	✓	✓	✓	✗
Fair Water Quality								
10	FB39	Ruamahanga River at Gladstone Bridge	✓	✗	✓	✓	✓	✗
11	FB40	Ruamahanga River at Waihenga Bridge	✓	✗	✓	✓	✓	✗
12	FB42	Whangaehu River at Waihi	✓	✗	✓	✓	✓	✗
13	FB46	Taueru River at Gladstone	✓	✗	✗	✗	✓	✓
Poor Water Quality								
14	FB41	Kopuaranga Stream at Stewarts	✓	✗	✗	✗	✓	✗
15	FB43	Whangaehu River 250 u/s confl.	✓	✗	✗	✗	✓	✗
16	FB49	Mangatarere River at SH2	✓	✓	✗	✗	✗	✗

Table 8-3: Water Quality Index Ranking. Source (Milne & Perrie, 2006)

The WQI indicates the downstream trend in water quality deteroration in the Ruamahanga River. The site at Mt Bruce is ranked the cleanest, followed by the site at Double Bridges (both with very good water quality). The site at Te Ore Ore is ranked with good water quality, and the two sites at the lower end of the Rumahanga River both have fair water quality. Watts & Perrie (2007, p. 29), recalculated the WQI for the four sites on the Ruamahanga River with data from the period 2003-06. They found that the same downstream trend occurred in the water quality for the four sites. In this study, Pukio (the site closest to the sea) was ranked poor, failing to comply with four of the six water quality variables.

8.2.2.3. Biological Variables

Biological monitoring in the Ruamahanga Catchment is carried out annually during the summer-autumn period and incorporates assessments on both in stream periphyton[39] and macroinvertebrate[40] communities (Milne & Perrie, 2006).

For the period July 1997 to July 2003, the amount of periphyton cover was estimated by the percentage of visible mats and filaments contained within a 1 m^2 hoop. The Ministry for the Environment (2000), set a guideline of a maximum of 30 percent filamentous algae cover of a visible stream bed. Those sites in the Ruamahanga Catchment that often exceeded this guideline included the Kopuaranga Stream at Stewarts, the Taueru River at Gladstone, and the Huangarua River at Ponatahi Bridge. These three sites flow through pastoral land, and are subject to low baseflows. Flows in the Kopuaranga Stream and the Taueru River are also reduced by high water abstractions in the upper reaches (Milne & Perrie, 2006). The Waingawa River site at South Road, which drains a forested catchment, never exceeded the guideline. Periphyton growth can occasionally be a problem in the Ruamahanga River in times of low flow. One exceedance of periphyton growth was recorded at Pukio (the monitoring site closest to the ocean on the Ruamahanga River) in 2006 (Watts & Perrie, 2007).

Four macroinvertebrate indices were used in the Freshwater Monitoring Report including MCI[41], SQMCI[42], %EPT[43] (Taxa) and %EPT (animals). These indices were used to rank

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[39] Periphyton can be described "organisms that live attached to a river bed" (Basher, 2003, p. 53), they are made up of algae, diatoms, bacteria and fungi and play an integral role in the aquatic food chain.

[40] Macroinvertebrates are organisms that contain no backbone and can be viewed with the naked eye as they are larger than 250 microns in size. Insects, molluscs, crustaceans, and oligochaetes make up the four major groups of macroinvertebrates (Milne & Perrie, 2006).

[41] Macroinvertebrate Community Index

[42] Semi-Quantative Macroinvertebrate Community Index

[43] Ephemeroptera, Plecoptera and Trichoptera (EPT)

each monitoring site from 'poor' to 'very good'. The only monitoring site within the Ruamahanga Catchment that received a poor ranking was the Whangaehu River (250 metres upstream from confluence) where the percentage of EPT animals was found to be low. Both the MCI and SQMCI indices at this site received 'fair' status, as did the same indices at the Mangatarere River site at SH2. Ultimately the 'fair' and 'poor' grades received at these sites are attributable to the pastoral land that these tributaries drain, and also the Mangatarere River receives Carterton's treated sewage in the winter months. The Waiohine River, by contrast, drains mostly indigenous forest and thus obtained 'very good' rankings for all four indices. A full list of the biological results can be obtained from Milne & Perrie (2006) on pages 42 and 44.

8.2.2.4. Limitations of monitoring program

Water quality variables such as temperature, DO and pH are measured only monthly. Such monitoring allows for inter-site comparison but does not allow for trends that occur diurnally for example. All three of these variables change considerably throughout the day, and can have "a significant impact on stream life" (Warr, 2002, p. 16). Installation of continuous monitoring stations at the sites would enable a more detailed understanding of trends that occur on time frames shorter than one month.

In addition, variables that are expressed as concentrations need to be monitored in relation to flow. Unfortunately in the Ruamahanga Catchment, only two flow monitoring sites coincide with water quality monitoring sites. These sites are at the Ruamahanga River at Gladstone and the Waiohine River at Gorge. In cases where flow data is not monitored, flow data from recorder sites near the water quality monitoring site can be used to adjust the data for flow (Warr, 2002). Another unfortunate reality is that four of the flow monitoring sites in the Ruamahanga Catchment are used for high flows and flood warning only; therefore data gathered from these sites cannot be used for day to day flow analysis. As stated by Warr (2002, p. 20), "it is important that water quality data be accompanied by accurate flow data in order to determine catchment loadings and flow variation effects".

The use of MCI is also not without limitations. The index assumes that the types of taxa present in freshwater are constant and that the absence of any one group of taxa is the result of degradation in the waterway. This is a fundamental flaw in this type of analysis and less generalised techniques should be adopted. An example that is used internationally utilizes predictive models to first establish which taxa should be present before inferring that they are not there because of pollution (M Joy, personal communication, April 30, 2007).

8.2.2.5. Conclusion

Surface water quality monitoring undertaken by GWRC found that the eastern tributaries are of lesser quality than the western and central tributaries, frequently breaching the GV for several physico-chemical and biological water quality variables. The WQI undertaken by GWRC ranked the Waiohine River at Gorge (a western tributary) as the cleanest river in the catchment, while two of the poorest three rivers were eastern tributaries. The lowest ranked river, with the most degraded water quality was the central Mangatarere River, which drains predominantly pastoral land, and is influenced by associated land use practices. Limitations with the data included lack of concentrations that were related to flow; inability to analyse trends occurring on time frames less than one month; and MCI generalisation problems.

8.2.3. Surface Water Quality Analysis

In this section, concentrations and loadings of DRP and various forms of nitrogen have been examined to determine how concentrations/loadings vary in each of the nutrients along the Ruamahanga River. *E.Coli* concentrations were also determined. *E.Coli* contamination occurs in localised areas; therefore this analysis should enable the designation of contaminated 'hot spots' in the area.

8.2.3.1. Methodology

Monthly monitored data for DRP, NO_3-N, TN, NH_4-N and *E.Coli* was obtained from GWRC for 20 monitoring sites in the Ruamahanga Catchment for the period September 2003 through to December 2006. This period was divided into three equal years, spreading from September to August in each case. Concentrations for the nutrients were given in (g/m^3) while *E.coli* was measured in colony forming units (cfu) in 100 mL of sample. Concentrations that were given as 'less than (<)' numbers, were replaced with halved concentrations, for example <0.005 became 0.0025. The median *E.Coli* concentration at each site was found in addition, the *E.Coli* readings were compared against the drinking water and recreational water thresholds (1 colony forming unit/100 mL and 550 colony forming units/100 mL respectively). The average concentration for DRP, NO_3-N, TN, NH_4-N was found for each year at each site, and nutrient loads were then calculated.

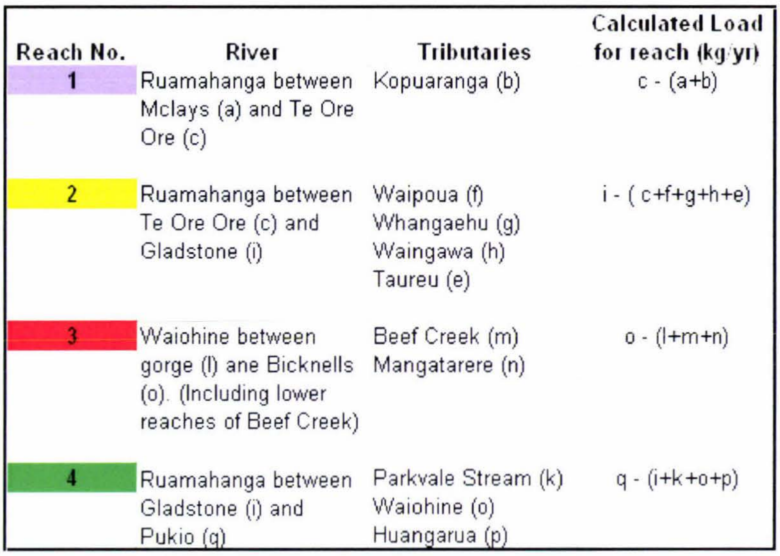
As noted in Section 8.2.2.4, concentration measurements could not easily be associated with water flow and thus limits the use of flow for nutrient loading calculations. Therefore in this study, nutrient loadings were calculated by multiplying the average concentrations of the nutrients for 2003-06 by the accumulated runoff, which was previously obtained from the REC data in Chapter 7 of this report (Eqn. 7.6). The possible limitations and errors associated with this approach to calculating flows were discussed in detail in Chapter 7.

$$\text{Nutrient Load (g/year)} = \text{Ave. Nutrient Concentration (g/m}^3\text{)} * \text{Accum. Runoff (m}^3\text{)} \tag{Eqn. 8.1}$$

This nutrient load could then further be divided by the area in hectares to give loss per hectare which gives a more comparable value.

$$\text{Nutrient Loss (g/ha)} = \text{Nutrient Load (g/year)} * 10000/\text{Area (m}^2\text{)} \tag{Eqn. 8.2}$$

By calculating the difference in load between various points on the Ruamahanga River (or other streams) the loss per hectare of the land area between sampling points can be calculated. Table 8-4 outlines these calculations and Figure 8-2 provides the schematic framework. Reaches that have significantly large nutrient loads, may indicate the presence of a point source discharge.



Reach No.	River	Tributaries	Calculated Load for reach (kg/yr)
1	Ruamahanga between Mclays (a) and Te Ore Ore (c)	Kopuaranga (b)	c - (a+b)
2	Ruamahanga between Te Ore Ore (c) and Gladstone (i)	Waipoua (f) Whangaehu (g) Waingawa (h) Taureu (e)	i - (c+f+g+h+e)
3	Waiohine between gorge (l) ane Bicknells (o). (Including lower reaches of Beef Creek)	Beef Creek (m) Mangatarere (n)	o - (l+m+n)
4	Ruamahanga between Gladstone (i) and Pukio (q)	Parkvale Stream (k) Waiohine (o) Huangarua (p)	q - (i+k+o+p)

Table 8-4: Estimates of nutrient loads originating from reaches in rivers between monitoring sites, after taking account of contributions from monitored tributaries. Numbers identifying reaches are as displayed in Figure 8-2.

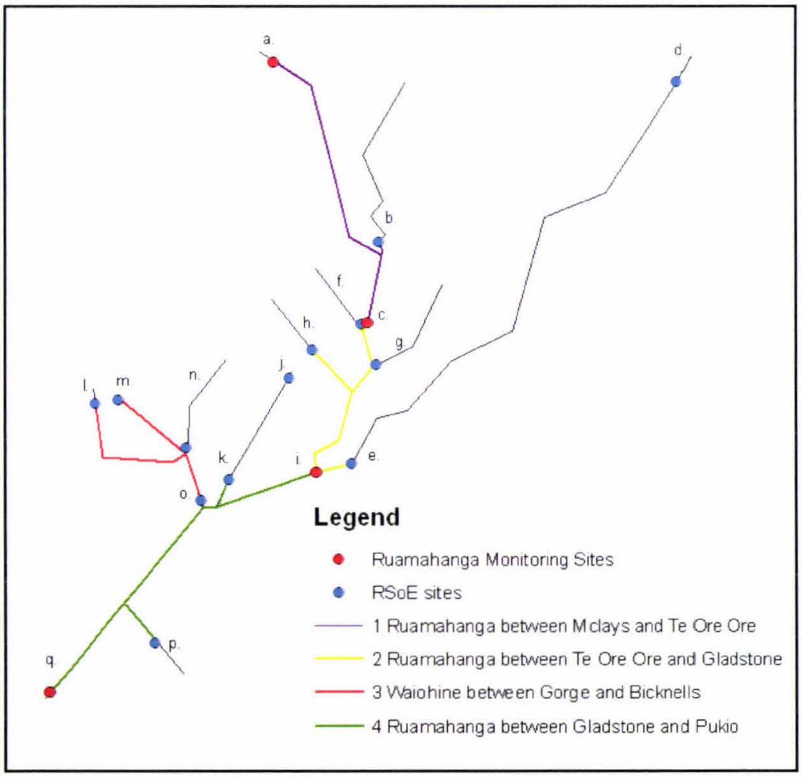


Figure 8-2: Schematic diagram of the river system in the Ruamahanga Catchment, displaying the location of the RSoE sites and colour coding the incremental areas which generate nutrient load.

8.2.3.2. Results and Discussion

The average concentrations of *E.Coli* and the average concentrations, loads and losses per hectare of DRP, NO_3-N, TN, NH_4-N from 2003-2006 are shown in Appendix 9 and 10. Appendix 11 provides the estimate of nutrient loadings calculations.

E.Coli

The three maps shown in Figure 8-3 through to Figure 8-5 provide a visual representation of the *E.Coli* hotspots occurring within the Ruamahanga Catchment, depending on certain criteria: median *E.Coli* counts (Map A), percentage of *E.Coli* readings larger that 1 cfu/100 mL (Map B) and percentage of *E.Coli* readings larger that 550 cfu/100 mL (Map C).

The guideline level at which water is considered unsuitable for bathing is 550 *E. coli* cfu/100 mL (Scarsbrook & McBride, 2004), while the Maximum Allowable Value (MAV) of *E.Coli* for drinking water standards is less than 1 cfu/100 mL (New Zealand Ministry of Health, 2005). The data for these maps is provided in Appendix 12.

The Parkvale Stream at Weir, ranks poorly on all criteria, most of the sites consistently exceed 1 cfu/100 mL, and thus breach the drinking water standard (Map b), and the Whangaehu River near its confluence with the Ruamahanga River, Parkvale Stream at Weir and the Kopuaranga Stream at Stewarts often exceeded the MAV for bathing water and thus can be designated as *E.Coli* hotspots. All of these waterways drain land that is predominantly pastoral, and likely to be subject to non point pollution such as animal waste. Presence of *E.Coli* in a waterway is a "definite indication of recent faecal contamination" (Ministry for the Environment, n.d, para 3.), sourced from either human or animal waste. *E.Coli* is not directly threatening to human health, but it can indicate the presence of harmful, disease causing micro-organisms (Ministry for the Environment, n.d).

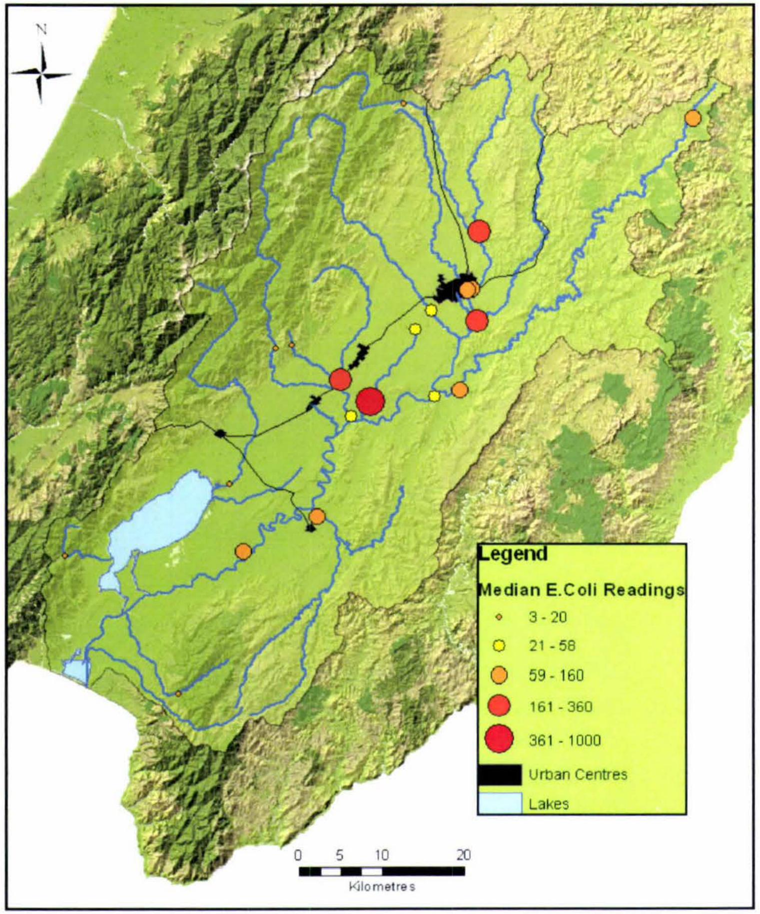


Figure 8-3: ***E.Coli*** **Hotspots - Median** ***E.Coli***

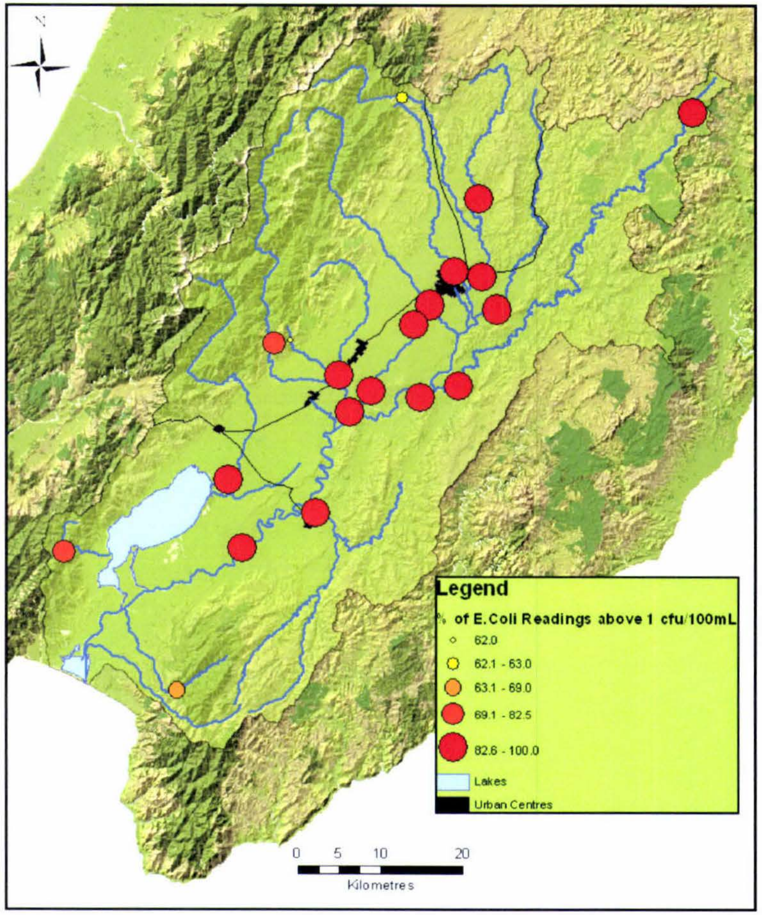


Figure 8-4: ***E.Coli*** **Hotspots - % of** ***E.Coli*** **readings above 1cfu/100 mL (Drinking Water MAV)**

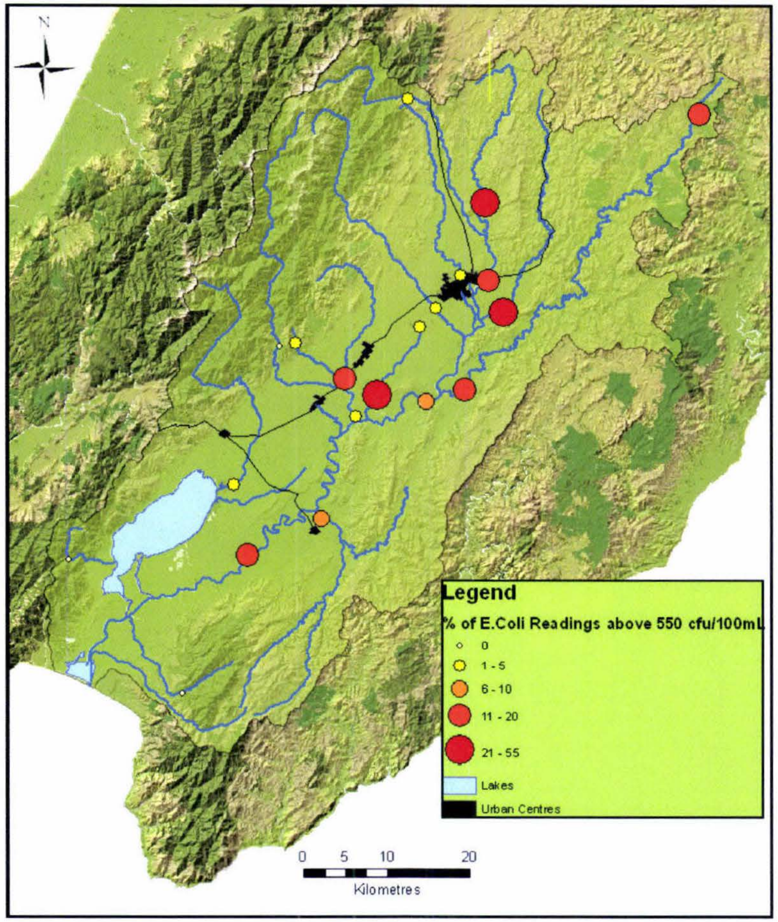


Figure 8-5: *E.Coli* Hotspots - % of *E.Coli* readings above 550cfu/100 mL (Bathing Water)

Nutrients

The data in Table 8-5 identify the sites with the highest average concentrations of DRP, TN, NO_3-N and NH_4-N. The Whangaehu River, the Mangatarere River and the Parkvale Stream at Weir had consistently higher levels of the selected nutrients than the other tributaries, although the Parkvale Stream at Lowes Reserve had the highest concentration of NO_3-N. This site is located in the central valley surrounded by pastoral land uses.

Site	Average DRP g/m^3	Average TN g/m^3	Average NO_3-N g/m^3	Average NH_4-N g/m^3
Whangaehu River	**0.0386**	**2.2076**	**1.7166**	**0.0256**
Mangatarere River @ SH2	**0.0848**	**1.7731**	**1.4599**	**0.0741**
Parkvale Stream @ Weir	**0.0488**	**2.9624**	**2.3399**	**0.0458**
Parkvale Stream @ Lowes	0.0192	**5.0655**	**4.5600**	0.0189
Waipoua River	0.0102	**1.4538**	**1.3130**	0.0149
Ruamahanaga River @ Gladstone	0.0250	0.7929	0.5629	**0.0261**
Taueru River @ Gladstone	0.0181	1.1962	0.6619	**0.0294**
Kopuaranga Stream	0.0217	**1.2692**	0.9540	0.0183

Table 8-5: Concentrations of nutrients at selected sites. Values in red indicate sites with high nutrient concentrations, and the underlined value indicates sites with the highest nutrient concentration. (GWRC, 2007)

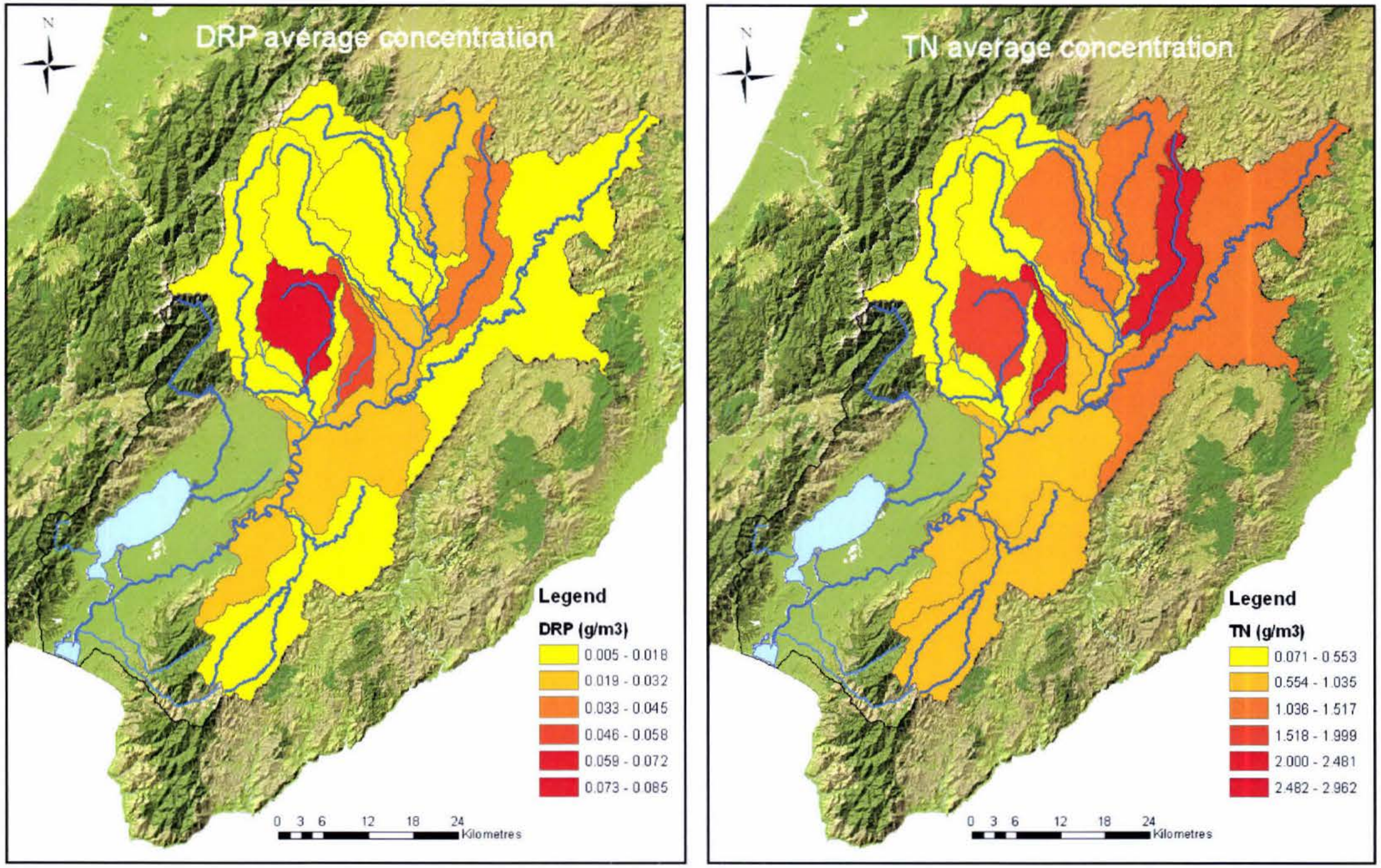


Figure 8-6: Average Concentrations of a) DRP and b) TN for 2003-06

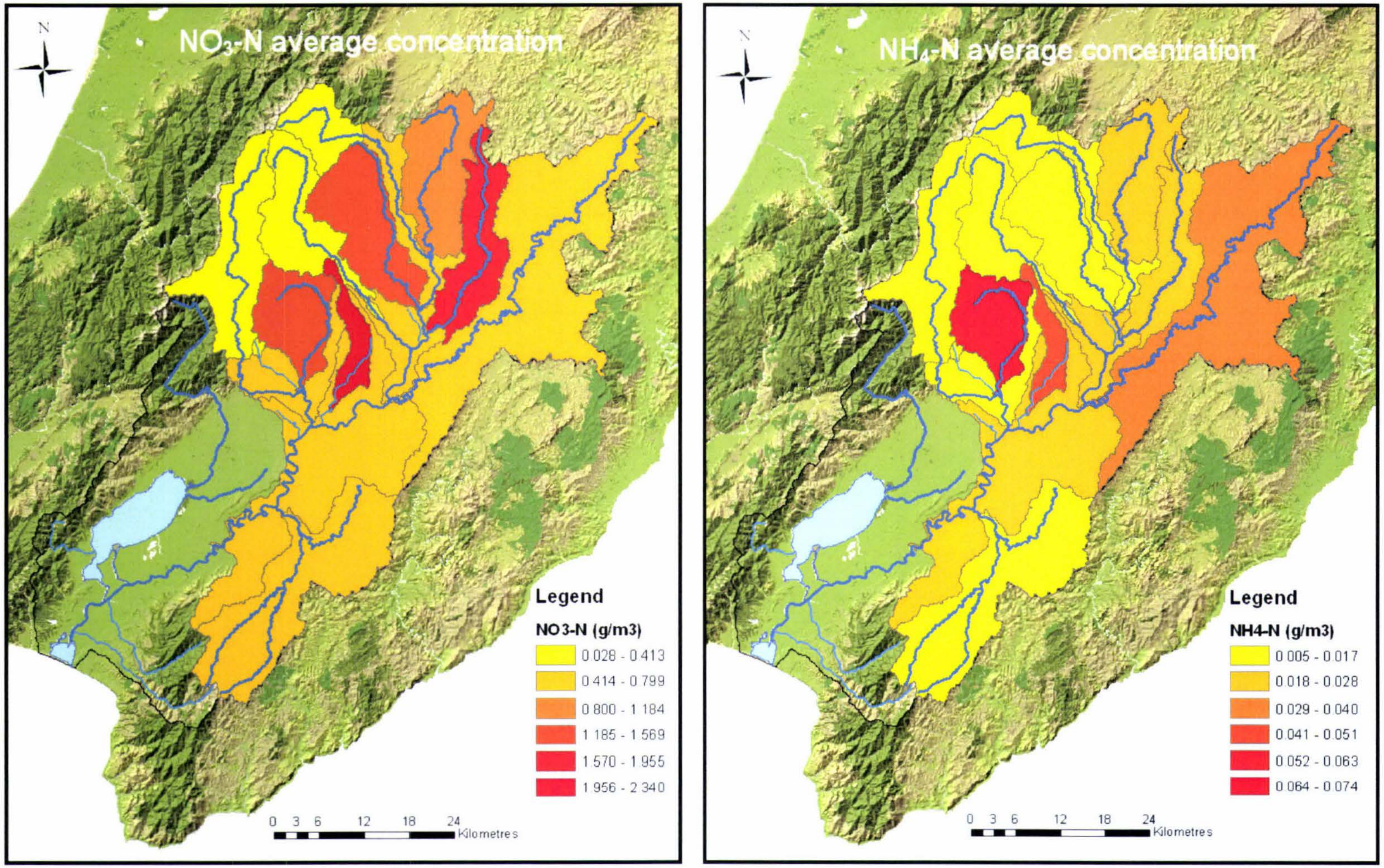


Figure 8-7: Average Concentrations of a) NO_3-N and b) NH_4-N for 2003-06

The maps shown in Figure 8-6 and Figure 8-7 provide a visual representation of the average concentrations of DRP, TN, NO_3-N and NH_4-N in the various catchments, measured at GWRC monitoring sites. The catchments shown in darker shades of red are those that feature the highest concentrations of the nutrients and coincide with the concentration values in bold in Table 8-5.

The catchment maps shown in Figure 8-8 provide the incremental DRP loads, and DRP loss per hectare for the contributing catchments. The darker red represents catchments that are contributing the most DRP (per catchment and per hectare), while the yellow represents the least contribution.

The catchments contributing the most DRP to the lower Ruamahanga River are the Mangatarere Catchment with 12,016 kg DRP per year, and the Ruamahanga River reach between Te Ore Ore and Gladstone with 13,838 kg DRP per year. The highest DRP loss per hectare also comes from these two catchments. However, the Waiohine at Gorge Catchment (considered to be the most pristine sub catchment in the region[44]) and the Ruamahanga River reach between McLays and Te Ore Ore also feature relatively high DRP losses per hectare, with values of 0.224 kg/ha and 0.332 kg/ha respectively.

The maps in Figure 8-9 provide incremental NO_3-N loads and NO_3-N loss per hectare for the contributing catchments. The Waipoua River, Mangatarere River and Taueru River catchments contribute the majority of the NO_3-N into the Ruamahanga River system. On a per hectare basis, the Waiohine River reach between Gorge and Bicknells, Mangatarere River Catchment, Parkvale Stream Catchment and Waipoua River Catchment have the highest losses per area. The change in the Taueru Catchment between the two maps is of note; once its large catchment area has been accounted for in Figure 8-9b the loss per hectare of NO_3-N is relatively minimal.

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[44] See Section 8.2.2.2 (WQI) for further discussion on this point.

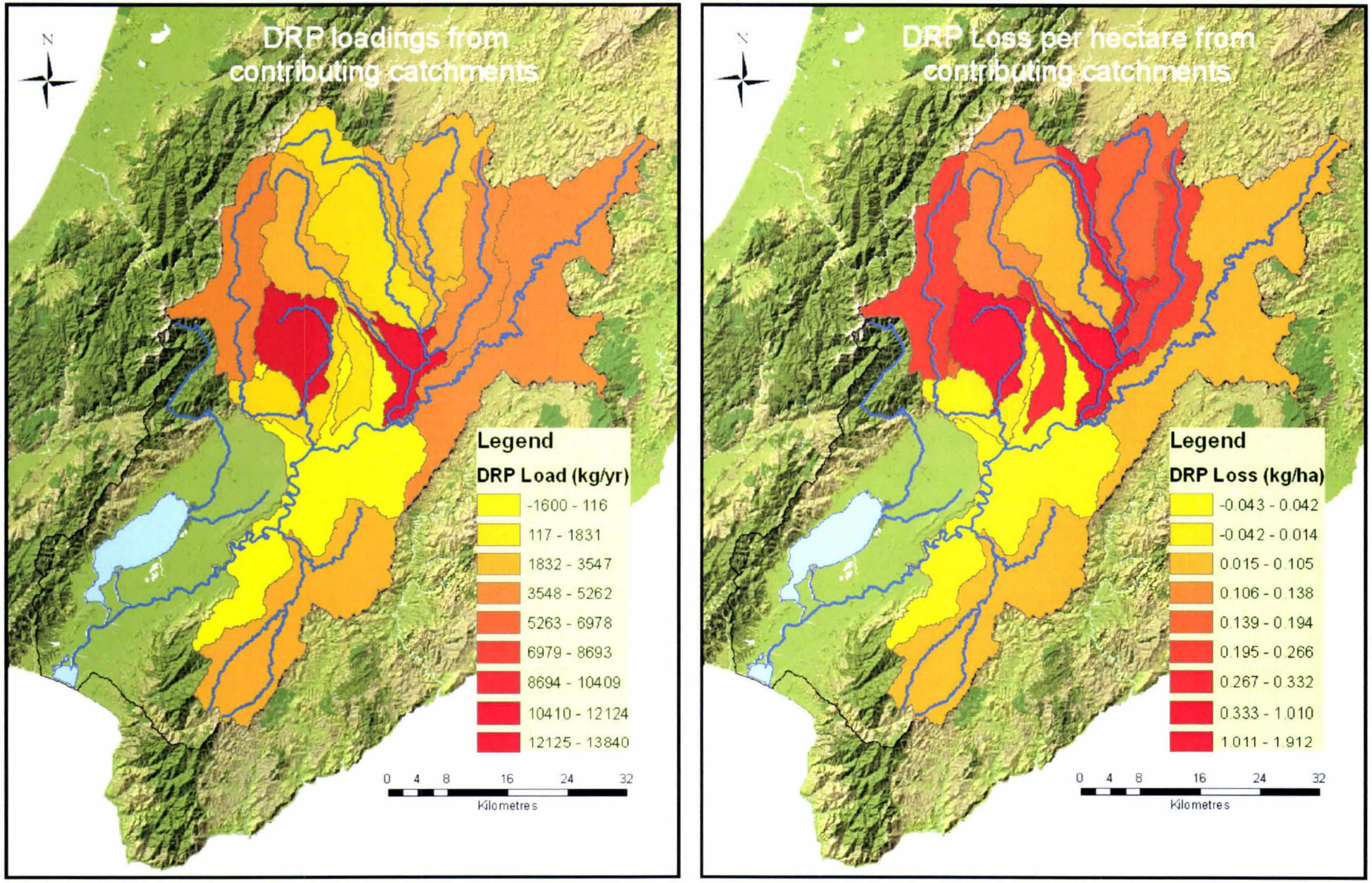

Figure 8-8: a) DRP loadings from contributing catchments and b) DRP loss per hectare from contributing catchments

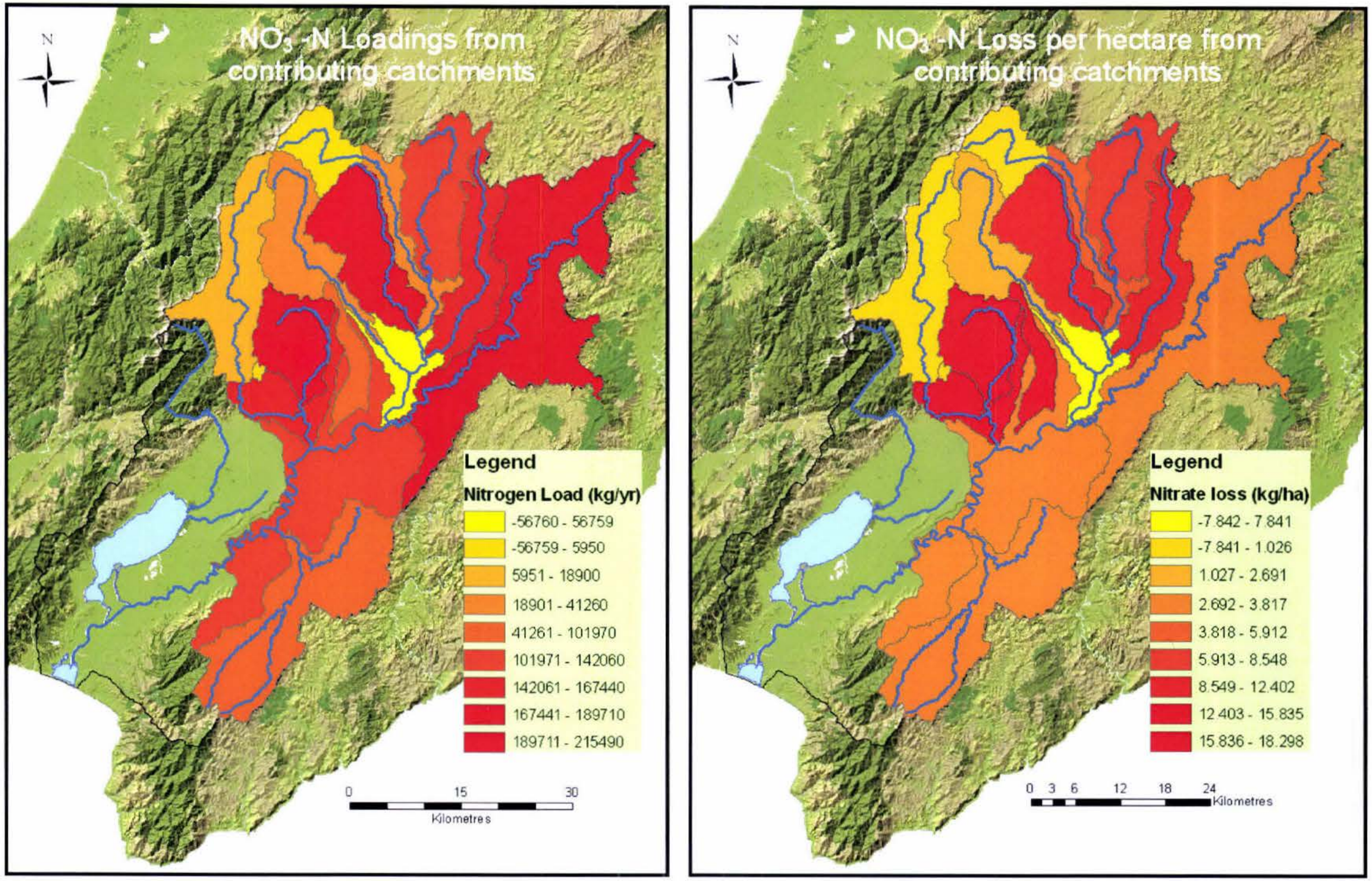

Figure 8-9: a) NO_3-N loadings from contributing catchments and b) NO_3-N loss per hectare from contributing catchments contributing

Concentrations of Nutrients versus Loadings

In calculating nutrient loads, the annual concentration of a nutrient is multiplied by the accumulated runoff (Eqn. 8.1). Therefore catchments with high runoff rates, but low overall concentrations, can give a nutrient load value that is larger than would otherwise be expected. The Waiohine at Gorge Catchment is a good example of where this has occurred. The maps provided in Figure 8-8 show that the Waiohine Catchment at Gorge produces a considerable weight of DRP when compared to other catchments. However the annual DRP concentration map (Figure 8-6a) indicates that the concentration of DRP within the Waiohine Gorge Catchment is very low (0.0062 g/m^3) and the Water Quality Index (Section 8.2.2.2) also demonstrates this, ranking this site the cleanest of all sites in the Ruamahanga Catchment. Although the Waiohine River at Gorge contributes a significant amount of DRP to the overall catchment, the volume of water also coming from this catchment acts to dilute the DRP in the Ruamahanga River downstream of the confluence with the Waiohine River. Therefore the difference between concentrations and loadings must be considered when making any conclusions about the state of each individual catchment.

Significant differences in loadings from Estimates of Nutrient Loads

As already outlined in this section, nutrient loadings should increase in a downstream direction, as the nutrients from different tributaries combine to give an overall larger nutrient load.

Comparing DRP loads along the Ruamahanga River at the four monitoring sites shows that with distance down catchment (toward Pukio), DRP loadings increase between each incremental point (pink line on Figure 8-10). The blue line representing the DRP loads being added to the Ruamahanga River from the side tributaries also increases with distance down catchment. A noticeable difference between the two lines is the large variation at the monitoring site in the Ruamahanga River at Gladstone. At this point the DRP load contributed by the side (upstream) tributaries is equal to 19,158 kg/year, and the DRP load calculated at the point on the river at Gladstone is 32,996 kg/year, this leaves a difference of nearly 14,000 kg of DRP that is not accounted for.

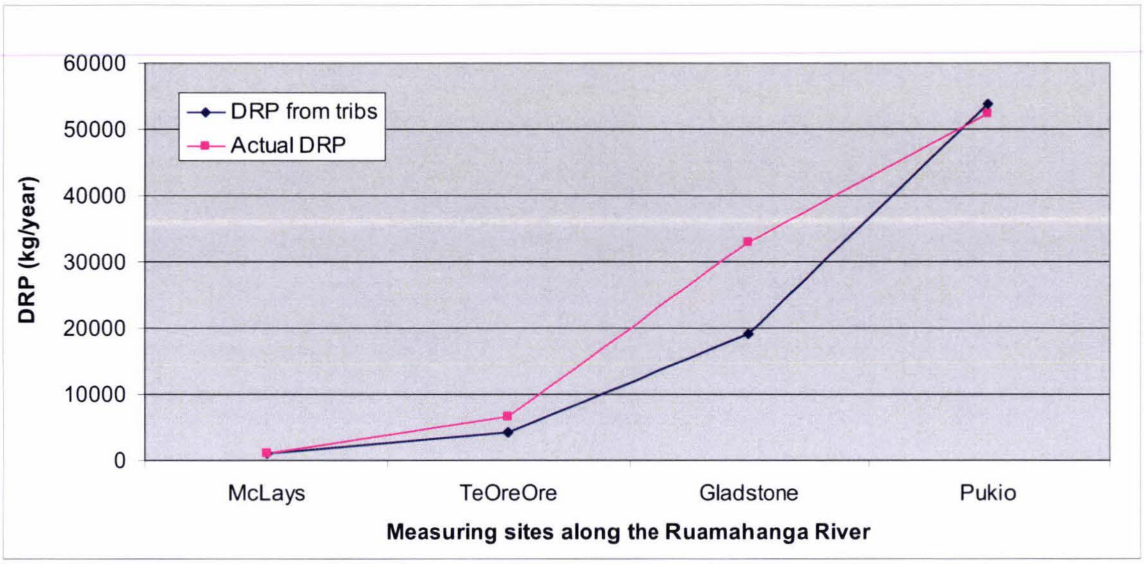

Figure 8-10: DRP load accruing from tributaries and actual DRP load measured at points down the Ruamahanga River

Interestingly, between the confluence of the upstream tributaries with the Ruamahanga River and the monitoring site at Gladstone, is the Masterton Municipal Sewage works where according to the 'Wairarapa Municipal Oxidation Ponds Water Quality Monitoring Report, July 1999- June 2001' (Watts, 2001), 12,500 kg/year of total particulate phosphorus (TP) is discharged into the Makoura Stream, which then discharges into the Ruamahanga River. Hence it is likely that the additional DRP load observed in the Ruamahanga River at Gladstone can be attributed to the effluent discharge from the oxidation ponds. Data from GWRC reveal that the median TP concentration in the sewage effluent since 2003 was 2.72 g/m^3 which equates to 13,204 kg/year (assuming the effluent volume is 13,300 m^3/day[45]). This is slightly more than the amount reported in 2001. The post-2003 median DRP concentration is 2.26 g/m^3, equating to 10,971 kg/year. This value is lower than the difference of 14,000 kg of DRP at Gladstone. The difference in values may be due to agricultural runoff generated from the land area in this segment, and averaging inaccuracies involved in obtaining the nutrient loads.

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[45] Figure derived by the Masterton District Council for 2005, cited in Forsyth (2005).

A similar comparison was undertaken with NO_3-N and NH_4-N loads. Unlike DRP, the concentration of N species in waterways can alter by biotic processes including mineralization and nitrification. These processes are driven by factors in the surrounding environment. During mineralization[46], organic N is converted to NH_3 (ammonia) and NH_4-N (ammonium), while during nitrification NH_4-N is converted to NO_3-N in the presence of oxygen.

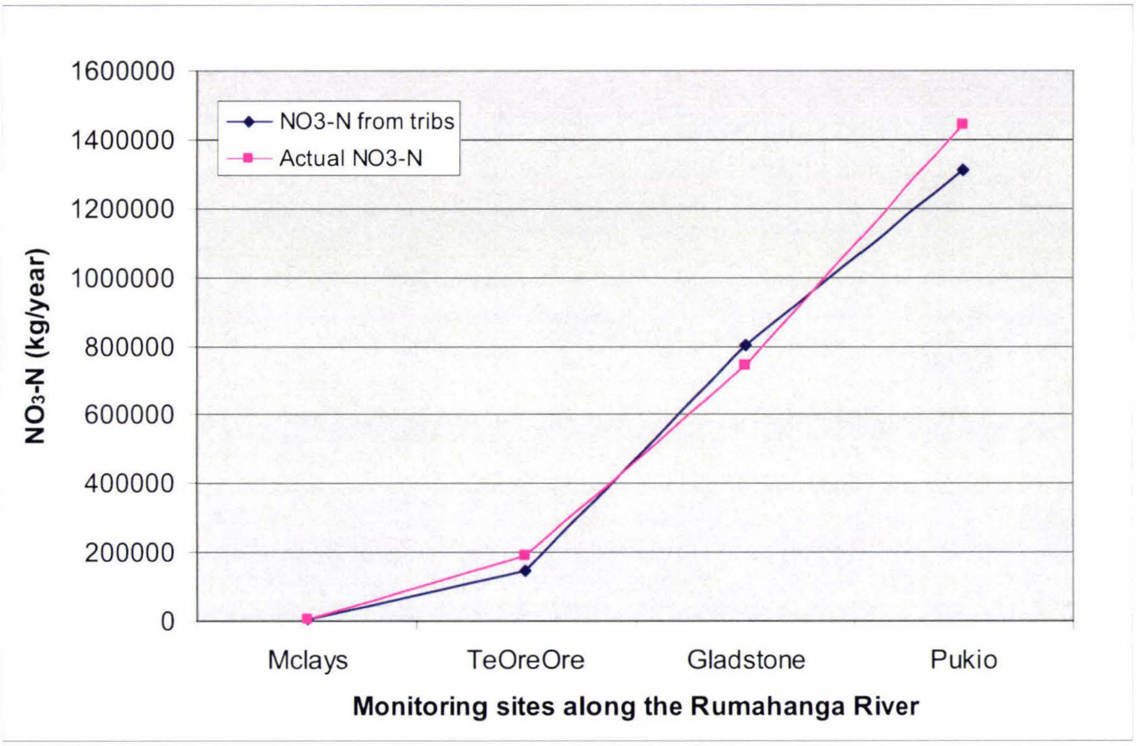

Figure 8-11: NO_3-N accruing from tributaries and actual NO_3-N measured at points down the Ruamahanga River

The graph in Figure 8-11 shows that the actual NO_3-N loadings (pink), measured at the points along the Ruamahanga River are only slightly higher than the accumulated NO_3-N loadings coming from the side/upstream tributaries (blue), except for the Ruamahanga River at Gladstone, where the actual loading is less. An analysis of the concentration of the components in the Masterton effluent (courtesy of GWRC) shows that around 4,000

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[46] Also called ammonification.

kg/yr[47] of NO_3-N is discharged from the treatment plant. Relative to the NO_3-N concentration already in the Ruamahanga River, this point source loading of NO_3-N is relatively insignificant, which explains why there is no noticeable increase in NO_3-N downstream of the sewage outfall (Figure 8-11).

The deviation between the actual NO_3-N load (pink) and the accumulated load from the tributaries (blue) at Pukio in Figure 8-11 indicates that there is a build up of NO_3-N in this part of river due to mineralization and subsequent nitrification.

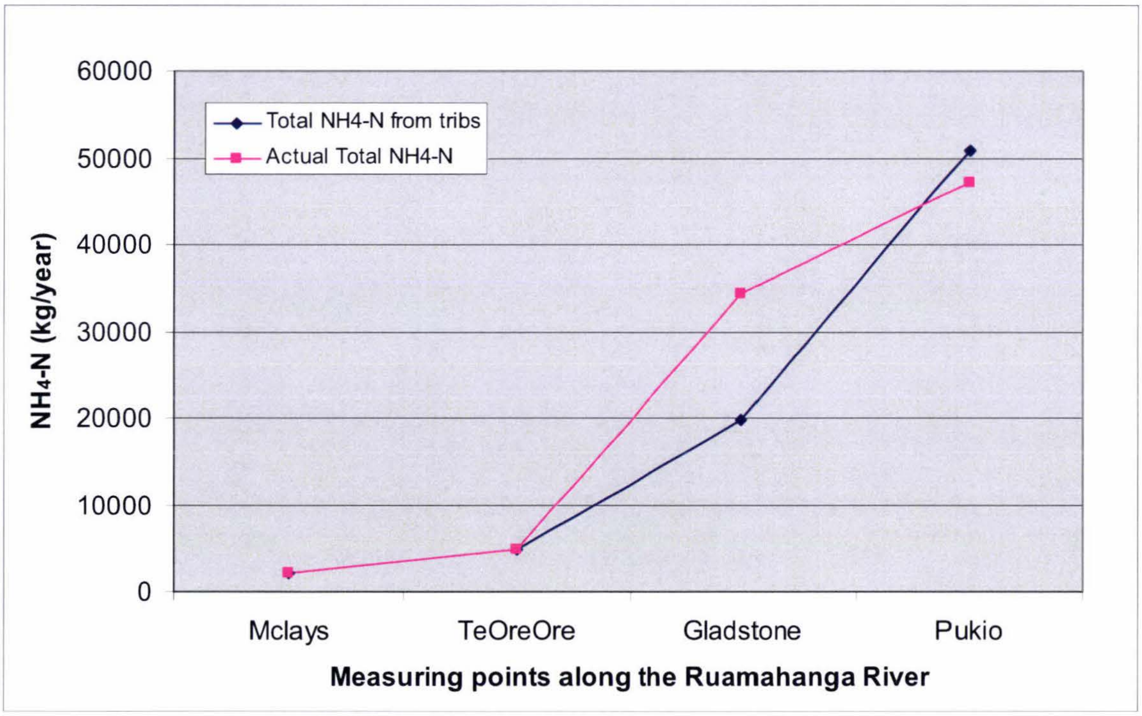

Figure 8-12: NH_4-N accruing from tributaries and actual NH_4-N measured at points down the Ruamahanga River

NH_4-N loadings (Figure 8-12) increase incrementally with distance downstream; however there is a large variation between the accrued NH_4-N loadings (blue line) and the actual NH_4-N loadings (pink line) at Gladstone. This difference indicates that in the vicinity of

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[47] The concentration of NO_3-N in the effluent is 0.80 g/m^3, assuming an effluent volume of 13,300 m^3/day

Gladstone there is a 14,651 kg/year increase in NH_4-N that cannot be attributed to sub catchment contribution, and therefore must come from elsewhere.

The actual concentration of NH_4-N in the Masterton sewage effluent is 6.94 g/m^3, which equates 33,690 kg/year[48]. Unlike the loading of NO_3-N from the treatment plant, the loading of NH_4-N into the river is significant when compared with the background levels of NH_4-N already present, and could be the cause of this large deviation between the accrued and actual loadings at Gladstone.

NH_4-N loadings at Pukio are the reverse to what was found for NO_3-N. At Pukio, the actual NH_4-N loadings in the river are less than the accrued NH_4-N loadings from the tributaries. This is evidence of the biotic processes occurring at this point. As previously mentioned, NO_3-N has built up due to mineralization and subsequent nitrification, and as a consequence of this latter process nearing completion, a decrease in NH_4-N is noticed.

The graph in Figure 8-13 shows the same comparison for TN loadings. Since TN by definition is the "sum of the organic and inorganic fractions of nitrogen" (Watts, 2001, p. 62), one may expect there to be a spike in TN after the sewage outfall, as was seen for NH_4-N, however this is not the case. The volume of TN generated from the Masterton Sewage works is around 50,000 kg/yr[49]. When compared to the total loading of TN already present in the Ruamahanga River (totalling almost 1,050,000 kg/year at Gladstone), this volume is insignificant and makes only a small (if any) impact on the quality of the river.

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[48] Assuming an effluent discharge volume of 13,300 m^3/day

[49] The concentration of TN in the effluent is 10.35 g/m^3, assuming an effluent discharge volume of 13,300 m^3/day.

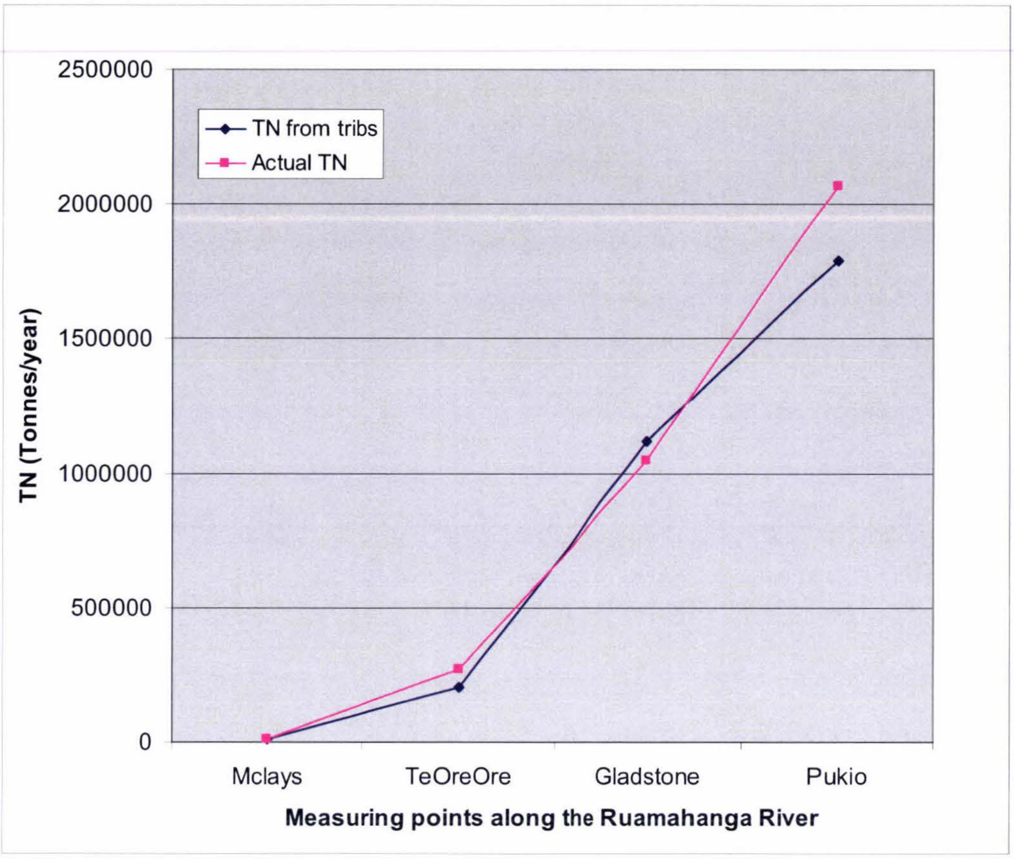

Figure 8-13: TN load accruing from tributaries and actual TN load measured at points down the Ruamahanga River

8.2.3.3. Conclusion

E.Coli hotspots were observed in the Whangaehu River, Parkvale Stream and lower reaches of the Kopuaranga Stream. At these points median *E.Coli* counts were high, and readings often breached the bathing water quality GV. The Whangaehu River, Parkvale Stream at Weir and Mangatarere River consistently had high average concentrations of all of the nutrients examined. The upstream Parkvale site at Lowes had the highest average concentration of NH_4-N over the period 2003-06. The WQI introduced in Section 8.2.2.2, did not include the Parkvale sites, however both the Whangaehu River and the Mangatarere River were ranked in the WQI as having the most degraded water quality.

In assessing the nutrient loads on a per catchment basis, it was critical to realise that no one measurement (e.g. concentration, load or loss per hectare), can adequately describe the impact of nutrients from a land area on downstream water quality. Loss per hectare for example can be misleading, as it can depend on the volume of rainfall. At very high rainfalls nutrient loss per hectare may be high but the actual concentration in the runoff water may be low and not of environmental concern. To accurately assess the contribution of nutrients from an area of land requires knowledge of both the volume of water and the concentration.

All nutrients were found to increase in the Ruamahanga River in a downstream direction. This was consistent with the findings in Watts and Perrie (2007). The majority of DRP found in the lower portion of the Ruamahanga Catchment was contributed by the Mangatarere Catchment and the Ruamahanga River reach between Te Ore Ore and Gladstone. The source of the DRP in this latter catchment was possibly effluent from the Masterton oxidation ponds.

The actual NH_4-N measured in the Ruamahanga River at Gladstone was significantly larger that the estimated NH_4-N from the tributaries at the same point. It is possible that this difference could be attributed also to the Masterton effluent discharge which occurs upstream of Gladstone. There were no other significant differences between actual and estimated nutrient loads at the four monitoring points studied in the nutrient load calculation exercise.

8.2.4. Turbidity and Suspended Sediment

The presence of sediment in rivers and streams can cause concern for two separate reasons: a) it can cause the waterway to appear dirty and b) it can cause sediment build up in the stream or river channel. Turbidity[50] is the parameter used to measure the former impact; while suspended sediment loads[51] measures the volume of sediment carried in suspension by the waterway and therefore is used to assess sediment build-up.

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[50] The definition of turbidity is "an optical property defined as the measurement of light scattered at 90 degrees to the incident light by suspended particles in an aqueous medium, typically expressed in nephelometric turbidity units (NTU)" (Uhrich & Bragg, 2003. p.11).

[51] Also termed suspended sediment concentration, and is measured in weight per volume.

Within the Ruamahanga Catchment, sediment build-up along the edges of the Ruamahanga River on the berms is an issue that is currently causing GWRC some concern. This build up is "pronounced in areas where there is long grass and scrub and between the stopbanks in the lower reaches below Martinborough" (D Peterson, personal communication, April 20, 2007).

Bench marker posts were erected in 1993 along the Ruamahanga River to mark survey lines to complete river cross section surveys. Many are now buried (Figure 8-14). According to Des Peterson (personal communication, April 20, 2007), silt and sand has built up on average about 600 mm over the past 14 years.

In order to ascertain which sub catchments and tributaries are contributing most of the sediment creating this build up, information on suspended sediment loads would be required. Unfortunately, as seen previously in Section 8.2.2.2 suspended sediment is not included in the suite of variables measured by GWRC at this time, only clarity and turbidity are currently measured. Therefore, in this section, GWRC turbidity data will be examined to see whether it could provide information on suspended sediment loads.

Figure 8-14: Bench marker posts over a 14 year time period. Courtesy of Des Peterson (GWRC)

8.2.4.1. Methodology

A literature review was undertaken to establish whether turbidity had previously been used as a surrogate for suspended sediment elsewhere. Various publications were researched, these included 'Suspended Sediment Load Determination' (Truhlar, 1978), 'Monitoring In-stream Turbidity to Estimate Continuous Suspended-Sediment Loads and Yields and Clay-Water Volumes in the Upper North Santiam River Basin, Oregon, 1998–2000' (Uhrich & Bragg, 2003), 'Suspended sediment monitoring in the Motueka catchment: data report to 1 May 2006' (Wild, Hicks, & Merrilees, 2006), 'Using turbidity to determine total suspended solids in urbanizing streams in the Puget Lowlands' (Packman, Comings, & Booth, 1999) and 'Clarifying Turbidity — The Potential and Limitations of Turbidity as a Surrogate for Water - Quality Monitoring' (Ankcorn, 2003).

Overall, the general consensus was that turbidity and sediment loadings can be correlated but the relationship is site specific as it is dependent on the characteristics of the catchment, for example, sediment types, erosion and flow rates. Truhlar (1978, p. 417) wrote that "there is no universal relationship between turbidity and suspended sediment concentration, but there is often a good correlation for individual streams, probably because the material in suspension in a stream is characteristic of the basin".

Ankcorn (2003, p.1) commented that "the physical properties such as size, shape, and colour of the suspended solids may bias the turbidity reading" as will the differing measuring techniques employed to measure turbidity, and Packman et al. (1999) agreed suggesting that the relationship between turbidity and suspended sediment must be established on a site by site basis as turbidity readings between streams vary due to water colour and suspended particle size and composition.

Although there was no universal relationship discovered, the turbidity measurements that were measured by GWRC, on a monthly basis from September 2003 to February 2007, were still analysed to see whether there was any noticeable differences in turbidity readings between the eastern and western tributaries of the Ruamahanga Catchment.

The analysis involved classifying the turbidity readings for each site into groups above and below 5.6 NTU which is the guideline stipulated in the ANZECC & ARMCANZ[52] freshwater quality guidelines for low land rivers (ANZECC, 2000, p. 3.3-18). The frequency of readings in each group were calculated as a percentage of the total number of readings for each site and then both groups (above and below 5.6 NTU) for all of the sites were plotted on the same axes for comparative purposes.

Sites with a higher percentage of readings above 5.6 NTU were the sites that could be classified as being dirtier, and their catchments more susceptible to erosion. Contrastingly, those sites with a higher percentage of readings below 5.6 NTU are generally cleaner, perhaps draining catchments dominated by indigenous forests. For visual representation purposes, small discs, showing the percentage of turbidity readings below 5.6 NTU were plotted on a map of the catchment (Figure 8-17).

8.2.4.2. Results

Most sites in the catchment have a higher percentage of turbidity readings below the threshold than above, in other words, for most of the time they were reasonably clear. The western tributaries including the Ruamahanga River at McLays, the Waipoua River, the Waingawa River, Beef Creek at Headwaters, the Mangatarere River at SH2, the Waiohine River at Gorge, the Tauherenikau River and the Wairongomai Stream were mostly clear during the monitoring period (Figure 8-15).

The tributaries with more than one monitoring site showed trends of increasing turbidity downstream. This held true for the Ruamahanga River, Taueru River, Parkvale Stream and Waiohine River. Only two sites had turbidity readings above 5.6 NTU on more than half of the sampling locations. Both sites were located on eastern tributaries, on the Taueru River at Gladstone and the Whangaehu River (Figure 8-17 and Figure 8-18).

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[52] Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand

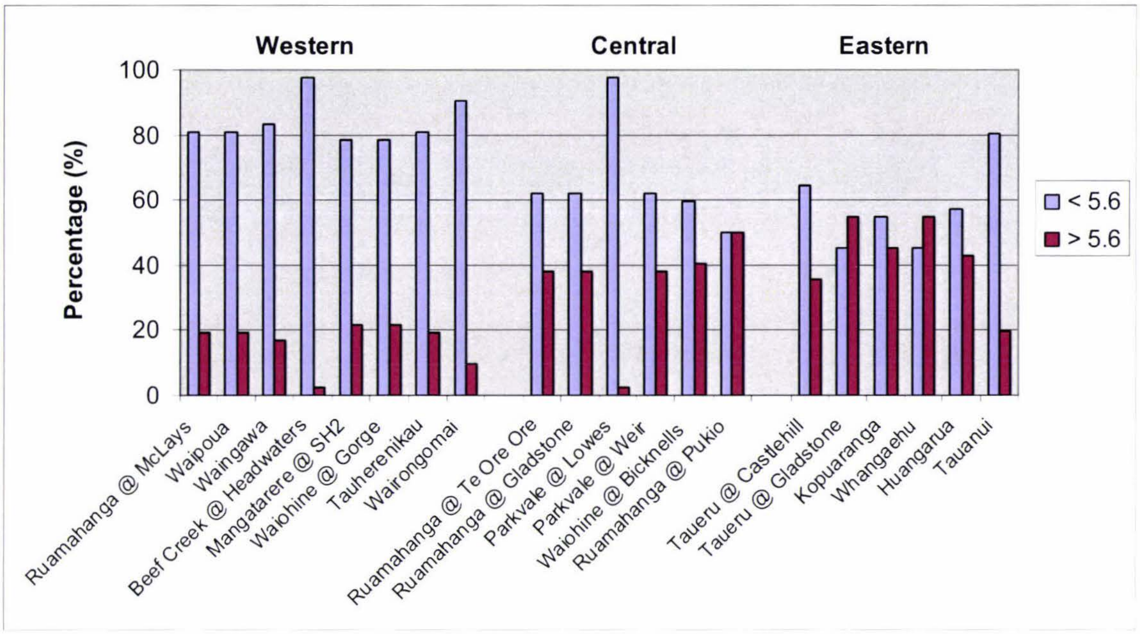

Figure 8-15: Percentage of Turbidity Readings above and below 5.6 NTU at selected sites in western, central and eastern tributaries

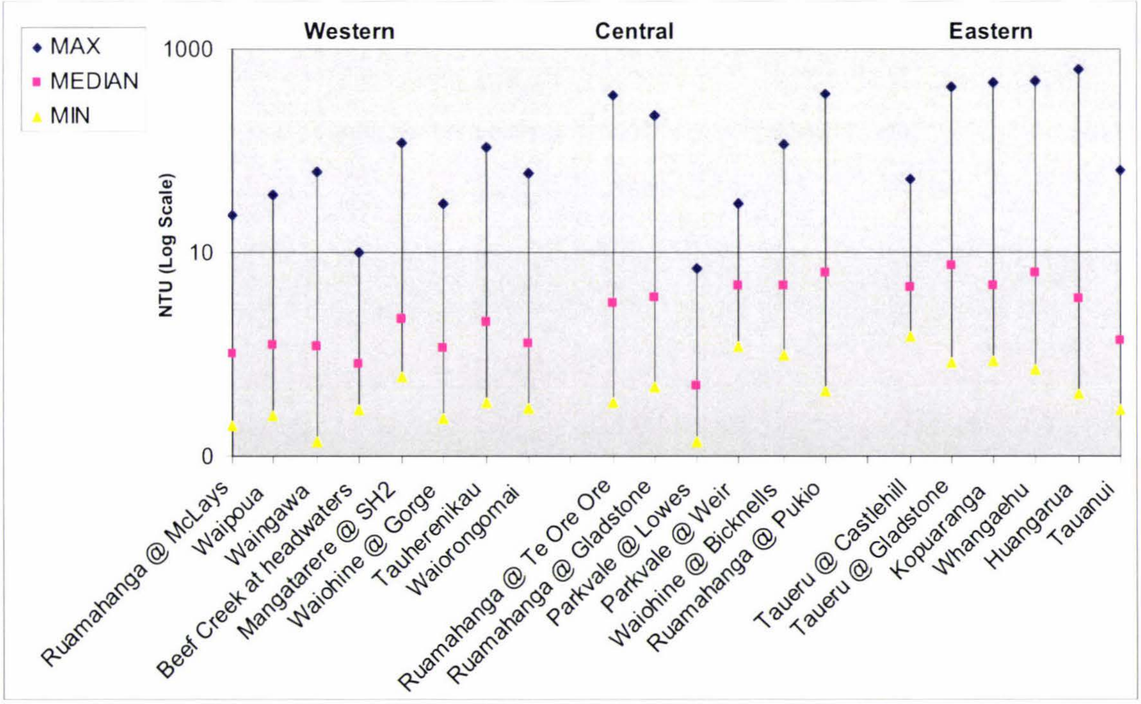

Figure 8-16: Maximum, Median and Minimum NTU values measured at sites in the Ruamahanga Catchment in the monitoring period

The frequency of turbidity readings analysed reveals nothing of the magnitude of the turbidity readings. Some of the eastern rivers including the Whangaehu River, the Taueru

River and the Kopuaranga River all had maximum turbidity readings of over 400 NTU, while the western tributaries including the Ruamahanga River at McLays, the Waipoua River, the Waingawa River and the Waiohine River at Gorge had much smaller maximum turbidity readings at 24, 37, 62, and 30 NTU respectively (Figure 8-16).

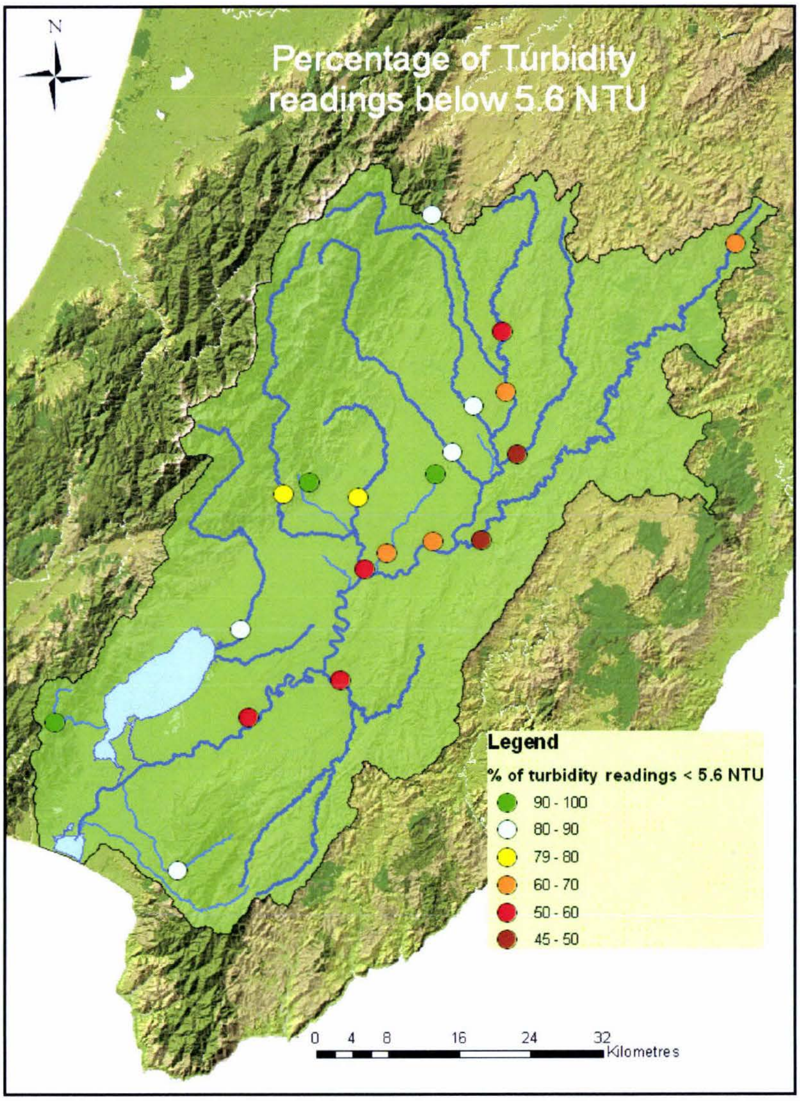

Figure 8-17: Percentage of Turbidity Readings below 5.6 NTU

8.2.4.3. Discussion

The results show that the eastern tributaries are more often turbid than the western tributaries, and also that tributaries become more turbid downstream. However, as was discovered in Section 8.2.4.1 using turbidity can be inaccurate in determining which tributaries contribute the majority of the sediment. As was outlined, there are many variables that need to be considered before judgement can be made, including the sediment size and type that is being transported and flow volumes in the water bodies.

Figure 8-18: a) the Taueru River and b) the Whangaehu River, both of which exceeded the turbidity threshold more than 50% of sampling occasions

The sediment type on either side of the Ruamahanga Catchment is remarkably different. The eastern tributaries drain catchments dominated by Tertiary mudstones and limestones, and therefore the river beds are sandy and/or silty resulting in high natural turbidity. The western tributaries drain the Tararua and Ruahine Ranges, and their river beds are comprised mostly of greywacke gravels, and as such the water is clear since it would require a lot of energy to carry the larger, heavier greywacke particles.

Hence the difference in sediment on either side of the catchment is likely to be the cause for the variance in turbidity readings. Furthermore, after high flows the western tributaries take less time to run clear, with the heavy greywacke particles dropping out of the water and becoming bed-load with a decrease in stream velocity, while in the eastern tributaries it takes a lot longer for the finer particles to settle out of the water, thus making the water seem dirtier for a longer period of time after a high flow.

The magnitude and frequency of floods have a large impact on how much sediment is carried by a waterway, and therefore water bodies in sub catchments that experience large floods most often, will likely to be those that contribute the most sediment. Maximum flows (m^3/s) for all of the tributaries in the Ruamahanga Catchment were provided in the previous chapter (Chapter 7, Table 7-8), and it was clear that overall the western tributaries and central river stem have experienced higher maximum flow rates than the eastern tributaries. This is with the exception of the Taueru River and Huangarua River on the eastern side of the catchment whose maximum flow rates were similar to those measured on the Waingawa River and Ruamahanga River at Mt Bruce.

Estimated return periods for these large floods are generally smaller in the western tributaries (i.e. they occur more often) than in the eastern tributaries[53]. Therefore, when looking at sediment concentration in terms of water flow it would be likely that a majority of the sediment that is found in the lower Ruamahanga Catchment is contributed by the western tributaries.

Due to the number of these above-mentioned inaccuracies it is difficult to assess sediment load based on turbidity. Suspended sediment concentration can only be accurately determined by undertaking a suspended sediment monitoring program which can result in establishing a relationship between turbidity and suspended sediment concentration as was done in the Motueka Basin recently (Wild et al., 2006). Lewis (1996, p. 2300) stated that "turbidity should not be used as a substitute for sediment concentration without careful study of the relation between turbidity and suspended load for any proposed monitoring sites. Without accompanying concentration data, there is no assurance in the quality of the estimates".

A relatively small investment by GWRC in establishing calibration curves between turbidity and suspended sediment concentration could add great value to the large existing database of turbidity measurements.

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[53] Based on estimated return periods (years) of highest recorded flow for the period 1999-2004 (Watts, 2005).

Another possibility in determining where the sediment that is contributing to the build up in the lower catchment is coming from is by undertaking a mineral provenance study, whereby the minerals found in the samples can be related back to either the geology on the western or eastern side of the catchment.

8.2.4.4. Conclusion

A universal relationship between suspended sediment load and turbidity does not exist. Such a relationship can be found for individual rivers once sets of suspended sediment samples have been obtained from that river. The turbidity data was still analysed for the Ruamahanga Catchment and it was found that the eastern tributaries are more often dirty or turbid than the western tributaries. However, it was realised that this conclusion could not conclusively be applied to suspended sediment concentration due to the different sediment sizes and types, and flow rates occurring on either side of the catchment.

It is recommended that a suspended sediment sampling monitoring program be carried out to generate calibration curves between turbidity and suspended sediment concentration. This will enable full use of GWRC's existing turbidity measurements and allow the identification of which sub catchment contributes the most sediment. This will eventually allow for the minimisation of sediment build up in the catchment.

8.2.5. Lake Water Quality Overview

8.2.5.1. Methodology

The water quality found in Lake Wairarapa, the largest lake in the Ruamahanga Catchment has been described by Perrie (2005) in the 'Lake Wairarapa water quality monitoring technical report'. This next section will provide a brief overview of the findings of this report. For further information on the topic, the reader is referred back to the cited publication. A description of Lake Wairarapa has been previously been provided in Section 5.4.4 of this report.

8.2.5.2. Water Quality of Lake Wairarapa

The quality of water in Lake Wairarapa has been monitored since 1994 and was reported on in 1996 (Stansfield, 1996) and in 1999 (Stansfield, 1999). The latter report concluded that from the time monitoring began until 1998, water quality had remained poor, and in a eutrophic/ supertropic state[54] (Stansfield, 1999). This means that the lake has a relatively higher concentration of nutrients and *chlorophyll a* when compared with other lakes and a lower secchi depth[55].

Some small changes in the water quality of Lake Wairarapa have occurred since 1999, including decreases in TN and increases in water clarity, however the biological significance of these changes are likely to be minimal. In addition, the bacterial contamination counts (FC) had reduced, although conductivity had increased, however this latter variable is strongly influenced by salt water entering the lake from Lake Onoke (Perrie, 2005). Therefore, the overall water quality of Lake Wairarapa has not significantly changed since the report in 1999 and it is still "classified as being in a supertropic state" (Perrie, 2005, p.12).

In a closing statement, Perrie (2005, p. 12) commented that "water quality in the lake is unlikely to improve with the current land use activities continuing to occur and operate within the catchment".

8.3. GROUNDWATER

8.3.1. Background

This groundwater quality section draws on information provided in two publications: the GWRC 'Groundwater Technical Monitoring Report' (Jones & Baker, 2005); and the

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[54] The trophic state of a lake can be defined as "the life-supporting capacity per unit volume of a lake. Six commonly measured variables are widely accepted as good indicators of the trophic level of a lake: chlorophyll a (Chla), Secchi depth (SD), total phosphorus (TP), total nitrogen (TN), hypolimnetic volumetric oxygen depletion rate (HVOD) and phytoplankton species and biomass (Burns, Bryers, & Bowman, 2000, p. v). There are six tropic levels, from the lowest level: Ultra –microtrophic; Microtropic; Oligotropic; Mesotropic; Eutrophic; Supertropic; Hypertropic.

[55] A parameter used to measure water clarity. High secchi depths indicate clear water, while low secchi depths indicate turbid, murky water.

IGNS 'Wairarapa Valley Groundwater Report' (Morgenstern, 2005). The former publication utilised data that had been collected as part of the Groundwater State of Environment Monitoring Programme (GWSOE). This program selected 78 wells to monitor quarterly in the Greater Wellington Region. Fifty eight of these wells are within the Ruamahanga Catchment boundary. Morgenstern (2005) selected 63 sample wells in the Wairarapa Valley for his IGNS study. Figure 8-19 provides the geographical locations of the wells used in the GWSOE sampling and the IGNS sampling. Several of these wells were used in both studies.

The GWSOE sites were selected on the basis of their "location, depth and suitability for sampling" (Jones & Baker, 2005, p. 49). These sites were also selected to represent aquifers in each of the Groundwater Management Zones.

In addition to taking part in GWSOE, GWRC monitors groundwater quality by participating in the National Groundwater Quality Monitoring Program (NGMP), carrying out pesticide monitoring and other localised studies (Jones & Baker, 2005). At this stage the NGMP does not extend into Wairarapa and the Ruamahanga Catchment, however it is a recommendation that sample sites in Wairarapa should be included in the program in the future.

Groundwater quality in the Wairarapa Valley is highly variable, and its characteristics are dependant on natural processes (e.g. age, rock-water reactions, aquifer confinement and depth etc.) as well as anthropogenic influences. What follows is an overall description of the groundwater quality in the Ruamahanga Catchment.

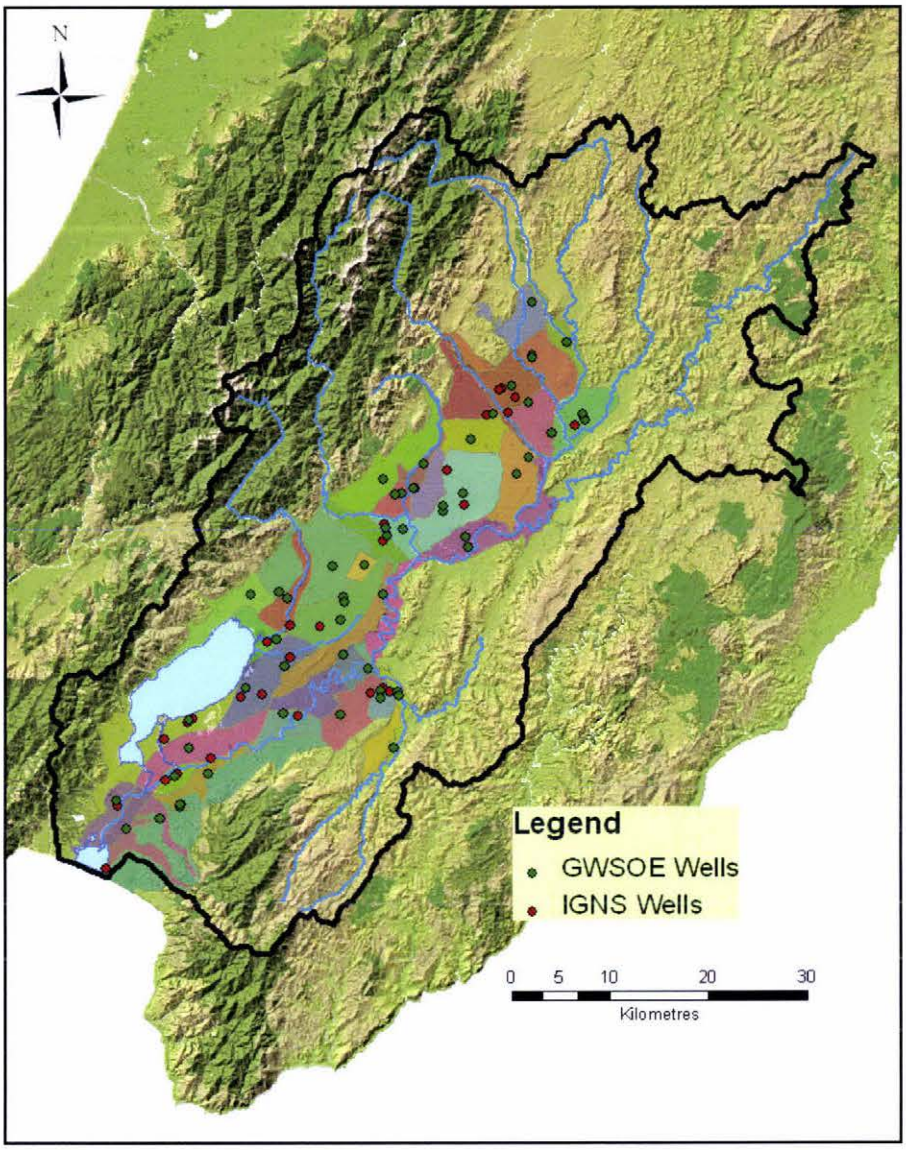

Figure 8-19: Location of sample wells from both GWSOE and IGNS studies. Nb. The coloured areas represent the different groundwater zones in the catchment.

8.3.2. Groundwater Quality Overview

Currently the dominant uses of groundwater in Wairarapa include public water supply (Carterton and Martinborough), irrigation and stock watering. In addition, vineyards, orchards and some industrial firms draw from groundwater bores. To enable continued use of groundwater for these purposes, the quality of the water needs to remain of a reasonably high standard to minimise the need for further water treatment.

8.3.2.1. Methodology

Raw data for the maps and analysis for this section were obtained from the tables in Morgenstern (2005, p. 4-6) and from the tables provided in the appendix of Jones & Baker (2005, p. 123-129). Additional information can be obtained from these sources.

8.3.2.2. Groundwater Quality Variables

The composition of groundwater varies both naturally and anthropogenically. Natural variation in the chemical composition can be the result of: 'rock-water' interactions, where groundwater flowing though the saturated zone becomes more concentrated in major ions (sodium, chloride, calcium, magnesium, bicarbonate, potassium, sulphate) and also contains increased amounts of total dissolved solids (TDS); and 'Redox' interactions, where the groundwater is subject to either an oxidizing (aerobic) or reducing (anaerobic) environment. Anthropogenic impacts on groundwater composition can result from changes in land use and land cover, discharges to land, and fertilizer use (Jones & Baker, 2005).

Most (40 of 58) of the sampled waters in the Ruamahanga Catchment in the GWSOE had sodium as their dominant cation, while the remaining 18 had calcium as the dominant cation. According to Rosen (2001, p. 87), "groundwater that is near the ocean, or in areas that are affected by certain land uses, such as land application of sewage effluent, are dominated by sodium" and calcium is often the dominant cation where the geology of the aquifer, or just the recharge area, is comprised mostly of limestone or carbonaceous sediments. Thus by determining the water chemistry, one may be able to identify areas that are being impacted by human influences (e.g. in the case of sodium). However the boundary between anthropogenic and natural causes may be difficult to define.

A large proportion of the wells (43) contained water with bicarbonate as the dominant anion and chloride was the dominant anion in the remaining 15 (Jones & Baker, 2005). The Chebotarev Sequence[56] (Jones & Baker, 2005 ,p. 42), shown below, states that the

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[56] Chebotarev wrote 'Metamorphism of natural waters in the crust of weathering' in 1955. The evolving sequence of natural waters that he identified in this paper is widely known as the Chebotarev Sequence.

anionic nature of groundwater naturally evolves towards the composition of seawater (i.e. high chlorine concentration).

Travel along flow path $\longrightarrow$

$$HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} + HCO_3^- \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^-$$

Increasing age $\longrightarrow$

The majority of groundwater samples taken in Wairarapa have not evolved past the bicarbonate stage of the Chebotarev Sequence. According to Morgan & Hughes (2001) this is not uncommon for New Zealand groundwater. They also mentioned that aquifers that were dominated by chloride as the anion, were not necessarily older or more evolved, but may have been influenced by other processes.

Older groundwaters tend to have large amounts of TDS and are generally anaerobic, and they therefore may not be as desirable for consumption as younger less mineralised water. The oldest groundwater in the Ruamahanga Catchment is found at the southern end of the basin, where deep wells contain anaerobic water older than 100 years, while water of a much younger age (two years) is found in shallow wells in the upper part of the valley (Morgenstern, 2005). Water also usually increases in age with depth, however there are areas of the valley where upwelling of older waters does occur (Morgenstern, 2005) (Figure 8-21).

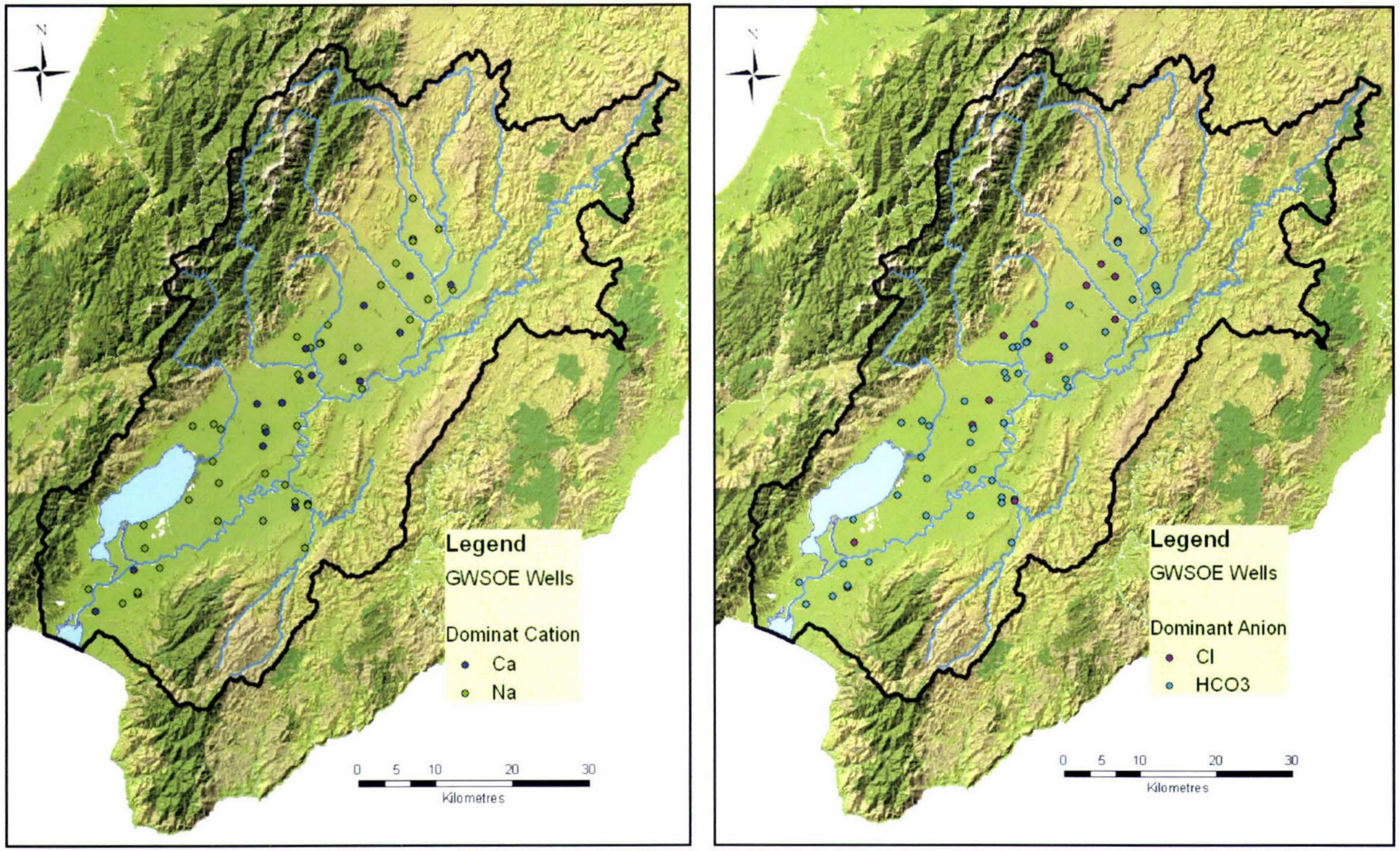

Figure 8-20: Groundwater Types: a) Dominant Cation, b) Dominant Anion

The hydrochemistry of groundwaters can become rather complex. Both the publication completed by Morgenstern (2005) and Jones & Baker (2005), provide a detailed overview of the natural and anthropogenic hydrochemistry occurring within the groundwater in the Wairarapa Valley. In the remaining part of this section the focus is mainly on groundwater wells that have been subject to anthropogenic influences.

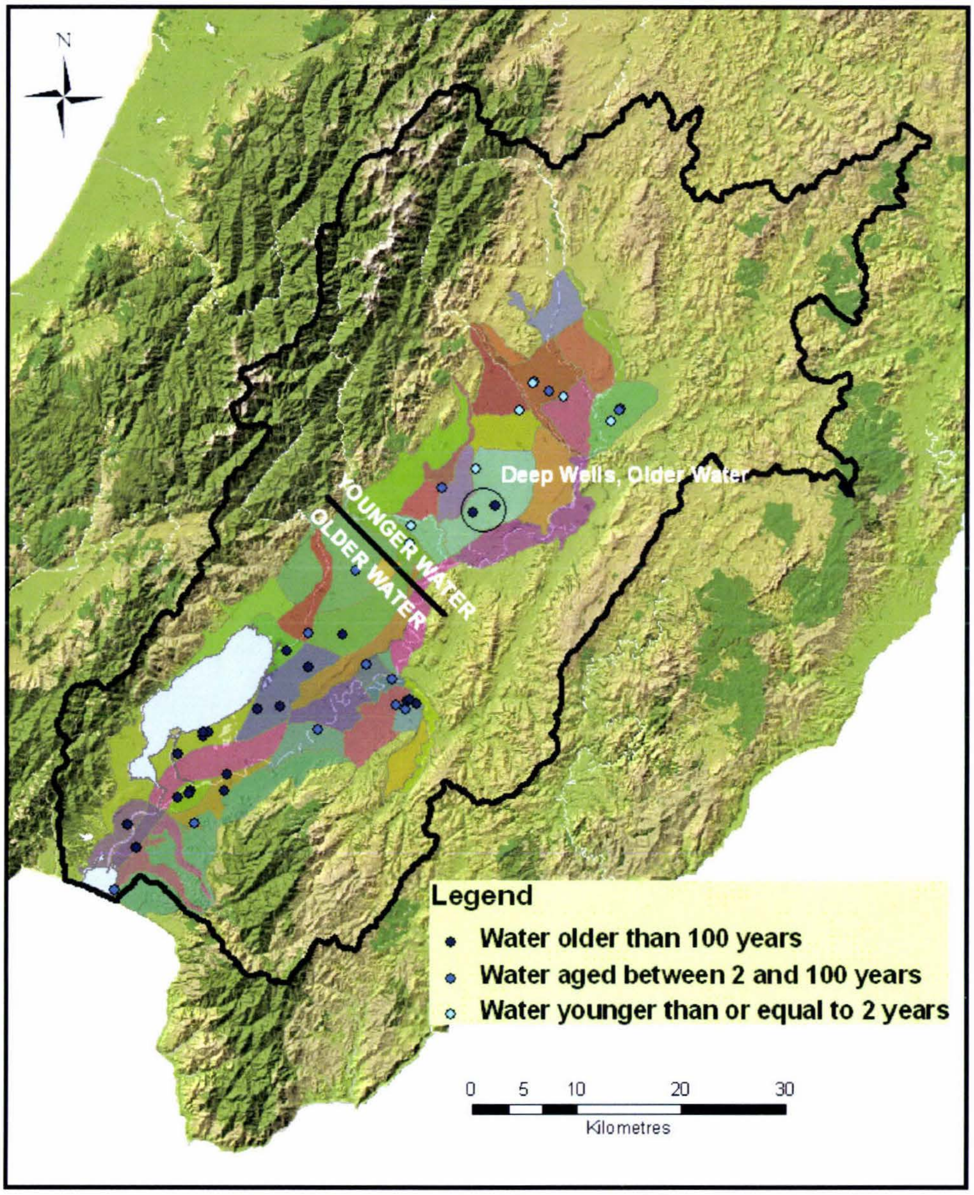

Figure 8-21: Visual Representation of Groundwater Age in the Ruamahanga Catchment. Nb. The coloured areas represent the different groundwater zones in the catchment.

In their report, Jones and Baker (2005) completed a hierarchical cluster analysis (HCA)[57] to group the GWSOE sites into four distinct clusters based on their chemical characteristics, while making no "assumptions about site location, aquifer lithology, and surrounding land use, etc" (Jones & Baker, 2005, pp. 118). They found that one cluster in particular (Cluster 4) showed evidence of anthropogenic impact (Figure 8-22).

Cluster 4 waters were thought to be impacted by human activities resulting in high sulphate (SO_4^{2-}) and/or NO_3-N levels. There was no NH_4-N present in the cluster 4 wells (Jones & Baker, 2005).

Morgenstern (2005) suggested that elevated concentrations of NO_3-N, $SO4_2^-$ and possibly lead (Pb) in some of the sample wells were a consequence of land use including: agricultural activities (NO_3-N, SO_4^{2-}); septic tanks and land treatment systems (NO_3-N); and use of leaded petrol (Pb). Figure 8-23 and Figure 8-24 identify those wells from both the IGNS study and the GWSOE study, with elevated concentrations of NO_3-N (above 3 g/m^3 NO_3-N), sulphate (above 5 g/m^3 SO_4), lead (above 0.0005 g/m^3 Pb) and zinc (above 0.06 g/m^3 Zn).

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[57] 'An agglomerative statistical method that finds clusters of observations within a data set. It allows the grouping of individuals on the basis of the similarity in their properties' (Nature Reviews, 2004). Refer to pages 71 – 74 of Jones & Baker (2005) or Daughney (2003) for more information on this.

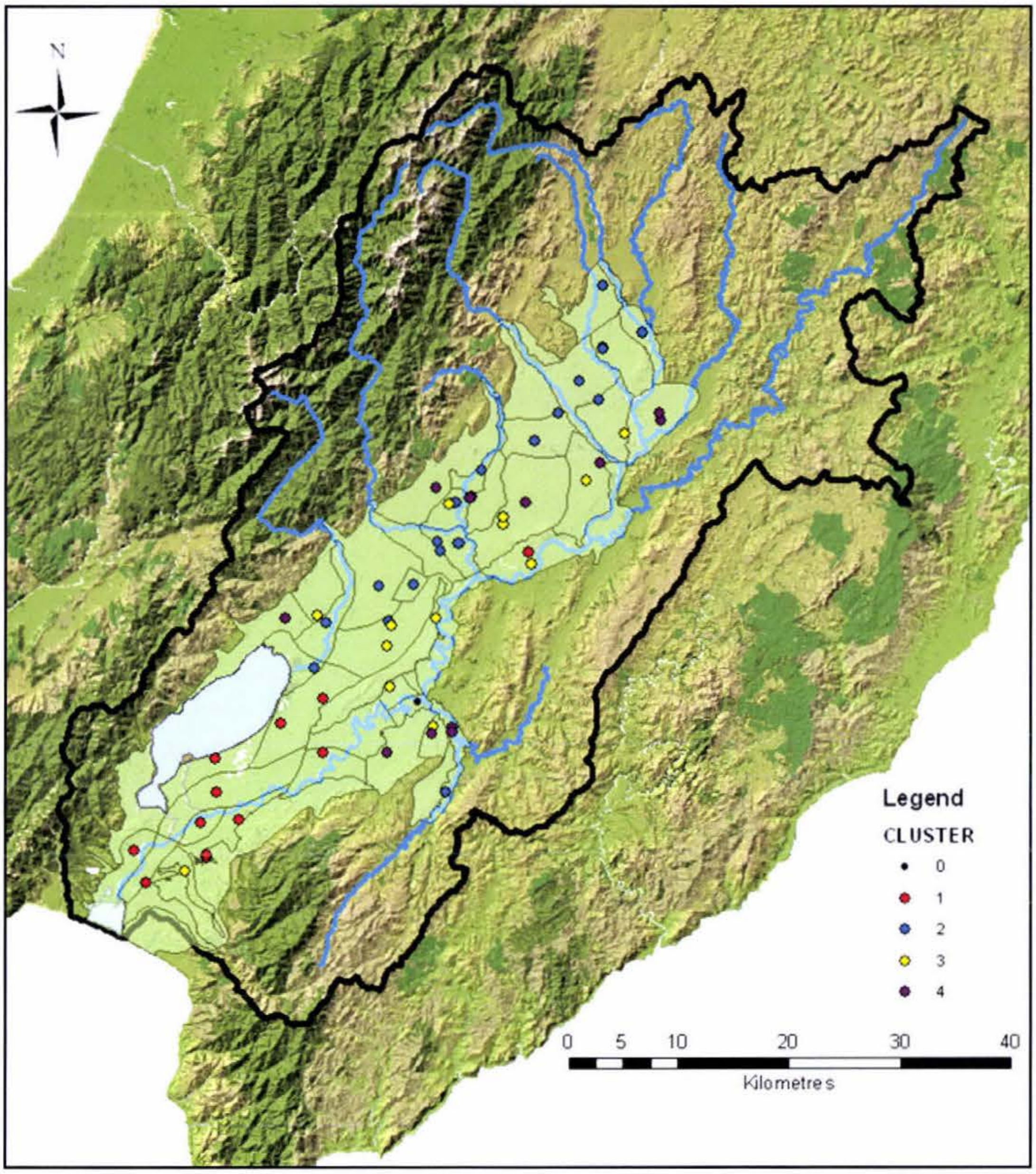

Figure 8-22: Results from Hierarchical Cluster Analysis that was carried out by Jones and Baker (2005), in order to group groundwater into similar classifications.

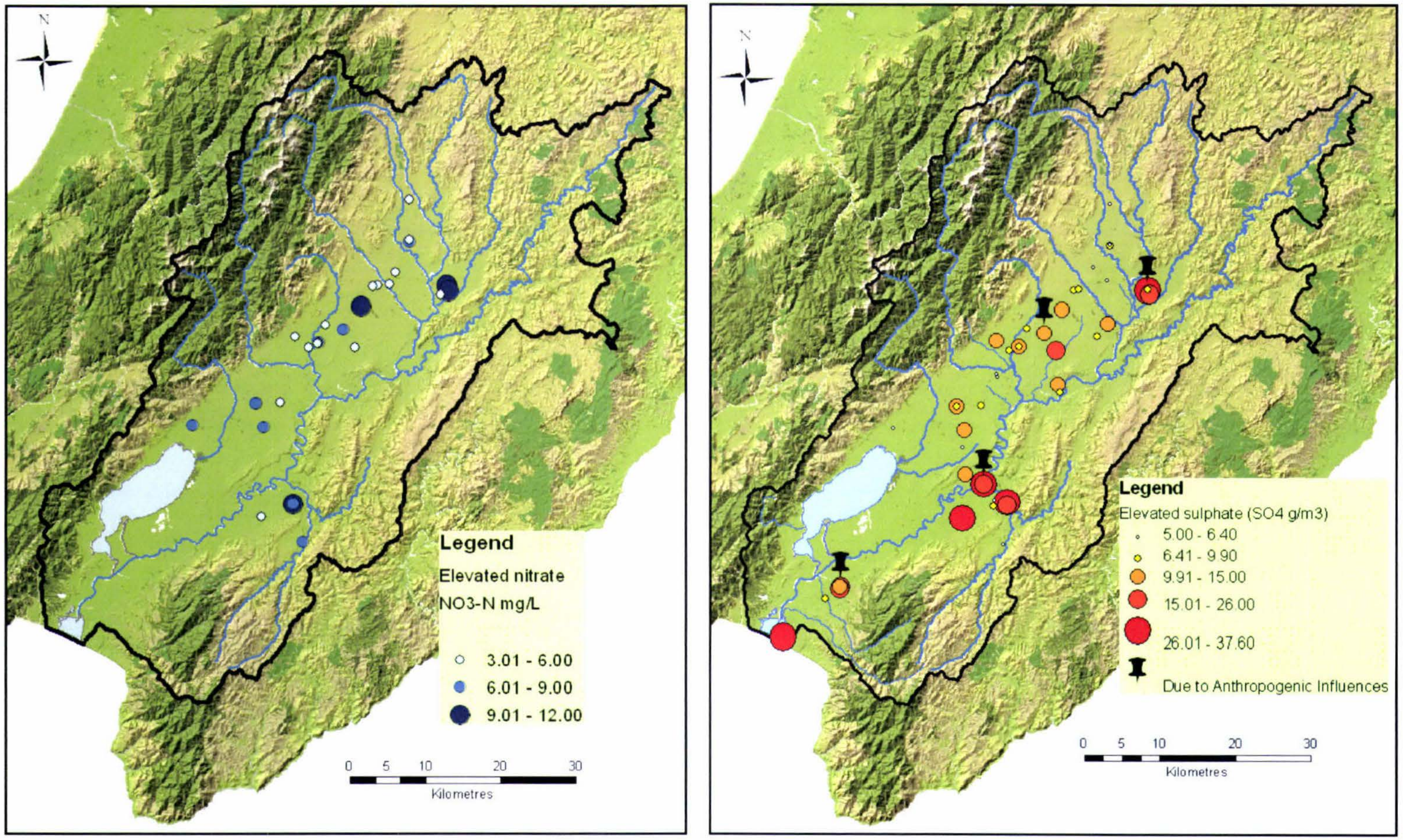

Figure 8-23: Location of wells within the Ruamahanga Catchment with a) elevated NO_3-N and b) elevated SO_4^{2-}. Data is from both IGNS and GWSOE studies.

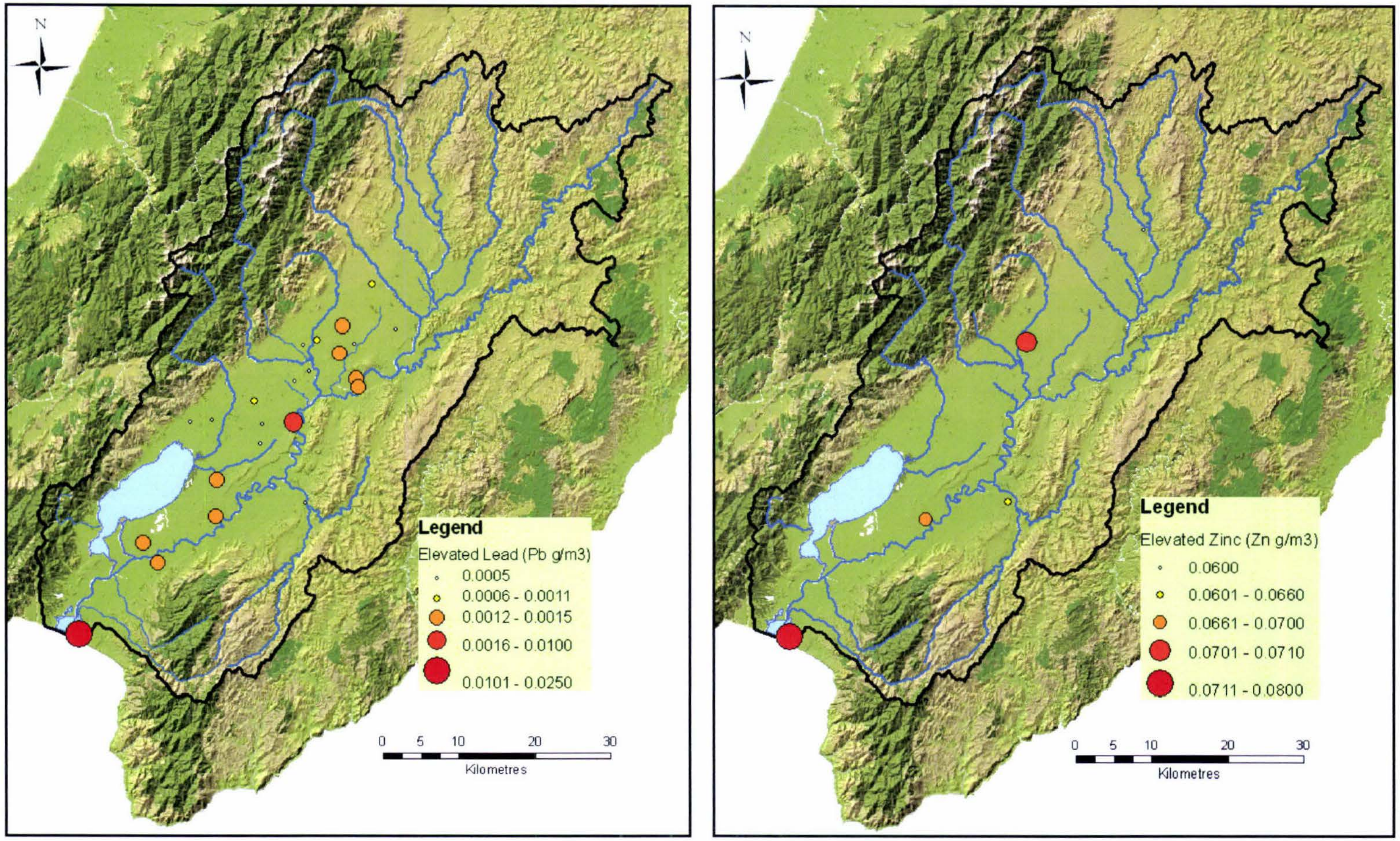

Figure 8-24: Location of wells within the Ruamahanga Catchment with a) elevated Pb and b) elevated Zn. Data is from both IGNS and GWSOE studies.

Although Figure 8-23 and Figure 8-24 show the highest values from the combined data sets (IGNS and GWSOE), in most cases these highest values are not over threshold values, e.g. maximum acceptable values (MAVs) for inorganic determinants of health significance, and guideline values (GVs) for aesthetic determinands, that have been published by New Zealand Ministry of Health (2005, p. 9 and 131) (Table 8-6).

Constituent	MAV	GV	Highest Value in Data set	Corresponding Well
NO_3-N	11.3 g/m^3	n/a	11.45 g/m^3	Nicholson (GWSOE)
SO_4^{2}	n/a	250 g/m^3	37.60 g/m^3	Duggan (GWSOE)
Pb	0.01 g/m^3	n/a	<0.05 g/m^3	Lake Ferry Motorcamp (IGNS)
Zn	n/a	1.5 g/m^3	0.08 g/m^3	Lake Ferry Motorcamp (IGNS)

Table 8-6: Summary of Maximum Acceptable Values (MAVs) and Guideline Values (GVs) for NO_3-N, SO_4^{2-}, Pb and Zn

The well located on the Nicholson property (hereafter referred to as Nicholson), exceeds the NO_3-N drinking water standard of 11.3 g/m^3. Wells featuring nitrate levels over this threshold were also identified by Morgan & Hughes (2001) who stated that individual bores in the Opaki, Upper Plain, Te Ore Ore, West Taratahi, East Taratahi, Carterton and Moroa zones all had water that exceeded 6 g/m^3 NO_3-N and sometimes 11.3 g/m^3 NO_3-N. According to an American study, all wells featuring NO_3-N concentrations over 3 g/m^3, indicate contamination of the aquifer from anthropogenic sources (Madison and Brunett, 1985 cited in (Close, Rosen, & Smith, 2001, p. 188), therefore assuming this statement is correct for New Zealand, all of the wells featured in Figure 8-23a show elevated NO_3-N due to anthropogenic influences and this is consistent with Wairarapa being named as one of the national nitrate problem areas by Lincoln Environmental (1998, cited in (Close et al., 2001, p. 192).

These elevated nitrate levels can be attributed to farming (dairying, and sheep and beef), from the animals and from the application of fertilizer, and from human wastes coming from septic tanks (Close et al., 2001). Another source of nitrate to groundwater can be from processing plants; this is likely to be an influence in Wairarapa, with the operation of the Waingawa Freezing Works. This operation emitted a great "level of ammonia and nitrate-nitrogen down gradient of the effluent treatment and disposal area" (Morgan & Hughes, 2001, p. 405). With the works closure in 1989, the levels of these particular contaminants declined, but surrounding aquifers still show concentrations above drinking water standards, which undoubtedly would have been kept elevated by the application of effluent sludge from the works on the immediate land area in 1995 (Morgan & Hughes, 2001).

All of the elevated sulphate sites in Figure 8-23b, are significantly below the GV of 250 g/m^3. Elevated sulphate levels indicated on the map are due to both natural and anthropogenic sources. Morgenstern (2005) found four wells in particular, shown on the map with the black marker, to be influenced by anthropogenic sources, generally from gypsum which is an additive in fertilizer. He also found that the "high concentration of SO_4 at the Lake Ferry well was due to connate seawater[58]" (Morgenstern, 2005, p. 26).

The lead concentrations found at the Lake Ferry Motorcamp appear to breach the guideline of 0.01 g/m^3 (Table 8-6). However the reported value of <0.05 g/m^3 is somewhat ambiguous[59]. Previously in this document "less than" values have been estimated as being half of the reported concentration. Therefore in this case 0.05 g/m^3 would become 0.025 g/m^3 and still be over the threshold. If it is incorrect to assume this, then the next highest lead concentration in the data set was 0.01 g/m^3 at Tucker (GWSOE) which is situated on the lower reaches of the Ruamahanga River and is indicated on the map in Figure 8-24a as the larger orange point. Elevated lead concentrations are thought to be either due to emissions from the utilization of lead petrol (in younger groundwater) or natural reaction processes in older groundwaters (Morgenstern, 2005).

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[58] Relic seawater as opposed to active seawater intrusion.

[59] The Pb concentration in both the GWSOE and IGNS studies ranged considerably, including various less than values e.g. <0.0005, <0.0001, <0.001, <0.003, <0.01, and <0.05. This made it difficult to compare with the Ministry of Health guideline of 0.01 g/m^3 and generate a judgment on the quality of the water with respect to lead (Pb).

High levels of zinc are found at five wells, the Lake Ferry Motorcamp, Te Kairanga, CDC north, Bosch, and Opaki Water Supply. Lake Ferry and CDC north have the highest concentrations of zinc. Coupled with this, the CDC north well also has elevated Pb and a high level of contamination from chlorofluorocarbons (CFC's, man-made contaminants). Morgenstern (2005, p. 20) therefore suggested that this well "may be affected by old landfills". He thought that this also may be the case for CDC south, since it exhibits similar trends in concentrations of these contaminants. Jones & Baker (2005) agreed that this was likely for CDC north.

Morgan & Hughes (2001, p. 405) stated that "levels of iron (Fe) and manganese (Mn) are above drinking water guidelines in many of the Wairarapa Valley aquifers, with the highest levels in the deeper aquifers of the Lower Valley (Fe ~ 15 g/m^3, Mn ~ 1 g/m^3)". In light of this statement Mn and Fe concentrations were also examined in each of the data sets.

Constituent	**MAV**	**GV**	**Highest Value in Data set**	**Corresponding Well**
Iron (Fe)	n/a	0.2 g/m^3	13.4 g/m^3	Findlayson (GWSOE)
Manganese (Mn)	0.4 g/m^3	0.10 g/m^3	3.42 g/m^3	Wither (IGNS)

Table 8-7: Summary of Maximum Acceptable Values and Guideline Values for Iron and Manganese

Figure 8-25 shows the spatial spread of elevated Fe (above 0.2 g/m^3) and Mn (above 0.4 g/m^3). The highest concentration of Fe was found at Findlayson, with other wells in the same vicinity around the south eastern side of Lake Wairarapa, also having high concentrations. These same wells also have elevated concentrations of Mn. According to the New Zealand Drinking Water Standards as cited in Rosen (2001), concentrations of Mn above 0.5 g/m^3 can be a potential health risk. Elevated levels of Mn and Fe are however not attributed to anthropogenic causes. Levels can increase naturally in "moderately reducing and anoxic conditions" (Rosen, 2001, p. 96), which is consistent with the conditions occurring in the lower part of the Ruamahanga Catchment, around the eastern periphery of Lake Wairarapa. Note that the Wither well is a deep well situated in the upper portion of the catchment; it contains anaerobic water and low levels of dissolved oxygen (Morgenstern, 2005).

As previously mentioned, Cluster 4 contained the most impacted sites from anthropogenic influences. Figure 8-26 visually displays the location of the wells that are part of Cluster 4, as well as the location of a selection of other wells present in the Wairarapa Valley that have been thought to be affected by land use. (These wells have come from both GWSOE and IGNS studies, and are listed in Table 8-8).

Well	Contaminant	Cause
Nicholson	High Nitrate	Land use
Dimittina	High P	Septic Tank
Percy	High and increasing SO_4	Dairy Farms
Opaki Water Supply	Increasing NO_3, SO_4	Septic Tanks
SWDC Martinborough	Significant increases in SO_4	Change in recharge source driven through pumping?
CDC North	High Pb and Zn	Old Landfill

Table 8-8: Selected wells influenced by human activities

Generally phosphorus is thought not to enter groundwater systems as it is usually intercepted before it reaches the saturated zone since it is so reactive. Morgenstern (2005) found there to be no anthropogenic source of DRP in any of the Wairarapa wells, however Jones & Baker (2005) found Dimattina to have high levels of DRP, and established the source to be a septic tank.

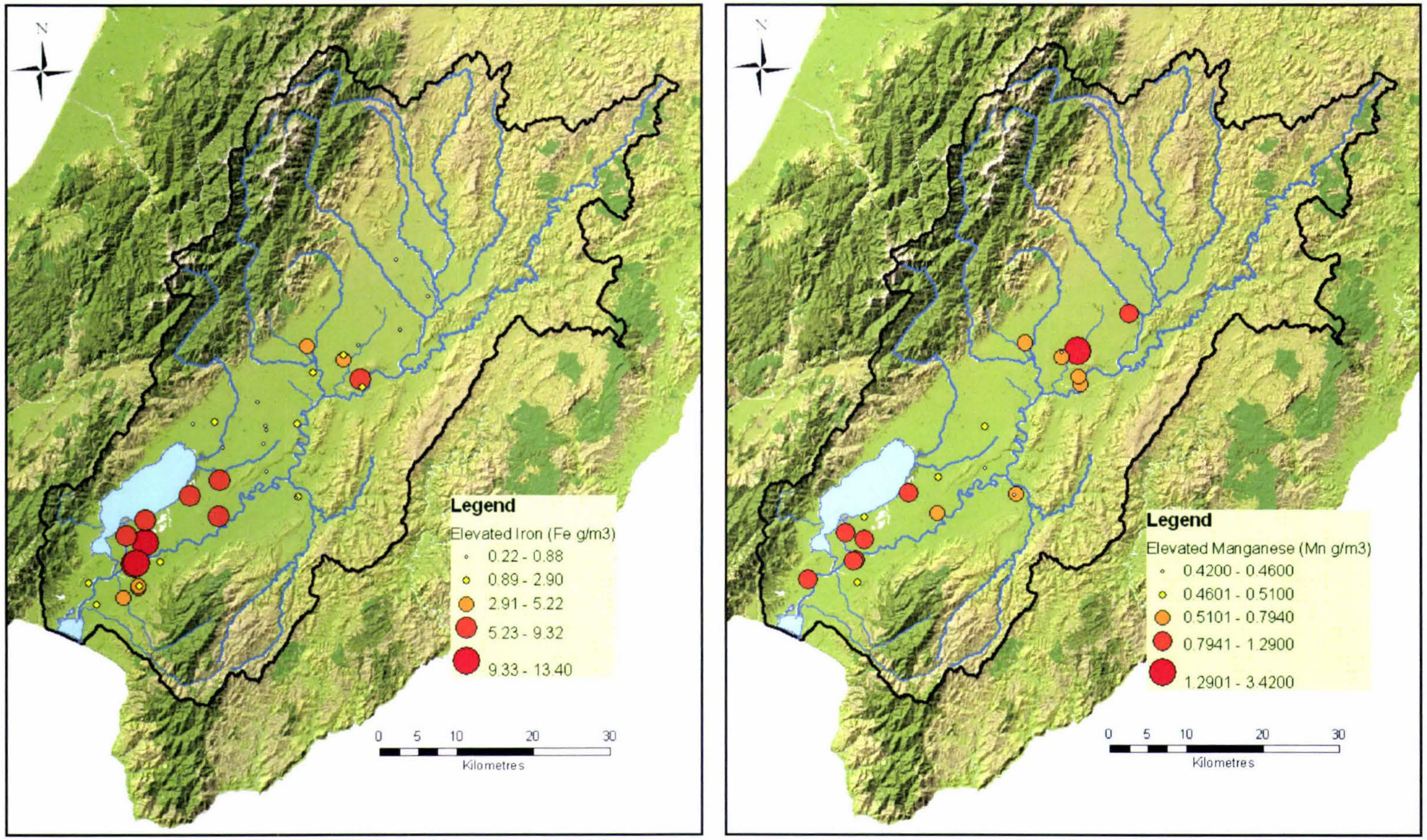

Figure 8-25: Location of wells within the Ruamahanga Catchment with a) elevated Fe and b) elevated Mn. Data taken from both IGNS and GWSOE studies.

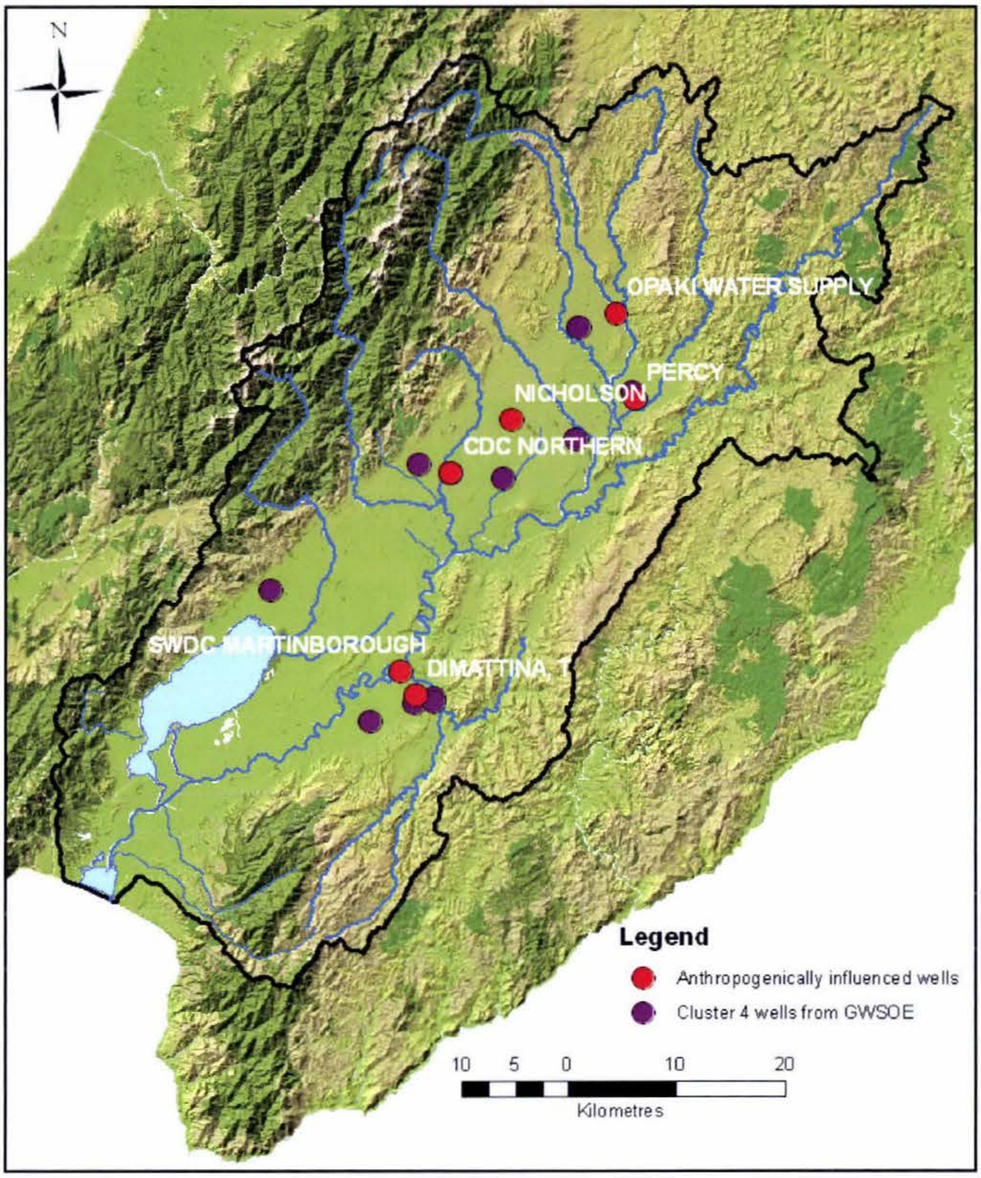

Figure 8-26: Map of wells showing Cluster 4 wells from the HCA and other selected wells influenced by human activities

Bacterial Contamination

Faecal coliforms, including *E.Coli,* are commonly used as indicators of faecal contamination of water (Jones & Baker, 2005). The presence of *E.coli* in water is almost certainly traced back to faeces, and the maximum allowable value (MAV) for New Zealand drinking water standards is one *E.Coli* in 100 mL of sample (Sinton, 2001).

The Groundwater Technical Report (Jones & Baker, 2005) included a list of wells that featured at least one positive coliform result. Eight of the wells within the Ruamahanga Catchment had been affected by faecal contamination since GWSOE recording began. Five of these tested positive for *E.Coli* on at least one occasion. These wells include: Croad, which tested positive for *E.Coli* on three occasions containing 1, 2 and 250 cfu[60]/100 mL respectively; Johnson, which contained 1 cfu/100 mL on one occasion; Dimattina, which had 5 cfu/100 mL and 12 cfu/100 mL on two separate occasions; Sorenson which had 10 cfu/100 mL once; and the Trout Hatchery which tested positive with 12 cfu/100 mL on one occasion.

It is not uncommon for elevated levels of bacteria to occur in shallow aquifers, and according to Morgan & Hughes (2001, p. 405) such contamination is usually only localised and is generally a result of "poor land use practices adjacent to bores". Jones and Baker (2005) suggested that the type of well can affect the amount of contamination and that larger diameters wells are more prone than those with a smaller diameter.

Contamination Vulnerability

Serious aquifer contamination has occurred on at least three known occasions in Wairarapa, one of which has already been previously mentioned at the Waingawa Freezing Works. The other occasions were in 1981 and again in 1986, when the shallow gravel aquifer adjacent to the Waingawa River (Upper Plain Groundwater Zone) was contaminated by varying concentrations and quantities of a preservative solution comprised of copper, chromium and arsenic which was spilt by a timber treatment plant. These incidents resulted in high levels of the elements occurring in bores around the area up to six months after the spill (Morgan & Hughes, 2001).

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[60] Colony forming units (cfu)

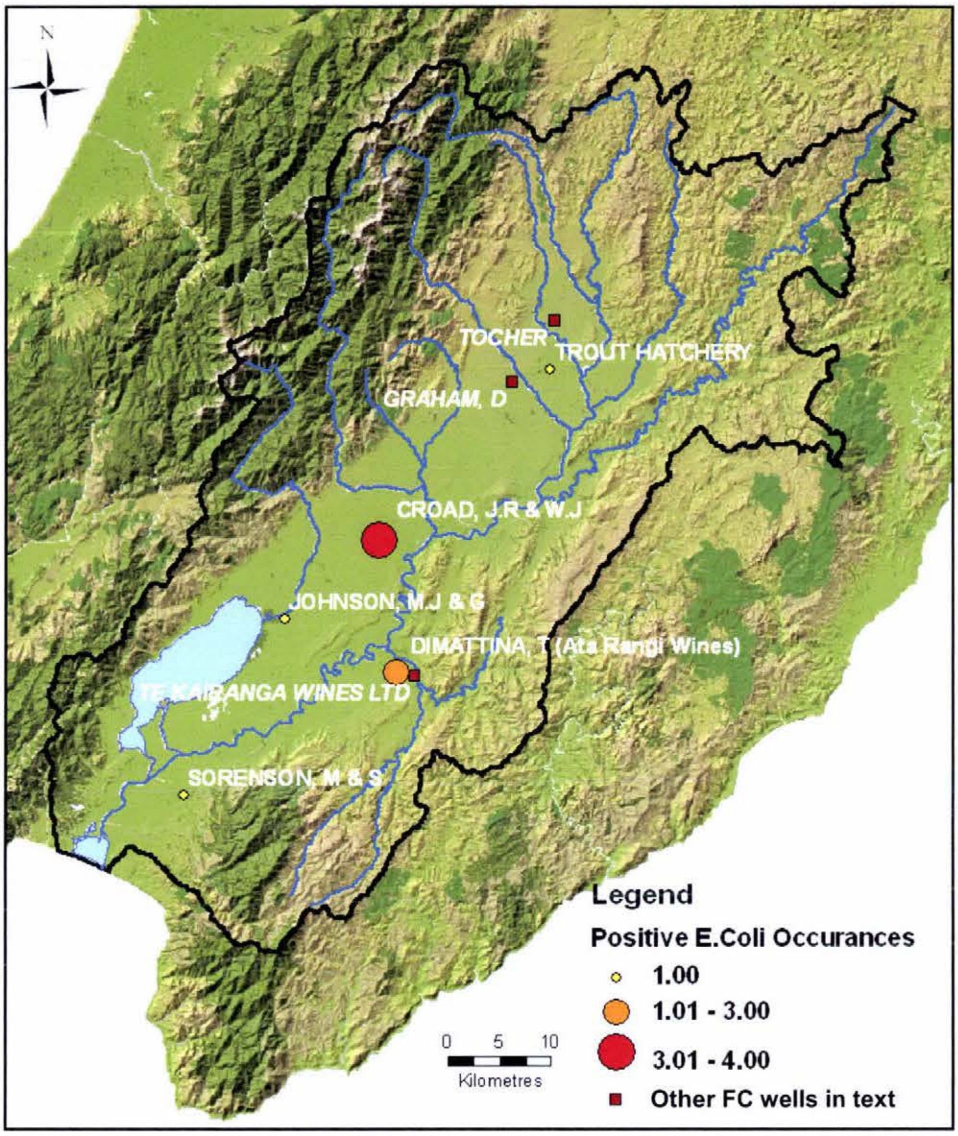


Figure 8-27: Wells with positive *E.Coli* and FC occurances in the Ruamahanga Catchment. Source (Jones & Baker, 2005)

Contamination is more likely to occur in shallow unconfined aquifers, but it is not uncommon for semi-confined or confined aquifers to be at risk, depending on flow conditions and the associated hydraulic conductivity between neighbouring aquifers. Land use practices centred around recharge zones should be restricted as contamination that occurs in these areas can quickly result in widespread contamination throughout the aquifer. Common sense and an understanding on the groundwater dynamics is paramount in ensuring prevention of groundwater pollution.

8.3.3. Conclusion

The composition of groundwater found in the Ruamahanga Catchment varies both naturally and anthropogenically. Some of the wells have been identified as having elevated levels of NO_3-N, SO_4^{2-}, Pb, Zn, Fe and Mn, however many of these elevated levels are attributable to natural processes. The most widespread anthropogenic groundwater contamination in the catchment is from NO_3-N. Wells in groundwater zones around Masterton, Carterton and Martinborough featured the highest levels of NO_3-N, in many cases breaching the MAV. Sources of the nitrate contamination are thought to be from septic tanks, processing plants, animal waste and fertiliser application.

Groundwater wells that were thought to be influenced by human activities with elevated level of contaminants including NO_3-N were identified and represented spatially. These wells included Cluster 4 from the Hierarchical Cluster Analysis and the six wells that were identified as having elevated levels of NO_3-N, SO_4^{2-}, Pb, Zn and P. Geographically these wells are located in the northern section of the central valley and around Martinborough.

Several wells recorded high levels of *E.Coli,* which is generally only localised and a result of surrounding land use practices. The aquifers in the region are moderately vulnerable to general contamination, and incidents have occurred in the past. Land use practices in unconfined areas and recharge areas need to be managed appropriately to limit the impacts on the water quality.

8.4. CONCLUSION

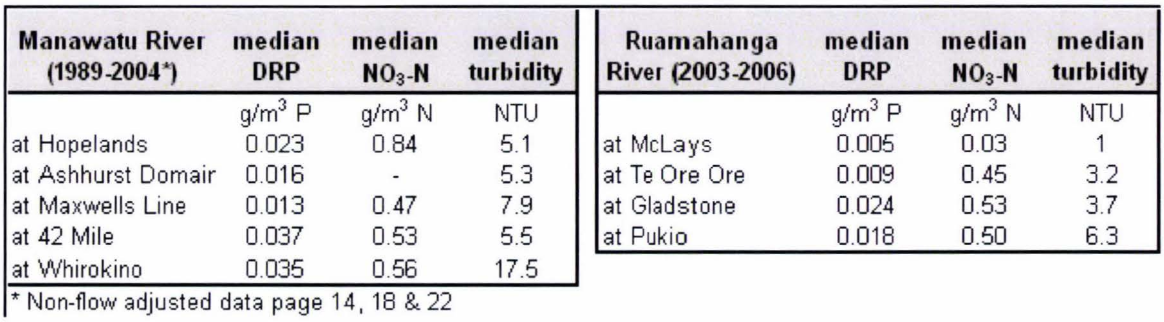
Generally, the water in the western sub catchments is of better quality than the water draining the eastern sub catchments. However, the most degraded water quality has been identified as occurring in the central Mangatarere River, which drains predominantly pastoral land and also receives Carterton's municipal sewage in the winter months.

The estimate of nutrient loads found the Ruamahanga River section between Te Ore Ore and Gladstone to have a spike of DRP not attributable to the contributing tributaries. This increase could be explained by the upstream sewage discharge at Masterton and agricultural runoff.

Only a limited suspended sediment analysis was able to be carried out by looking at turbidity measurements. Overall it was found that the western tributaries were less turbid than the eastern, which linked to river flows and sediment type. The quality of the water in Lake Wairarapa was classified as being in a supertropic state, with high concentrations of nutrients and *chlorophyll a*. It was suggested that the quality is unlikely to improve with the dominant land use around the lake continuing.

NO_3-N contamination is a problem in the catchment's groundwater, with several wells having concentrations that exceed the MAV. The cause of this contamination was identified as being land use practices.

This chapter has assessed water quality within the catchment, and compared the water quality in different tributaries. To really assess the state of the Ruamahanga River in terms of water quality, comparison should be made with another similar sized river. Table 8-9 provides median DRP, NO_3-N and turbidity data for sites on the Manawatu and Ruamahanga Rivers, listed in a downstream direction. Note that the data is from different time periods.



Manawatu River (1989-2004*)	median DRP	median NO_3-N	median turbidity
	g/m^3 P	g/m^3 N	NTU
at Hopelands	0.023	0.84	5.1
at Ashhurst Domair	0.016	-	5.3
at Maxwells Line	0.013	0.47	7.9
at 42 Mile	0.037	0.53	5.5
at Whirokino	0.035	0.56	17.5

* Non-flow adjusted data page 14, 18 & 22

Ruamahanga River (2003-2006)	median DRP	median NO_3-N	median turbidity
	g/m^3 P	g/m^3 N	NTU
at McLays	0.005	0.03	1
at Te Ore Ore	0.009	0.45	3.2
at Gladstone	0.024	0.53	3.7
at Pukio	0.018	0.50	6.3

Table 8-9: Comparison of Water Quality Data in the Manawatu and Ruamahanga Rivers. Manawatu River data. Source (Gibbard, Roygard, Ausseil, & Fung, 2006)

The water quality in the Manawatu River is worse than the Ruamahanga River in terms of DRP and turbidity, while the two rivers are very similar in terms of NO_3-N. This comparison puts this water quality chapter in perspective. Horizons MW (Manawatu Wanganui Regional Council) has recently produced the 'One Plan', which focuses its attention of four main environmental problems in the region, one of which is water quality. Amongst other things, the 'One Plan' proposes to maintain the standard of water quality in cases where the water quality is already good, and to enhance water quality in rivers and streams that are already degraded. To do this, land use practices in certain areas will be regulated for nutrients and bacterial contamination, discharges to land instead of water are encouraged, and by 2020 no human sewage shall be directly discharged into any water body (Horizons MW, 2007).

The outcomes of the 'One Plan' in terms of both successes and failures in trying to enhance water quality should be closely watched by GWRC. As they to, experience similar levels of degraded water quality, which will need to be addressed in the future.

9. Land Use

9.1. INTRODUCTION

Different land uses in the Ruamahanga Catchment place varying pressures on the natural resources of the catchment, especially freshwater. The amount of water that they each require and the amount of waste that they produce must be managed appropriately to limit irreversible damage on the environment.

This chapter aims to present the different types of land uses occurring within the catchment and to outline the level of pressure that each land use places on the environment. This chapter will also include sections on riparian management, impacts on water from land use change, and a review into current and projected land use change in the catchment.

9.2. METHODOLOGY

In this chapter, land use practices are broken down into five sections, agriculture, horticulture, forestry, industry and human settlement. A brief overview of the land use is given, followed by an indication of the pressure they exert on the environment in terms of water abstraction, and discharge to air, land and water. Some links will then be made between the degraded water sites and land use practices. The chapter concludes with comments on land use change and trends in the catchment.

9.3. DATA SOURCES

Numerous data sources have been used in compiling this chapter, including AgriBase, the Digital Cadastral Database (DCDB), the New Zealand Land Resource Inventory (NZRLI), the Land Cover Database (LCDBv2), various Greater Wellington Regional Council (GWRC) databases, and information from Go Wairarapa.

9.3.1. AgriBase

AgriBase is a national spatial farm database. It contains information on the size of the farm, farm type, number of each type of livestock and areas of crops, forestry and native bush (V. Froude, 1999). It was launched in 1993 by AgriQuality Limited, and was initially set up for the management of properties susceptible to foot and mouth disease (AgriQuality, 2007).

Data for AgriBase is collected by livestock consultants and farm owners, annual updating of the database is desired but limited funds means that this rarely occurs. Updating of the database erases old records, and therefore no historical data is kept, inhibiting the ability to make judgement on land use change over time. Unfortunately there are also gaps in the database e.g. horticulture (V. Froude, 1999).

9.3.2. Digital Cadastral Database (DCDB)

The DCDB is a nationwide digital database, funded by the land transfer levy which holds information on land ownership and the "location, shape and area of land parcels, and the legal definition of roads, road centrelines, railways and hydrographic features" (V. Froude, 1999, section 12.3). The database is managed by Land Information New Zealand.

9.3.3. New Zealand Land Resource Inventory (NZLRI)

Details have previously been given in Section 5.3.1 of this report.

9.3.4. Land Cover Database (LCDBv2)

Details have previously been given in Section 5.8.1 of this report.

9.3.5. GWRC Databases and 'Go Wairarapa' Information

These include water abstraction and discharge consent databases, supplied in a spreadsheet from GWRC. GIS consent vector data also from GWRC, and Go Wairarapa has supplied information pertaining to land use change and land use projections.

9.4. LAND USE IN THE RUAMAHANGA CATCHMENT

The Ruamahanga Catchment hosts a diverse range of land uses that have changed considerably throughout the years. Home to one of New Zealand's first sheep runs and the country's fourth co-operative dairy factory, Wairarapa grew to be one of the "country's leading pastoral areas" (Wairarapa Regional Development Council, 1978, chp 4, p.1), dominated by sheep, beef and dairy farms. Land use practices have since expanded to include viticulture, deer farming, pig farming, horse studs, mushroom cultivation, organic farming and hydroponics to name a few. Industry within the area has also expanded and now includes large sawmilling operations, lime works, and food processing factories.

9.4.1. Agricultural Overview

Agricultural practices in the Ruamahanga Catchment include: sheep and beef farming, dairy farming, deer farming, arable cropping and seed production, horse farming, poultry farming, pig farming, goat farming, ostrich bird farming, and emu bird farming. Sheep farming, beef farming or a mixture of both make up nearly 80 percent of the land area in the catchment[61]. These farms are located mostly to the north of Masterton, and on the eastern side of the Ruamahanga River. Dairy farming predominates on the alluvial plains around Carterton and around the shores of Lake Wairarapa (Figure 9-1). Dairying comprises 13 percent of land area, and ten percent of farms in the catchment.

In 2006 there were around 63,500 dairy cows in the Masterton, Carterton and South Wairarapa Districts, comprising 175 farms, with an average herd size of 367 (Livestock Improvement, 2006, p.4). As at November 2006, there were 179 consents to discharge dairy effluent to land in Wairarapa, and only three consents to discharge effluent to water.

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[61] Note that not all of the Ruamahanga Catchment has been divided up into AgriBase parcels, i.e. the Tararua Ranges, and the Aorangi Ranges have not been included.

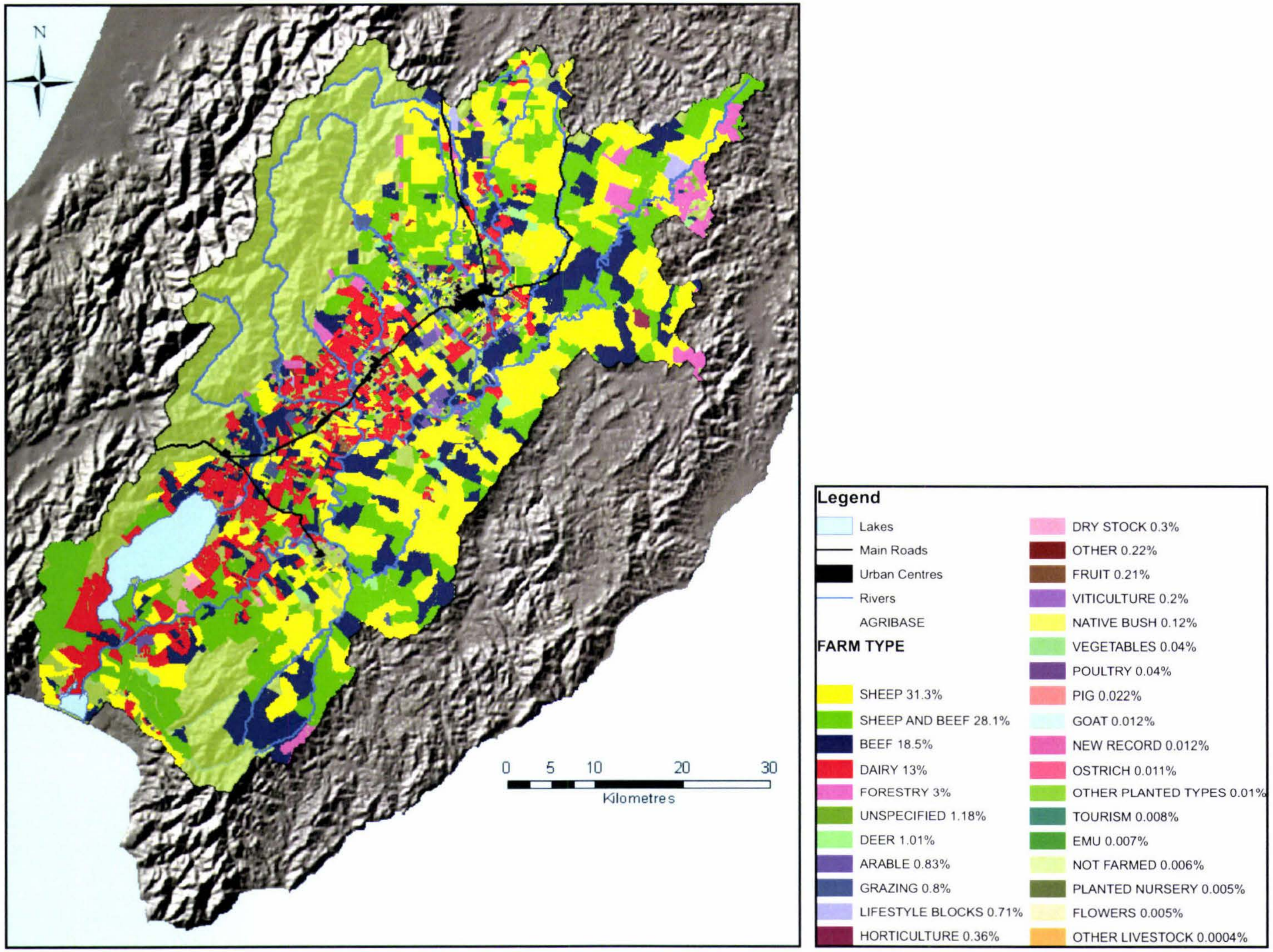

Figure 9-1: Land use in the Ruamahanga Catchment derived from AgriBase (2001), a full version of this data is supplied in Appendix 13.

The number of consents to discharge effluent to water has dropped significantly in recent years. A list of the expired or superceded consents as at November 2006, showed that 96 of these 366 expired consents were to allow discharge to water bodies (GWRC consent information; (K. Forsyth, 2005)). Forsyth (2005, p. 15) concluded that the shift in effluent discharges from water to land has meant a decrease of 60 tonnes of nitrogen being discharged directly into rivers annually in the Wellington Region.

As at November 2006, there were a number of consents to abstract water for the agricultural sector. Many farms also utilise the water races when supplying water to their properties.

One of the largest piggeries in the country is located within Wairarapa, near Carterton. It holds around 11,000 pigs. This operation "discharges up to 550 cubic metres of effluent to land per day" (K. Forsyth, 2005, p. 14).

9.4.2. Horticultural Overview

Horticultural enterprises, including pip fruit, berry fruit, grape and vegetable growers were operating within Wairarapa from an early stage. The first vines were planted in the region around 1882, when some French nationals settled in the area. Viticulture and fruit growing are now the dominant horticultural land uses in the Ruamahanga Catchment - although they only occupy 0.21 percent and 0.20 percent of the farmed land area respectively.

As at 2001, there were 38 fruit growers in Wairarapa, with pear and apple orchards scattered around Masterton and Greytown, and a few east of Martinborough. Twenty one vineyards were identified in AgriBase. The majority of these are located around Martinborough, which is thought to be Wairarapa's oldest and best known wine area. However, several larger vineyards are located south of Masterton, on the banks of the Waingawa River, and also near Gladstone, on the banks of the Ruamahanga and Taueru Rivers. Six market gardens were recorded, the largest of which are located around the

Greytown area. The popular Parkvale Mushroom is also grown in, and distributed from, Wairarapa, on the outskirts of Carterton.

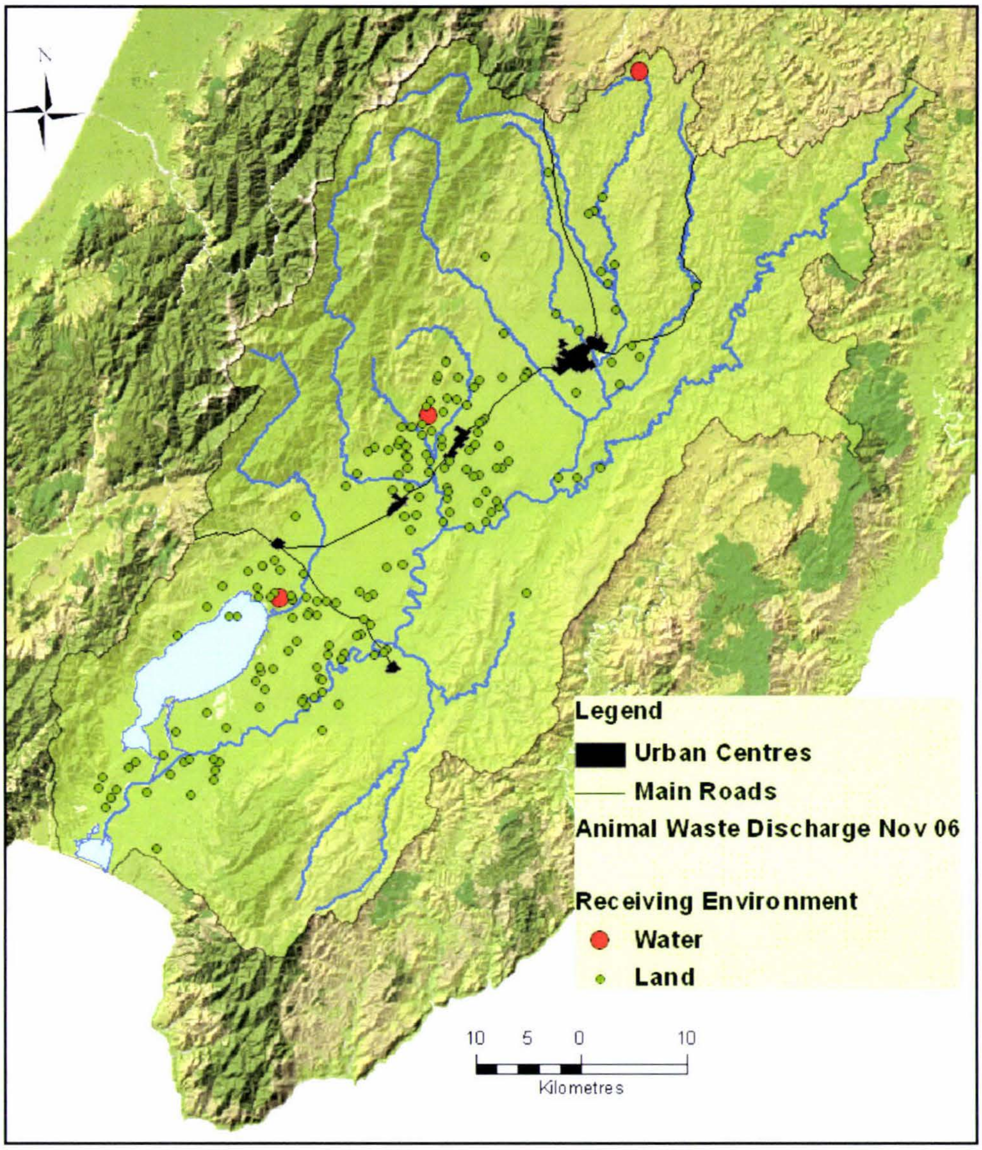

Figure 9-2: Animal waste discharge consents to land and to water as at November 2006.

Although horticultural practices do not generate significant amounts of discharge that directly enters the waterways, some of them abstract large volumes of water for irrigation and frost control. In the Ruamahanga Catchment there are about five water abstraction consents for horticultural practices ranging from 691 m^3/day to 12,614 m^3/day, taken from rivers and streams, and around 31 water abstraction consents ranging from 28.8 m^3/day to 1,048 m^3/day taken from groundwater bores[62].

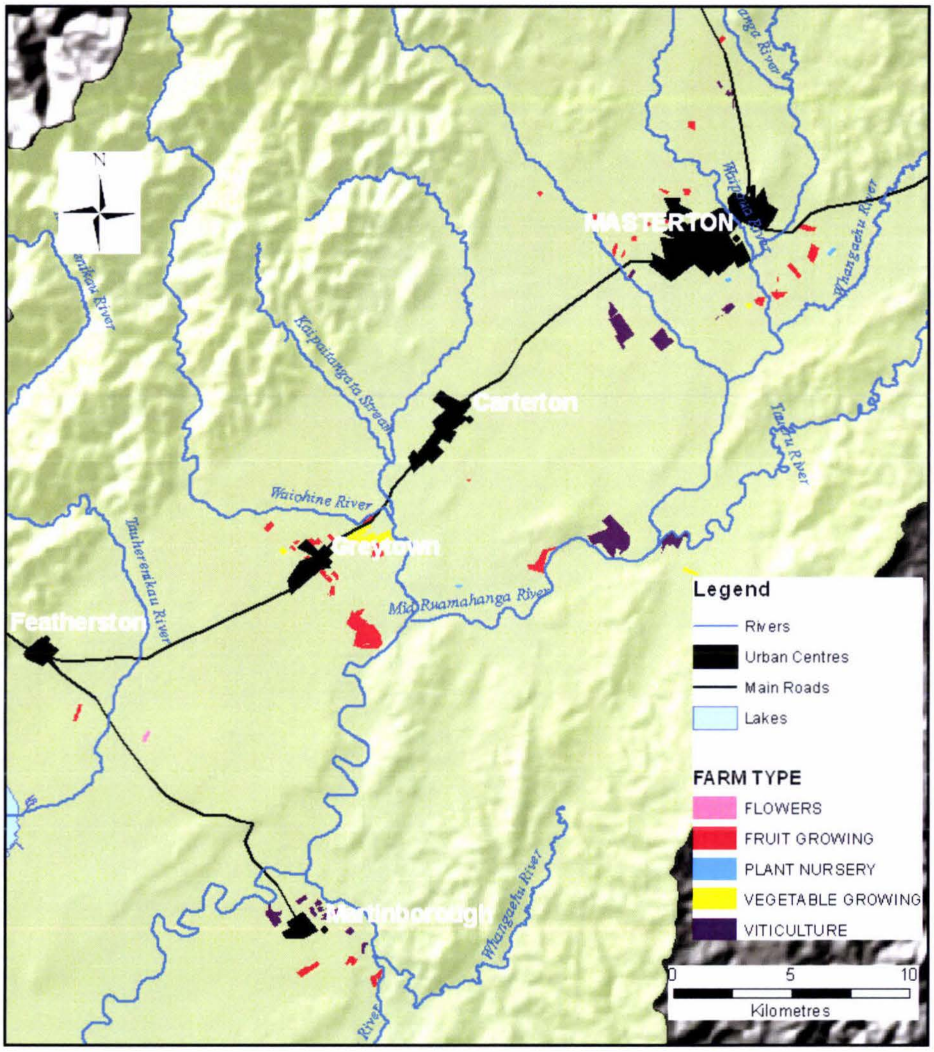

Figure 9-3: Horticultural land use in the Ruamahanga Catchment derived from AgriBase

9.4.3. Forestry Overview

Indigenous forest, including broadleaved hardwoods is the most dominant forest type in the catchment; they are widespread over the Rimutaka and Tararua ranges, and Aorangi Mountains. Remaining forestry in the catchment is patchy, as evident in Figure 9-4.

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[62] These are estimated figures only, due to the inability to relate all consents to a land use type.

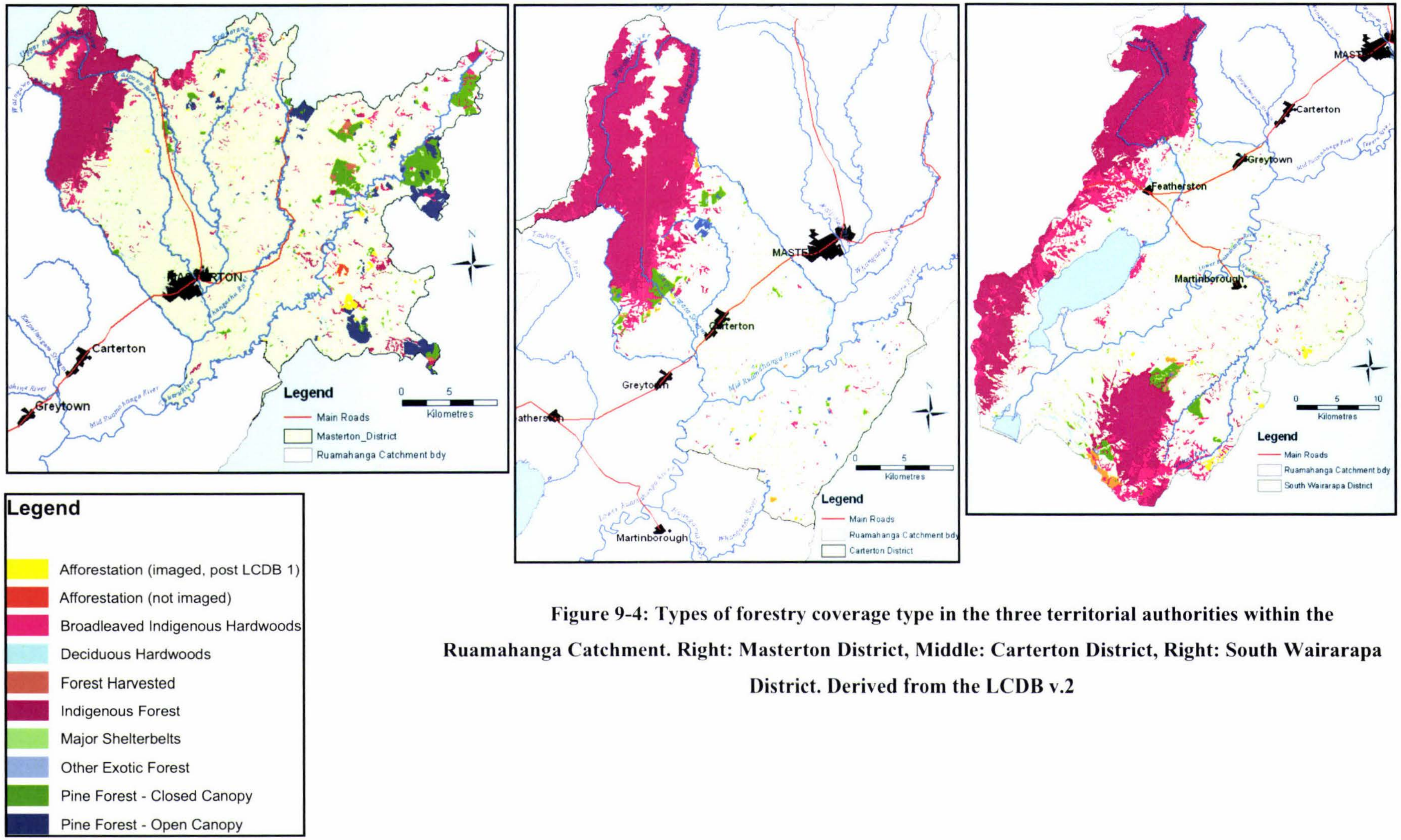


Figure 9-4: Types of forestry coverage type in the three territorial authorities within the Ruamahanga Catchment. Right: Masterton District, Middle: Carterton District, Right: South Wairarapa District. Derived from the LCDB v.2

Commercial pine forests are located in the northeast quadrant of the Masterton District, in the foothills in the Carterton District and around the Aorangi Mountains in the South Wairarapa District. Some of the trees in this latter area have since been felled but were originally strategically planted by GWRC to reduce erosion (G. Copps, Personal Communication, 7 August 2007). The maps in Figure 9-4 were separated into Territorial Authority (TA) boundaries to enable identification of the individual types of forestry cover. At the whole catchment scale this was not possible.

Table 9-1 provides the plantation statistics for the three TAs in Wairarapa. The corresponding areas and standing volumes for just the Ruamahanga Catchment would be considerably less than these values since the majority of the plantations (e.g. Ngaumu Forest) are outside the catchment boundary located on the eastern Wairarapa hill country.

Territorial authority	**Area (ha)**	**Standing volume (000 m^3)**	**Area-weighted average age (years)**
Masterton District	33 194	8 617	15.07
Carterton District	12 852	3 045	13.65
South Wairarapa District	9 044	1 828	13.08
Region total	**168 447**	**39 460**	**13.87**
North Island total	**1 267 060**	**329 498**	**14.48**

Table 9-1: Plantation Statistics for the TAs in the Ruamahanga Catchment. Source (MAF, 2006)

9.4.4. Industry Overview

Several large companies operate out of the Ruamahanga Catchment including: primary manufacturing industries (e.g aggregate companies, wood manufacturing plants, lime works etc.); food processing companies (e.g. Hansells (NZ) Ltd and Breadcraft Ltd); and electronics companies (Marconi Online). The impact these industries exert on the waterways in the catchment varies.

A number of aggregate companies in the Ruamahanga Catchment extract gravel from the river beds. These companies include Oldfield aggregates, Bruce Buchanan Ltd, Winstone Aggregates, Wairarapa Aggregates, K Pope and J Grey Contractors, Martinborough sand

and gravel, Martinborough Transport, Master Roads and Services and PJ Warren Earth Moving.

According to GWRC, the main extractors are Oldfield Aggregates Ltd and Wairarapa Aggregates who take approximately 100,000 m^3 of gravel and shingle annually. Other companies including Wairarapa Sand & Metal Ltd, R.E.Brooks Ltd, Fulton Hogan, Martinborough Transport Ltd, Kelvin Pope & John Gray Contractors Ltd extract around 2,000-5,000 m^3 annually (D. Peterson, Personal Communication, 14 June 2007). These figures are provided to GWRC by the extractors. There may also be some unlicensed extraction. Gravel extractors are charged a royalty of $1 per m^3 of gravel.

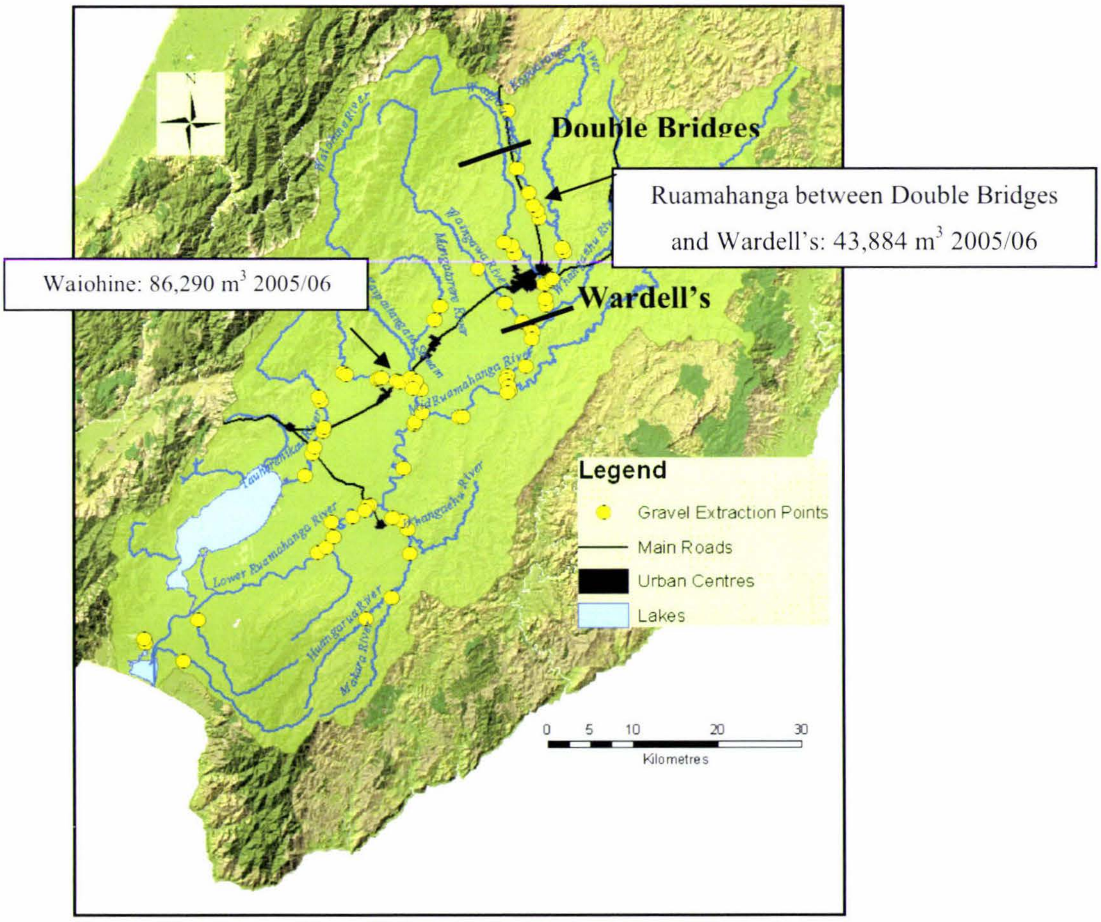


Figure 9-5: Location of gravel extraction points in the Ruamahanga Catchment, and indications of the two main extraction areas and volumes that were extracted in the 2005/06 period.

The Waingawa Freezing Works once operated on the southern side of the Waingawa River, south of Masterton. This plant closed down in 1989, but the facilities were later taken over by Affco NZ Limited. Affco held consents for discharging treated works processing waste into the Waingawa River, and onto land by travelling irrigators.

A number of primary wood manufacturing plants exist within the catchment, including Juken Nissho Ltd NZ, Renall Limited, Davis Sawmill, East Taratahi Sawmill, Green Crow Pacific, Kiwi Timber Products and Trading Ltd/Kiwi Wood Processing Ltd, Horowhenua Saw Doctors, Eurocell Sawmilling and Kiwi Lumber. A number of these manufacturing plants hold consents to discharge waste to waterways and discharge odour and contaminants to the air.

The eastern hills in the Ruamahanga Catchment provide areas suitable for quarrying lime. Lime companies in the catchment include Taueru Lime, Hatuma Lime, Central Lime, Pakohe Lime Co Ltd and the Mauriceville lime works. Generally lime companies hold consents to discharge dust to the air.

Figure 9-6: a) Taueru Limeworks b) Mauriceville Limeworks

Genesis Energy operates a hydro power scheme in the eastern Wairarapa hill country, commissioned in 1923. The Kourarau scheme generates 1MW of renewable energy and consists of two small power stations and a reservoir created by damming the Kourarau Stream (Genesis Energy, 2006). The scheme was significantly damaged in the 2005 floods, and repairs were completed in mid 2006. The power station has resource consent to discharge water and any material associated with hydroelectricity generation at a maximum rate of 0.9 m^3/s into the Kourarau Stream.

The Hau Nui Wind Farm is situated on the eastern Wairarapa hills. This wind farm consists of seven turbines, and a new consent has been granted for another eight. Meridian Energy also has consent to carry out further wind testing (G. Copps, Personal Communication, 14 August 2007).

9.4.5. Human Settlement

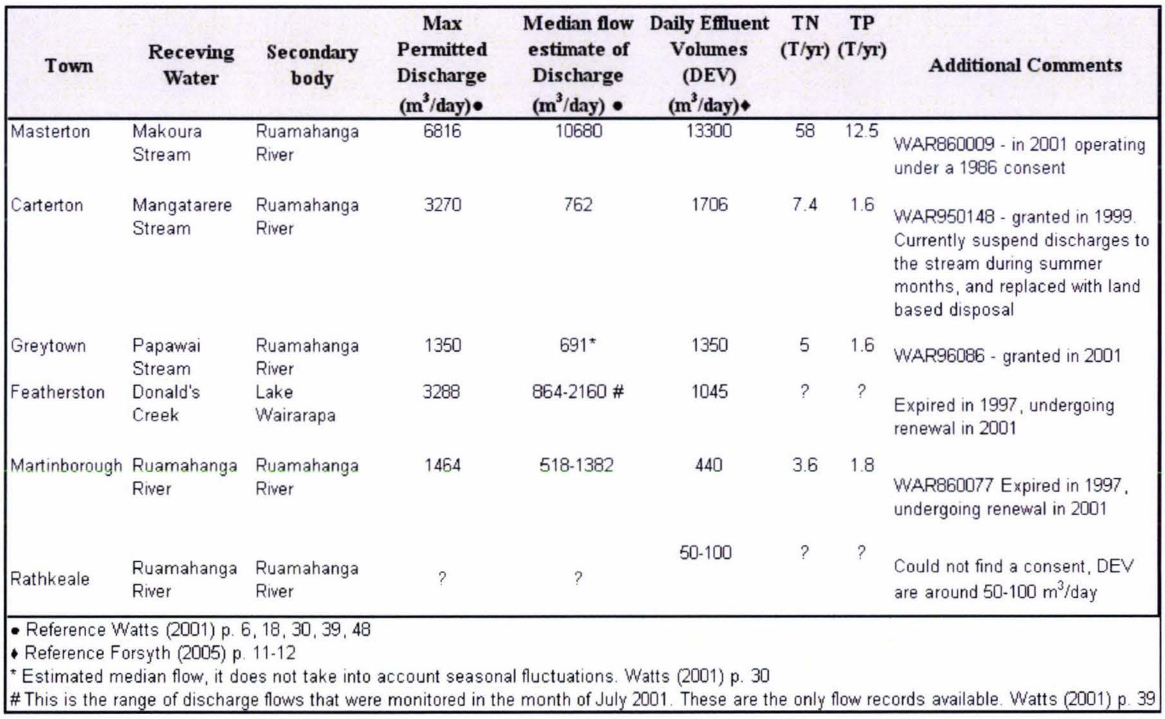
The location and size of the settlements in the Ruamahanga Catchment have been previously described in Chapter 4, and their water supply and sewerage systems were outlined in the infrastructure section of Chapter 5. The information in Table 5-5 and Table 5-6 summarised these systems which were subsequently shown in Figure 5-16.

The maximum consented water abstractions for each of the five main population centres in the catchment are provided in Table 9-2. In addition to these, water is abstracted for three separate water supply associations within the Ruamahanga Catchment: Fernridge water supply association; Gladstone water supply association; and Opaki water supply association, however the quantity that they abstract is considerably less.

Town	Water Supply	Max Consented Abstraction (m^3/day)	Consent Number
Masterton	Waingawa River	40000	WAR94008004
Carterton	Kaipatangata Stream	6912	WAR020050
	Bore water	3456	WAR 050013
Greytown and Featherston	Waiohine River, diversion channel	15552	WAR99014201
	Bore water (when required)	8184	WAR040067
Martinborough	Groundwater (2 bores 1500 m from town)	7776	WAR990001
	Huangarua River (when required)	3456	WAR93012401

Table 9-2: Water abstracted for public water supply in the main centres

The data provided in Table 9-3 outlines the discharge information for each of the main population centres in the Ruamahanga Catchment, and for Rathkeale College in Masterton. The table also provides the Total Nitrogen (TN) and Total Phosphorus (TP) loadings from each discharge point. These values have been gathered from Watts (2001), Forsyth (2005) and Milne & Perrie (2006). Four of the five town's discharges had median flows well below the maximum permitted discharge apart from Masterton, whose median discharge flow was significantly higher. Watts (2001, p. 6) stated that the high median flows have been "attributed to leaks in the reticulation system and partial submersion of the system below groundwater level at times". Masterton District Council is in the process of upgrading the treatment plant. At the time of writing the resource consent renewal process for the plant had just completed the submission stage and a hearing is likely to take place in early 2008 (S. Thawley, Personal Communication, 5 October 2007).



Town	Receving Water	Secondary body	Max Permitted Discharge (m^3/day)●	Median flow estimate of Discharge (m^3/day) ●	Daily Effluent Volumes (DEV) (m^3/day)♦	TN (T/yr)	TP (T/yr)	Additional Comments
Masterton	Makoura Stream	Ruamahanga River	6816	10680	13300	58	12.5	WAR860009 - in 2001 operating under a 1986 consent
Carterton	Mangatarere Stream	Ruamahanga River	3270	762	1706	7.4	1.6	WAR950148 - granted in 1999. Currently suspend discharges to the stream during summer months, and replaced with land based disposal
Greytown	Papawai Stream	Ruamahanga River	1350	691*	1350	5	1.6	WAR96086 - granted in 2001
Featherston	Donald's Creek	Lake Wairarapa	3288	864-2160 #	1045	?	?	Expired in 1997, undergoing renewal in 2001
Martinborough	Ruamahanga River	Ruamahanga River	1464	518-1382	440	3.6	1.8	WAR860077 Expired in 1997, undergoing renewal in 2001
Rathkeale	Ruamahanga River	Ruamahanga River	?	?	50-100	?	?	Could not find a consent, DEV are around 50-100 m^3/day

● Reference Watts (2001) p. 6, 18, 30, 39, 48
♦ Reference Forsyth (2005) p. 11-12
* Estimated median flow, it does not take into account seasonal fluctuations. Watts (2001) p. 30
# This is the range of discharge flows that were monitored in the month of July 2001. These are the only flow records available. Watts (2001) p. 39

Table 9-3: Receiving bodies for discharge and discharge volumes for the main centres in the Ruamahanga Catchment.

With the large area of land being converted into lifestyle blocks, there has been an increase in the number of septic tanks in the region. Poorly managed septic tanks can potentially contaminate the groundwater surrounding them. GWRC are currently compiling a database of information on the characteristics of existing septic tanks, and the Ministry for the Environment is considering introducing legislation that relates to a "warrant of fitness" for septic tanks (Wellington City Council, 2005).

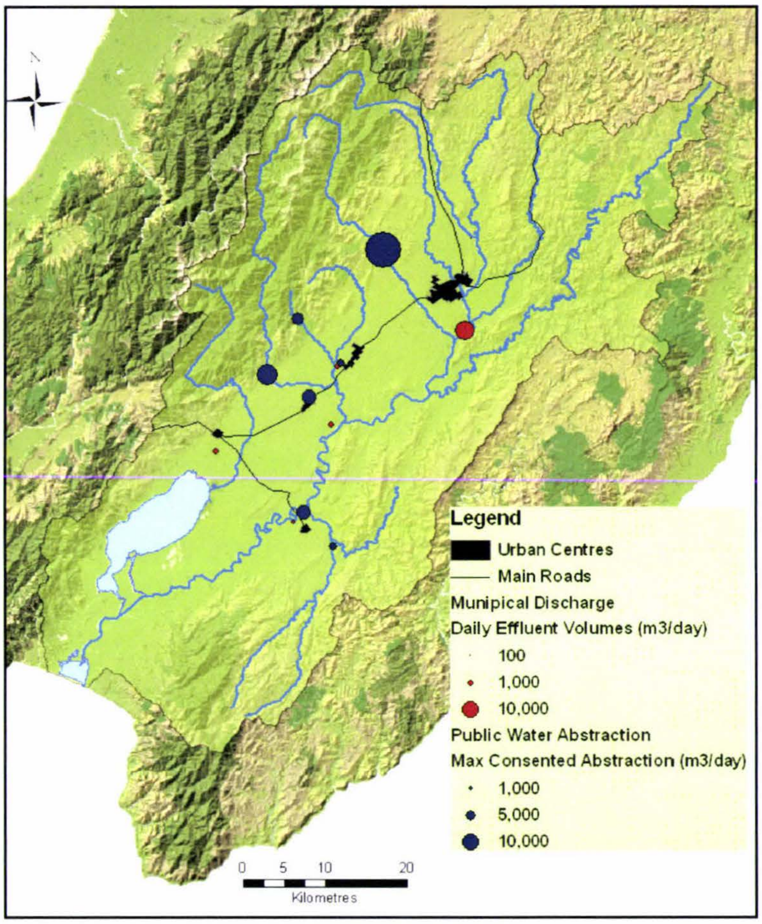


Figure 9-7: Daily effluent volumes (m^3/day) and maximum consented water abstraction (m^3/day) for the main centres in the catchment

9.4.5.1. Solid waste

Although solid waste does not directly impact on water quality in the catchment, it can have secondary effects on groundwater quality as landfills can generate leachate which can filter into the aquifers. Since October 2006 most of the solid waste generated in Wairarapa has been transported to the landfill at Bonny Glen in the Rangitikei District, at a cost of around $2 million annually (Waste Management Wairarapa, 2006). Historical landfills may still be impacting on both surface water quality and groundwater quality, especially since some are located directly adjacent to the river and stream beds.

Thirty one landfills have been identified in the Ruamahanga Catchment (Purchas, 1998), but only a few are still operational as transfer stations: Nursery Road (Masterton Landfill), Dalefield Road (Carterton Landfill), Martinborough - Pirinoa Road (Martinborough Landfill). Transfer stations are also located in Mauriceville, Featherston (Johnson Street), Greytown (Cotter Street) and Pirinoa. These latter three accept recycling and green waste only. The location of some of these transfer stations are shown in Figure 9-8.

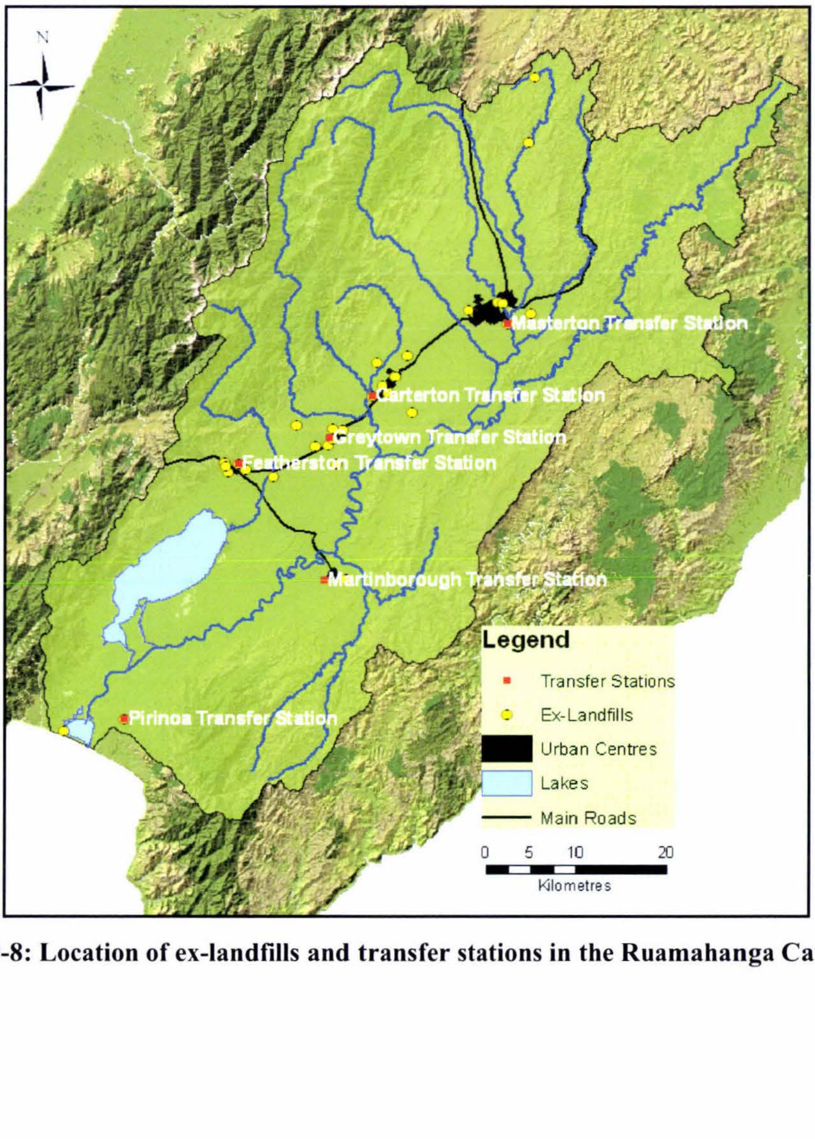


Figure 9-8: Location of ex-landfills and transfer stations in the Ruamahanga Catchment

9.5. OVERVIEW OF WATER ABSTRACTION AND DISCHARGE

The abstraction points and the associated land uses that individually take over one percent of allocated water are shown in Figure 9-9 for both surface water and groundwater. The South Wairarapa and Masterton District Councils are the only two public water supply points that comprise over one percent each of total surface water abstraction. Martinborough's public water supply makes up a large proportion of total groundwater abstractions. A number of the larger surface water abstractions are for water race replenishment, and irrigation, while the majority of the larger groundwater takes are for irrigation only.

The maps provided in Figure 9-10 indicate the surface water management zones and groundwater management zones that are currently under severe pressure from water abstraction. Due to this current pressure, water availability in the future will be a big issue for the Ruamahanga Catchment. "Wairarapa's land-based economy can only raise productivity and profitability if limiting factors are removed – and, for many farmers, a major barrier is access to water" (Go Wairarapa, 2007, para. 3).

Nineteen of the most significant current discharge consents are shown in Figure 9-11 as identified by GWRC. The consent with the largest maximum allowed flow (L/sec) is for the Masterton District Council to discharge urban stormwater into a river after being diverted through the QE11 Park Lake.

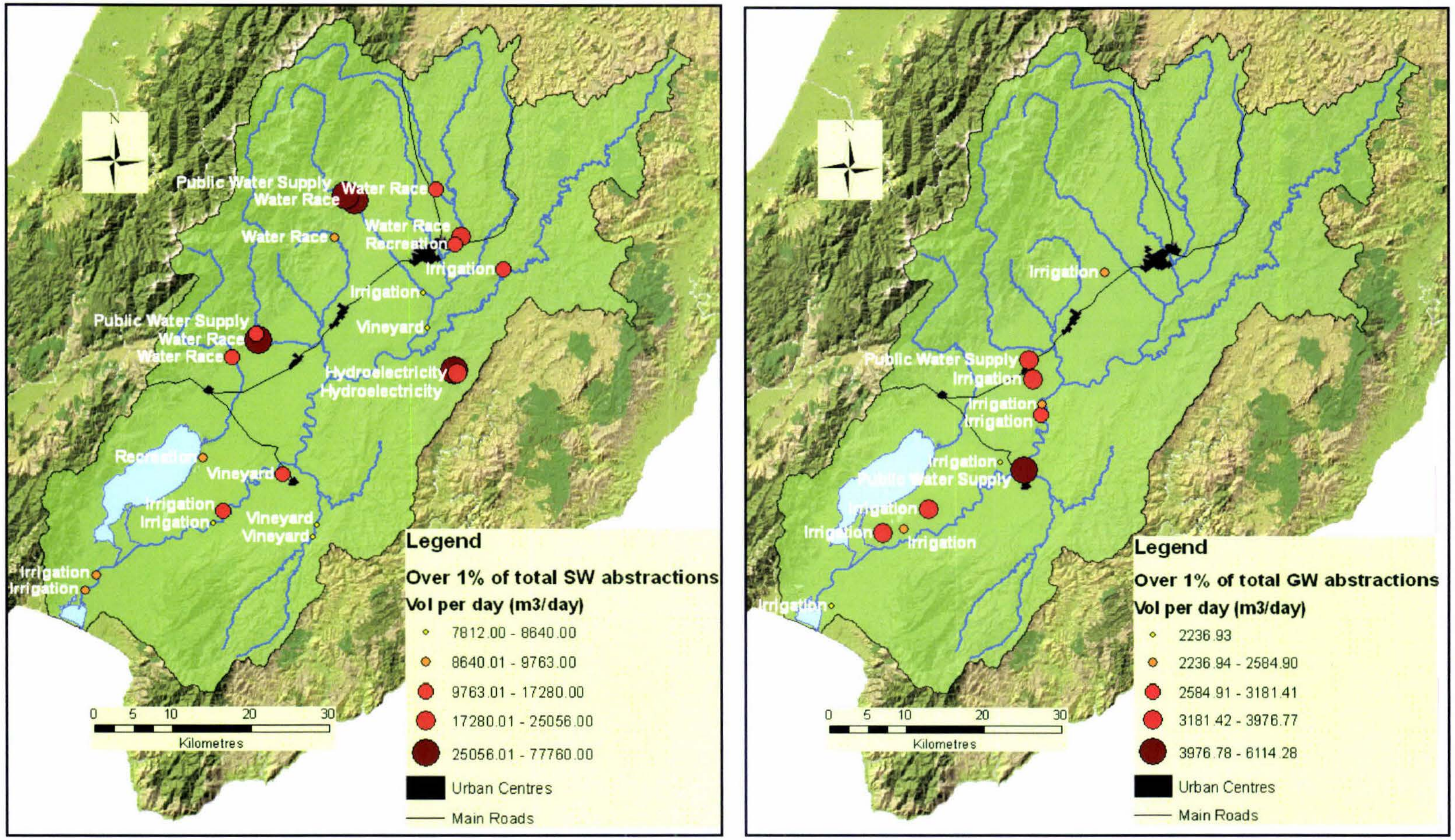


Figure 9-9: a) Surface water abstraction points that individually take over 1 percent of allocated surface water and b) Groundwater takes that individually take over 1 percent of allocated groundwater

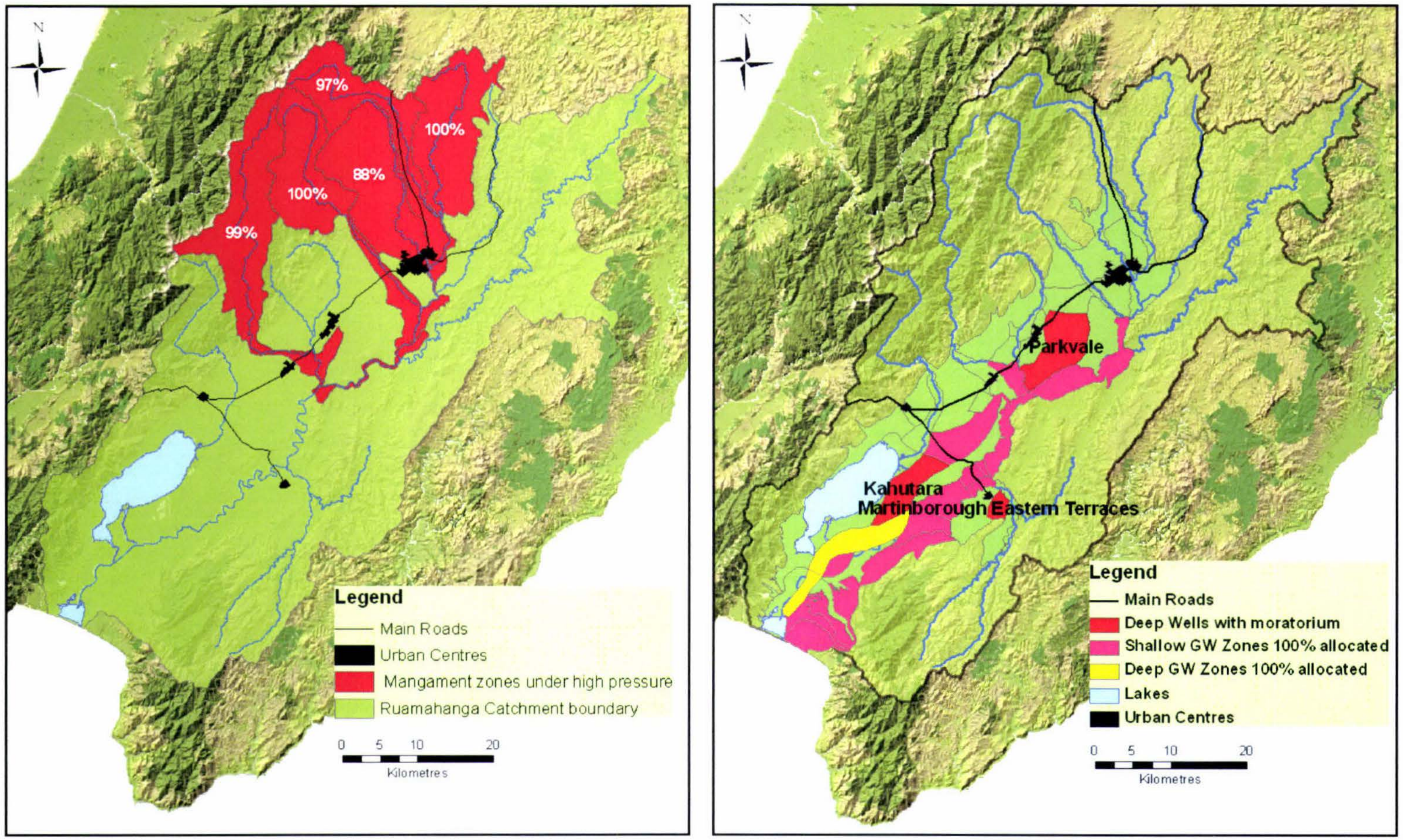


Figure 9-10: a) Surface Water Management Zones with abstraction totaling more than 95% of core allocation. Source (Watts, 2005, p. 11-12). b) Groundwater Management Zones with 100% water allocation or with a moratorium

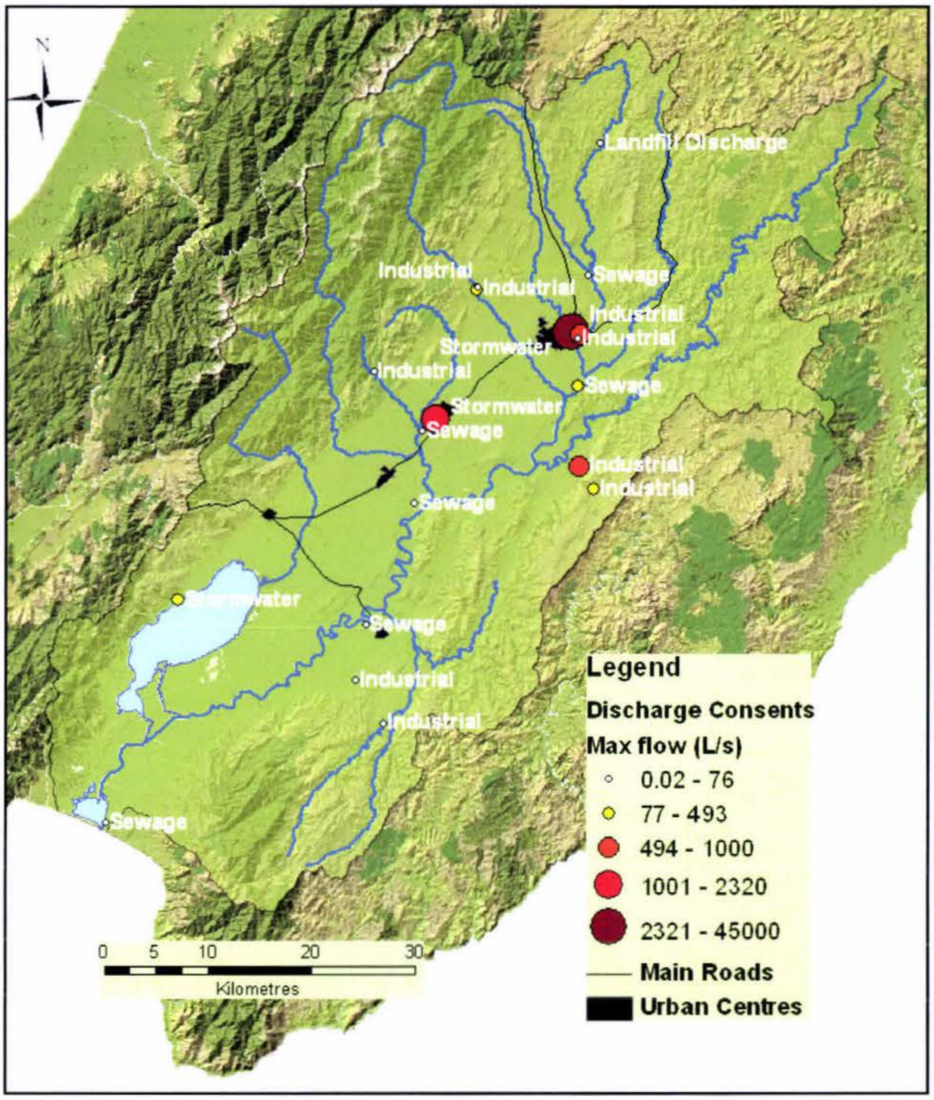


Figure 9-11: Significant current discharge consents in Ruamahanga Catchment

9.6. EFFECT OF LAND USE ON WATER QUALITY

Chapter 8 of this report outlines certain rivers and streams with degraded water quality. The chapter concluded that the eastern and central tributaries were of lesser quality than the western tributaries, which drained the Tararua and Rimutaka Ranges. Milne and Perrie (2006) ranked the water quality monitoring sites for the period 1997-2003 according to the Water Quality Index in Section 8.2.2.2, Table 8-3. A similar ranking process was used in this section for fifteen of the River State of Environment (RSoE) sites for the period 2003-06[63]. This was carried out using only limited data and thus is only a first approximation. Each of the sites was ranked from one to 15 according to their average annual concentration of NH_4-N, NO_3-N and DRP for the 2003-06 period, and the median *E.Coli* coliform count for the same period. A site was given its overall ranking by averaging the four individual water quality rankings (Table 9-4).

The percentage of dairying per catchment area in each of the catchments upstream of the water quality monitoring sites was determined, using data from AgriBase. Upstream catchment areas integrate all of the land upstream of the site. For example, the Ruamahanga River at Pukio's catchment area included all of the Ruamahanga Catchment above the monitoring site at Pukio. The results are provided in Table 9-4 and Figure 9-12.

The REC land use classification rankings are also included in Table 9-4. These land use rankings can give some indication of relationships between land use and water quality. The catchments ranked from 5th to 15th in terms of water quality all drain pastoral land while the top four catchments with better water quality drain land indigenous forest/scrub land.

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[63] These 15 RSoE sites were selected to be used based on their relative positions in the catchment.

					Ranking of Ave Concentrations 03-06								
Rank	Site No.	Site Name		Upstream Area of site (km^2)	E.Coli Median cfu count	NO_3-N (g/m^3)	Amm.N (g/m^3)	DRP (g/m^3)	TOTAL - Average of Rankings	Area of dairying in upstream catchment (km^2)	% of dairying on land upstream from montioring site	# of granted discharge consents as at Nov 2006^ in upstream catchment	River Environment Classification (REC)
1	RS47	Waiohine River at Gorge	Upland River	184	3	1	3	2	2.25	0	0	0	CX/H/HS/IF
2	RS31	Ruamahanga River at McLays	Upland River	72	2	2	4	1	2.25	0	0	0	CX/H/HS/IF
3	RS49	Beef Creek at Headwaters	Upland River	3	1	3	2	6	3	0.2	5.4	0	CW/L/HS/S
4	RS41	Waingawa River at South Road	Lowland River	144	4	4	1	3	3	2.2	1.5	7	CX/H/HS/IF
5	RS51	Huangarua River at Ponatahi Bridge	Lowland River	309	10	5	5	5	6.25	0	0	5	CD/L/SS/P
6	RS31	Ruamahanga River at Te Ore Ore	Lowland River	308	8	7	6	7	7	16.7	5.4	7	CW/L/SS/P
7	RS48	Waiohine River at Bicknells	Lowland River	392	6	6	7	9	7	66.1	16.9	68	CW/H/HS/P
8	RS40	Waipoua River at Colombo Road Bridge	Lowland River	174	7	12	8	4	7.75	1.7	1	15	CW/L/HS/P
9	RS34	Ruamahanga at Pukio	Lowland River	2459	9	8	9	10	9	144.4	5.9	195	CW/L/SS/P
10	RS33	Ruamahanga River at Gladstone Bridge	Lowland River	1337	5	9	12	12	9.5	35.7	2.7	69	CW/L/SS/P
11	RS37	Taueru River at Gladstone	Lowland River	497	11	10	13	8	10.5	3.0	0.6	5	CD/L/SS/P
12	RS38	Kopuaranga Stream at Stewarts	Lowland River	166	13	11	10	11	11.25	11.5	6.9	15	CW/L/SS/P
13	RS39	Whangaehu River 250 u/s confl.	Lowland River	142	14	14	11	13	13	5	3.6	5	CD/L/SS/P
14	RS50	Mangatarere River at SH2	Lowland River	119	12	13	15	15	13.75	31.8	26.8	30	CW/L/HS/P
15	RS46	Parkvale at Weir	Lowland River	51	15	15	14	14	14.5	10.4	20.4	11	WD/L/AL/P

^ Discharges to land and water including sewage, animal waste, stormwater, agrichemical and industrial. Excludes discharges to air

Table 9-4: Water Quality Ranking Sites

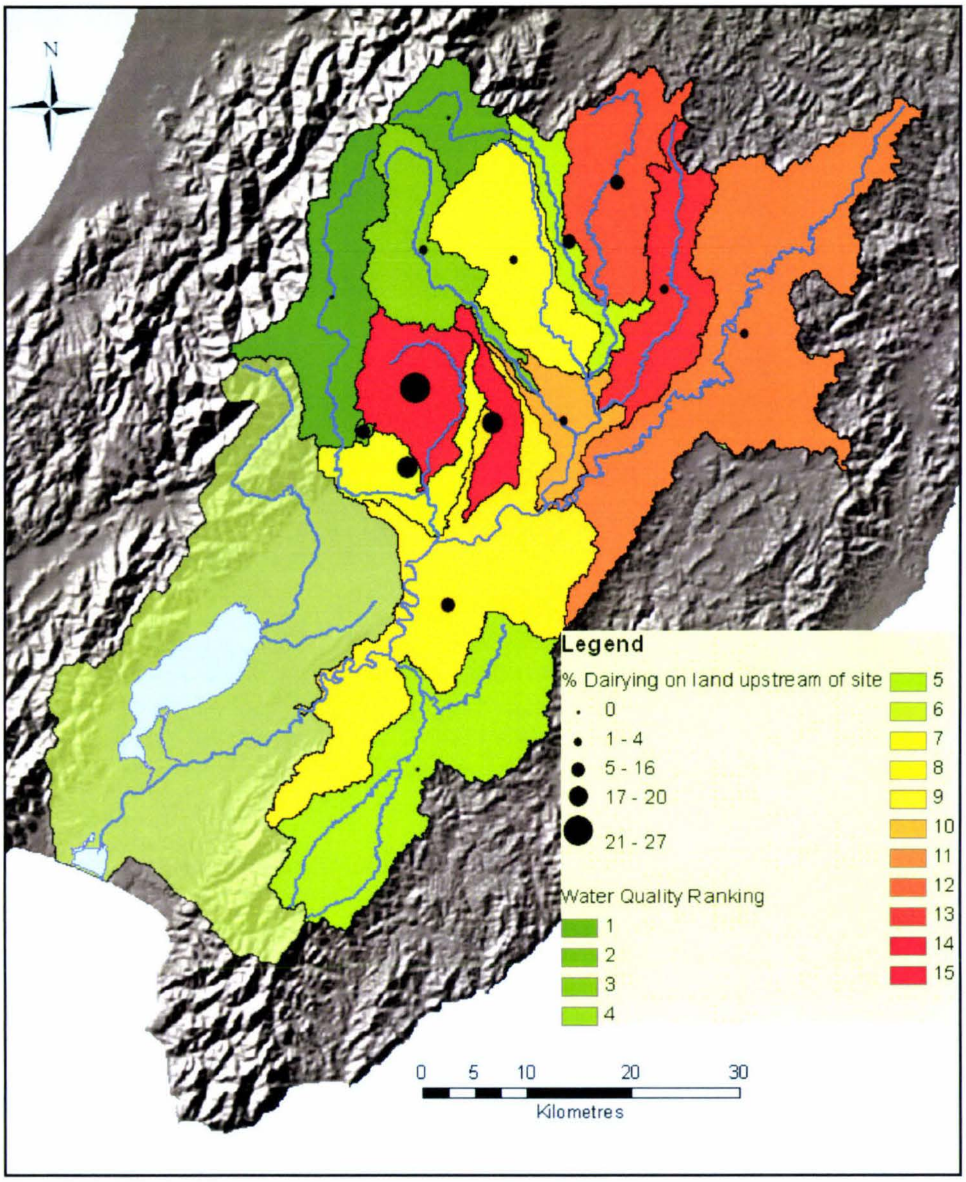

Figure 9-12: Catchments ranked according to water quality and percentage of dairying on land upstream of monitoring site

Figure 9-12 shows the catchments ranked according to the average annual concentrations for the four variables and the sizes of black circles indicate the percentage of dairying per upstream catchment area. The two most degraded catchments, Mangatarere and Parkvale (ranked 14th and 15th) have around one quarter to one fifth of their upstream land area in dairying. The Waiohine River at Bicknell's has the third largest percentage of upstream land in dairying at just under seventeen percent, but is only ranked about average (7th) in regards to water quality. Reasons for this could be put down to the large volumes of water that move through this particular catchment, diluting any contaminants that may be in the waterway.

Figure 9-13 displays the relationship between the ranking of the water quality sites and the percentage of dairying upstream from the monitoring point. This plot reveals that there is not a straight forward relationship between the two variables. There are some monitoring sites that were ranked quite poorly in terms of water quality with only small amounts of dairying in their upstream catchment. This highlights that in the Ruamahanga Catchment, there are other factors contributing to degraded water quality apart from dairying.

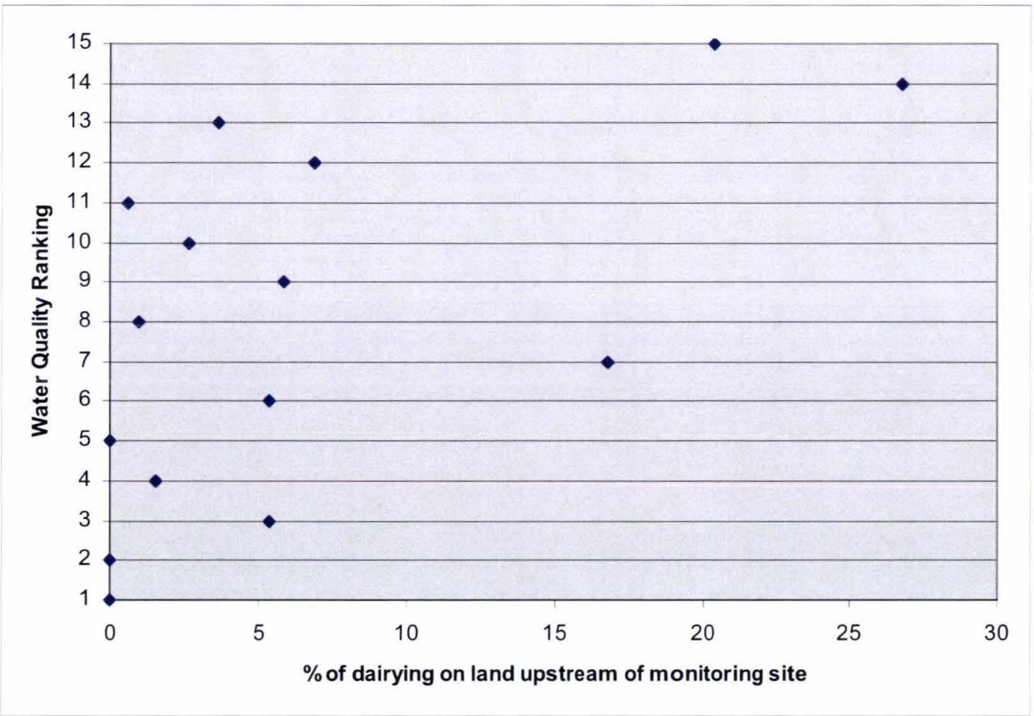

Figure 9-13: Ranking of Water Quality sites versus the percentage of dairying on the land upstream of the monitoring site.

The water quality chapter of this report (Chapter 8) indicated that municipal sewage discharge plays a significant part in water degradation in the Ruamahanga Catchment. The volume of total nitrogen (TN), total phosphorus (TP) and dissolved reactive phosphorus (DRP) discharged from the Masterton Sewage works was discussed in

Section 8.2.3. A sharp peak in DRP loading was noted between two monitoring sites in the Ruamahanga River, between Te Ore Ore and Gladstone, however the volume of TN discharged into the river was not as evident due to the background loadings of TN already present in the Ruamahanga River. Watts (2001, p. 16) found similar results in regard to the Masterton Sewage Works, downstream of the confluence of the Makoura Stream and the Ruamahanga River, significant increases in NH_4-N and DRP loadings were identified in addition to "a conspicuous change in water clarity"

The Ruamahanga River at Gladstone (the site directly downstream of the sewage outflow) was ranked 10th of the 15 monitoring sites for water quality in Table 9-4. However it was found that only a small percentage (three percent) of the upstream land was in dairying. This indicates that at Gladstone, the water quality degradation is likely to be more influenced by the sewage works rather than dairying.

The effects of the other municipal discharges on the water quality in the Ruamahanga River were not analysed in Section 8.2.3 of this report because no other large abnormalities were found in the downstream estimates of nutrient loads. However, Watts (2001) commented on the negative effects the Martinborough municipal discharge was having on the Ruamahanga River downstream of the outlet. These include considerable increases in DRP, NO_3-N and NH_4-N, and in *E.Coli* and faecal coliform bacteria counts. The Ruamahanga River site at Pukio, which is the downstream monitoring point from Martinborough and the last point on the river before the sea, showed high levels of *E.Coli*, frequently breaching the drinking water MAV, and often breaching the bathing water MAV.

In conclusion, land use (which is not limited to dairying), and municipal effluent discharges are having a large negative impact on the water quality in the Ruamahanga Catchment. If the intensification of agricultural practices continues it is expected that water quality in the catchment will be subject to further degradation. In regards to municipal effluent, consideration should be given to land based application as is done in

Carterton in the summer months, this allows for further filtration before the waste water reaches the water system.

9.7. RIPARIAN MANAGEMENT

Riparian management, involving fencing and planting along a stream margin, is a technique commonly employed to minimise the effects on water ways from land use. In addition to "filtering sediment and nutrients from runoff before it enters the water" it can "help stablise banks, shade out water weeds, cool the water for aquatic life and provides a variety of habitats for birds, fish and animal life" (Environment Waikato, 2002, p. 21).

The usefulness of riparian strips in preventing nutrients from reaching water ways stems from the fact that they are located in the zone between terrestrial and aquatic ecosystems and that most surface and shallow sub surface water must pass through them to reach the waterway (Naiman, Decamps, & McClain, 2005).

GWRC realises the importance of riparian management in the region and provides farmers and landowners with advice on implementing management programs. Currently GWRC assists in 12 catchments in the region, four of which are in the Ruamahanga Catchment (Upper Ruamahanga River, Upper Waiohine River, Waihora Stream and Owhanga Stream), by supplying assistance in creating a management plan and by providing free native plants, planting and weed control. This initiative is called the "Streams Alive" program and has identified the 12 catchments to have high ecological value, with at least 40 percent of the stream length to be in good condition (Greater Wellington Regional Council, 2007c).

GWRC has also produced a stream-side manual "Mind the Stream" (Greater Wellington Regional Council, 2004c), that can be downloaded from their website. An additional resource for riparian management is 'Managing waterways on farms' (Ministry for the Environment, 2001).

There are various care groups that operate within the Ruamahanga Catchment improving a variety of environments around streams and wetlands with the support of GWRC.

These include Papawai Stream Community Group, Fensham Wetland Group, Henley Wetland Care Group, Friends of Millennium Reserve, Enaki Stream Care Group. Waihora KNE, and Whangaehu River Group.

9.8. LAND USE CHANGE AND TRENDS

9.8.1. Agriculture

Statistics New Zealand release agricultural production statistics. A problem with utilising this data is that it is provided according to the regional council boundary or territorial authority (TA) boundary. Since the Ruamahanga Catchment boundary overlaps all of the TA's but excludes large amounts of the land area, specifically on the east coast of Wairarapa, the data cannot be accurately used. However, it is likely that overall trends in agricultural statistics will still apply, even though specific numbers for the catchment can not be obtained.

Statistics New Zealand measure agricultural data according to a 'mesh block'[64] which is defined as "the smallest geographic unit for which statistical data is collected and processed by Statistics New Zealand" (Statistics New Zealand, 2007d). However this information is not publicly available due to confidentiality reasons, because at this scale property owners may be identified.

Data that can be freely obtained from Statistics New Zealand includes 'Hectares Used and Farms by Land Use by Territorial Authority', 'Farms by Farm Type (ANZSIC) and Territorial Authority', and 'Fertiliser Applied by Territorial Authority'. Information on dairy cows, sheep, beef, cropping, fruit trees, vines, vegetables and forestry can also be obtained, but at the TA level. Statistics New Zealand release Agricultural Production Statistics Reports, and Agricultural Statistics Reports, the latest of which was done in 2003, and work is underway on a 2007 report (Statistics New Zealand, 2007a). The results from this latter study will not be released until 2008. Statistics supplied by

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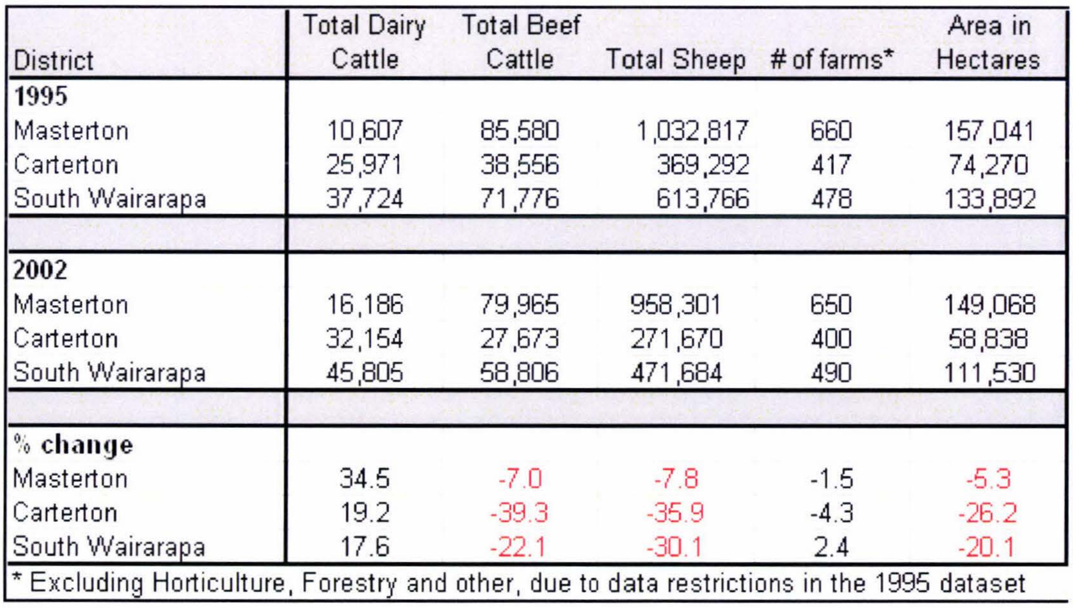
[64] Mesh blocks are merged to form larger geographic areas such as TA boundaries.

Ministry of Agriculture and Forestry (MAF)[65] and Livestock Improvement, are also presented at the TA level.

The identification of trends between the 1996 and the 2003 Agricultural Statistics were limited by the smaller number of categories that were included in the 1996 report. However stock and farm numbers, and areas of farmed land could be compared (Table 9-5). Obvious trends between these two data sets include the significant decrease in sheep and beef cattle (specifically in Carterton and South Wairarapa Districts) and the increase in dairy cows. The number of farms decreased slightly in the Masterton and Carterton districts, and the area of farmed land decreased significantly. This large decrease in the area of farmed land (used for sheep, beef and dairy farming), is likely to be caused by the increase in the number of subdivisions (Section 9.8.2) and also an increase in the number of vineyards and other horticultural practices in the area.



District	Total Dairy Cattle	Total Beef Cattle	Total Sheep	# of farms*	Area in Hectares
1995					
Masterton	10,607	85,580	1,032,817	660	157,041
Carterton	25,971	38,556	369,292	417	74,270
South Wairarapa	37,724	71,776	613,766	478	133,892
2002					
Masterton	16,186	79,965	958,301	650	149,068
Carterton	32,154	27,673	271,670	400	58,838
South Wairarapa	45,805	58,806	471,684	490	111,530
% change					
Masterton	34.5	-7.0	-7.8	-1.5	-5.3
Carterton	19.2	-39.3	-35.9	-4.3	-26.2
South Wairarapa	17.6	-22.1	-30.1	2.4	-20.1

* Excluding Horticulture, Forestry and other, due to data restrictions in the 1995 dataset

Table 9-5: Comparison of Stock and Farm numbers, and farmed land area in 1995 and 2002 for the three TA's in Wairarapa

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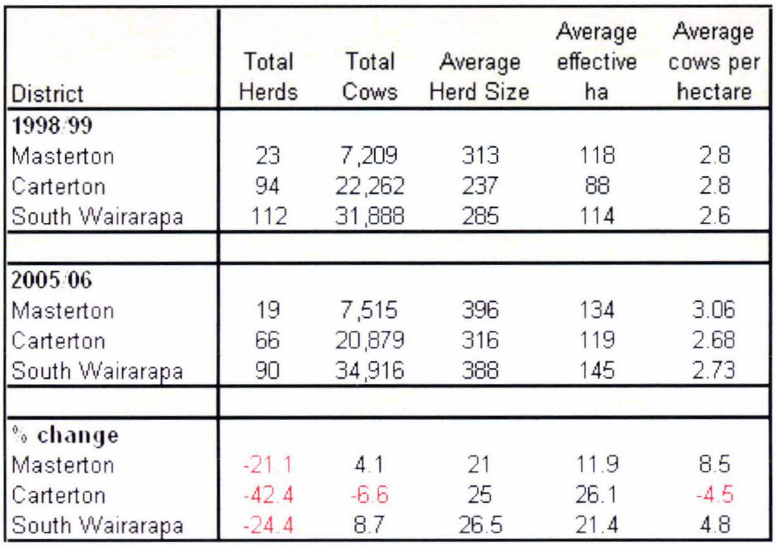
[65] MAF obtains their raw data from Statistics New Zealand

A further comparison of dairy herds using the TA boundaries was carried out using more recent Livestock Improvement data. The data shows that although the total number of herds has decreased since 1998/99, the average herd size has increased by one fifth to one quarter in all districts, and the average number of cows per hectare (i.e. the stocking rate) has increased in both the Masterton District and South Wairarapa District (Table 9-6). These increases are likely to worsen the impact on the environment. Some future projections for agriculture can be found on the MAF website[66] (Ministry of Agriculture and Forestry, 2006), however these are not per TA or regional council boundary.



District	Total Herds	Total Cows	Average Herd Size	Average effective ha	Average cows per hectare
1998/99					
Masterton	23	7,209	313	118	2.8
Carterton	94	22,262	237	88	2.8
South Wairarapa	112	31,888	285	114	2.6
2005/06					
Masterton	19	7,515	396	134	3.06
Carterton	66	20,879	316	119	2.68
South Wairarapa	90	34,916	388	145	2.73
% change					
Masterton	-21.1	4.1	21	11.9	8.5
Carterton	-42.4	-6.6	25	26.1	-4.5
South Wairarapa	-24.4	8.7	26.5	21.4	4.8

Table 9-6: Comparison of Dairy Herds in 1998/99 and 2005/06 for the three TA's in Wairarapa. Source (Livestock Improvement, 1999, 2006)

9.8.2. Subdivisions

Subdivision information can be obtained from district councils. After conferring with a member of the planning department in each of the three district councils in the Ruamahanga Catchment, it was confirmed that there has been a huge proliferation of lifestyle block conversions in the past 5 years.

In the new combined district plan there are significant issues in regards to subdivisions. The plan has introduced the concept of classifying rural land into 'Rural (Primary

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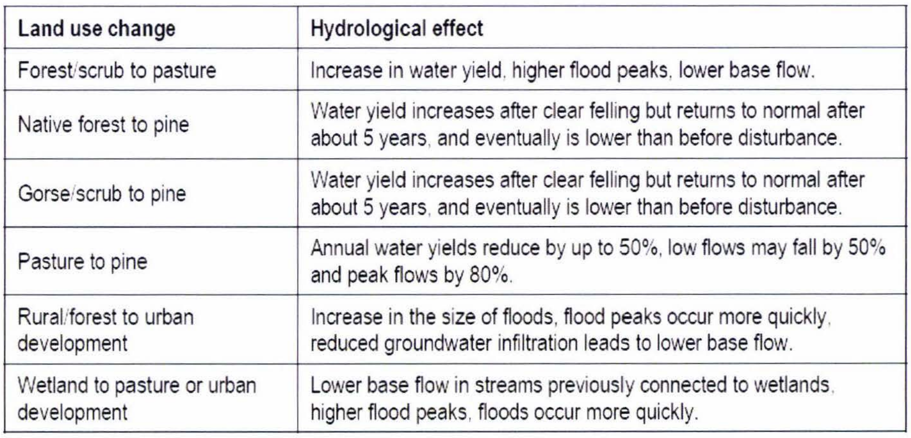
[66] www.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/sonzaf/2006/index.htm

Production) Zones', and 'Rural (Special) Zones' therefore enabling the councils to control the areas which can be subdivided. There is expected to be a flood of subdivision consents being applied for before the changes in the district plan come into force. The majority of the subdivisions are occurring near the main centres in the valley, and most of them are away from the rivers, but close to railway stations for the commuters to Wellington.

As seen in Chapter 4, there has not been a significant change in population in Wairarapa since the last census, however there has been a large increase in the number of dwellings, this has been put down to the increase in subdivisions, a smaller number of people per dwelling, and weekenders from Wellington buying properties. This translates to a developmental pressure occurring in Wairarapa rather than a population pressure (G. Copps, Personal Communication, 14 August 2007).

9.8.3. Impacts of Land Use Change on Water Resources

Watts (2005) and Basher (2003) have both made reference to how land use change can impact on water yields.



Land use change	**Hydrological effect**
Forest/scrub to pasture	Increase in water yield, higher flood peaks, lower base flow.
Native forest to pine	Water yield increases after clear felling but returns to normal after about 5 years, and eventually is lower than before disturbance.
Gorse/scrub to pine	Water yield increases after clear felling but returns to normal after about 5 years, and eventually is lower than before disturbance.
Pasture to pine	Annual water yields reduce by up to 50%, low flows may fall by 50% and peak flows by 80%.
Rural/forest to urban development	Increase in the size of floods, flood peaks occur more quickly, reduced groundwater infiltration leads to lower base flow.
Wetland to pasture or urban development	Lower base flow in streams previously connected to wetlands, higher flood peaks, floods occur more quickly.

Table 9-7: Hydrological impacts of land use change. Source (Watts, 2005, p. 7)

Table 9-7 was taken from Watts (2005, p. 7), it describes how altering certain land uses can impact on the hydrological regime of the catchment. Some studies have been undertaken in the Wellington region to quantify hydrological impacts from land use change (Watts, 2005, p.7-8), and in the Tasman Bay region, several small experimental catchment studies have been carried out to analyse the effect of land use change on water yields, these have been described in Basher (2003, p. 51-52).

As seen above (Section 9.6) land use practices impact on water quality, therefore change in land use over time will also have an effect on water quality. Further analysis of this area however is beyond the scope of this report.

The amount of water allocated for irrigation has increased in the Wellington region since 1999, with a significant increase in 2001. Water for frost protection also increased in 2003 (Watts, 2005). The availability of water will limit land use change to some extent, especially in regards to dairy conversions where the land requires irrigation, and vineyards that require water for frost protection. Figure 9-10 indicated the surface water and groundwater zones that are already fully allocated, therefore in order for there to be an increase in irrigated land, various water management techniques would need to be adopted including "water storage, high flow harvesting, or flow sharing methods" (Watts, 2005, p. 13).

According to Go Wairarapa, significant land use change is predicted in Wairarapa as a result of the regional water storage and distribution irrigation project that is being drafted. The project will enable the watering of a minimum of 30,000 ha of the valley floor, and intensify land use, including sheep, beef, dairy, cropping and viticulture (G. Copps, Personal Communication 2 March 2007). The Wairarapa Regional Irrigation Trust (WRIT) was formed in 2007. It is comprised of eight members including farmers and individuals from the business community to implement the project (Go Wairarapa, 2007). Further information on the WRIT can be sought from Go Wairarapa.

9.9. CONCLUSION

Land use in the Ruamahanga Catchment is dominated by agriculture, but also includes horticulture, forestry and smaller areas of industry. Human settlement was also classed as a type of land use in this chapter. Each of these land use types exerts differing pressure on the environment. These pressures range from discharges to land, water and air, to water abstraction. The largest discharges in the catchment are from industrial operations and stormwater. Although these are the largest in volume, they may not cause the most harm to the environment, if the content of the discharge is low risk. Four of the five main population centres in the catchment are still discharging municipal waste into the waterways. Masterton's sewage treatment plant in particular discharges a significant volume to the Makoura Stream, which enters the Ruamahanga River in the upper part of the catchment. The largest water abstractions occurring in the catchment are for public water supply, irrigation and for the water races. The hydroelectricity scheme on the Kourarau stream also abstracts a high percentage of surface water.

A study into the effect of land use on water quality found that there was no strong relationship between the percentage of dairying on the land upstream of a water quality monitoring site, with the level of water quality in the rivers. This shows that there are other factors contributing to degraded water quality in the Ruamahanga Catchment apart from dairying (e.g. point source discharges), and highlights the complexity of assessing the relative causes of degraded water quality in a multi-use catchment.

The agricultural profile of the Ruamahanga Catchment has changed considerably since 1995, with a large decrease in sheep and beef numbers, especially in Carterton and South Wairarapa. Coupled with this decrease of sheep and beef is a significant increase in dairy cows and stocking rates. This intensification of dairying will place further pressure on the already deteriorating water resources in the catchment. Developmental pressure from the increase in the number of dwellings and subdivisions in the Ruamahanga Catchment may also have implications for the future sustainability of the catchment.

10. Freshwater Ecology

10.1 INTRODUCTION

Assessing and documenting the biodiversity (the variety of life) in a catchment is a significant task, as the number of living species is enormous. As the main focus of this inventory is on the water resources of the catchment, this chapter will focus solely on freshwater ecology.

10.2 METHODOLOGY

This chapter will include information on freshwater fish and invertebrates, as the health of both fish and invertebrate communities can reveal a considerable amount about the quality of the water. Redfin bullies, Koaro, and Banded Kokopu for example are particularly sensitive to degraded water quality, while non migratory bullies, eels and trout are often found in rivers with poor water quality (M. Joy, personal communication, 4 July 2007).

A selection of the data sources[67] outlined below has been used to describe the measured and predicted taxonomic richness of freshwater fish species in the Ruamahanga Catchment. Similarly, the Macroinvertebrate Community Index (MCI) scores at each of the measured water quality sites in the Ruamahanga River have been presented[68]. Macroinvertebrate abundance reveals information about localised areas while fish communities and abundances provide information on a more regional level.

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[67] Some of the listed data sources have not been used in this section but have been included to inform the reader of other sources of information on this topic.

[68] These were previously introduced in the water quality section of this report.

10.3 DATA SOURCES

10.3.1. New Zealand Freshwater Fish Database (NZFFD)

The occurrence of freshwater fish in New Zealand can be found in the New Zealand Freshwater Fish Database (NZFFD) and is stored at the National Institute of Water and Atmospheric Research (NIWA). The database includes "site locations, the species present, their abundance and size, fishing methods used and a physical description of the site" (NIWA, 2007a, para.1). Data is voluntarily submitted to the database from numerous institutions including NIWA, Fish and Game Councils, the Department of Conservation (DoC), universities and individuals (V. Froude, 1999).

Each point on the database is grid referenced and thus is GIS compatible. Other advantages of the database are that it is being updated constantly and that it has funding provided. Limitations of the database are that it is only a recording database, and not a monitoring database; those who submit records have different abilities in fish identification; and there is not a specific program targeted at updating particular sites on a set timeframe (V. Froude, 1999). Although the database is widespread nationally, conclusions regarding the presence and absence of fish species can only be made in reaches that have been assessed. A large proportion of reaches in New Zealand, and their associated fish data are missing from the database. Furthermore, data for the database has been collated over a long time frame (1921-current); therefore fish distribution maps can be outdated. An example of this is the citing of the grayling (*Prototroctes oxyrhynchus)* which is thought to be now extinct (Strickland & Quarterman, 2001).

10.3.2. Predictive Fish Maps

Predictive fish maps can overcome the problem of limited entries in the NZFFD. Joy and Death (2004a) modeled fish and decapod occurrences, using data from the NZFFD and from additional surveys, based on a "set of predictor variables including latitudinal and elevational position of the site reach, catchment area, average air temperature, the vegetation type, land use proportions of the catchment, and catchment geology" (M.K Joy & Death, 2004a, p. 1036). These predicted maps have numerous benefits in resource management, overcoming problems of non-existent, incomplete or dated data sets (M.K Joy & Death, 2004a). These maps can be used in the identification of ecologically important areas that require protection, and areas that require ecological enhancement. Overall these maps allow a holistic appreciation of the fish species occurring in a region. The predictive fish data for the Wellington Region was obtained from Mike Joy, Massey University, and were used to create predictive maps with ArcGIS.

10.3.3. Conservation Management Strategy (CMS)

The Conservation Management Strategy (CMS) for the Wellington Conservancy was released in 1996 by DoC for the period 1996-2005, and prepared as a statutory requirement of the Conservation Act 1987 (Department of Conservation, 1996). The strategy includes an inventory of all of the land units managed by DoC, and provides a description of natural resources that exist there, including flora, fauna, and fish. Although there is a requirement for the CMS to be revised no longer than ten years after it has been approved, the revision of the Wellington CMS not yet begun, and therefore some parts may be out of date. The Minister of Conservation has extended the period before review through to July 2008 (under s.17H(4)(c) Conservation Act 1987) (J. Flavell, Personal Communication, 8 October 2007).

10.3.4. Macroinvertebrate Community Index (MCI) Scores

Macroinvertebrates have been measured annually in the Ruamahanga Catchment since 1993. MCI scores for all of the River State of Environment sites for the years 1999 through to 2003 are presented in Appendix 4 of the GWRC Freshwater Quality Monitoring Technical Report.

10.3.5. Aquatic Plants and Bioweb Databases

An Aquatics Plants database exists, that details the plants existing in 100 lakes nationwide. This database is managed by NIWA (V. Froude, 1999). The Bioweb threatened plants database has been created by the DoC. It includes information on nationally threatened species of freshwater vascular plants (V. Froude, 1999).

10.3.6. Ecological Districts

Ecological Districts (EDs) were previously introduced in Section 5.9 of this report. The Ruamahanga Catchment includes segments of five different EDs. The ecological character of these EDs have been described by McEwen (1987). Indigenous fish and invertebrate information are included in these descriptions, although they may be somewhat dated.

10.3.7. GWRC GIS Data

This data includes recommended areas for protection (RAP), water bodies containing nationally threatened species, and water bodies with important trout habitat.

10.3.8. Other Relevant Studies and Publications

Other relevant publications pertaining to freshwater fish in New Zealand and Wellington include 'The Distribution and Abundance of Fish in Freshwater in New Zealand Rivers' (Jowett & Richardson, 1996), 'Freshwater Fishes of New Zealand' (McDowall, 2001) and 'Review of Freshwater Fish in the Wellington Region' (Strickland & Quarterman, 2001).

General publications relating to New Zealand macroinvertebrates include 'A Macroinvertebrate Community Index of Water Quality for Stony Streams' (Stark, 1985) and 'Performance of the Macroinvertebrate Community Index' (Stark, 1993). In their study, Death & Death (2005 unpublished) presented trend analysis data on macroinvertebrate data for the River State of Environment sites (RSoE) in the Wellington Region.

10.4. FRESHWATER ECOLOGY IN THE RUAMAHANGA CATCHMENT

10.4.1. Native and Exotic Freshwater Fish

There are around 50 native freshwater fish species in New Zealand, and the three major families are the galaxiids, the bullies, and the eels. The distribution of the freshwater fish species in the Ruamahanga Catchment has been described by Jowett & Richardson (1996), Strickland & Quarterman (2001) and also in the NZFFD. The publication by Strickland & Quarterman was based on data from the NZFFD as at June 2001. Joy (2002 unpublished) carried out a more recent freshwater fish survey in the Wellington Region, investigating fish at sites that had not been included in the NZFFD so to increase the overall number of entries in the database.

As at 29 July 2007, there were 36 species of freshwater fish present in the Ruamahanga Catchment (Table 10-1), 23 of which are native species, and seven of which are exotic (introduced species) and one, the grayling is extinct[69]. The species most frequently recorded were the longfin eel, brown trout, shortfin eel and brown mudfish. The dwarf galaxias, the crans bully and the upland bully are three of the species that are non-migratory, and many of the other species identified migrate between salt and freshwater (diadromous) (Strickland & Quarterman, 2001).

Figure 10-1 to Figure 10-5 have been created from the NZFFD. They show the presence and absence of specific species and hence the spatial distribution of fish in the Ruamahanga Catchment. Species presence is indicated by a coloured symbol while absence is represented by a black dot. Many of the fish species occupy the western rivers, rather than the eastern e.g. longfin eel, brown trout and the dwarf galaxid, and only some species have a high frequency of occurrence on the valley floor e.g. brown mudfish, shortfin eel, and giant kokopu. Introduced species in Figure 10-5 occupy mainly the valley floor with only the perch and tench species reaching higher elevations.

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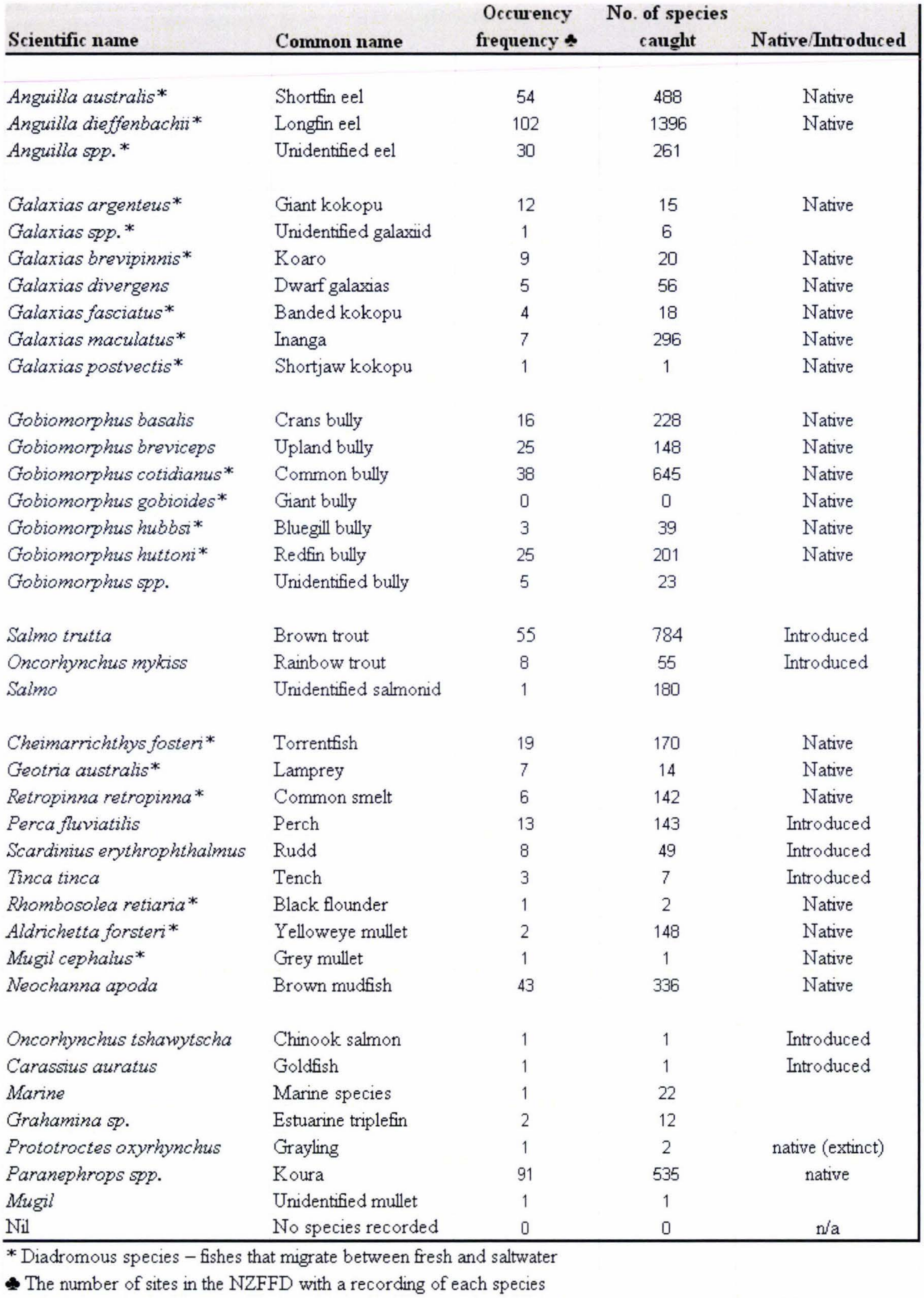
[69] See comments previously made (Section 9.3.1) about the long time frame that the NZFFD has been collated over, and therefore some species cited in the database are now thought to be extinct.



Scientific name	Common name	Occurency frequency ♣	No. of species caught	Native/Introduced
*Anguilla australis**	Shortfin eel	54	488	Native
*Anguilla dieffenbachii**	Longfin eel	102	1396	Native
*Anguilla spp.**	Unidentified eel	30	261	
*Galaxias argenteus**	Giant kokopu	12	15	Native
*Galaxias spp.**	Unidentified galaxiid	1	6	
*Galaxias brevipinnis**	Koaro	9	20	Native
Galaxias divergens	Dwarf galaxias	5	56	Native
*Galaxias fasciatus**	Banded kokopu	4	18	Native
*Galaxias maculatus**	Inanga	7	296	Native
*Galaxias postvectis**	Shortjaw kokopu	1	1	Native
Gobiomorphus basalis	Crans bully	16	228	Native
Gobiomorphus breviceps	Upland bully	25	148	Native
*Gobiomorphus cotidianus**	Common bully	38	645	Native
*Gobiomorphus gobioides**	Giant bully	0	0	Native
*Gobiomorphus hubbsi**	Bluegill bully	3	39	Native
*Gobiomorphus huttoni**	Redfin bully	25	201	Native
Gobiomorphus spp.	Unidentified bully	5	23	
Salmo trutta	Brown trout	55	784	Introduced
Oncorhynchus mykiss	Rainbow trout	8	55	Introduced
Salmo	Unidentified salmonid	1	180	
*Cheimarrichthys fosteri**	Torrentfish	19	170	Native
*Geotria australis**	Lamprey	7	14	Native
*Retropinna retropinna**	Common smelt	6	142	Native
Perca fluviatilis	Perch	13	143	Introduced
Scardinius erythrophthalmus	Rudd	8	49	Introduced
Tinca tinca	Tench	3	7	Introduced
*Rhombosolea retiaria**	Black flounder	1	2	Native
*Aldrichetta forsteri**	Yelloweye mullet	2	148	Native
*Mugil cephalus**	Grey mullet	1	1	Native
Neochanna apoda	Brown mudfish	43	336	Native
Oncorhynchus tshawytscha	Chinook salmon	1	1	Introduced
Carassius auratus	Goldfish	1	1	Introduced
Marine	Marine species	1	22	
Grahamina sp.	Estuarine triplefin	2	12	
Prototroctes oxyrhynchus	Grayling	1	2	native (extinct)
Paranephrops spp.	Koura	91	535	native
Mugil	Unidentified mullet	1	1	
Nil	No species recorded	0	0	n/a

* Diadromous species – fishes that migrate between fresh and saltwater

♣ The number of sites in the NZFFD with a recording of each species

Table 10-1: Scientific names, common names, occurrence frequency and number of fish species caught in the Ruamahanga Catchment

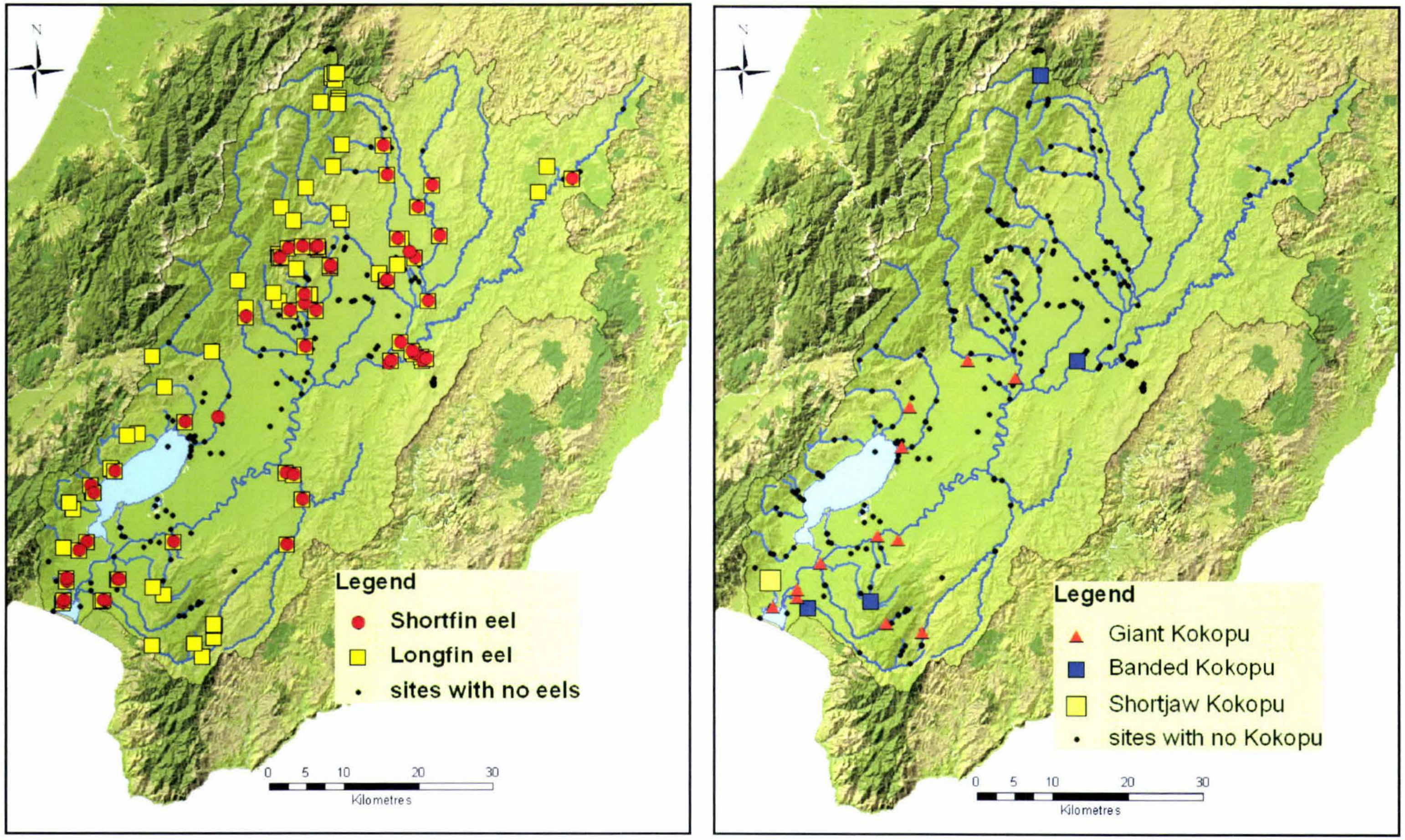


Figure 10-1: NZFFD Presence – absence distribution map of eel and kokopu species

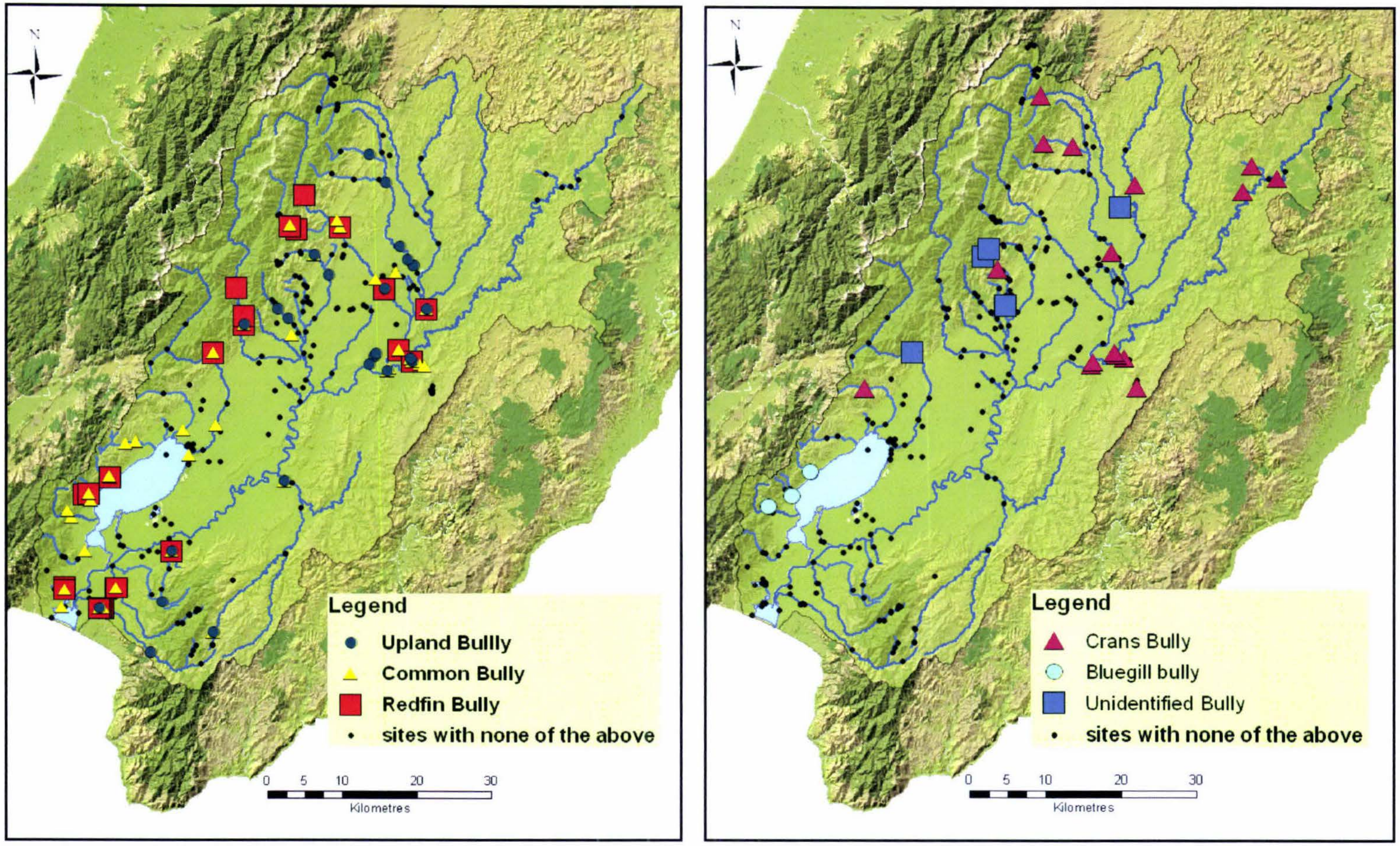


Figure 10-2: NZFFD Presence – absence distribution map of bully species

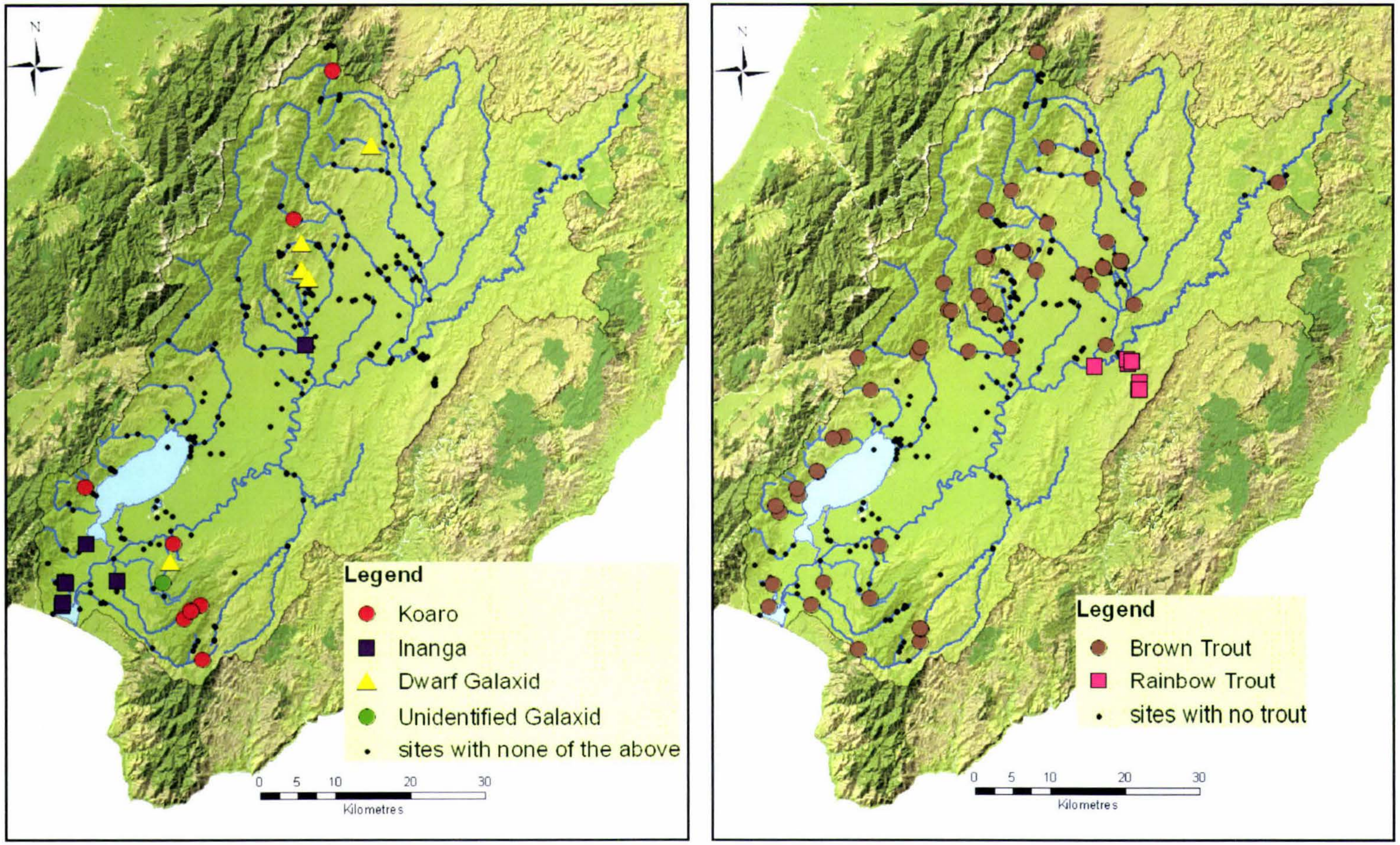


Figure 10-3: NZFFD Presence – absence distribution map of galaxid and trout species

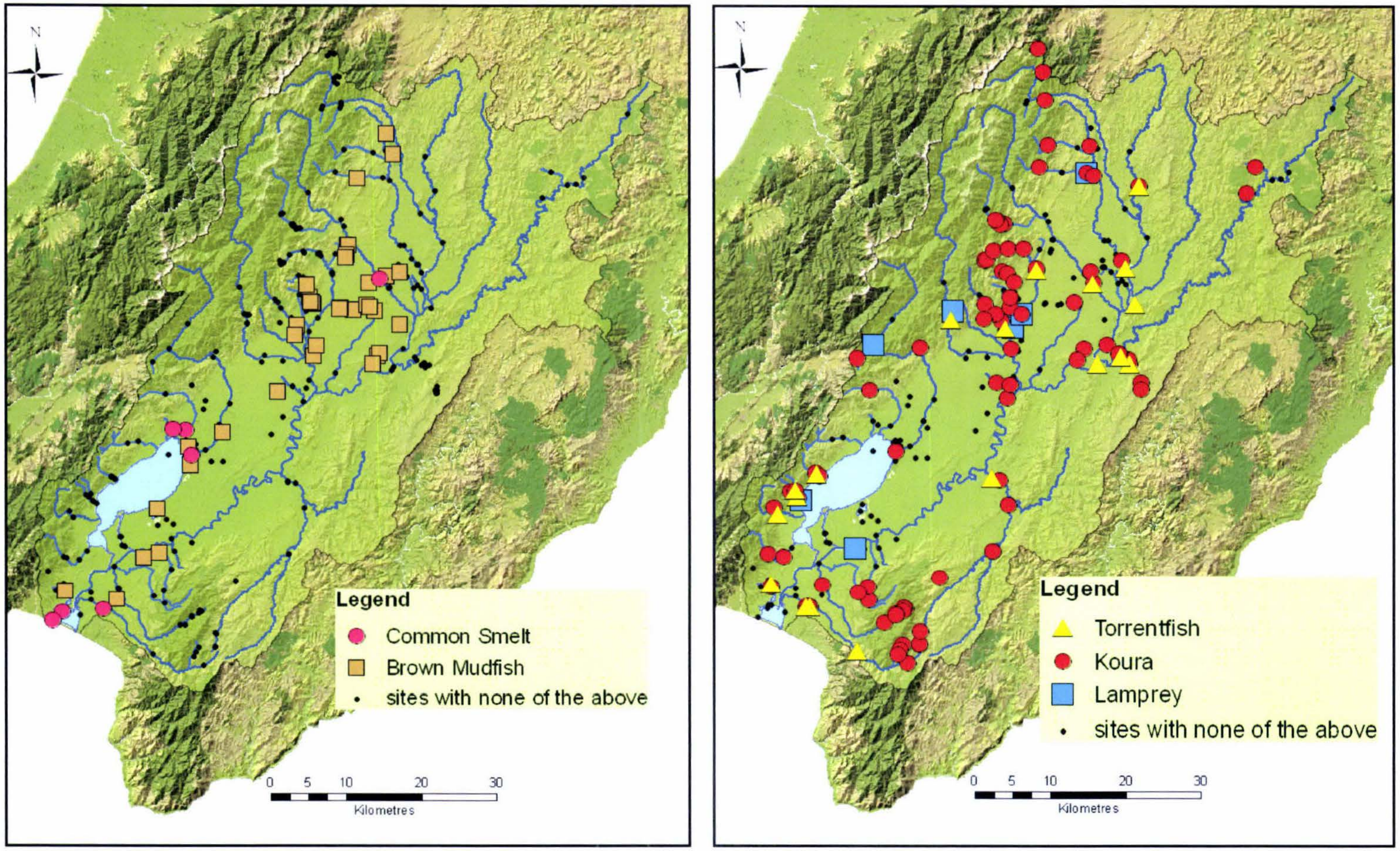


Figure 10-4: NZFFD Presence – absence distribution map of additional native species

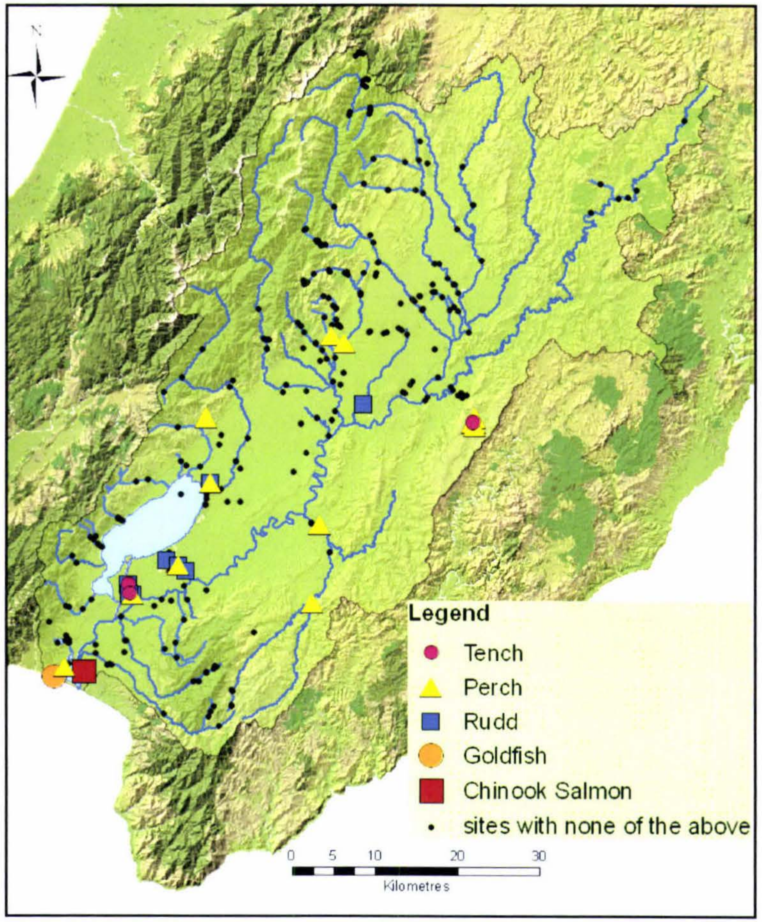


Figure 10-5: NZFFD Presence – absence distribution map of introduced species

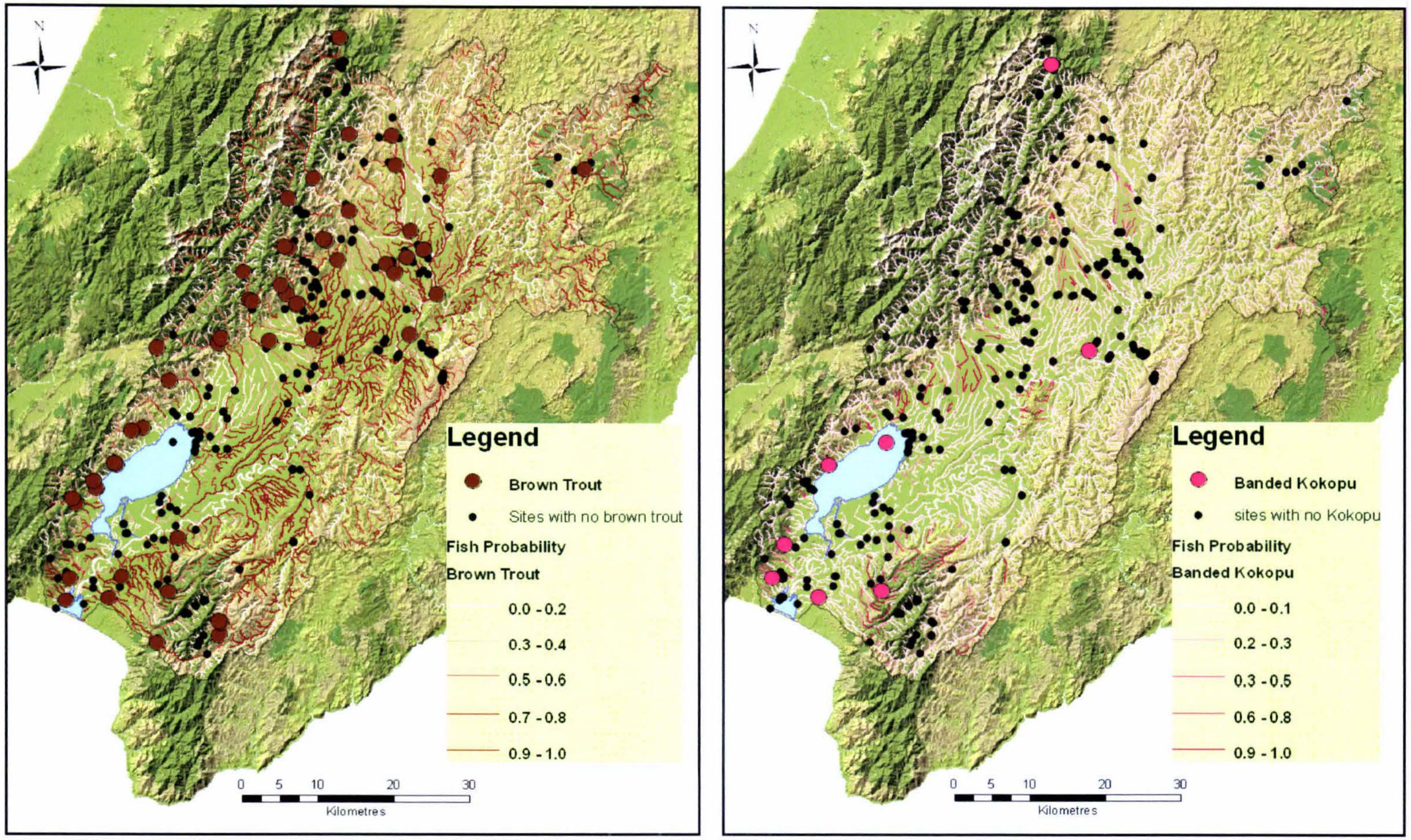


Figure 10-6: Predicted fish maps for Brown Trout (a) and Banded Kokopu (b). Coloured symbols represent actual occurrences and black spots represent remaining NZFDD sites

An alternative to using the NZFFD are predictive fish maps. As described in Section 10.3.2, these maps are based on a series of predictor variables, and can help overcome the problem of limited fish sampling sites in the NZFFD. Figure 10-6 provides two examples of predicted fish maps for brown trout and banded kokopu. The darker river reaches represent sections that have a high probability of a particular fish species being present, the coloured symbols are from the NZFFD and show presence of the species and the black dots show absence. With the existing land use, predicted areas suitable for some species are quite restricted (e.g. banded kokopu, Figure 10-6b) compared to other species (brown trout, Figure 10-6a) which are predicted to be ubiquitous. This is supported by the smaller number of observations of banded kokopu relative to brown trout. These predicted maps are an extremely useful extension of the NZFFD, allowing the assessment of fish probabilities in areas that have not been covered by the NZFFD.

10.4.2. Macroinvertebrates

Macroinvertebrates[70] were previously introduced in Section 8.2.2.3. Insects, molluscs, crustaceans, and oligochaetes[71] make up the four major groups of macroinvertebrates (Milne & Perrie, 2006). Healthy macroinvertebrate communities are indicative of good water quality, and also provide a key food source for freshwater fish.

The Macroinvertebrate Community Index (MCI) is an important indicator of water quality. It aggregates the community structure into one single score. A larger score is indicative of a community of invertebrate organisms that are sensitive to poor water quality, and conversely a lower score indicates a community of invertebrate organisms that are insensitive to degraded water (Snelder & Scarsbrook, 2005) (Table 10-2).

The map in Figure 10-7 indicates the RSoE sites where MCI sampling is routinely carried out. For the period 1999-2003, the two sites with the most unpolluted conditions were the

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[70] Macroinvertebrates are organisms that contain no backbone and can be viewed with the naked eye as they are larger than 250 microns in size.

[71] Insects include mayflies, caddisflies and dragonflies, molluscs include snails and mussels, crustaceans include shrimp and amphipods, and oligochaetes include aquatic worm species.

Waiohine at Gorge site and the Ruamahanga River at Mt Bruce site. There were no sites with an average MCI score in the severe pollution bracket; however two sites, the Whangaehu River and the Mangatarere River had their average MCI scores in the probable moderate pollution bracket.

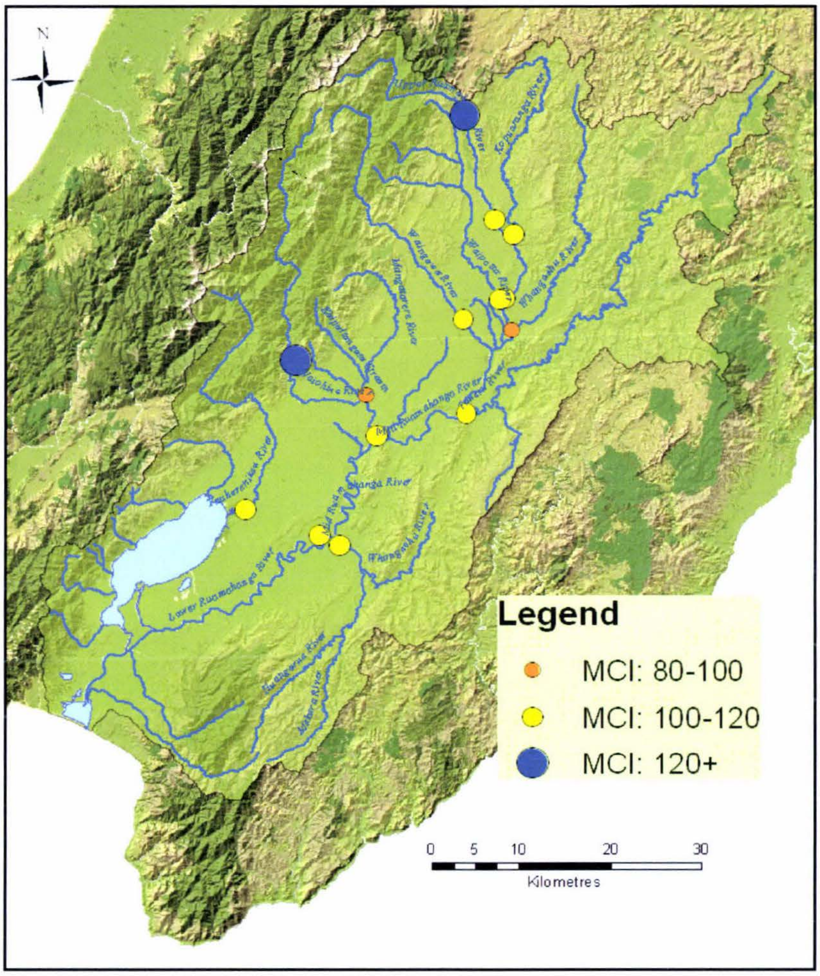
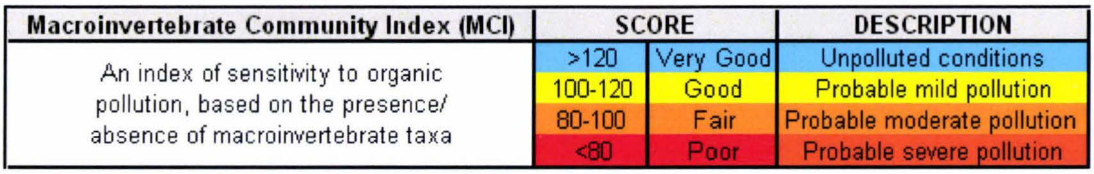


Figure 10-7: River State of Environment Sites in the Ruamahanga Catchment with Average MCI scores for the period 1999-2003



Macroinvertebrate Community Index (MCI)	SCORE		DESCRIPTION
An index of sensitivity to organic pollution, based on the presence/ absence of macroinvertebrate taxa	>120	Very Good	Unpolluted conditions
	100-120	Good	Probable mild pollution
	80-100	Fair	Probable moderate pollution
	<80	Poor	Probable severe pollution

Table 10-2: Definition of MCI and its associated scores. Source (Milne & Perrie, 2006; Stark, 1985, 1993)

10.5. COMPARISON OF FISH AND MACROINVERTEBRATE POPULATIONS WITH OTHER RIVERS IN THE WELLINGTON REGION

10.5.1. Introduction

The preceding section of this report has highlighted the fish species and macroinvertebrate health of the Ruamahanga Catchment. In this section, the Ruamahanga Catchment will be compared against other catchments in the Wellington Region including the Hutt Catchment, and the combined Waikanae and Otaki Catchments (Figure 10-8).

10.5.2. Freshwater fish

The NZFFD database was utilised to obtain the sampling points within each of these catchments, and the number of fish species within each catchment at various elevation bands were calculated. Sites were grouped according to the number of species found at the site e.g. less than 1, 2 – 4, and more than 5. The bar graphs in Figure 10-9, Figure 10-10 and Figure 10-11, show the proportion of sites in each elevation band, with the number of species present for each catchment. In the lowest elevation band the Ruamahanga Catchment has the highest number of sites with more than 5 species. With increasing elevation, the proportion of Ruamahanga Catchment sites with 5 or more species decreases and the proportion of sites with 5 or more species in the Waikanae and Otaki Catchments increases. In the lowest elevation band, more than half of the sites in all three catchments have one or less species present. A greater number of species are observed at higher elevations.

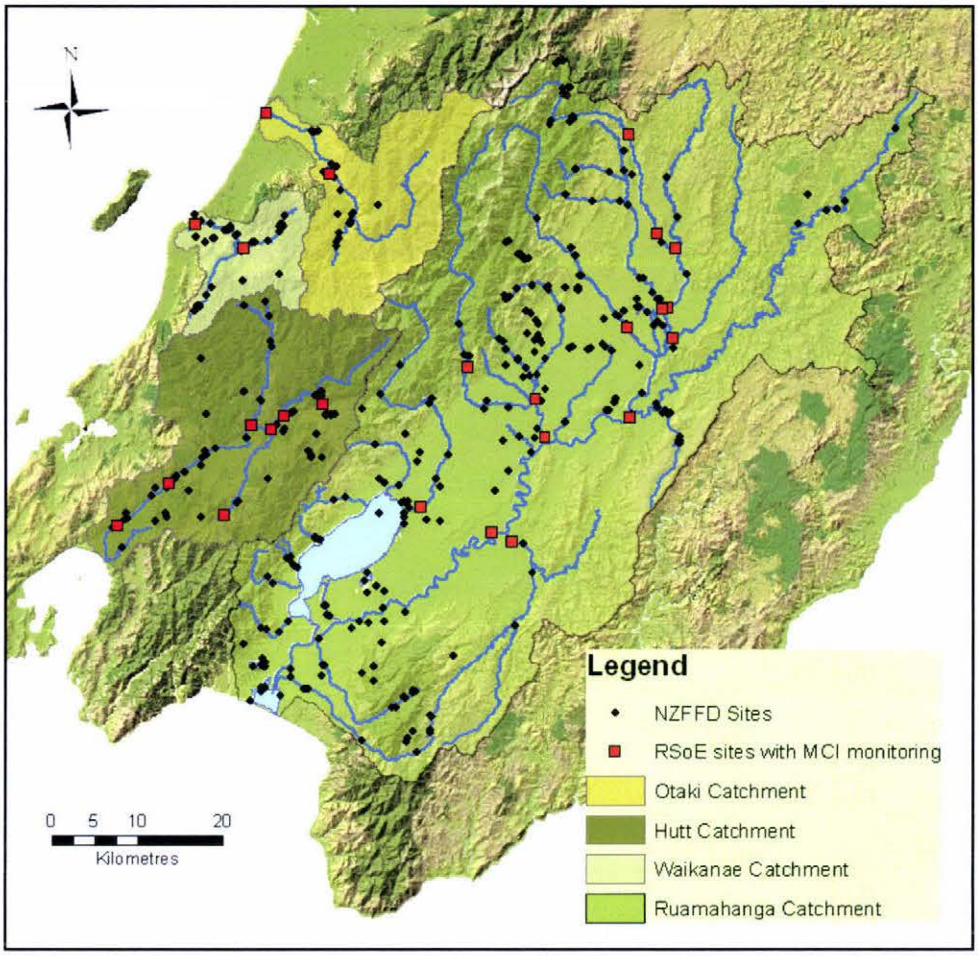


Figure 10-8: Four catchments in the Wellington Region and corresponding New Zealand Freshwater Fish Database sites and River State of Environment Reports (RSoE)

This comparison shows that the Ruamahanga Catchment has similar species diversity to the other catchments in the Wellington Region, especially at lower elevations. Problems with this comparison technique include the disproportionate number of sites in each of the catchments e.g. the Ruamahanga Catchment has 280 sites, Hutt Catchment has 83 and the Waikanae and Otaki have 75 combined sites, and the fact that no allowance has been made for the ease or time involved in catching a species indicating relative abundances. For example, a species may be so abundant at a site that they are immediately spotted, however, at other sites it may take a lot longer to find a fish.

Similar findings were published by Jowett & Richardson (1996) who established fish densities (number of fish per 100 m^2) for numerous New Zealand Rivers. Interpreting their results from species presence only and not density, the Ruamahanga River had seven of the ten studied species present, the Hutt River also had seven, while the Otaki had only half of the species present. The Waikanae River was not included in the study.

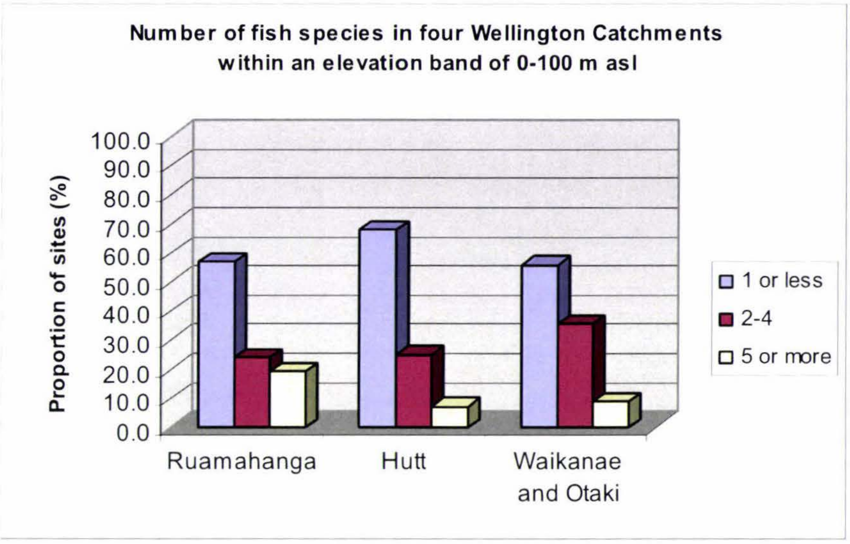


Figure 10-9: Bar graph of fish species in four Wellington Catchments at an elevation band of 0-100 m

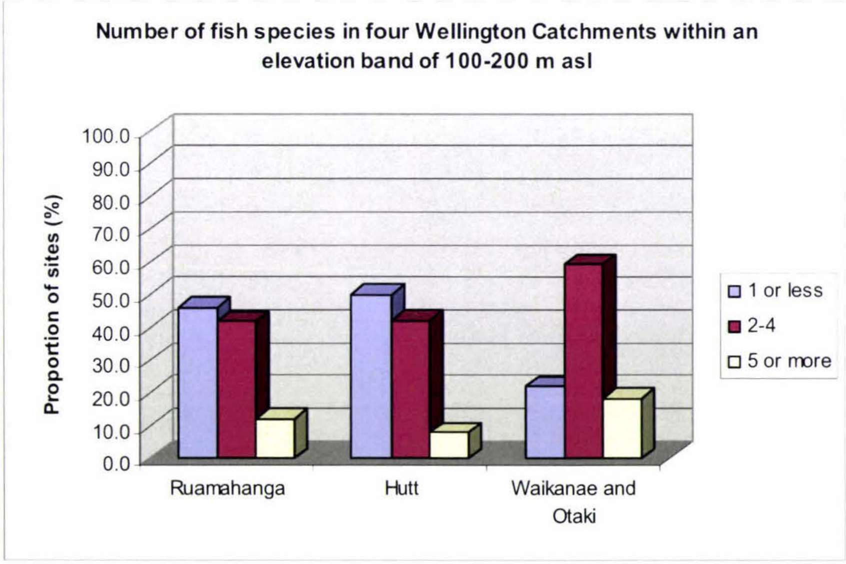


Figure 10-10: Bar graph of fish species in four Wellington Catchments at an elevation band of 100-200 m

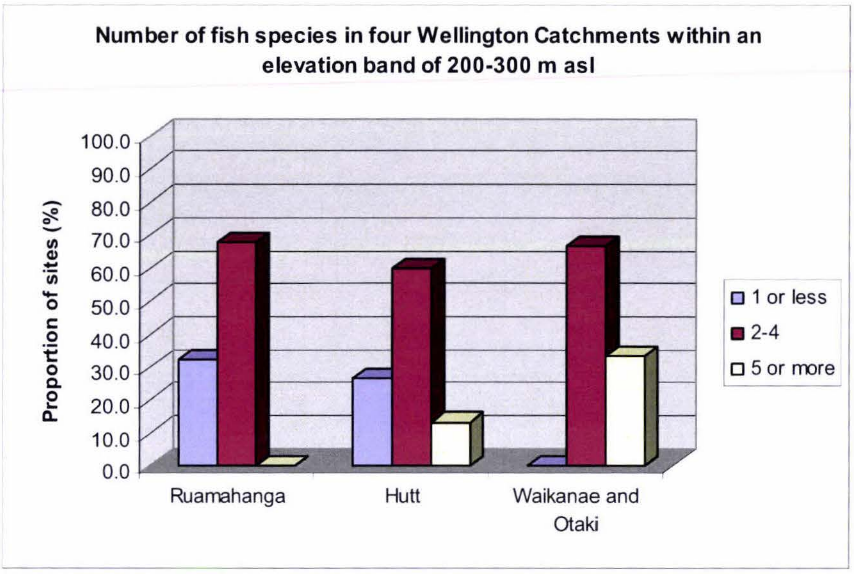
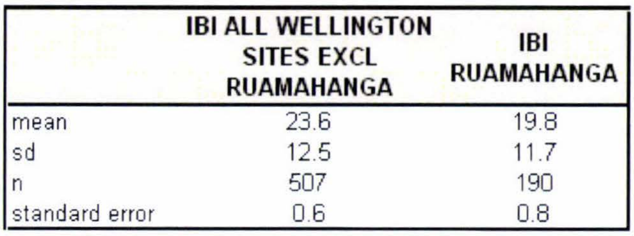


Figure 10-11: Bar graph of fish species in four Wellington Catchments at an elevation band of 200-300 m

Another comparative technique to measure freshwater fish health between different catchments in the Wellington Region is the index of biotic integrity (IBI). The IBI was developed for freshwater fish in New Zealand by M. Joy & R. G. Death (2004b). It utilised six metrics "(1) the number of native species, (2) the number of native riffle-dwelling species, (3) the number of native benthic pool species, (4) the number of native pelagic species, (5) the number of intolerant or sensitive native species, and (6) the proportion of alien species" (M. K Joy & Death, 2004b, p. 418). The first five metrics were scored from the Maximum Species Richness Line (MSRL), "which reflects the number of species expected in relatively undisturbed sites of various elevations and distances from the sea". The area under the MSRL was split into three segments. Where a site occurred in the upper third segment, it would receive the maximum score of 5, (reflecting a high level of species richness), 3 points were obtained in the middle segment, and 1 point in the lower segment. For calculating metric 6, the proportion of native species at a site was examined. A site where more than two-thirds of the species were native would receive 5 points, between one-third and two-thirds, 3 points, and less than one-third, 1 point (M. K Joy & Death, 2004b).

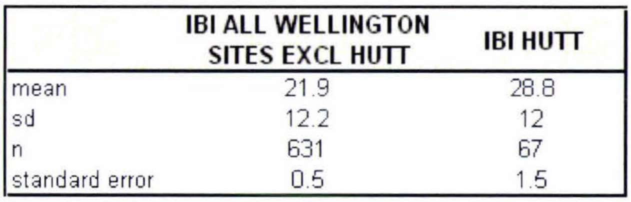
The overall IBI score was obtained by adding the 6 individual metric scores for a site together. A score of 1-20 represents 'low quality', 20-40, 'medium quality' and 40-60 'high quality'. A score of 0 would mean that no freshwater native fish were caught (M. K Joy & Death, 2004b).

The IBI score was calculated for the Ruamahanga, Hutt, Waikanae and Otaki Catchments and compared with the Wellington Region's overall IBI score (Figure 10-12 and Figure 10-13).



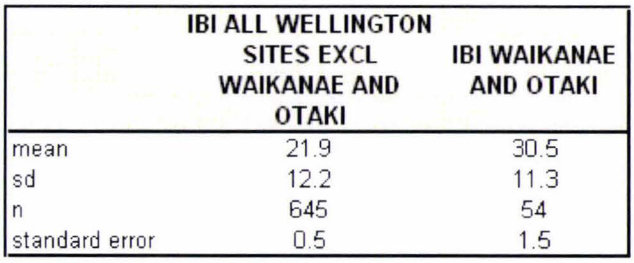
	IBI ALL WELLINGTON SITES EXCL RUAMAHANGA	IBI RUAMAHANGA
mean	23.6	19.8
sd	12.5	11.7
n	507	190
standard error	0.6	0.8

$F_{1,697} = 13.3$ $P = 0.0003$



	IBI ALL WELLINGTON SITES EXCL HUTT	IBI HUTT
mean	21.9	28.8
sd	12.2	12
n	631	67
standard error	0.5	1.5

$F_{1,696} = 18.9$ $P = 0.000016$

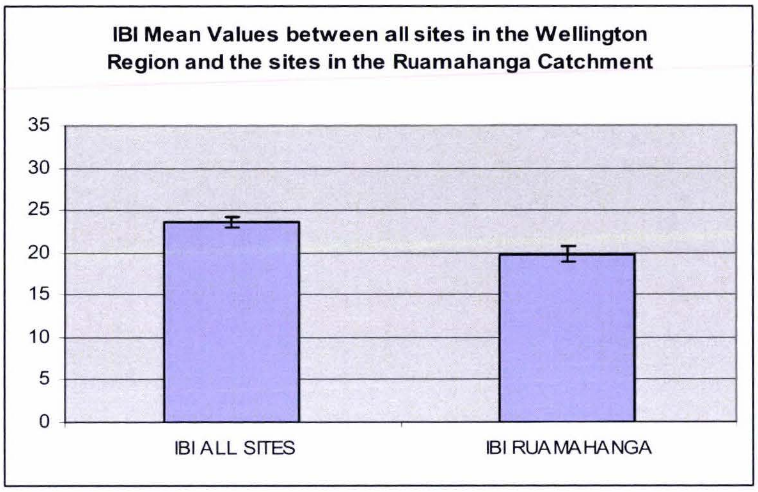


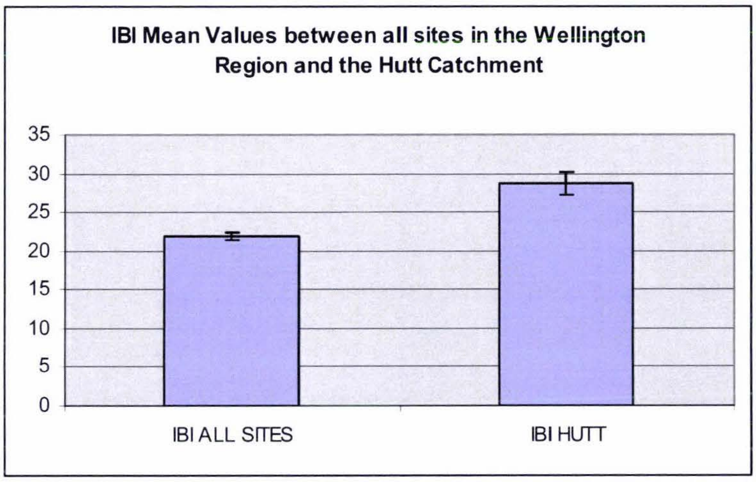
	IBI ALL WELLINGTON SITES EXCL WAIKANAE AND OTAKI	IBI WAIKANAE AND OTAKI
mean	21.9	30.5
sd	12.2	11.3
n	645	54
standard error	0.5	1.5

$F_{1,694} = 22.27$ $P = 0.000003$

Figure 10-12: Comparison of the IBI means between all sites in the Wellington Region and the four studied catchments and the analysis of variance results (ANOVA)

There is a statistically significant difference between the mean IBI value for all studied catchments and the Wellington Region's mean IBI value. The Ruamahanga Catchment mean IBI is less than the average of all other rivers in the region, while both the Hutt Catchment, and Waikanae and Otaki Catchments had mean IBI values above the average mean value for Wellington. These relationships are depicted in the bar graphs in Figure 10-13.





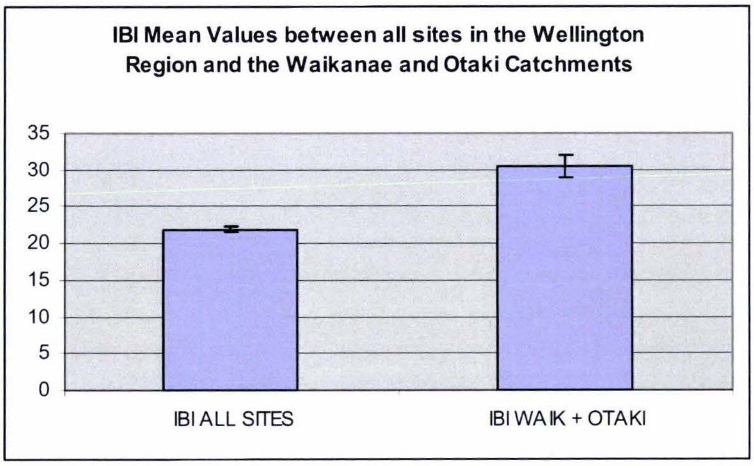
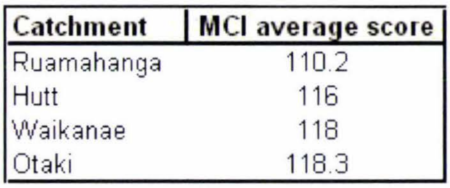


Figure 10-13: IBI bar graphs and error bars, showing IBI mean values for the studied catchments versus the Wellington Region. "IBI all sites" exclude the subject catchments in each case.

The non overlapping error bars in each of the bar graphs confirms the strong likelihood that the means in each of the data sets are statistically different. Calculating the analysis of variance (ANOVA), and comparing error bars cannot indicate the relativity of the IBI between the studied catchments. From this exercise however we can confirm that the Ruamahanga Catchment has an average IBI value below the average of the rest of the rivers in the region, falling in the 'low quality' group (IBI values 1-20), while the remaining catchments are above the remaining regions average, and have their mean values falling in the 'medium quality' category (IBI values 20-40).

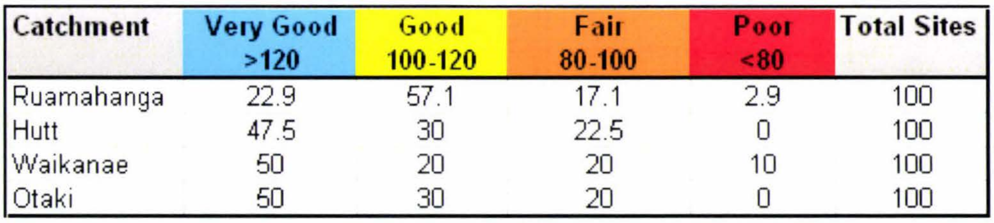
10.5.3. Macroinvertebrates

Macroinvertebrate Community Index (MCI) scores sampled at the RSoE monitoring sites for the period 1999-2003 were obtained from the GWRC Freshwater quality monitoring report (2006) for each of the four catchments. Some of the sites used in this analysis are now historical sites, since many locations changed after 2003. Further details on the RSoE sites can be obtained from the Freshwater quality monitoring report (Milne & Perrie, 2006).



Catchment	MCI average score
Ruamahanga	110.2
Hutt	116
Waikanae	118
Otaki	118.3

Table 10-3: Average MCI score for each catchment 1999-2003



Catchment	Very Good >120	Good 100-120	Fair 80-100	Poor <80	Total Sites
Ruamahanga	22.9	57.1	17.1	2.9	100
Hutt	47.5	30	22.5	0	100
Waikanae	50	20	20	10	100
Otaki	50	30	20	0	100

Table 10-4: Percentage of sites with average annual MCI scores in each grade (1999-2003)

All catchments had an average MCI score ranked in the 'good' category; however the Ruamahanga Catchment had the lowest average MCI score overall (Table 10-3). The Hutt, Waikanae and Otaki Catchments all had nearly half of their average annual MCI scores above 120, while the Ruamahanga Catchment had just over one fifth in the same category. Most of the Ruamahanga Catchments sites fell within the 'good' category, with MCI scores between 100-120 (Table 10-4).

10.5.4. Conclusion

By using freshwater fish species counts, the IBI, and MCI scores, the ecological health of the Ruamahanga Catchment was able to be compared against other large catchments in the Wellington Region. At an elevation band between 0-100 m all studied catchments had a similar number of fish species present, but with increasing elevation, the diversity of fish species in the Ruamahanga Catchment decreased. The IBI showed that the Ruamahanga Catchment was in the 'low quality' group, and its average IBI score was lower than the average for the Wellington Region. Finally the MCI scores also found that the Ruamahanga Catchment was of lesser quality than the other studied catchments.

10.6. IMPACTS OF LAND USE AND WATER QUALITY ON FRESHWATER ECOLOGY

Freshwater ecosystems can be altered hugely by land use change which can bring associated degradation in water quality. Changes in the hydrological regime, including drainage patterns and increased water abstraction; increases in pollution and sedimentation; and nutrient enrichment can all impact on freshwater ecosystems and dictate which invertebrates and consequently which fish will occupy certain waters.

The effect of different types of land use on ecosystems has been examined thoroughly in New Zealand and worldwide. Streams draining pasture, native forest, and exotic forest have been compared in many studies, and results show that although invertebrate taxa richness does not differ between land uses, the density does change (Quinn, Cooper, Davies-Colley, Rutherford, & Williamson, 1997). Streams draining pasture have higher invertebrate densities than native streams, but "mayflies, stoneflies, and caddisflies densities are higher in forest streams than pasture (Quinn et al., 1997, p. 479) thus indicating their sensitivity to agricultural land use practices.

Changes in fish communities as a response to land use practices has also been studied. As mentioned previously in the methodology, some fish species are prevalent in degraded water, while other are more sensitive to pollution and are only found in reaches that are more pristine. Streams in native or exotic forest contain banded kokopu although these are absent in pastoral catchments (Rowe, Chisnall, Dean, & Richardson, 1999). Eels generally have the highest abundances in pastoral catchments along with large inanga populations (Jowett & Richardson, 2003; Rowe et al., 1999)

Richardson, Williams, & Hickey (2001) studied the avoidance behaviour of freshwater fish and shrimp from ammonia and low levels of dissolved oxygen (DO). The results found that only the common smelt avoided both ammonia and low DO. "Inanga and bullies showed no negative response to either contaminant, rather inanga were attracted to low ammonia and bullies to low DO" (Richardson et al., 2001, p. 625), while shrimp avoided high ammonia.

Assessing the health of a waterway from freshwater fish and invertebrate data is a complex process. Relying on fish densities and taxonomic numbers alone can be misleading. Before judgement can be made, researchers need to identify which fish species occupy environments with differing water qualities, and designate such species as indicators of that level of water quality. For example Richardson et al. (2001) suggest the common smelt is a suitable indicator for the health of lowland waterways, another candidate for an indicator of good water quality would be the banded kokopu. This type of approach for assessing water quality overcomes the problem that not all fish avoid degraded or polluted water.

10.7. CONCLUSION

Data from the NZFFD revealed that the there were around 36 different freshwater fish species occurring in the catchment[72], of the approximate 50 freshwater fish species found nationally. The longfin eel, brown trout, shortfin eel and brown mudfish were the most

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[72] This number includes the Grayling, which is now extinct.

common species. Limitations of the NZFFD were explained, followed by the usefulness of fish prediction maps. The MCI scores for the RSoE sites varied throughout the catchment. Only two sites (Waiohine at Gorge and Ruamahanga River at Mt Bruce) had very good MCI scores, while the Whangaehu and Mangatarere Rivers had the lowest MCI scores, indicating probable moderate pollution in these tributaries.

Compared to the other catchments in the Wellington Region (the Hutt Catchment, and the combined Waikanae and Otaki Catchments) the Ruamahanga Catchment has similar species diversity at lower elevations, but at higher elevations the diversity of species in the Ruamahanga Catchment decreased. When comparing the IBI between the catchments, it was found that the Ruamahanga Catchment had a lower average IBI value than the average for the Wellington Region and was classed as 'low quality'. Finally, the comparison of MCI scores between the same Wellington catchments showed that the Ruamahanga Catchment had a lowest MCI score. In conclusion, these three comparative techniques indicate that the Ruamahanga Catchment is worse off in terms of freshwater ecology than the other sub catchments in the Wellington Region, which can probably be directly related to land use and consequent poorer water quality.

11. Natural Hazards

11.1. INTRODUCTION

Historically, the Ruamahanga Catchment has been subject to numerous significant natural hazards. These include the 1855 Wairarapa earthquake which resulted in land displacement of 18 m horizontally and the great Wairarapa floods in the 1880's and in the 1940's. Due to its location and climatic regime, which is often dominated by continuous anticyclones, the region is also prone to droughts. This chapter focuses on the historical floods and droughts that have occurred in the catchment and briefly examines some of the secondary effects that result from such severe weather conditions. This chapter does not attempt to predict the likely frequency and severity of future floods or droughts; however reference has been made to certain publications that provide such information.

Additional information on other extreme meteorological phenomena occurring in the Wellington Region including windstorms, extreme temperatures, snow and frost etc can be found in Tait et al (2002) and Wairarapa Engineering Lifelines Association (2003). This latter publication also documents hazards occurring from tectonic forces e.g. earthquakes.

11.2. METHODOLOGY

The weather regime of Wairarapa and hence the Ruamahanga Catchment has previously been described in Chapter 6 of this report, and some information on river flows has been covered in Chapter 7. This Natural Hazards chapter has utilised the information gained from the listed data sources[73] to provide an overview of the significant floods and droughts that have occurred in the Ruamahanga Catchment. Secondary effects of floods (e.g. rain triggered landsides) and droughts have also been commented on. Finally the chapter concludes with comments on the link between El Nino and meteorological hazards, and prediction methods.

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[73] Some of the listed data sources have not been used in this section but have been included to inform the reader of other sources of information on this topic.

11.3. DATA SOURCES

11.3.1. NIWA and GNS National Hazards Centre

The National Hazards Information Centre has been created by NIWA and GNS. It provides information on the various natural hazards that occur in New Zealand, including floods, tsunami, earthquakes and landslides, to emergency groups and resource managers (NIWA and GNS, n.d.). They produce a free quarterly newsletter "Natural Hazards Update", and from 2006 plan to publish an annual publication on the Natural Hazards in New Zealand. The 2006 review can be obtained from the Centre's website. (http://www.naturalhazards.net.nz/).

11.3.2. GWRC Hazards Online Database

Resources (plans, reports, maps, books etc.) relating to natural hazards can be searched for according to location, hazard type and agency who produced the resource on the GWRC Hazards online database. The search engine can be found on the GWRC website (www.gw.govt.nz) under 'information and services – hazards and emergency management'.

11.3.3. GWRC GIS data

This data includes shape files on various flood and drought events. The data includes the extent of flood waters around 1850, which indicates how serious flooding could be prior to the introduction of the Lower Wairarapa Valley Development Scheme (LWVDS). The extent of flood waters at a 50 year flood event is also included in the GIS data.

11.3.4. Other Relevant Studies and Publications

National

- 'Floods and Droughts: the New Zealand Experience' (Mosley & Pearson, 1997b).
- 'Floods in New Zealand 1920-53'(The Soil Conservation and Rivers Control Council, 1957)
- 'High water: Floods in New Zealand' (Hutchins, 2006)
- 'The 1978 Drought in New Zealand' (Crawford & Hamlin, 1982)

- 'The 1969-70 Droughts in New Zealand' (Finkelstein, 1971)
- 'Droughts in New Zealand' (Bondy, 1950)

Wellington Specific

- Wairarapa Lifelines Association (WELA) –'Risk to lifelines from Natural Hazards' (Wairarapa Engineering Lifelines Association, 2003)
- 'Flooding Hazards Wairarapa' (Greater Wellington Regional Council, 2003)
- 'Metrological Hazards and the potential impacts of climate change in the Wellington Region' (Tait et al, 2002)
- 'Meteorological Hazards Relevant to Wairarapa Engineering Lifelines' (Porteous et al., 1999)
- 'Wairarapa Storm Events 1880-1998' (Saunders, 2000)
- GWRC reports on specific storms: 'The 15-16 February 2004 storm in the Wellington Region: hydrology and meteorology' (Watts, 2004). 'The 4 - 7 July 2006 storms in the Wellington region: hydrology and meteorology' (Watts & Gordon, 2006).
- 'Hydrological Monitoring Report' (Watts, 2005), reports on flooding in the period 1999-2004.
- 'The Weather and Climate of the Wairarapa Region' (Thompson, 1982) a New Zealand Meteorological Service Miscellaneous Publication.

11.4. FLOODS AND DROUGHTS

Floods and droughts can be characterised by three properties 1) magnitude, 2) duration, and 3) frequency. For floods in New Zealand, the most important property is often magnitude. However for droughts, duration is more important as they tend to occur over longer time frames (months to years) while floods generally occur over a number of days (Ibbitt, Woods, & McKerchar, 1997). Floods are also more localised geographically while the impacts from drought are at a much larger regional scale (Mosley & Pearson, 1997a).

Floods can be characterised by large volumes of water or high intensity rainfall, the former can trigger landslides, while the latter can result in river and surface flooding

(Wairarapa Engineering Lifelines Association, 2003). Droughts can be defined according to the number of days with no rain. "A meteorological drought is defined as a period of 15 days with no measurable rain (<0.1 mm per day), and a dry spell as a period of 15 days or more with no more than 1 mm of rain each day" (Mosley & Pearson, 1997a, p. 6). Droughts in New Zealand, usually occur in the summer and last around 3-4 months (Waugh, Freestone, & Lew, 1997), floods however can occur at any time of the year.

11.5 FLOODS IN THE RUAMAHANGA CATCHMENT

Numerous floods of varying magnitudes have occurred in the Ruamahanga Catchment since 1880. Figure 11-1 below indicates the extent of floodwaters around 1850, prior to the introduction of any flood protection measures. From this map, the potential severity of floods in Wairarapa is obvious.

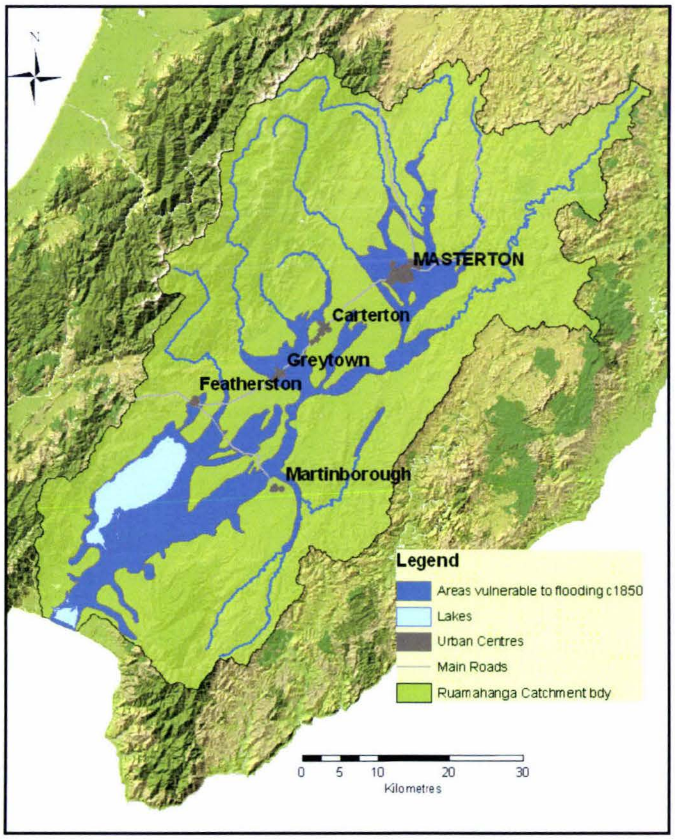

Figure 11-1: Areas in the Ruamahanga Catchment vulnerable to flooding prior to any flood protection measures. Source (Wairarapa Engineering Lifelines Association, (2003) ; (Greater Wellington Regional Council, n.d.)

Some of the significant floods in which rivers had flows over 1200 cumecs are listed in Table 11-1.

Date	**Rivers in Flood**	**Largest Flow (Cumecs)**	**Comments**
24 March 1880	Ruamahanga and Lake Wairarapa	2830 (Ruamahanga)	Region's biggest flood since European Settlement. The > 100 year flood affected an area of more than 20,000 ha (Greater Wellington Regional Council, 2004a).
27-29 August 1932	Western Tributaries and the Ruamahanga	1800 (Ruamahanga)	Heavy rain and snowmelt lead to high flows in the western tributaries (Thompson, 1982).
27-29 June 1947	Ruamahanga	2580 (Ruamahanga at Waihenga)	This 100 year event was one of the most destructive in the catchment. Most of the main towns were flooded, and water breached many stopbanks. Farm land was flooded resulting in stock losses. Overall this flood affected an area of around 24, 000 ha (Greater Wellington Regional Council, 2003, 2004a).
June 1953	Lower Wairarapa Valley	2580 (Ruamahanga)	Flooding equalled that of the 1947 flood. However, at Papawai waters exceeded the 1947 levels (Greater Wellington Regional Council, 2003; The Soil Conservation and Rivers Control Council, 1957).
September 1977	Ruamahanga	1145 (Ruamahanga at Waihenga)	Continuous days of rain falling on already saturated ground caused severe flooding south of Gladstone (Thompson, 1982).
May/June 1981	Ruamahanga and Waiohine	1700 (May), 1490 (June) (Ruamahanga)	During this monthly period, around half of the normal annual rainfall fell in many areas (Thompson, 1982).
1982	Waiohine	1558 (Waiohine)	
7-9 March 1994	Ruamahanga	1800 (Ruamahanga)	(Greater Wellington Regional Council, 2003)
October 1998	Ruamahanga	1500 (Ruamahanga at Wardells)	Large volumes of rain falling in the Tararua Ranges led to rising rivers on the western side of the catchment. The Ruamahanga River peaked at 4.4 m at the Martinborough Bridge (Greater Wellington Regional Council, 2004a).
October 2000	Ruamahanga	1500 (Ruamahanga)	Similar volumes of rain fell as in Oct 1998, resulting in record river flows in most of the rivers, damaging infrastructure and causing stock losses(Greater Wellington Regional Council, 2004a).
12 February 2004	Northern Wairarapa, Tararua Fed Rivers	1362 (Waiohine at Gorge)	(Watts, 2005)
15-16 February 2004	Ruamahanga some and Eastern Rivers	1950 (Ruamahanga at Waihenga)	Significant flows in many of the Rivers including the Ruamahanga, Kopuaranga and Huangarua. Lake Wairarapa reached

			high water levels (Watts, 2004).
March 2005	Ruamahanga	1530 (Ruamahanga at Waihenga)	Significant volumes of rainfall in the central Wairarapa Valley (Watts & Gordon, 2006).
4-7 July 2006	Ruamahanga River at Waihenga	1501 (Ruamahanga at Waihenga)	This flood event was characterised by large volumes of water: surface flooding, and record-high volumes of water passing through the Wairarapa floodways into Lake Wairarapa (Watts & Gordon, 2006).

Table 11-1: Significant floods (>1200 cumecs) in the Ruamahanga Catchment. Source (Wairarapa Engineering Lifelines Association, 2003)

Many floods of smaller magnitude have also occurred within the catchment: at the Ruamahanga River at Mt Bruce (467 cumecs in 1982); the Waipoua River (326 cumecs in 1994); the Tauherenikau River (670 cumecs in 1994 and 420 cumecs in 2003); the Ruamahanga River at Wardells (814 cumecs in 2000); and the Waingawa River and Waipoua River (317 and 425 cumecs respectively in 2004). Historical floods in the eastern catchments include floods of: 56 cumecs in 1998 on the Kopuaranga River; 80 cumecs in 1991 on the Whangaehu River; 488 cumecs on the Taueru River in 1992 and 465 cumecs in 2004; 135 cumecs in 1997 and 519 cumecs in 2004 on the Huangarua River (Wairarapa Engineering Lifelines Association, 2003; Watts, 2005).

Major floods prior to the 1960's were affecting large areas of land (12,000 ha) in the lower Wairarapa Valley. Such floods were recurring often - sometimes as many as eight in one year (Poole, 1983). The frequency of these floods was the impetus for implementation of the LWVDS[74]. When the scheme was near completion in the late 1980's it was hit with two floods. Effects from these floods were widespread, but were nowhere near as detrimental as they would have been without the nearly completed works (Poole, 1983).

Around 40,000 ha of land benefits from the flood protection scheme, which "comprises nearly 200 km of stopbanks, floodways which carry flood waters into Lake Wairarapa, and over 100 floodgated culverts to drain farmland" (Greater Wellington Regional

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[74] The Lower Wairarapa Valley Development Scheme (LWVDS) has been previously introduced in the land chapter of this report.

Council, 2006a). The scheme caters for both a 20 year flood level from Martinborough to Tuhitarata, and a 100 year flood level downstream of Tuhitarata (Greater Wellington Regional Council, 2006a). Figure 11-2 shows the location of the up to 20 year stopbanks and the 100 year stopbanks. The extent of the 50 year flood event breaches the 20 year stopbanks. In addition, water banks up on the either side of the 100 year stopbanks, this water comes from land runoff and other tributaries.

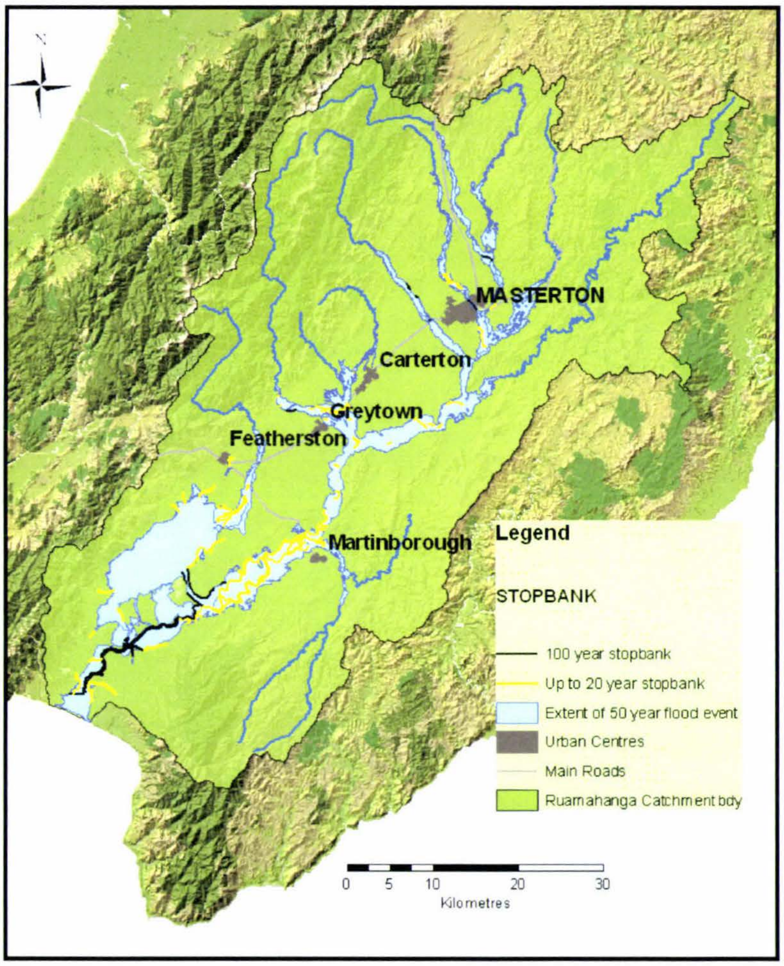

Figure 11-2: Stopbanks and the extent of a 50 year flood event (with stopbanks) in the Ruamahanga Catchment

In addition to inundating farmland, townships and homes, floods can have negative secondary effects of landslides and erosion. Generally, landslides occur when daily rainfall totals exceed 120 mm (Glade, 1998 cited in (Wairarapa Engineering Lifelines Association, 2003). In Wairarapa such landsliding occurred in 1924, 1932*, 1941, 1947*, 1953*, 1961, 1977* and 1991 (Wairarapa Engineering Lifelines Association, 2003)[75]. Further information on landslides triggered by rainfall can be obtained from the Wairarapa Engineering Lifelines (2003) publication and from the following reports:

- Crozier, M. J., McConchie, J. A., Owen, R. C., & Eyles, R. J. (1982). *Mass Movement Erosion Wairarapa.* Wellington: Department of Geography, Victoria University of Wellington.
- Glade, T. (1998). Establishing the frequency and magnitude of landslide-triggering rainstorm events in New Zealand. *Environmental Geology, 35*(2-3), 160-174.
- Hicks, D. L. (2000). *Threshold Rainfalls for Landslides.* Masterton: Wellington Regional Council Internal Report.

11.6. DROUGHTS IN THE RUAMAHANGA CATCHMENT

The Wairarapa region usually experiences at least one period of low rainfall per year. There were 87 droughts recorded from the year 1884 to 1981, the majority of which occurred in the months November to March (Thompson, 1982). Table 11-2 outlines several of the droughts that occurred in the Wairarapa region. In most cases, droughts impact more severely on the eastern side of the Ruamahanga Catchment, away from the more consistent rainfall associated with the Tararua ranges.

Year	**Comments**
1886-87	Drought lasted a record of 40 days (Thompson, 1982).
1930-31	Affected eastern areas of North Island (Waugh et al., 1997).
1941	Drought lasted 38 days (Thompson, 1982).
January – April 1943	65 days with severe soil moisture deficit at Masterton (Tait et al, 2002).
1945-46	Affected most of New Zealand (Waugh et al., 1997).
1962 and 1964	Severe droughts in eastern areas of both islands (Waugh et al., 1997).
1969-70	Wairarapa received only 35-45% of normal rainfall in January and February. (Finkelstein, 1971).
1973	65 days with severe soil moisture deficit at Masterton, 72 days at East Taratahi (Tait et al, 2002).
February – March 1978	The effects of the drought were widespread in Wairarapa, lasting 29 days (Thompson, 1982), Gladstone received less than 30% of normal rainfall for January, February and March (Crawford & Hamlin, 1982). 69 days with severe soil moisture deficit at Masterton (Tait et al, 2002).

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[75] * coincide with the significant flood events listed in Table 11-1

1987-88	Eastern parts of both islands were affected (Pearson, 1992).
1992	Severe droughts affected the entire country in the winter months (Pearson, 1992)
1997-98	68 days with severe soil moisture deficit at Masterton, 74 days at East Taratahi. (Tait et al, 2002). Water levels are low with some dams only half full compared with overflowing at this time in some past years (Campbell, 1998).
2000/01	23 days with severe soil moisture deficit at Masterton, 12 days at East Taratahi (Tait et al, 2002).
2007	Minimal rain for a three month period (Black, 2007; Crombie, 2007). Affecting most of the North Islands East Coast.

Table 11-2: Historical droughts occurring in the Ruamahanga Catchment. Source (Thompson, 1982)

The implications of droughts are widespread and range from "shortages or restrictions on water supplies, crop failure and loss of productive land, damage to horticulture and lack of feed and consequences for agriculture, as well as increased potential for wild fire, and other socio-economic factors" (Tait et al, 2002, p. 42). Careful planning must therefore be carried out in regards to drought management in Wairarapa to limit the impact that droughts can cause. The accuracy of predicting drought events has increased in recent years, and is central to drought management. For sometime the relationship between natural weather phenomenon such as the El Nino – Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) and flood and drought events has been studied and has enhanced prediction methods.

11.7. LINK BETWEEN EL NINO AND METEOROLOGICAL HAZARDS

The El Niño – Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) were previously introduced in Section 6.4.2.3 of this report. Reiterating the links:

- Drought is more prevalent in Wairarapa in the summer during El Niño periods (Harkness, 2000; Tait, 2002).
- La Niña periods generally mean the west coast regions are more subject to dry spells (Tait et al, 2002), however La Niña periods can increase the likelihood of the Wairarapa region having a low autumn rainfall (Harkness, 2000).
- The shift of the IPO into the negative phase indicates that more La Niña events rather than El Niño events are expected. This can be interpreted as a decreased possibility of droughts in Wairarapa in summer, but they could still occur in

autumn, depending on the time of year the La Niña events occur (Tait, 2002; Watts, 2005).

11.8. PREDICTING FLOODS AND DROUGHTS

Predicting floods and droughts in the Ruamahanga Catchment are beyond the scope of this report. However the following references cover prediction methods for both scenarios in detail.

- Predicting Rainfall Droughts in the Wairarapa using the Southern Oscillation Index (Harkness, 2000)
- Floods and Droughts: Forecasting their occurrence and predicting their effects – NIWA service (www.niwascience.co.nz/rc/prog/floods/)
- Stochastic Methods (Pearson & Davies, 1997).

11.9. CONCLUSION

With the onset of climate change and predicted increase in variable weather, the threat of floods and droughts in the Ruamahanga Catchment is still very serious. Significant floods have occurred in catchment in 2004, 2005 and 2006, with a drought hitting most of the east coast of the North Island in the start of 2007. Managing for such extreme weather conditions can be difficult. A variety of flood protection devices are operational in the lower half of the catchment to protect land, but floods can still impact on the public water supply and public access. Furthermore, droughts can be just as serious, and they often occur for longer periods of time. The severity of droughts can also place pressure on public water supplies by reducing the volume of water available while causing the demand for water to increase. In times of drought, the consents for public water supply are subject to a cutback restriction. Similarly, irrigation and other 'non essential' water supply consents are subject to a mixture of cutback restrictions and cessation of take (S. Thawley, Personal Communication, 9 October 2007).

With the potential to seriously impinge on the health of the catchment, in both economic and environmental terms, floods and droughts should comprise key issues in a future integrated catchment management plan.

12. Māori Culture

"Ko Waiohine ko Ruamahanga enei
e wairua tipu mai
I Tararua maunga
E oranga e te iwi"

- Whatahoro Jury (tupuna/ancestor)

"These are Waiohine and Ruamahanga, they are like mothers milk flowing out of the Tararua Mountains for the prosperity of the people"

12.1. INTRODUCTION

The Ruamahanga Catchment is an area of cultural and spiritual importance for both Rangitaane ki Wairarapa and Ngati Kahungunu. There is no definitive geographic boundary that separates each of the iwi in Wairarapa.

12.2. METHODOLOGY

Initial consultation through a series of meetings and interviews with iwi and GWRC has occurred to discuss how to undertake this particular chapter. It was decided that due to time constraints only the generic relationship between Māori and freshwater will be discussed in this report. This can then be further expanded at a later stage by the appropriate people of Wairarapa to ensure that each iwi's interests in the catchment are appropriately and effectively identified and implemented in the Integrated Catchment Management (ICM) process.

The overview of the generic relationship between iwi and freshwater will be completed by using a combination of existing research and initial comments available from iwi representatives. This chapter also includes comments on the iwi's role in the catchment and will conclude with two sections highlighting the presence of Tangata Whenua in the Ruamahanga Catchment.

12.3. THE NAMING OF WAIRARAPA LANDMARKS

The naming of sites within an area or rohe of an iwi is an important cultural practice that provides links with and identity to the land.

Haunui-a-nanaia, a Rangitaane ancestor of Kurahaupo descent, named many of the rivers and landmarks in Wairarapa and lower North Island. On his journey returning from following his runaway wife, Wairaka, he headed north via the east coast. He called Rimutaka, Remutaka meaning 'to sit down' once he had climbed up the mountain. He called the area he saw before him 'Wairarapa' because the reflection of the sun in the lake below made his eyes water. The first river he came to had a maemae built next to it, built of Nikau Palm leaves, hence he called this river 'Tauwharenikau' meaning the 'house made of nikau'. At the next river he came to on his north bound journey, he saw an illusional face in the water, he thought it to be the face of his wife, and made him shed some tears. He called this river 'Wai o Hine Wairaka' – meaning 'water for his woman'. This river is now known as the Waiohine (Rangitaane o Wairarapa & Greater Wellington Regional Council, 2005, p. 11).

Haunui also named the Waingawa, Waipoua and Ruamahanga Rivers on his journey. He noticed the braided nature of the Waingawa and named it 'Waiawangawanga, awangawanga' meaning 'troubled or uncertain'. At the Waipoua River he tested the depth of the water with his 'tokotoko' which is also known as 'pou' and 'wai' as water. Finally he named the Ruamahanga River after the many tributaries that joined this river. Ruamahanga translates to 'twin forks' (Rangitaane o Wairarapa & Greater Wellington Regional Council, 2005, p. 10).

There are many other areas and features in the Ruamahanga Catchment that have Māori names. The Māori often used names that described the area. For example Papawai (papa meaning land, and wai water) is the name given to the area that has abundant water resources and is one of the greenest parts of Wairarapa (P. Amundson, Personal Communication, 27 August 2007).

12.4. SIGNIFICANCE OF LAKE WAIRARAPA (WAIRARAPA MOANA)

Lake Wairarapa is known as 'the eye of the fish of Maui' or 'Te Whatu o Te Ika a Maui'. The fish of Maui is thought to have one salt water eye (Wellington Harbour) and one freshwater eye (Lake Wairarapa) (Rangitaane o Wairarapa & Greater Wellington Regional Council, 2005, p. 7). Culturally, Lake Wairarapa is hugely significant and is thought of as the spiritual hub of the valley (P. Ammundson, Personal Communication, 27 August, 2007).

Lake Wairarapa was gifted to the Crown in 1896 by Hāmuera Tamahau Mahupuku, to "ensure the mana (spiritual power) of the lakes remained with Wairarapa Māori" (Schrader, 2007, para. 6). The Crown, in return, paid £2,000 for the lakes and set aside land near Mangakino in the Waikato for the Māori. This land consisted of "swamp and bush-covered hills, with infertile pumice soils" (Schrader, 2007, para. 6). There are claims that the deal was one of coercion, and to this day there is still dispute over the terms of the actual agreement.

There are important links with Lake Wairarapa and mahinga kai. The lake provided an important eel fishery. In the eels' migration season, Māori would dig side channels around the lake's edge which eels would swim into. Once these channels were full they would be blocked off. This kind of small scale alteration of the natural environment was all that was undertaken by the Māori, and its purpose was for fishing and irrigation only (Rangitaane o Wairarapa & Greater Wellington Regional Council, 2005). Māori actively manage their environment and develop their own methods and practices to ensure the sustainable use of their resources.

Over time, the state of Lake Wairarapa has changed. Māori elders remember the lake to be of a blue/green colour. Now it is permanently brown, possibly due to the fact that the lake no longer naturally flushes itself out. Māori elders also remember the lake when its edge was black with eels. Back then eel was the food that the Wairarapa Iwi were known for (P. Ammundson, Personal Communication, 27 August, 2007). Today there is nowhere near the same volume of eels in the lake.

In 1886 there was a battle between Europeans and Māori over the 'opening of the spit' (the sand margin that separates Lake Onoke from the ocean). The Europeans wanted to open it to control water levels in the lake and hence in the entire river system. This was disputed strongly by the Māori. Some time later after many legal hearings, it was found the Māori had "been wronged and recommended their grievances be redressed" (Schrader, 2007, para 5).

12.5. THE RELATIONSHIP BETWEEN IWI AND FRESHWATER

Rivers and waterways have been likened to veins in the human body by the Māori. They are interconnected, bringing life to all regions that they pass through. This analogy reinforces the interconnectedness that Māori have for the land and water resources in New Zealand, realising and appreciating that degrading one part of the system will weaken the whole (Tipa, 2001).

This world view and holistic approach to management recognises the spiritual aspects of waterways alongside their physical and biological uses. Māori appreciate the mauri or life force that has a presence in all elements of nature, including water and people (Tipa, 2001). Mauri binds the physical and spiritual components of nature. It "empowers all living things, and is integral to the mana and lifeblood of iwi, hapu and whanau" (Parliamentary Commissioner for the Environment, 2000, p. 11). The drainage patterns that waterways form in the landscape are seen as a conduit supplying mauri to the surrounding environment. Therefore, tupuna (ancestors) have recognised waterways having their own spirit or wairua, and their own identity (Kereama-Royal & Ashton, 2000).

The mauri or life force of waterways is not static and can be altered by the way that the water is treated. Water can be classed into seven different categories, each with different levels of mauri. Mauri is degraded by many mechanisms, including discharging wastes into waterways and by mixing and diverting waters with different mauri. As well as being detrimental to the mauri status, these practices are offensive to Tangata Whenua (Parliamentary Commissioner for the Environment, 2000).

In addition to this interconnectedness that the Māori people have with water, it is also a highly valued resource, providing the people with drinking water, forms of transportation, and places to gather food and other resources (mahinga kai[76]) (Parliamentary Commissioner for the Environment, 2000). The river and water also provides cleansing, healing and calming properties, and is utilised in times of crisis (Kereama-Royal & Ashton, 2000) and during certain rituals and spiritual practises. The capacity of the river to provide for future generations is also highly valued by the Māori (Tipa, 2001).

Understanding this intricate relationship that Māori have with freshwater resources is crucial to recognising that all water is sacred and is culturally significant. At a regional level, the relationship of iwi with local rivers and streams depends on "the nature of the waters, traditional uses of these waters, and historical and contemporary experiences of the Māori communities associated with these waters" (Roskruge, 2007, p. 5). Therefore in the Ruamahanga River context, only after consultation with and the active involvement of the local iwi, the Ngati Kahungunu and Rangitaane ki Wairarapa, can this specific relationship be realised.

12.6. CULTURAL HEALTH INDEX (CHI)

A way of incorporating cultural values into standard freshwater monitoring has been developed by Gail Tipa in the Cultural Health Index (CHI). This index can be used as a tool to monitor the cultural health of any water body.

Work on the CHI first began in 1999 on the Taieri River, for the Environmental Performance Indicators Programme of the Ministry for the Environment (MfE). In this first study, the author worked closely with the Komahtua (Kaumatua) of Ngati Tahu who

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[76] Mahinga Kai – Food Source

live in the Otago Region. The outcome of this research was 30 Māori Indicators that could be used to assess the health of a waterway. These indicators were divided into 'general', 'touch', 'smell', 'sound', 'sight' and 'taste' categories, and include 'the greasiness of water', 'the sound of the current in the water', 'a visible flow', 'colour', 'continuity of vegetation', 'health of the fish found in the river' and 'the extent of tidal influences on the river' (Tipa, 1999)[77].

Following on from the previous research, the MfE produced a publication outlining the CHI and its use in recognising and assessing Māori values of a waterway (Tipa & Teirney, 2003). The CHI is comprised of three parts, 1) traditional association, 2) the mahinga kai measure, and 3) the cultural stream and health measure.

The first component asks whether there is a traditional association between runanga and the site, and whether Māori would come to this site in the future. The second component is derived from asking four separate questions relating to mahinga kai features, these features are ranked from 1-5 and the final score is the average of the four 1-5 ratings[78]. The four questions are as follows: 1) How many mahinga kai species are present? 2) Are the mahinga kai species that were gathered in the past still here? 3) Are the mahinga kai species accessible for gathering? 4) Would Māori come to the site in the future?

In the final component, streams are assessed for their cultural stream health. This measure utilises the indicators that were initially developed in Tipa (1999), however only 18 of these are used and were chosen by their suitability to "produce consistent and repeatable results irrespective of iwi members who use it" and also they must "embody Māori values" (Tipa & Teirney, 2003, p. 30). These 18 indicators were then reduced to five by a multitude of analytical steps. The final five included 1) catchment land use (1–5; land and margins grazed / natural condition), 2) use of riparian margins (1–5; riparian zone grazed / natural), 3) use of the river – modification (1–5; evidence of modification / appears natural), 4) river flow - visible (1 or 5; no movement / movement visible), and 5) water

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[77] A full list of these indicators can be found in Tipa (Tipa, 1999).

[78] A score of 1 is poor, while 5 is the highest Mahinga Kai ranking.

quality – pollution (1–5; foams or oils / none evident). Each of these indicators was scored from 1-5, added and averaged out to give the final score (Tipa & Teirney, 2003).

A publication outlining how the CHI can be used in assessing the health of streams and water ways was produced by the Ministry for the Environment in (2006). Ultimately it is a step by step guide allowing individual groups to set up their own CHI monitoring program.

12.7. THE ROLE OF IWI IN THE CATCHMENT

Both Ngati Kahungunu and Rangitaane play a large part in the resource consent process. Under the Resource Management Act (1991), both the regional and district councils must recognise and provide for the relationship of Māori and their culture and traditions with their ancestral land, water, air, sites, wahi tapu and other taonga when making resource consent decisions ("Resource Management Act," 1991). The Local Government Act (2002) (Part 6) also stipulates that local authorities "ensure they have processes in place for consulting Māori in the decision making process" (Department of Internal Affairs, n.d., planning) Furthermore under the Act, local councils need to maintain relationships with Māori, providing them with relevant information and fostering their input in decisions (Department of Internal Affairs, n.d.).

GWRC sends all 'non-notified' consent applications to the iwi in the Wellington Region, so that any concerns with a particular application can be raised before the decision is made (Greater Wellington Regional Council, 2004b). Assessing these consents is a significant job.

In addition to this, Rangitaane O Wairarapa has been involved in several projects in conjunction with GWRC, educating councils, landowners and the community about Māori values.

One of the projects completed in 2005 was the production of Ngati Hamua Environmental Education Sheets. These sheets are provided in a booklet form, and were published to inform the reader "about the environment from the perspective of the Ngati Hamua hapu of Rangitaane o Wairarapa" (Rangitaane o Wairarapa & Greater Wellington Regional Council, 2005, p. 2).

In addition to this, Rangitaane o Wairarapa has been involved in using geographical information systems (GIS) to record 250 historical sites in Wairarapa (Greater Wellington Regional Council, 2005), with a majority of the sites "falling in the Masterton District Boundary reflecting the traditional stronghold of Rangitaane" (Kerehi, 2005, p. 8). Visible and obvious sites, such as monuments and Marae are included as well as not so obvious sites such as burial sites which lie beneath the ground surface. The values and importance of these sites from a planning perspective are difficult to identify due the holistic approach of Māori environmental management. For example, archaeologists' value sites for gathering historical information, while for Māori the most important sites are those that are associated with life or death e.g. a burial site or a place where the afterbirth is buried (Kerehi, 2005, p.12).

The creation of this database has allowed the district councils and GWRC to be alerted if a consent proposal will affect a particular site. However, the locations of these sites are not available to the public in order to maintain the 'spiritual integrity of the sites'. Only six GWRC staff members have access to the database. Some of the sites Rangitaane have identified have however been included in the draft Combined Wairarapa District Plan (Kerehi, 2005).

It has been decided that an assessment of the relative significance of individual sites in relation to the Ruamahanga catchment not be included in this report due to the sensitive nature of the information. This process should be undertaken by the appropriate people under full consultation of Rangitaane ki Wairarapa.

12.8. CONCLUSION

The purpose of this chapter was to try and highlight how significant the waterways in the Ruamahanga Catchment are to the Tangata Whenua of the area. To the Māori people, waterways are synonymous to the veins in the human body, and are of utmost importance to the health of the environment and the people. Tangata Whenua have a number of significant issues and concerns with the current state and management of the waterways in the catchment. For example, it is totally unacceptable and offensive to the Māori people to be discharging sewage into the catchment's waterways, which are used for food gathering and spiritual practices. Some discharges in the Ruamahanga Catchment are now being discharged to land instead of directly into the rivers and streams (e.g. Carterton's Sewage), and several of the other towns (e.g. Greytown) are investigating this option also. Although these changes are a step in the right direction, the Māori people would like to see further steps taken to improve the overall water quality in the catchment. Integrating the Cultural Health Index (CHI) into the freshwater monitoring program in the catchment could be a way of incorporating Māori values into the current management of water resources.

13. Heritage

13.1. INTRODUCTION

Heritage can be defined as "valued things such as historic buildings that have been passed down from previous generations and things of historic or cultural value that are worthy of preservation" (Oxford English Dictionary, 2007, para 1). In this section, heritage will include cultural heritage sites and natural heritage sites (e.g. significant landforms) within the boundaries of the catchment.

13.2. METHODOLOGY

This chapter aims to capture the essence of the cultural and natural heritage in the Ruamahanga Catchment. For these purposes, cultural heritage has been defined to include sites which reflect past times or significance of our ancestors such as historic places (buildings, monuments, pas, burial sites etc) and archaeological sites. Natural heritage by contrast, will include areas of significant native vegetation and habitats, and outstanding natural features and landscapes. Examples include: geological landforms; remnant native bush; and protected species habitat. There is some overlap of the natural heritage sites with sites identified in the recreation chapter of this report.

The data sources from which information on cultural and natural heritage can be obtained are listed below. Individual sections on cultural heritage and natural heritage in the Ruamahanga Catchment are then provided, focusing briefly on catchment-wide heritage, and then identifying any sites in close proximity to the water bodies in the catchment.

13.3. DATA SOURCES

13.3.1. New Zealand Historic Places Trust

The New Zealand Historic Places Trust (NZHPT) is New Zealand's main heritage agency. It provides "recognition, protection, and promotion" of the historic and cultural heritage (New Zealand Historic Places Trust, 2001, para 1). The Trust maintains the

Register (Rarangi Taonga) of Historic Places[79], Historic Areas[80], Wahi Tapu[81] and Wahi Tapu Areas[82] under the Historic Places Act 1993.

"Places may be significant because they possess aesthetic, archaeological, architectural, cultural, historical, scientific, social, spiritual, technological or traditional significance or value" (New Zealand Historic Places Trust, 2001, para 4). Locations and names of specific sites can be found on the on-line register, excluding wahi tapu and wahi tapu areas which can only be obtained directly from the local NZHPT office.

A technical report was produced by the NZHPT in 2005 pertaining to the historic heritage in the Wellington region. The purpose of this report was to improve understanding of historic heritage in the area, formulate indicators and a monitoring framework and assist GWRC in drafting the next Regional Policy Statement (RPS) (McClean, 2005). The number and distribution of heritage sites are listed in this publication for the Wellington region.

13.3.2. New Zealand Archaeology Association Site Recording Scheme

Archaeological sites are "places in New Zealand that were associated with human activity that occurred before 1900 and are or may be able … to provide evidence relating to the history of New Zealand" ("Historic Places Act," 1993). A site recording scheme was established by the New Zealand Archaeology Association (NZAA) in 1958. The scheme contains over 55,000 records that reference sites nationwide. Each record is paper-based (includes plans, drawings, photographs, field notes), but there is a digital database that acts as the index to the paper records. This database is known as the Central Index of New Zealand Archaeological Sites (CINZAS). The records and CINZAS are maintained by the Department of Conservation (DoC) "under agreement with NZAA" (New Zealand Archaeology Association, n.d., para 5).

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[79] Historic Places include bridges, buildings, pa, memorial sites etc

[80] Historic Areas are groups of historic places

[81] Wahi Tapu are sites that are sacred to Māori

[82] Wahi Tapu areas are groups of Wahi Tapu

Local authorities are one of the main users of the scheme, in their role of "land and heritage management and protection" (New Zealand Archaeology Association, n.d., para 4). In addition to local authorities, the general public, iwi/hapu, DoC and the NZHPT all utilise the resource, realising its potential in assisting historic resource management. Records for the Scheme have been gathered over many years, and therefore the quality of each may vary considerably. In addition, absence of an archaeological site in the database does not always imply that there is not one there, it may mean that an archaeological survey has not been carried out in that area (New Zealand Archaeology Association, n.d.).

The NZHPT technical report (McClean, 2005, p. 23-25), introduced in 13.3.1, details information on NZAA sites in the Wellington Region.

13.3.3. New Zealand Geopreservation Inventory

The New Zealand Geopreservation Inventory lists and provides information about "nationally and regionally significant (for science and education) geological sites, landforms and soil sites in New Zealand" (Statistics New Zealand, 2007b, para.1). The inventory was compiled during 1987-1993 by the Joint New Zealand Earth Science Societies' Working Group on Geopreservation. Records from 1996-1999 are currently being updated. The inventory is used in the compilation of DoC's Conservation Management Strategies (CMS), and in regional and district plans (Statistics New Zealand, 2007b).

Important geological sites and landforms in the Manawatu and Wellington regions are listed in 'Inventory and maps of important geological sites and landforms in the Manawatu and Wellington regions' (Kenny & Hayward, 1996).

13.3.4. Queen Elizabeth II Trust

The Queen Elizabeth II (QEII) National Trust New Zealand is an organisation independent of the government, set up to assist private land owners in protecting special features on their land. The trust was established under the Queen Elizabeth the Second

National Trust Act 1977, which was put in place "to encourage and promote, for the benefit of New Zealand, the provision, protection, preservation and enhancement of open space", where 'open space' is translated as "any area of land or body of water that serves to preserve or to facilitate the preservation of any landscape of aesthetic, cultural, recreational, scenic, scientific, or social interest or value" (Queen Elizabeth II National Trust, n.d., para 5 & 6). Through the trust a QEII open space covenant can be placed on private land, binding the current and future land owners to its stipulations.

13.3.5. Conservation Management Strategy (CMS)

The Conservation Management Strategy (CMS) was introduced in Section 10.3.3 of this report. The CMS includes reference to historic sites resources in the Wellington Conservancy, outlines the management issues involved in historic sites, and lists some of the historic places that are actively managed by the Department (Department of Conservation, 1996). As mentioned previously, the document is now over ten years old, and some parts may be dated. The document is scheduled to be revised in 2008 (J. Flavell, Personal Communication, 8 October 2007).

13.3.6. Department of Conservation (DoC)

The Department of Conservation (DoC) website has a lot of information on historical sites that the Department manages. Historic heritage sites are listed by heritage 'topic' e.g. bridges, Māori sites, European discovery, and by region[83] (Department of Conservation, n.d.-b). DoC also assists in maintaining some of the above-mentioned databases, including the NZAA site recording scheme, and the New Zealand Geopreservation Inventory

13.3.7. Other Sources of Information

At a local level, information on heritage sites can be obtained from the three district councils and also from local historians and libraries e.g. the Wairarapa Archive. 'Measuring up' the GWRC State of Environment Report (Greater Wellington Regional Council, 2005), dedicates a section to landscape and heritage. Two reports have been

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[83] See www.doc.govt.nz for further information.

produced by John Holmes of GWRC, regarding the objectives, methods and policies for 'Landscape and Heritage' in the RPS. Holmes (2005) outlines the 'Landscape Objectives' while Holmes (2006), evaluates the objectives, methods and policies for the RPS.

13.4. SIGNIFICANT HERITAGE SITES IN THE RUAMAHANGA CATCHMENT

13.4.1. Cultural Heritage

13.4.1.1. Catchment wide

There are 373 heritage sites within the Ruamahanga Catchment recorded with the Historic Places Trust. These include churches, libraries, war memorials, homesteads etc. An additional three sites defined by DoC include the Rimutaka Incline, Cone Hut and Field Hut in Tararua Forest Park (Department of Conservation, 1996, p. 158).

There are 64 archaeological sites in the Ruamahanga Catchment as defined by NZAA. A large number of these sites are at the southern end of the catchment. Many of these relate to pre European times, when various Māori tribes resided on the terraces in this area. Archaeological sites include ovens (13), raised rim pits (7), pits (6), historic period settlement or marae (6), pas (5), pa with pits (5), wooden artefacts (4), and burial sites (3) (New Zealand Archaeology Association, 2007).

Sites that were not recorded in the NZAA site recording scheme have been listed in Appendix 1 of McFadgen (2003). These sites were recorded by archaeologist, Keith.R.Cairns, and are termed Cairns Archaeological sites in the remainder of this chapter. There are 74 of these sites in the Ruamahanga Catchment Boundary. These include 30 pa, 15 historic pa, 8 historic gardens, and 5 historic villages. Further information on these sites can be obtained from McFadgen (2003, p. 64-75).

13.4.1.2. Sites close to waterways

235 of the NZHPT sites are within 1 kilometre from the main tributaries in the catchment.

46 of the NZAA sites and 64 of the Cairns Archaeological sites are within 1 kilometre of a water body in the catchment. Matahiwi Cottage, Kopuaranga Truss Bridge, Raho Ruru Homestead, and Mangaakuta Cairn are four NZHPT sites within 100 metres of the main rivers and streams in the catchment and there are two pits, one historical period settlement, one burial site, one wooden item find spot, and one pa within the same buffer zone, listed with the NZAA.

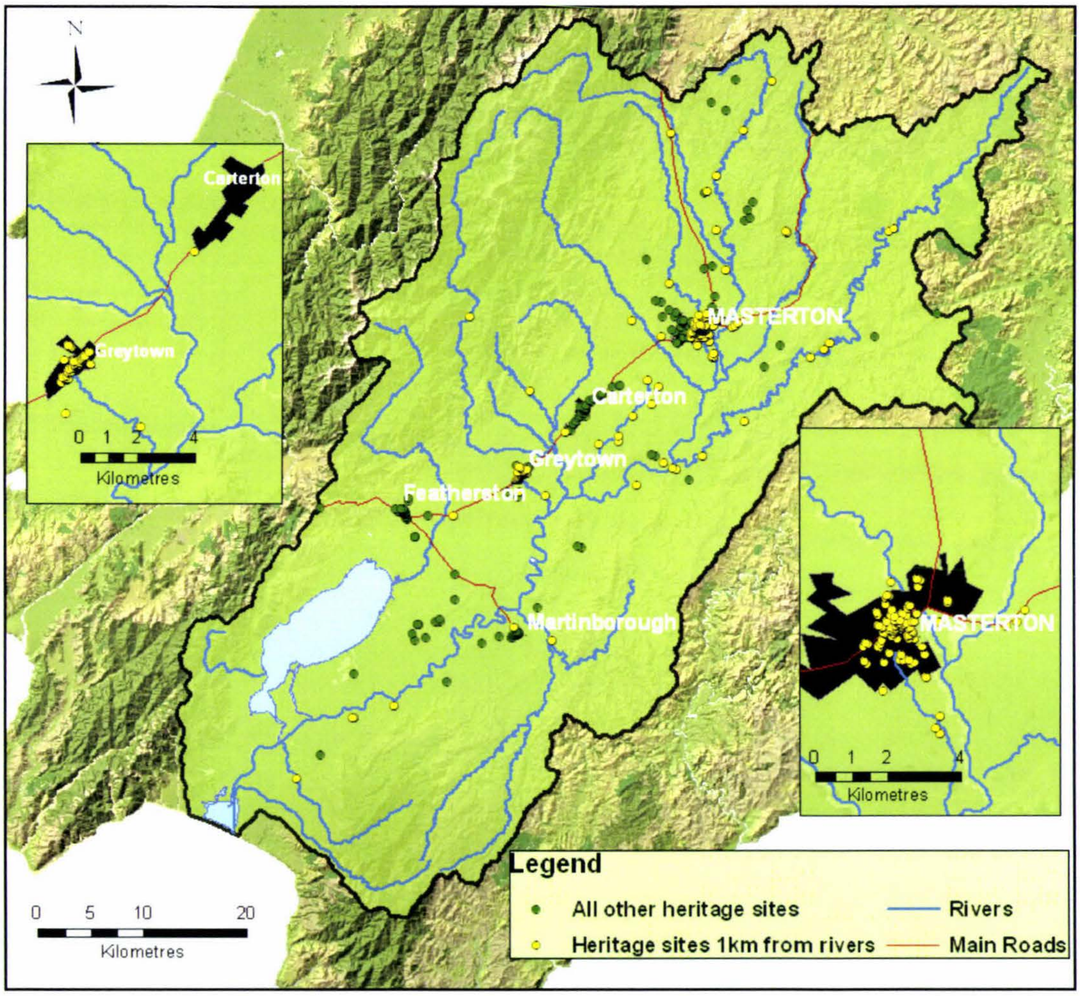


Figure 13-1: New Zealand Historical Places Trust Sites

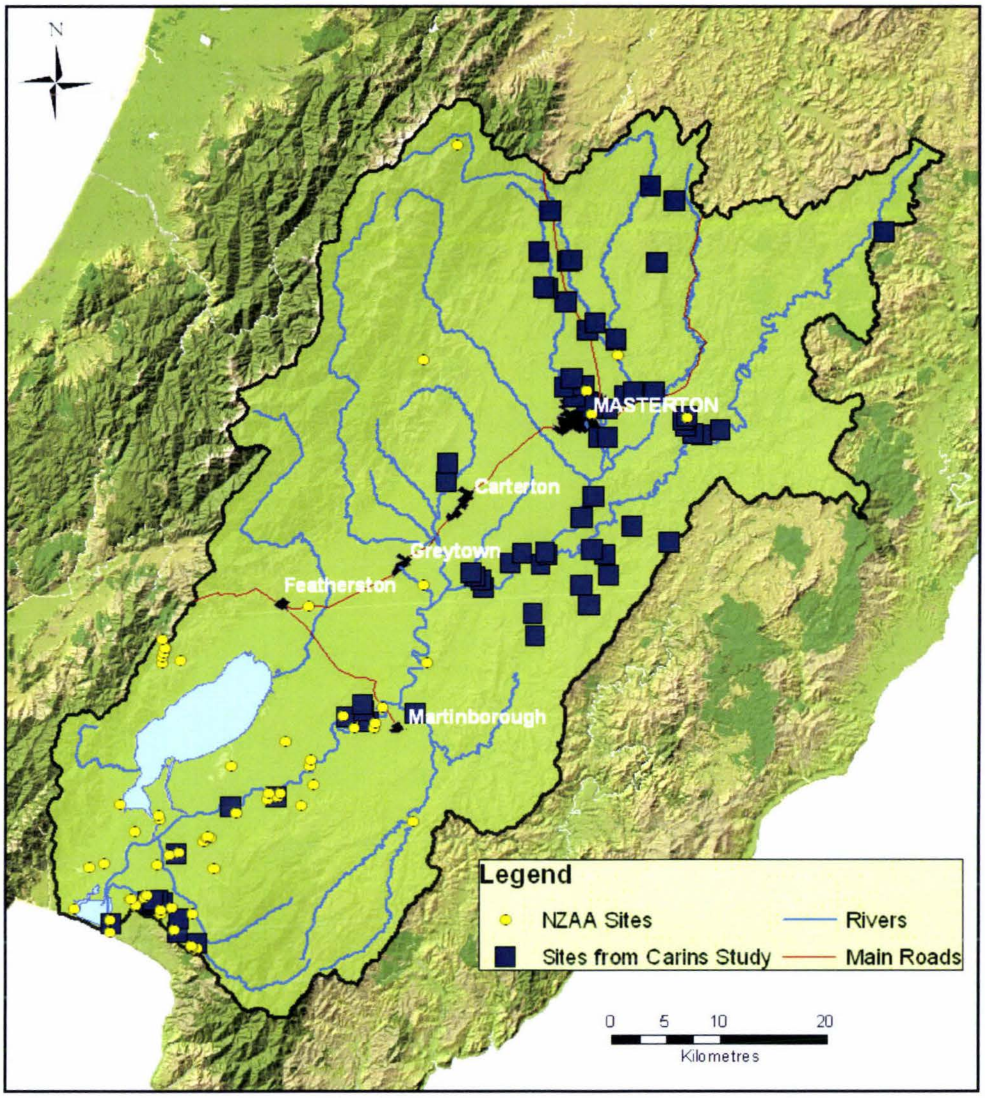


Figure 13-2: New Zealand Archaeological Association registered sites and Sites reported to K.R Cairns. Source (New Zealand Archaeology Association, 2007)

13.4.2. Natural Heritage

13.4.2.1. Catchment wide

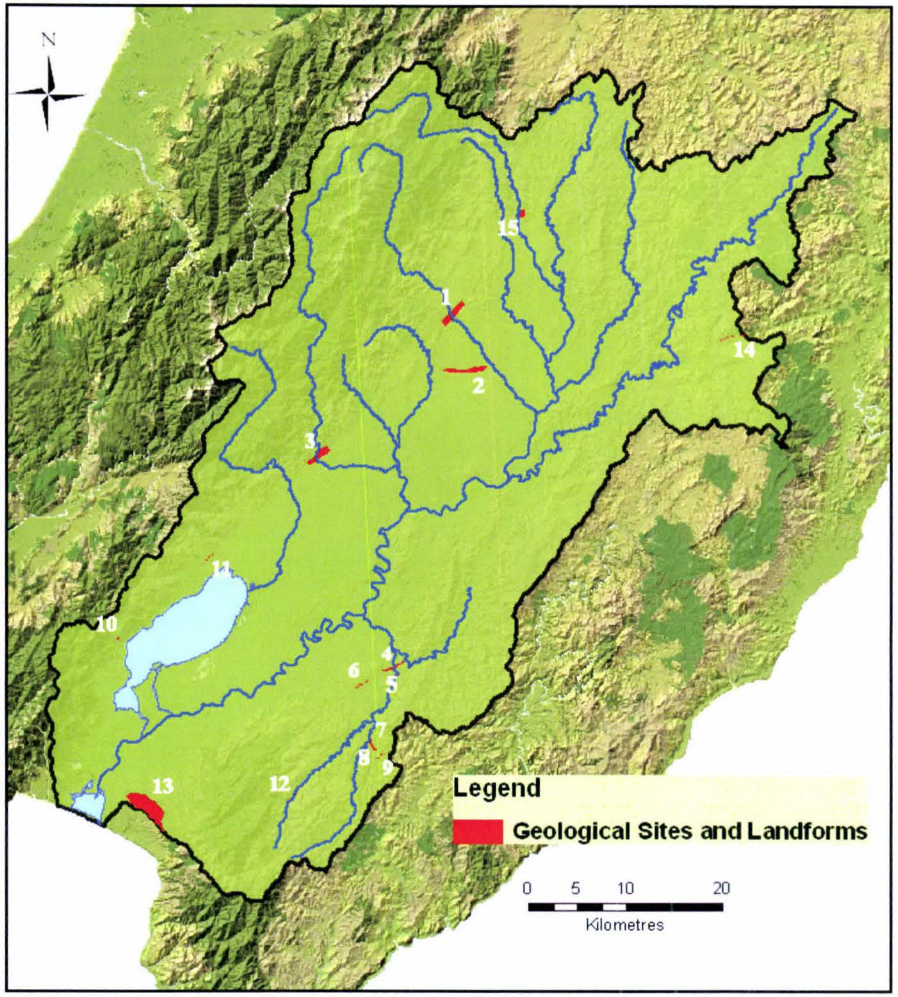
The majority of the land area in the Ruamahanga Catchment has now mostly been developed for productive purposes; however there are still areas that are managed and held under covenants to preserve their natural heritage. The largest of these areas in the Ruamahanga Catchment are the three forest parks, Tararua, Rimutaka and Aorangi.

These three forest parks are each individually unique. "There is a fascinating and subtle pattern to the vegetation" in the Tararua Forest Park (Department of Conservation, n.d.-f, para 1), which is also home to a variety of special birds, bats, giant snails, weevils and slugs and freshwater fish. In addition this area was one of the last known refuges for the huia (Department of Conservation, n.d.-i). The Rimutaka Forest Park, at the southern end of the catchment once had eight species of moa inhabiting the area. Today the forest is home to bellbirds, tui, kaka, kereru and ruru, and the brown kiwi was released into the park in 2006 (Department of Conservation, n.d.-h). Vegetation patterns in all of the three forest parks have been partially modified, especially the Aorangi Forest Park, where significant land clearing and logging have occurred (Department of Conservation, n.d.-e).

In addition to these forest parks, small patches of conservation reserves occur on the Wairarapa Valley floor. These include Carters Scenic Reserve and the Lake Wairarapa Wetlands. Carters Scenic Reserve offers protection to one of the last areas that has a "landscape once typical of the Wairarapa" (Department of Conservation, n.d.-a, para 1). Fensham Reserve (near Carterton) is another area where work has been done in regenerating native bush and wetlands. The reserve is owned by the Wairarapa Branch of Forest and Bird.

There are 151 approved and registered QEII covenants in the Wairarapa Region. These are distributed as follows: 22 in Carterton District, 54 in South Wairarapa District and 75 in Masterton District. In total, these covenanted areas cover around 4,600 hectares, although not all covenanted areas have been surveyed yet (M. Hodgkinson, Personal Communication, 15 August 2007).

The Waiohine Faulted Terraces have been defined as being "one of the most famous geological features in New Zealand". These terraces show the movement of the Wairarapa Fault over the last 35,000 years. "Over the last 15,000 years the average lateral displacement has been about 0.8 metres per 100 years" (Department of Conservation, n.d, para. 1).(Number 3 in Figure 13-3).



#	Description	Importance/ Vulnerability
1	West Wairarapa Fault, Waingawa River Faulted Terraces	C/3
2	Masterton Fault (Waingawa Fault)	C/2
3	West Wairarapa Fault, Waiohine River Faulted Terraces	A/2
4	Huangarua Fault	C/3
5	Huangarua Syncline, Flexural Slip Faults	B/3
6	Dry River Fault, White Rock Road Scarp	C/3
7	Huangarua River Cyclothems	B/3
8	Mangaopari Miocene-Pleistocene Paleomagnetic Section	A/3
9	Sunnyside Miocene Conglomerate	C/3
10	West Wairararpa Fault, Burlings Stream	C/3
11	West Wairararpa Fault, 1855 Scarp	B/2
12	Ruakokopatuna Gorge	C/3
13	Eparaimu Uplifted Marine Benches, Palliser Bay	C/3
14	Carterton Fault, Blairlogie Road Trace	C/3
15	McClouds Trig Rock Slump	B/3

	Importance
A	International
B	National
C	Regional
	Vulnerability
1	Highly vulnerable to destruction
2	Moderately vulnerable
3	Unlikely to be damaged by humans

Figure 13-3: Important Geological sites and Landforms in the Ruamahanga Catchment. Source (Kenny & Hayward, 1996)

13.4.2.2 Waterway sites or sites close to waterways

McLea (1995, p. 14), defined the following rivers and lakes as having regionally significant values.

Natural Features, indigenous vegetation or habitats of indigenous aquatic fauna	**For landscape and scenic qualities**	**For landforms and geological characteristics**
Waiohine River (Gorge and above)	Ruamahanga River (gorge and above)	Ruakokopatuna Gorge
Lake Onoke	Waiohine river (gorge and above)	McClouds Trig Rock Slump (Hidden Lakes)
Lake Wairarapa		

Table 13-1: Rivers and Lakes with Regionally Significant Values. Source (McLea, 1995, p. 14)

Other sites, including both the Waingawa and Waiohine River Faulted Terraces have regionally and internationally significant geological values respectively and are also adjacent to waterways in the catchment. At this stage it is unclear which QEII covenants are located near the rivers and streams.

13.5. IMPACTS OF WATER ON HERITAGE SITES

The most obvious impact that water resources in the catchment can have on both cultural and natural heritage sites is flooding. As previously outlined in Chapter 11 of this report, flooding is a common occurrence in the Ruamahanga Catchment. Figure 13-4 reveals the proximity of the heritage sites (cultural and natural) to the boundary of a 50 year flood event. 57 sites would actually be inundated with a flood of this magnitude.

13.6. CONCLUSION

The Ruamahanga Catchment has a rich cultural heritage, with many historic places and sites that document it. Especially at the southern end of the catchment, where in the pre European times, various Māori tribes resided on the terraces in these parts. Furthermore, the Ruamahanga Catchment hosts a variety of natural heritage sites, including three forest parks, a variety of significant geological landforms, and areas of remnant native bush. Although there are no internationally significant cultural or heritage sites within the catchment (apart from two geological landforms), they are still important regionally, and should be managed as such to maintain the identity of Wairarapa.

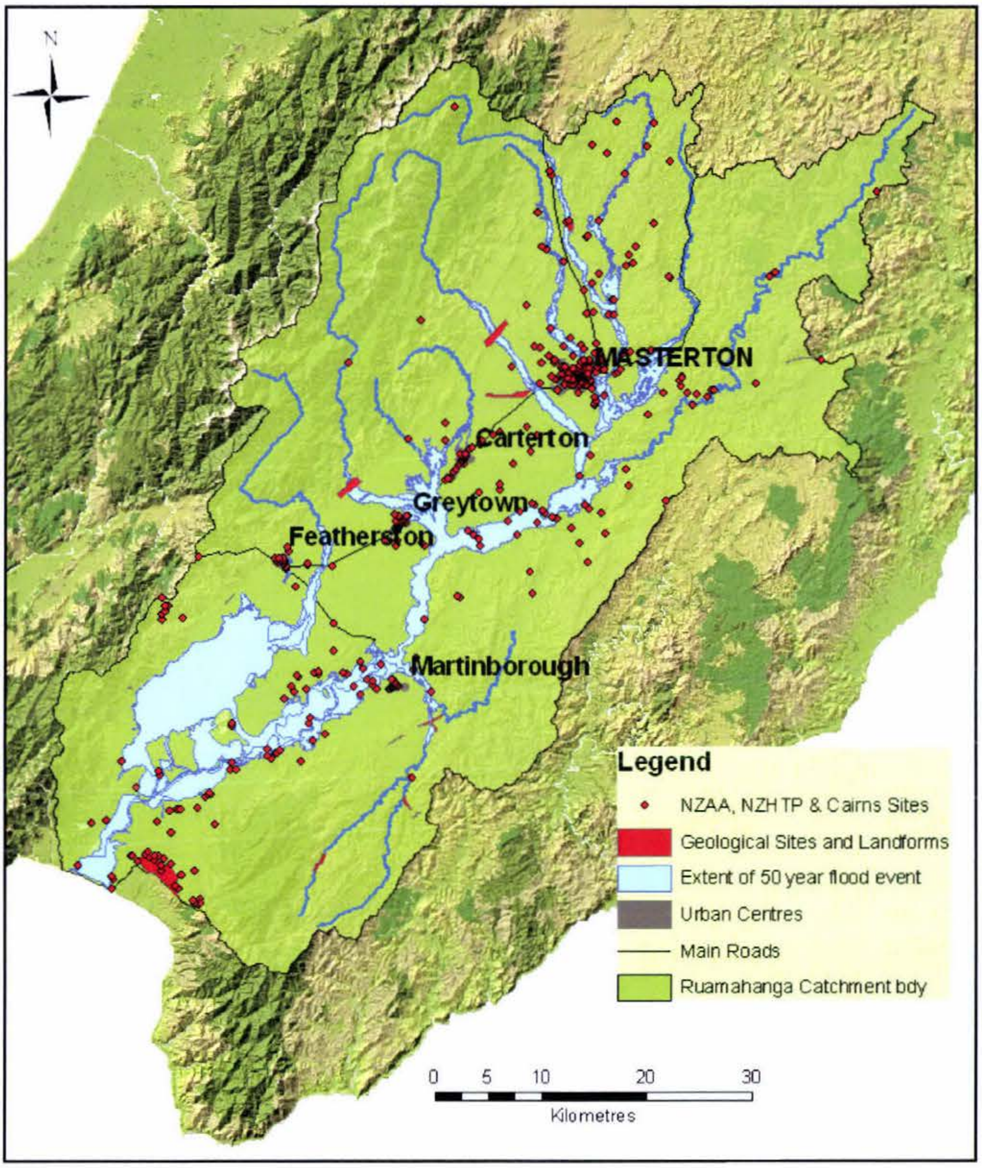


Figure 13-4: New Zealand Archaeological Association Sites, New Zealand Historic Places Trust sites, Cairns sites and Geopreservation sites and the extent of a 50 year flood event

14. Recreation

14.1. INTRODUCTION

Recreational activities carried out within the Ruamahanga Catchment are widespread and range from hunting and fishing to hot air ballooning and wine tasting. Activities covered in this chapter will include those that are directly related to the use of the waterways in the catchment. Further information on additional activities can also be obtained from the data sources that are listed in Section 14.3.

14.2. METHODOLOGY

This chapter identifies recreational sites according to particular activities e.g. swimming and fishing, and then identifies sites at which a number of different activities are carried out.

14.3. DATA SOURCES

14.3.1. Conservation Management Strategy (CMS)

The Conservation Management Strategy (CMS) was previously introduced in Section 10.3.3 of this report. The CMS is an inventory of the land units that are managed by the Department of Conservation (DoC). It also lists the recreational function of the land areas, including recreational opportunities, facilities, access and walkways, and includes a section on managing recreational impacts (Department of Conservation, 1996, p. 231 - 257. Vol.1). Appendix 3 in Volume 1 of the CMS lists all of the Recreational Facilities in the Wellington Conservancy. As mentioned previously, the current document is now somewhat dated, but is scheduled to be revised in 2008 (J. Flavell, Personal Communication, 8 October 2007).

14.3.2. Fish and Game

Fish and Game New Zealand have produced a brochure on fishing spots in the Ruamahanga Catchment. It includes a location map and a description of each site (Fish and Game New Zealand (Wellington Region), n.d.). The brochure can be downloaded from www.fishandgame.org.nz.

A National Angling Survey is carried out every seven years by NIWA for the Fish and Game Council. The last survey was done over the period October 2001 to September 2002 (Unwin & Image, 2003). The next survey will be carried out during 2007/08. The survey splits the catchment into individual rivers and assesses the number of anglers on that river for the period. This estimate includes a margin of error.

14.3.3. Department of Conservation (DoC) Website

DoC provides a nationwide activity finder on their website (www.doc.govt.nz) under parks and recreation. The finder lists numerous activities from abseiling, bird watching and photography to sand boarding and skiing. The site includes information on each activity and locates places throughout New Zealand where each of the activities are done. In addition to the activity finder, the DoC website lists places to visit by region. There are eight places listed on this website that are within the Ruamahanga Catchment boundary.

14.3.4. Tourism New Zealand

The Wairarapa New Zealand website (www.wairarapanz.com) set up by Go Wairarapa[84] lists tourist information including activities, accommodation, and events throughout the Wairarapa region. In addition to this, there are several national tourism websites that provide information on recreational activities in Wairarapa, these include www.tourism.org.nz and www.newzealand.com.

14.3.5. Local Tourism and Recreational Operators

There are several tourism and recreational companies that operate within the Ruamahanga Catchment. These include Wairarapa Outdoor Pursuits (www.wairarapa.co.nz/outdoor-pursuits), Wet and Wild Adventure Tours (www.wetnwild.co.nz/) and Kahutara Canoes (www.wairarapa.co.nz/kahutara).

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[84] Go Wairarapa is the economic development and tourism agency for the Wairarapa.

14.3.6. Local Knowledge

In regards to recreational sites, often the best sites are known only by the locals.

14.3.7. Publications

Several GWRC publications have been produced to assess the water quality at sites used by the public for contact recreation including swimming, canoeing and rafting. These reports include 'Recreational water quality monitoring technical report' (Milne, 2005), 'Will I get sick if I swim?' (Milne & Wyatt, 2006) and 'On the Beaches 2006/07' (Milne, 2007). Other national publications have been produced by the Ministry for the Environment (MfE) relating to water and recreation. One in particular is the 'Water bodies of National Importance – Potential water bodies of National Importance for Recreation Value' (Ministry for the Environment, 2004). 'Healthy River, Healthy People' (Mills, 2002) is a strategic overview of the Ruamahanga Catchment from a health perspective. Included in this document is information about recreational activities and numbers of participants, although these statistics are now somewhat dated.

14.4. RECREATIONAL ACTIVITIES

14.4.1. Swimming

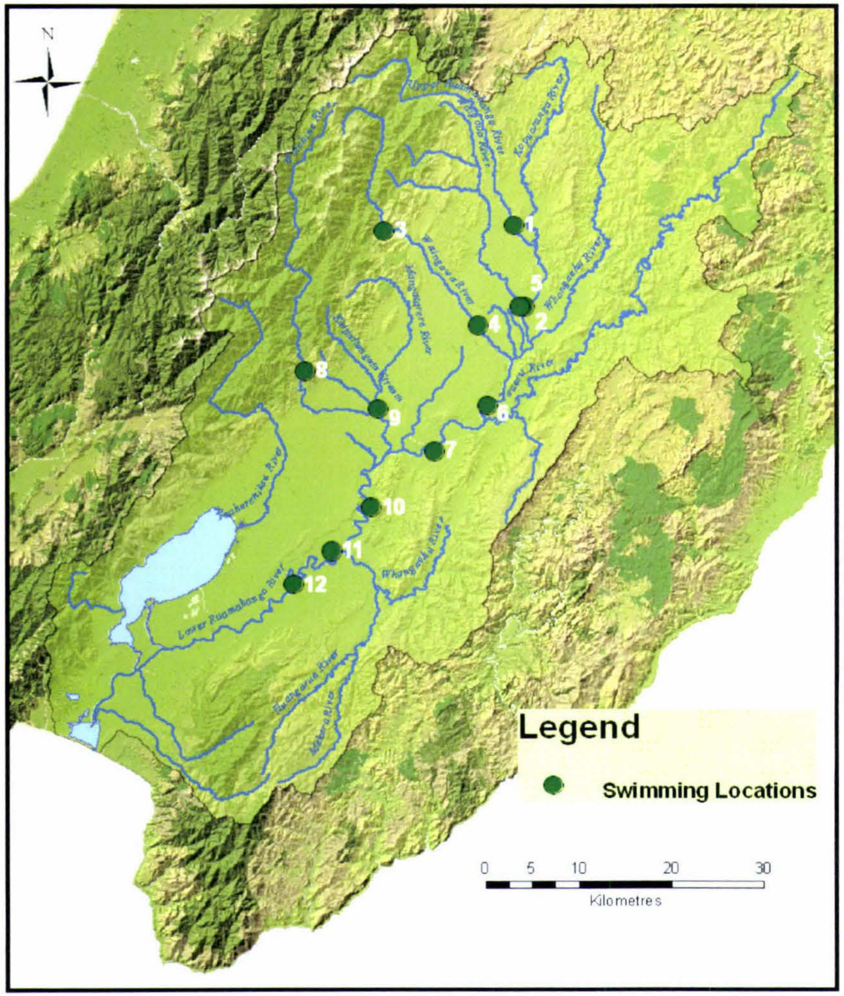
In their recreational water quality publications, GWRC have identified 12 freshwater sites in the Ruamahanga Catchment that are commonly used for swimming (Figure 14-1). At these sites bathing water quality is monitored routinely, and are compared against the Ministry for the Environment/Ministry of Heatlh (MfE/MoH) (2003) recreational water quality guidelines. These guidelines use three levels: green/survellance, amber/alert, and red/action. Water quality in the 'action' category indicates that it is unsafe for swimming (Ministry for the Environment & Ministry for Health, 2003). For the summer of 2006/07, water quality at three sites on the Ruamahanga River reached the action catergory on two occasions. These sites were 'The Cliffs', 'Kokotau' and 'Waihenga'. Five other sites reached the action category on a single occasion (Milne, 2007). The Ruamahanga River at Te Ore Ore, The Cliff's, Kokotau, Morrison's Bush, Waihenga, and Bentley's Beach were all classed as having very poor suitability for recreaction grades (SFRG) by Milne

& Wyatt (2006). These are based on combined Microbiological Assessment (MAC) and Sanitary Inspection Category (SIC).

14.4.2. Fishing

The Ruamahanga River and catchment is a popular place for fishing, in particular trout fishing. Historically, Lake Onoke was "an important eel catchery, especially at the mouth (Okourewa) when the outlet was closed" (Mills, 2002, p. 38). Figure 14-2 locates the main fishing sites on the Ruamahanga River as identified by the Fish and Game Council (Fish and Game New Zealand (Wellington Region), n.d.). In addition to these spots, fishing is carried out up many of tributaries of the Ruamahanga River. The numbers of anglers fishing in the main water bodies in the catchment for two separate seasons are provided in Table 14-1. According to Mills (2002, p. 36), the fishing activity during the 1995 fishing season, "rank the Ruamahanga River as the third most important fishery in the Wellington Fish & Game Region behind the Hutt and Manawatu Rivers"

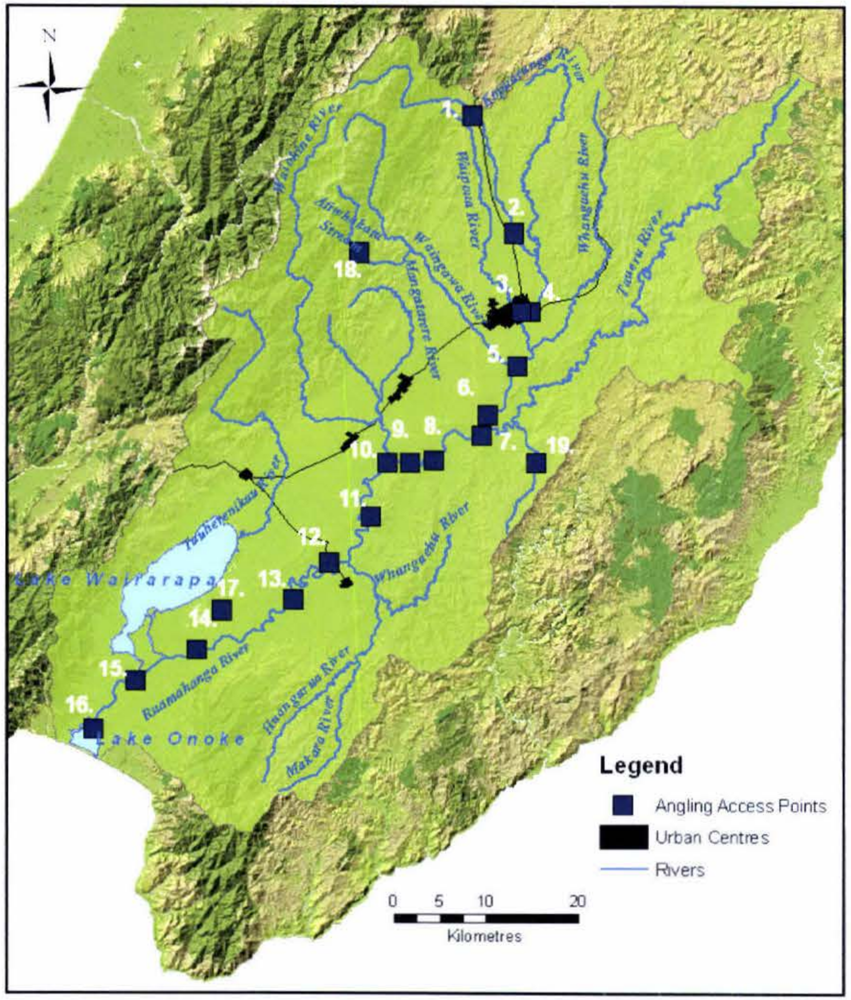
Fish and Game aims to carry out annual trout counts for the rivers that they manage. Unfortunately, the past two attempts in the Ruamahanga River have been unsuccessful due to limited underwater visability. Therefore there is no data to dictate whether fishing in the river is becoming better or worse. However, Fish and Game commented that if trout numbers were in decline, they would know about it by being informed by the anglers directly and also indirectly by the change in angler numbers. Since the anglers surveys started there has been no significant drop in angler numbers on the Ruamahanga River, indicating that the quality of fishing has probably not changed considerably over the years (P. Taylor, Personal Communication, 11 October 2007).



KEY

1. **Ruamahanga River @ Double Bridges**
2. **Ruamahanga River @ Te Ore Ore**
3. **Waingawa River @ Kaituna**
4. **Waingawa River @ South Road**
5. **Waipoua River @ Colombo Road Bridge**
6. **Ruamahanga River @ The Cliffs**
7. **Ruamahanga River @ Kokotau**
8. **Waiohine River @ Gorge**
9. **Waiohine River @ SH2**
10. **Ruamahanga River @ Morrison's Bush**
11. **Ruamahanga River @ Waihenga**
12. **Ruamahanga River @ Bentley's Beach**

Figure 14-1: Swimming sites in the Ruamahanga Catchment. Source (Milne, 2007)



KEY

1. **SH2 Mt Bruce Bridge**
2. **Double Bridges –Mel Parkinson Reserve**
3. **Henley Lake**
4. **Te Ore Ore Bridge – Percy Reserve**
5. **Wardells Bridge**
6. **The Cliffs**
7. **Gladstone Bridge**
8. **Kokotau Bridge**
9. **Forman Jury Road**
10. **Gliding Wairarapa**
11. **Morrison's Bush**
12. **Martinborough Bridge**
13. **Pahautea Road Access**
14. **Diversion Stopbank Access/ Tuhitarata Bridge**
15. **Ruamahanga River Boat Club/ Barrage Gates**

Figure 14-2: Fishing sites in the Ruamahanga Catchment as identified by the Fish and Game Council

	TOTAL	
River/Lake	**2001/02**	**1994/96**
Atiwhakatu Stream	30 ± 30	-
Henley Lake	280 ± 250	2250 ± 800
Huangarua River	60 ± 40	-
Kopuaranga River	520 ± 190	520 ± 240
Kourarau Dam	610 ± 170	850 ± 230
Mangatarere Stream	160 ± 90	260 ± 130
Onoke Lake	30 ± 20	-
Oporua Spillway	-	80 ± 80
Ruamahanga River	6910 ± 810	7390 ± 910
Tauherenikau River	220 ± 150	360 ± 280
Taueru River	140 ± 60	50 ± 40
Waingawa River	140 ± 60	430 ± 210
Waiohine River	960 ± 450	1320 ± 410
Waipoua River	260 ± 180	140 ± 80
Wairarapa Lake	150 ± 80	200 ± 140
TOTAL	10470 ± 1030	13860 ± 1390

Table 14-1: Angler Usage (2001/02) of Lakes and Fisheries managed by Fish and Game. Source (Unwin & Image, 2003)

14.4.3. Other Recreational Activities

Other water based activities that are carried out in the catchment include but are not limited to jet boating, rafting, kayaking and canoeing. Three operators have been identified in the catchment as Wet and Wild Adventure Tours in Martinborough, Adventure Jet in Masterton, and Kahutara Canoes in Kahutara.

14.5. POPULAR RECREATIONAL SITES IN THE RUAMAHANGA CATCHMENT

There are various popular recreational sites within the Ruamahanga Catchment (Figure 14-3). These sites are expanded on in this section.

14.5.1. Lake Wairarapa Wetlands

Lake Wairarapa is the only water body in the Ruamahanga Catchment that is listed in the MfE 'Potential water bodies of National Importance for Recreation Value' (Ministry for the Environment, 2004). Numerous recreational activities are carried out on and within the Lake Wairarapa environs, including recreational fishing (flounder, eels, trout, inanga (whitebait), kahawai and perch), game bird hunting, kayaking, canoeing, sailing, bird watching, and walking (Cromarty & Scott, 1996; Department of Conservation, n.d.-g). Unfortunately, the water quality in Lake Wairarapa is poor (Section 8.2.5.2).

14.5.2. Waiohine Gorge

Waiohine Gorge is a spectacular recreational spot in the Ruamahanga Catchment. Set within the boundaries of the Tararua Forest Park, west of Carterton, the Waiohine River has carved out a remarkable gorge. Recreational activities at the gorge include water based activities such as swimming, tubing, rafting (heli-rafting), kayaking and trout fishing and land based activities: tramping, picnicking, camping, abseiling, caving and hunting (red deer) (Bevin, 1998; Department of Conservation, 2003, n.d.-g; Wairarapa Outdoor Pursuits, 2002).

14.5.3. Henley Lake – Masterton

Henley Lake on the outskirts of Masterton is an artificial lake, 11 hectares in area, which was formed in 1988 to be used for a variety of water sports. Currently the lake is used for windsurfing, jet-skiing, dragon boat racing, model yacht racing and fishing (Masterton Tourism, 2005). The lake is contained within a 43 hectare park area which includes the Henley wetland complex. The water quality in Henley Lake is poor. The Lake has occasional outbreaks of phytoplankton which can be harmful to health (A. Perrie, Personal Communication, 7 August 2007).

14.5.4. Other sites with water based activities

Holdsworth and Carters Scenic Reserve are two other spots that fall within the Ruamahanga Catchment boundary providing fishing (brown trout and eels) and swimming opportunities.

14.5.5. Major Forest Parks

Parts of three major forest parks fall within the Ruamahanga Catchment Boundary. These include the Rimutaka Forest Park, Aorangi Forest Park and Tararua Forest Park. The majority of recreational activities that are carried out in these forest parks are land based e.g. tramping, hunting etc.

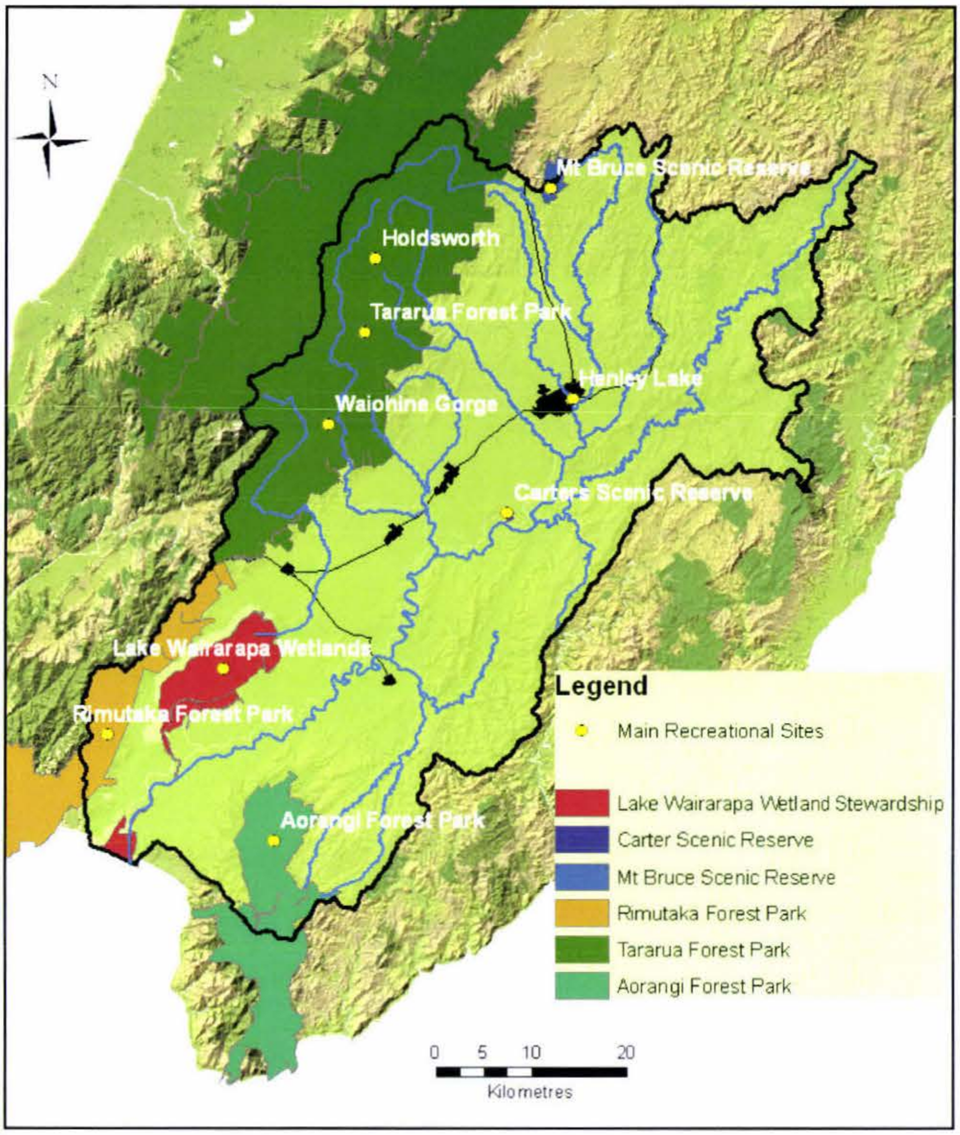


Figure 14-3: Main Recreational Sites in the Ruamahanga Catchment

14.6. IMPACTS OF WATER ON RECREATION

Changes in water quality can severely impact the recreational value of rivers and streams. Increased runoff resulting from periods of heavy rain often renders water ways unsuitable for bathing. This is also true for the collective impact on the river from point source discharges. Many locals choose not to swim in the lower reaches of the Ruamahanga River at Waihenga and at Bentley's Beach because of the sewage discharges that occur upstream from these points.

As discussed in Chapter 7 of this report, some fish species such as trout and eels are still present in degraded water. Therefore it is difficult to assess how changes in water quality will impact recreational fishing in the Ruamahanga Catchment. However there must be a definitive point over which additional units of discharge will irreversibly impact on the abundance of even the most robust fish species.

14.7. CONCLUSION

Swimming and fishing are the two main recreational activities carried out in the waterways of the Ruamahanga Catchment. The enjoyment gained from undertaking these activities can be affected by the quality of the water. On several occasions in the summer of 2006/07, water quality tested at three sites on the Ruamahanga River reached the 'red/action' level guideline. This is is the highest cateogory in the MfE/MoH guidelines and resulted in the closure of bathing sites. It is not uncommon during a summer monitoring period for the water quality at some of the sites on the Ruamahanga River to reach the 'action' level at least once. In the summer seasons from 2002-2005, all of the sites on the Ruamahanga River reached the the 'action' level on around 10 percent of sampling occasions (Greater Wellington Regional Council, 2005).

Similarly, fishing can be affected by changes in water quality. However the trout surveys that Fish and Game carry out annually are inconsistent, and therefore it is difficult to predict whether the river as a fishery is getting better or worse with time. The angler numbers indicate that the quality of the river for fishing has not changed considerably over recent years.

15. Public Perceptions

15.1. INTRODUCTION

Prior to the commencement of this research, several of the stakeholders in the Ruamahanga Catchment had met to discuss the possibility of implementing an Integrated Catchment Management Plan in the region. It became clear at these meetings that there were mixed thoughts about the current state of the river and the issues that surround it. In light of this, this chapter aims to record a range of opinions regarding the state of the Ruamahanga River and its tributaries.

15.2. METHODOLOGY

This survey was not intended to be a comprehensive study of what all people in the Ruamahanga Catchment think about the river and its tributaries. Rather, it was intended to obtain opinions on the river from a small number of people who might be expected to view the river from different perspectives. These opinions could then provide a starting point for more comprehensive debate within the community.

15.2.1. Participants

A person from each of the following organisations/groups were asked to participate in the survey: Greater Wellington Regional Council; Masterton District Council; Carterton District Council; South Wairarapa District Council; Wairarapa District Health Board; Rangitaane o Wairarapa; Ngati Kahungunu o Wairarapa; Fish and Game Council; Forest and Bird; Department of Conservation; Federated Farmers and Go Wairarapa. Interviewing members of these groups was an alternative to randomly selecting people in the community, some of whom may have had no interest in the river whatsoever. It was made clear to the selected participants that they were not expected to 'represent' an agreed view of their organisation. They were simply asked to give their own personal view. Several of the representatives from above groups or organisations referred the survey on to someone else outside of their particular group/organisation who they thought were better equipped to participate.

The above twelve groups were chosen because they cover the following categories and have a distinguished link with the water bodies in the catchment:

1) Organisations that have a regulatory function;
2) Organisations that represent land owners and users;
3) Conservation and environmental groups;
4) Organisations that represent recreational users;
5) Organisations that have a responsibly for society and health
6) Organisations that represent Tangata Whenua interests

15.2.3. Survey Confidentially

To maintain the confidentially of each individual, specific names of the participants will not be included in the findings of this research. However, due to the small number of people in certain positions in the region, full confidentiality cannot be guaranteed.

15.2.4. Survey Format

Each interview was dependent on the particular interviewee. Therefore there was no set format for the interviews, apart from the first two questions that asked the participants to describe their relationship to the river, and to describe their view on the current state of the river. The interview path then depended on the response to these questions.

15.2.5. Review of Submissions to Regional Policy Statement

In addition to directly speaking to people from the Ruamahanga Catchment, an alternative way of capturing the public's views on the state of the Ruamahanga Catchment is by referring to the submissions made on any of GWRC's regional plans.

Summaries of the submissions on the Regional Policy Statement (RPS) review discussion document 'Our Region – their future' which was released in May 2006, are available from GWRC's website[85]. The document 'Our Region – their future' reported on the

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[85] www.gw.govt.nz

performance of the Policy Statement over the last 10 years, and also posed questions in regards to the current management of resource issues.

Furthermore, submissions on the latest draft of the RPS which was released in June 2007 have also been compiled by GWRC. There were 27 submitters as at August 2007, relating to 15 different topics for which there is a regional plan e.g. fresh water, soil, air, energy, natural hazards, Iwi resource management issues etc.

15.3. PUBLIC PERCEPTIONS SURVEY ON THE STATE OF THE RUAMAHANGA CATCHMENT

15.3.1. State of the Water bodies in the Catchment

When asked about the state of the water bodies in the Ruamahanga Catchment, most participants responded in terms of water quality, with only a few individuals commenting on the water ways with respect to water carrying capacity and bank erosion.

15.3.1.1. Water Quality

The general consensus in terms of water quality in the Ruamahanga River was that it was degraded but no one was certain how degraded it is. *Verbatim* comments included:

- *"Not too bad, but it is not pristine, whatever that means"*
- *"Alright kind of condition, it is quite poor at the lower end, all things considering it could be a lot worse with the high level of agriculture that we have in our region and all of the other stresses on it, water allocation issues etc. There is potential for it to get worse, rather than it to stay where it is, or to get better"*
- *"I foresee that it is being degraded. It is a question of how far down the slippery slope we happen to be. A lot of the things I see in the Ruamahanga catchment that lead me to say that it is degraded is common to a lot of other low land catchments that we have an involvement with. So, degraded but I am not sure how far down the slippery slope we are"*
- *"Overall I don't see a major issue with the water quality of the river"*

- *"I don't think it is pristine, but it is not horrendously bad. In saying that any sewage and human waste discharges should be improved and anything that can be done the better it is"*
- *"From what I have read indicates that it is a little bit degraded"*
- *"It should be better and it can be better, and it will be better"*
- *"I think the quality of the Ruamahanga River, north of the ponds is typical of any river, with the same amount of runoff"*
- *"I perceive them as being not up to a really good standard"*
- *"Quality of the water is deteriorating"*
- *"I think the river is degraded"*
- *"At times of the year I go down to Martinborough and the river is frothing. I look at it and think that is tragic. Even the Waiohine is probably not flash, but it is the nicest"*
- *"Water quality is still not good in the Papawai Stream, even after the planting"*

15.3.1.2. Cause of Degradation

Most participants agreed that the cause of the deteriorated water quality in the Ruamahanga River was a combination of both rural non point discharges and municipal waste water discharges. However some individuals placed more emphasis on one or the other, revealing the urban versus rural emotional debate that occurs in these types of situations.

- *"It (the river) is degraded through many many reasons, it is because of sewage discharges (and that is not just Masterton Sewage discharges), it is also around land use in the catchment, and if you think about where it starts and where it ends up, there are many many things that discharge into the river, dairy farms, sheep and beef, stations, roads, storm water runoff. Lots of things are contributing to the degradation of the river, and that is probably consistent with many rivers in New Zealand"*

15.3.1.3. Other comments on the state of the water bodies in the catchment

- *"The state of river here is pretty good at the moment" (In terms of bank erosion)*

- *"Major problems with the amount of shingle coming down the river which is leaving large deposits and large islands"*
- *"Problems with the lake system being an artificial one now, affects fish and weeds growing on the edges of the lake"*
- *"As a corridor to carry water I think that they (water bodies) are in a pretty good state. Structures in them now are friendly to fish"*

15.3.2. Other issues identified

15.3.2.1. Masterton Sewage Treatment Ponds

The timing of this survey inadvertently coincided with the Masterton Sewage Plant upgrade resource consent application. Several of the participants made comment on their concerns with the proposal. Many felt that the option chosen by the Masterton District Council was not the best option available. Participants were worried about the current leakage of the ponds, future flood occurrences around the ponds, location of the current ponds, and the volume of storm water that is currently entering the treatment plant.

- *"I struggle with Masterton District Councils contribution with their sewage, if anything, in terms of virus's, that would be the most significant contributor as a potential human health issue"*
- *"Perception of the Ruamahanga River downstream of Homebush being a bit of a problem, but I don't know, some say it is ok, some say it is not"*
- *"19,000 people (of Masterton) causing 10% of the problem in the river, there is a very small number of people causing 90% of the problem"*
- *"What they are doing I think is a band-aid. Short-term gain for long-term pain"*
- *"It seems to me that they are doing it (the upgrade) the cheapest way. They should be looking more forward"*

At the time of writing, the resource consent for the upgrade was still going through the application process.

15.3.2.2. Reducing effects of non point discharge

Several of the participants commented on the need for more research into reducing the effects of non point discharge. There are many good concepts out there e.g. riparian planting, effective fertiliser budgeting etc, but there is concern with the conflicting messages farmers were receiving from different agencies about what the best and most effective methods are. These conflicting messages can act to discourage farmers from implementing any practices.

- *"One of the problems that farmers have, and have conveyed to me, is that everyone is full of ideas about non point pollution, but no one has any hard and fast recommendations on what to do, and what it will actually translate into in terms of pollution reduction"*
- *"There is no one answer and there is no one size fits all in riparian management"*

The additional comment below reinforces the need for further research into methods to reduce agricultural impacts on the environment.

- *"Dairy farming in its current form is not sustainable, and I think that makes you sit and think"*

15.3.2.3. Cultural Issues

- *"It is culturally repulsive to us to put sewage in water bodies. When you ask Māori people about putting sewage into water bodies, there is something that touches a cultural button which says that it is barbarian. Increasingly this is the case with all New Zealanders"*
- *"Issue of perception rather that reality. There are cultural values. People don't like the idea that there is human effluent in the river, no matter how well treated. However they have no problems that there is animal effluent"*
- *"Our view of the Ruamahanga River is sacred, it is the main vein of Papatuanuku (mother earth) and when there is a flood, we believe that the Ruamahanga is being cleaned and all of the pollution is washed to the sea"*

15.3.3. Thoughts on Integrated Catchment Management (ICM)

Many of the survey participants had positive remarks regarding Integrated Catchment Management (ICM).

- *"There is a comment that the better you can treat things the better that they are. I do have a view that an ICM experiment should get underway, and I think that it* *should be trialled on a smaller catchment (e.g. Kopuaranga), so that it can be monitored and then it is easier to educate and get people to buy in when you have the results to show them"*

- *"Support management on catchment wide basis "*
- *"Would be good to get good dialogue going between all of the interested parties, and not just have these isolated patches and battles, where we are losing context to where these issues lie"*
- *"It is a significant challenge for the urban area managing its footprint but it is perceived to be the only footprint"*
- *"Implementing an ICM plan would be ideal"*
- *"Catchment conditions are reasonably low in my opinion, and if any changes are required upstream, due to a change in code of practice, i.e. the Clean Streams Accord being pushed forward. And those sorts of increases in technology for dairy farms or other discrete discharges need to be applied also to other big polluters, and I think we often adopt a lesser standard in New Zealand because of cost, and you can look at other rivers in New Zealand where the same thing has happened"*

15.4. REVIEW OF THE SUBMISSIONS TO THE REGIONAL POLICY STATEMENT

15.4.1. Submissions on the discussion document – 'Our region – their future'

Fifteen environmental issues were identified from the submissions to the discussion document 'Our Region – their future', two of which were directly related to water resources:

- "Water use/conservation – increasing demand for water, the need for water conservation.
- Pollution of water – discharges, storm water, runoff and the health of wetlands and freshwater ecosystems"

(Greater Wellington Regional Council, 2007a)

15.4.2. Submissions on the draft RPS

There were no submissions on the draft RPS specifically regarding the Ruamahanga Catchment, but what follows is a selection of the comments made regarding freshwater from submitters that are present in Wairarapa e.g. excluding submissions made by Wellington City Council, Hutt City Council, Kapiti Coast District Council etc. These submissions were obtained from Tami Woods, RPS Project Manager, GWRC, Wellington.

15.4.2.1. General Freshwater Management

- We strongly agree with the Māori world view that "water represents the life blood of the land". We would like to see this view be at the centre of this (Freshwater) chapter. The challenge in freshwater management going forward is to integrate land use with the management of water quality and quantity at a catchment or individual groundwater resource level.

15.4.2.2. Water Allocation and Storage

- Ensure that when allocating volumes or setting sustainable limits for water bodies, local authorities give appropriate consideration of the four well beings (social, cultural, economic and environmental well being of their communities).
- Require water management plans take adequate account of the foreseeable needs of future generations and also the impacts of future changes in the nature of the water resource due to factors such as climate change or metropolitan growth as required under the Local Government Act.
- Ensure that when allocating water, primacy is given to the needs of domestic and community water supplies and stock water. This is on the basis that the managing authority can demonstrate an efficient use of water (e.g. on the basis of a per head consumption, a demand management plan and minimal leakage from the distribution system) and that adverse effects can be adequately managed.
- Federated Farmers New Zealand (FNNZ) recognises that demand on limited water resources is increasing and we support the encouragement of storage options under Policy 11. Water storage allows erratic rainfall events to become a

reliable water resource. Water can be stored in either in-stream or out-of-stream purpose-created dams, or in artificially raised lakes. Natural watercourses are often used to transport water from storage to irrigation cannels. This provides an opportunity for natural flows to be augmented and enhanced.

- FNNZ believes that water storage and augmentation provides opportunities for integrated water-land management options to be designed so as to provide 'win – win' outcomes for the farm, the river and the regional community. Further, we believe that stored water is a property right, which can be traded, gifted and used to the benefit of the owner(s).
- Overall the Wairarapa Regional Irrigation Trust is most supportive of the concepts outlined in the "Objectives" particularly the emphasis on efficient water use.
- One of the key drivers for the consideration of a regional irrigation scheme based on water harvesting and distribution is the increasing pressure of the easily accessible resources and the recognition that much of the pressure on the water resources in Wairarapa is due to timing issues rather than annual quantities.

15.4.2.3. Land use, Discharges and Water Quality

- Non point source discharges. Most point source discharges are now consented. To maintain vibrant waterways, policy needs to be developed to both control and minimize non point source discharges. This is a land use issue. A contributor to this problem is likely to be the continued increase in stock numbers, primarily dairy cows, on river flats.
- FFNZ recognises that land use can detrimentally affect the quality of rives, lakes, wetlands and ground water. The organisation has always supported incentives to remove stock from waterways.
- While it is raised as an issue under 2.1 there is no forthright Policy to deal with the adverse effects of farming on water quality. I think this is a serious omission in the Draft. There are trout fishing rivers of concern to us: the Ruamahanga, Kopuaranga, Taueru, Mangatarere, Wainuiomata and Mangaroa. Added to these are a number of trout spawning streams especially the Waipoua and tributaries. With the predicted Fonterra payout, one would be very silly indeed to not

anticipate another surge in dairying conversions and intensification of existing ones – not that they are necessarily the primary or sole cause of nutrient leaching and sediment input – sheep and beef can also be damaging.

- Targeting river/stream crossings and fencing of waterways is good, but again, as with the above comments, it is the quality of the waterway that needs focused on not just our best guess as to activities directly contributing contaminants.
- History has shown that left to their own devices farmers will not generally make the necessary changes to avoid or mitigate the adverse effects of their activities. They will not spend money where they are not convinced there is a problem and therefore will not come up to speed on how it may be fixed. There must be a combination of carrot and stick in dealing with this issue. There has to be a setting of environmental targets (as discussed above) and the farming fraternity has to be equally culpable in meeting those: the harmful activities of farming cannot continue to be absolved from the regulatory framework.
- FFNZ supports the intentions of the objectives which safeguard the quality of freshwater and measures taken designed to meet RMA obligations. However, in our opinion the anticipated environmental result to have no deterioration of water quality in any lake, river or aquifer from that measured in 2007 is both unrealistic and sets an unnecessarily high standard.
- People who use the land for agricultural and horticultural purposes are as concerned about water quality as the wider community. They also acknowledge their role on avoiding negative impacts on water quality. The implication that farming/agriculture is a sole or dominant cause of poor water quality needs to be avoided unless there is science to back this.

15.4.2.4. Weeds on Waterways

- Weeds are a big issue on waterways. Wild willows and alders for example degrade streams and wetlands yet they are not considered. Management of weeds, including Didymo, could be issue 4. There is already a problem with Hornwort in Lake Wairarapa.

- There is no mention of the issue of wilding trees (Salix fragilis, Alnus glutinosa in particular) on the ecosystem function of rivers and wetlands or on their impact on water quality.
- The effects of wild willows are to reduce the hydraulic efficiency of river channels. This leads to a number of impacts on water and ecosystem quality, such as:
    - Reduced flow velocity
    - Higher water levels, including flood levels (sometimes threatening and damaging infrastructure, access and human life)
    - Poorer drainage of adjacent land
    - Reduced ability to transport sediment – leading to increased sedimentation of the stream bed, degradation of aquatic habitat, and opportunities for blockages and weed infestation
- Wild willow and common alder are seriously degrading the wetland ecosystems associated with Lake Wairarapa. Infestations are particularly rife along the eastern shoreline and rapidly expanding in extent as areas are retired from grazing under restoration initiatives.

15.5. CONCLUSION

The public perception survey and a review of the submissions to some of GWRC's plans has provided a range of views on the state of the water bodies in the Ruamahanga Catchment, and also an insight into freshwater management issues that people perceive to be important. For the most part, the consensus was that the water quality of the Ruamahanga River was degraded to some extent, and this was due to a combination of point and non point discharges occurring in the catchment. There were also concerns expressed about the volume of gravel in the rivers and the inability of Lake Wairarapa to naturally flush itself out.

The Masterton Sewage Treatment Plant upgrade sparked many comments from participants; overall people were concerned about the upgrade option chosen. Several people were worried about the sustainability of dairy farming in the region, and also about the proven effectiveness of methods to reduce the effects of non point source discharge. The cultural significance of putting human sewage into waterways was also addressed. Finally, ICM was viewed as a positive management technique to those who commented on it.

The range of topics and issues brought up from the submissions were more general than those obtained from the survey. Water allocation, water storage, land use, discharge, water quality, and weeds on waterways were all found to be important issues to the people in the Wellington region.

16. Conclusions and Recommendations

16.1. CONCLUSIONS

The Ruamahanga Catchment is a highly valued resource to the people of Wairarapa. The Ruamahanga River and tributaries host a wide variety of values including recreational, aesthetic, ecological and economic values. There is potential for the catchment to maintain and enhance these values associated with the rivers in the future. However this potential is being compromised to some extent by current land use practices and discharges of waste directly to the river. The people of Wairarapa have the opportunity to be proactive in restoring the state of the waterways in the catchment ensuring the future sustainability of the resource and enhancement of its values.

The quantity of the water in the catchment is directly related to the climatic regime and human demands. Due to the topographical profile of the catchment, the western ranges receive a more consistent and larger volume of rainfall annually, when compared to the eastern hill country. This difference in rainfall directly translates to the variation in the river flows on either side of the catchment. The eastern tributaries have the lowest mean and median flow rates, and are smaller in size. However, these tributaries can still inflict severe flood damage on the catchment, with the potential to contribute large volumes of water to the Ruamahanga River during storm events. At the same time, some parts of the Ruamahanga Catchment are prone to severe droughts, due to the large variability in rainfall that can occur on the valley floor and on the eastern side of the catchment.

Over the past decade, land use change in the Ruamahanga Catchment has been significant. Sheep and beef farming has been replaced with dairy farming in many places. This land use intensification has been accompanied by a large increase in the demand for water. This in turn has generated problems for the catchment, with some surface water management zones near full allocation and several groundwater sub zones fully allocated. The Wairarapa Regional Irrigation Trust has proposed a regional water storage and distribution irrigation project to overcome the lack of water availability in the catchment and allow for land intensification.

Water quality in the Ruamahanga Catchment varies. Generally the tributaries on the western side of the catchment are cleaner than those on the eastern side. However, two central tributaries - the Mangatarere River and the Parkvale Stream - both have very poor water quality due to both point source and diffuse discharges. Water quality in the Ruamahanga River is only marginally better than the water in the Manawatu River, even though the Manawatu River drains a more heavily populated catchment.

On its southward journey, the water quality in the Ruamahanga River deteriorates soon after it moves out of the forested land (near Mt Bruce) and into the pastoral land. Nutrient loadings increase, clarity decreases and the incidence of high levels of *E.coli* increases. This deterioration is noticeable before the river reaches Masterton and the first major discharge of municipal effluent. Between the Ruamahanga River's monitoring sites at Te Ore Ore and Gladstone, there is a sharp increase in the load of DRP in the river, increasing from 6,550 kg/year of DPR to 33,000 kg/year of DRP. Once the DRP contributed by the upstream tributaries had been accounted for, it was found that around 14,000 kg/year of DRP was added in this section of Ruamahanga River. This equates to around a 27 percent increase of DRP load in this section of the river. More than three quarters of this DRP load increase is likely to have been generated from the Masterton Sewage Treatment Plant, with the remaining quarter coming from direct land runoff. Between these same monitoring points, a significant increase in the loading of NH_4-N was also found. However, the increase in Total Nitrogen between these points was not significant compared to background levels already in the river.

Downstream of Gladstone, nutrient loads continue to increase in the Ruamahanga River. This is consistent with the findings of Watts & Perrie (2007). Municipal effluent from Carterton (via the Mangatarere River in the winter months only), Greytown (via the Papawai Stream), Featherston (via Donald's Creek and Lake Wairarapa) and Martinborough (directly into the Ruamahanga River) enters the Ruamahanga River.

However, it was difficult to measure the changes in the DRP load in the river as a result of these discharges.

Land use practices also place significant pressure on the waterways. Nutrient runoff from farmed land, unfenced waterways, and point discharges from farms and industry all contribute to the state of the rivers. Furthermore, they can have an impact on groundwater quality. Many aquifers in the Ruamahanga Catchment are already contaminated by NO_3-N and SO_4^{2-} - particularly around Masterton and Martinborough.

The water quality in Lake Wairarapa is poor, and it was suggested that it was unlikely to improve with the current land use and projected land use intensification around its shores. Since the lake is effectively an 'artificial' system, (once the flood control scheme was erected) the lake has been unable to 'flush' itself out. This has caused some concern amongst members of the local community including iwi. Tangata Whenua are also deeply concerned about the continued discharge of human sewage into the waterways. Not only is it diminishing the quality of the waterways, it is also extremely offensive.

Water degradation, caused by point source discharges and land use practices, negatively impacts on other aspects of the catchment. The Ruamahanga River has a lower diversity of species, a lower Index of Biotic Integrity (IBI), and a lower MCI score than the average for the other catchments in the Wellington region. Furthermore, recreational and aesthetic values are also compromised. Three sites on the Ruamahanga River ('The Cliffs', 'Kokotau' and 'Waihenga') reached the alert recreation bathing water quality on several occasions last summer, and six of the seven bathing sites tested on the Ruamahanga River have been graded as having 'very poor' suitability for recreation. Periphyton growth can sometimes impact on recreational values in the Ruamahanga River, especially in the summer months, during times of low flow.

Some significant temporal trends in water quality in the Ruamahanga River were identified by Scarsbrook et al. (unpublished) cited in Milne & Perrie (2006). Of note was a 4.2 mg/m^3 (0.0042 g/m^3) increase in DRP concentration at Waihenga over the 14 years from 1989 to 2003. A similar increase in DRP concentration was identified upstream at Wardells over the same period.

16.2. INFORMATION GAPS AND LIMITATIONS

The following information gaps and limitations have been identified:

- There is a limited number of water quality monitoring sites that have flow metres attached in the Ruamahanga Catchment. This limits the ability to calculate nutrient loading and accurately determine the source of the nutrients.
- Suspended sediment concentrations are not currently measured by GWRC, which limits the ability to assess which sub catchments are contributing the most sediment to the lower parts of the catchment.
- AgriBase was the primary database used in the land use chapter. Due to the large cost of obtaining the updated version, the 2001 version was used.
- Available statistical information on land use change was mostly defined according to territorial authority boundaries. This makes the data less accurate for the catchment boundary. Statistics New Zealand (and other information sources) uses a smaller unit (a mesh block) to define most data, but at this small scale the information is considered sensitive and is therefore not readily available.
- The land chapter relied heavily on the Land Resource Inventory (LRI). Although dated it was the most readily available database for several of the land characteristics e.g. physiography, soils and erosion, and the only database that provided full coverage of the Ruamahanga Catchment area.
- The LRI could only provide erosion for the time of mapping. Therefore this data is out of date and should be updated if required.
- The soils groups were updated from the generic nomenclature to the New Zealand Soil Classification using the New Zealand Soils Database (NZSD). Several of the soils groups in Heine's geological map of Wairarapa (1975) did not feature in the NZSD, so some conversions of the soils had to be estimated. Actual field work would ensure accuracy.

- Further analysis of the climatical regime of the catchment can be carried out with New Zealand's National Climate Database (CliDB) which since writing this document has become freely available on the Internet.

16.3. RECOMMENDATIONS

16.3.1. Recommendations to improve data in this report

- Water flow monitors should be installed at water quality monitoring sites so that nutrient loading can be more accurately determined and the relationship between flow and water quality determined.
- A suspended sediment sampling monitoring program should be initiated to generate calibration curves between turbidity and suspended sediment concentration. This would allow the identification of those sub catchments that contribute the most sediment, and add value to the large database of turbidity measurements.
- Local iwi should make amendments and additions to the Māori Culture chapter of this report as required.
- The Cultural Health Index (CHI) should be incorporated into the freshwater monitoring program.
- The 2003 and 2007 agricultural production statistics should be compared to obtain a more accurate picture of land use change occurring in the catchment (at the time of writing the 2007 statistics had not been released).

16.3.2. Recommendations for the future

This report has identified that parts of the Ruamahanga Catchment have a less diverse range and abundance of freshwater species than other parts of the Wellington region. Chemical and biological measures indicated that water quality is degraded, and in some parts is not much better than the water quality in the Manawatu River. It is interesting to note that Horizons Regional Council is proposing quite drastic policy measures to address these water quality issues in the Manawatu Catchment.

One cause of the degraded water quality in the Ruamahanga Catchment is the elevated level of DRP. This study suggests that this DRP originates from both rural land use and municipal discharge. On-going land intensification and possible increases in occupied dwellings will almost certainly exacerbate this problem in the future unless corrective action is taken.

This report will provide a starting point for stakeholders to engage in discussion of future management of the catchment. In saying this, the outcomes of Horizon Regional Council's One Plan should be observed, and future freshwater management plans should be tailored with the success and failures of the One Plan in mind.

17. References

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AgriQuality. (2007). *AgriBase*. Retrieved 20 June, 2007, from http://www.agriquality.com/corporate/it_services/agribase.cfm

Ankcorn, P. D. (2003). *Clarifying Turbidity — The Potential and Limitations of Turbidity as a Surrogate for Water - Quality Monitoring*. Paper presented at the Proceedings of the 2003 Georgia Water Resources Conference, 23-24 April 2003., Athens, GA.

Annear, L. C., Butcher, G. M., Gunn, I., Montgomery, K., & Wright, C. F. (1989). *Wairarapa Ground Water Study*: Wairarapa Catchment Board and Regional Water Board.

ANZECC. (2000). *An Introduction to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (No. 4a): Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand.

Bagnall, A. G. (1976). *Wairarapa: An Historical Excursion*. Masterton: Hedley's Bookshop Ltd for Masterton Trust Lands Trust.

Baker, T. (2006). *Groundwater 2005-06*. Retrieved 9 May, 2007, from http://www.gw.govt.nz/section1248.cfm

Basher, L. R. (2003). *The Motueka and Riwaka catchments*: Manaaki Whenua Landcare Research, Tasman District Council, Cawthron Institute.

Begg, J. G., Brown, L.J., Gyopari, M. & Jones, A. (2005). *A review of Wairarapa geology - With a groundwater bias*. Wellington: Institute of Geological and Nuclear Sciences Limited.

Begg, J. G., & Johnston, M. R. (Cartographer). (2000). *Geology of the Wellington area, New Zealand. Geological Map 64 (Scale 1:250,000).*

Begg, J. G., & Legg, J. G. (Cartographer). (2002). *Geology of the Wairarapa area. Geological Map 11 (Scale 1:250,000).*

Begg, J. G., & Mazengarb, C. (Cartographer). (1996). *Geology of the Wellington area. Geological Map 22. (Scale 1:50,000)*

Bevin, G. (1998). *Wairarapa Water Races: Issues and Consent Requirements*. Masterton: Water Resource Investigations, Wellington Regional Council.

Black, R. (2007, 4 July). Drought talks fail to reach farmers. *Straight Furrow*.

Bondy. (1950). Droughts in New Zealand. *New Zealand. New Zealand Journal of Science and Technology, 32 B(2)*, 1-10.

Burns, N., Bryers, G. G., & Bowman, E. (2000). *Protocol for Monitoring Trophic Levels of New Zealand Lakes and Reservoirs* (No. Client Report 99/2). Pauanui: Lakes Consulting (Prepared for the Ministry for the Environment).

Butcher, G. (1996a). *Ground Water Resources of the Lower Wairarapa Valley*: Wellington Regional Council.

Butcher, G. (1996b). *Ground Water Resources of the Ruamahanga River Floodplain Martinborough to Pukeo.*: Wellington Regional Council.

Butcher, G. (1996c). *Safe Yield Estimates for Identified Aquifers in the Wairarapa Valley*: Wellington Regional Council.

Butcher, G. (1997). *Te Ore Ore Plains Ground Water Study*: Wellington Regional Council.

Butcher, G. (2000). *Evaluation of Rainfall Recharge to the Aquifers of the Te Ore Ore Plains, Masterton*: Wellington Regional Council.

Butcher, G. (2001a). *Ground Water Resources of the Martinborough Terraces Ground Water Zone*: Wellington Regional Council.

Butcher, G. (2001b). *Ground Water Resources of the Huangarua Ground Water Zone*: Wellington Regional Council.

Butcher, G. (2001c). *Ground Water Resources of the Battersea Ground Water Zone.*: Greater Wellington Regional Council.

Butcher, G. (2004). *Ground Water Resources of the Parkvale Ground Water Zone*: Greater Wellington Regional Council.

Campbell, N. (1998, 18 July). Mild spell boon for farmers. *Wairarapa Times-Age*.

Christchurch City Council. (2008). *State of Environment Monitoring*, from http://www.ccc.govt.nz/christchurch/soemonitoring/water/2167_water_dissolved%20reactive%20phosphorous%20levels%20in%20the%20avon-heathcote%20estuary.pdf

Chrystall, L. (2006). *A Proposal for a Resource Inventory for the Ruamahanga Catchment, Wairarapa, New Zealand.* Unpublished Honours Thesis, Massey University, Palmerston North.

Close, M. E., & Davies-Colley, R. J. (1990a). Baseflow water chemistry in New Zealand rivers. 1. Characterisation. *New Zealand Journal of Marine and Freshwater Research, 24*, 319-341.

Close, M. E., & Davies-Colley, R. J. (1990b). Baseflow water chemisty in New Zealand rivers 2. Influence of environmental factors. *New Zealand Journal of Marine and Freshwater Research, 24*, 343-356.

Close, M. E., Rosen, M. R., & Smith, V. R. (2001). Fate and transport of nitrates and pesticides in New Zealand's aquifers. In M. R. Rosen & P. A. White (Eds.), *Groundwaters of New Zealand* (pp. 185-220). Wellington: New Zealand Hydrological Society Inc.

Clough, P., & Hicks, D. (Cartographer). (1992). *Susceptibility to Erosion Map. Landcare Research (1:3,000,000)*

Crawford, J. P., & Hamlin, C. A. (1982). *The 1978 Drought in New Zealand.* Wellington: New Zealand Meteorological Service.

Cromarty, P., & Scott, D. A. (1996). Lake Wairarapa Wetlands. In D. A. Scott (Ed.), *A Directory of Wetlands in New Zealand.* Wellington: Department of Conservation.

Crombie, N. (2007, 10 March). It's bone dry out there. *Wairarapa Times-Age,* p. 1.

Croucher, B. (2005). *Soil quality monitoring technical report.* Wellington: Greater Wellington Regional Council.

Crozier, M. J., McConchie, J. A., Owen, R. C., & Eyles, R. J. (1982). *Mass Movement Erosion Wairarapa.* Wellington: Department of Geography, Victoria University of Wellington.

Darby Creek Watershed Joint Board of Supervisors, & Darby Creek Watershed Planning Group. (2005). *Darby Creek Watershed Inventory.* Marysville, OH.

Darby Watershed. (2006). *Darby Watershed - About us*. Retrieved 5 November, 2006, from http://www.darbywatershed.com/AboutUs.htm

Daughney, C. J. (2003). *Definition of hydrochemical facies for New Zealand's groundwaters using data from the National Groundwater Monitoring Programme*. Lower Hutt, Wellington: Institute of Geological and Nuclear Sciences Ltd.

Death, R. G., & Death, F. (2005 unpublished). *Analysis of Wellington water quality data for river state of the environment reporting 1999-2004*. Palmerston North: Massey University.

Denton, P. (2006). *Soils and Minerals - Background Report*. Wellington: Greater Wellington Regional Council.

Department of Conservation. (1996). *Conservation Management Strategy for Wellington 1996-2005. Vol.1*. Wellington: Department of Conservation.

Department of Conservation. (2003). Waiohine Gorge - Tararua Forest Park Brochure. Wellington: Department of Conservation.

Department of Conservation. (n.d). *Tararua Forest Park - Waiohine Faulted Terraces*. Retrieved August 22, 2007, from http://www.doc.govt.nz/templates/page.aspx?id=34987

Department of Conservation. (n.d.-a). *Carter Scenic Reserve*. Retrieved 13 August, 2007, from http://www.doc.govt.nz/templates/PlaceProfile.aspx?id=34968

Department of Conservation. (n.d.-b). *Historic Heritage Topics*. Retrieved 6 August, 2007, from http://www.doc.govt.nz/templates/summary.aspx?id=34003

Department of Conservation. (n.d.-c). *Legislation*. Retrieved 23 July, 2007, from http://www.doc.govt.nz/templates/summary.aspx?id=41975

Department of Conservation. (n.d.-d). *Statutory Mandate*. Retrieved 23 July, 2007, from http://www.doc.govt.nz/templates/page.aspx?id=41967

Department of Conservation. (n.d.-e). *Vegetation. Aorangi Forest Park*. Retrieved 13 August, 2007, from http://www.doc.govt.nz/templates/page.aspx?id=34953

Department of Conservation. (n.d.-f). *Vegetation. Tararua Forest Park*. Retrieved 13 August, 2007, from http://www.doc.govt.nz/templates/page.aspx?id=34983

Department of Conservation. (n.d.-g). *Wairarapa: Places to Visit*. Retrieved 24 July, 2007, from http://www.doc.govt.nz/templates/PlaceProfile.aspx?id=34977

Department of Conservation. (n.d.-h). *Wildlife. Rimutaka Forest Park*. Retrieved 13 August, 2007, from http://www.doc.govt.nz/templates/page.aspx?id=35047

Department of Conservation. (n.d.-i). *Wildlife. Tararua Forest Park*. Retrieved 13 August, 2007, from http://www.doc.govt.nz/templates/page.aspx?id=34982

Department of Internal Affairs. (n.d.). *Local Government Act 2002*. Retrieved 17 August, 2007, from http://www.localcouncils.govt.nz/lgip.nsf/wpg_url/About-Local-Government-Local-Government-Legislation-Local-Government-Act-2002?OpenDocument

Environment Waikato. (2002). *Trees on Farms. A guide with local experience of growing trees in the Waikato Region*. Hamilton: Environment Waikato.

Environment Waikato. (2006). *Water Quality Glossary*. Retrieved 19 February, 2007, from http://www.ew.govt.nz/enviroinfo/water/healthyrivers/glossaryhr.htm

Finkelstein, J. (1971). *The 1969-70 Droughts in New Zealand*. Wellington: New Zealand Meteorological Service.

Fish and Game New Zealand (Wellington Region). (n.d.). *Ruamahanga River Fishery*. Palmerston North.

Flack, J. (1998, 12 September). Governor Grey had big influence on Greytown. *Wairarapa Times Age*.

Forsyth, F., & Dixon, M. (2004). *Wairarapa Wetlands - an overview* (No. GW/RP-T-04/76). Wellington: Greater Wellington Regional Council.

Forsyth, K. (2005). *Waste Management and hazardous substances - background report* (No. GW/RP-T-05/301). Wellington: Greater Wellington Regional Council.

Froude, V. (1999). *Review of National Databases Relating to Land, Water and Biodiversity*. Wellington: Ministry for the Environment.

Froude, V. A., & Beanland, R. A. (1999). *Review of Environmental Classification Systems and Spatial Frameworks*. Wellington: Ministry for the Environment.

Genesis Energy. (2006). *Genesis Energy Annual Report 2006*. Retrieved June 14, 2007, from http://www.genesisenergy.co.nz/shadomx/apps/fms/fmsdownload.cfm?file_uuid=39F9999F-F172-A398-1F68-07FAB65A9FC3&siteName=genesis

Gibbard, R., Roygard, J., Ausseil, O., & Fung, L. (2006). *Water Quality Trends in the Manawatu-Wanganui Region 1989-2004* (No. 2006/EXT/702). Palmerston North: Horizons Regional Council.

Glade, T. (1998). Establishing the frequency and magnitude of landslide-triggering rainstorm events in New Zealand. *Environmental Geology, 35*(2-3), 160-174.

Go Wairarapa. (2007). Wairarapa Regional Irrigation Trust in Business.

Gordon, M. (2005). *Annual Hydrology Report*. Masterton: Greater Wellington Regional Council.

Greater Wellington Regional Council. (1999). *Regional Freshwater Plan for the Wellington Region* (No. WRC/RP-G-99/31). Wellington.

Greater Wellington Regional Council. (2003). Flooding Hazard - Wairarapa: Greater Wellington Regional Council.

Greater Wellington Regional Council. (2004a). *Big floods in the Wellington Region*. Retrieved 9 July, 2007, from http://www.gw.govt.nz/story6388.cfm

Greater Wellington Regional Council. (2004b). *Consulting Iwi*. Wellington: Greater Wellington Regional Council.

Greater Wellington Regional Council. (2004c). *Mind the Stream*. Wellington: Greater Wellington Regional Council.

Greater Wellington Regional Council. (2005). *Measuring Up - State of the Environment Report for the Wellington Region*. Wellington: Greater Wellington Regional Council.

Greater Wellington Regional Council. (2006a). Flood control scheme review. *Greater Wellington Regional Council Rural Services Newsletter*.

Greater Wellington Regional Council. (2006b). *Greater Wellington Regional Council Hilltop Records*

Greater Wellington Regional Council. (2006c). *Our Region - Their Future*. Wellington: Greater Wellington Regional Council.

Greater Wellington Regional Council. (2007a). *Feedback from the discussion document "Our Region - their future"*. Retrieved 16 August, 2007, from http://www.gw.govt.nz/story21228.cfm?

Greater Wellington Regional Council. (2007b). *Regional Policy Statement Review*. Retrieved 20 July, 2007, from http://www.gw.govt.nz/section1236.cfm

Greater Wellington Regional Council. (2007c). *Streams Alive*. Retrieved 18 June, 2007, from http://www.gw.govt.nz/section1167.cfm

Greater Wellington Regional Council. (n.d.). *Geographical Information Systems (GIS) files*, obtained in 2007, from Greater Wellington Regional Council GIS Department

Harkness, M. (2000). *Predicting Rainfall Droughts in the Wairarapa using the Southern Oscillation Index* (No. WRC/RINV-T-00/15): Greater Wellington Regional Council.

Hawke, R. M., McConchie, J. A., & Trueman, T. P. (2000). *Wairarapa Irrigation Study. Moisture Availability as a result of climate* (No. No.6): Earth Sciences, Victoria University of Wellington for the Wairarapa Division, Wellington Regional Council.

Hawke, R. M., Watts, L., & McConchie, J. A. (2000). *Wairarapa Irrigation Study: soil classification and characterisation* (No. Research Report No. 8). Wellington: Victoria University.

Heathcote, I. W. (1998). *Integrated Watershed Management: Principles and Practice*. New York: John Wiley and Sons.

Heine, J. C. (1975). *Interim Reports on soils in the Wairarapa Valley (1:126 720)*: NZ Soil Bureau #40.

Henderson, R., & Diettrich, J. (2007). *Statistical analysis of river flow data in the Horizons Region* (No. CHC2006-154). Christchurch: NIWA, prepared for Horizons Manawatu Regional Council.

Hewitt, A. (1998). *New Zealand Soil Classification* (2nd ed.): Landcare Research science series no.1.

Hicks, D. L. (1995). *Control of Soil Erosion on Farmland. A summary of erosion's impact on New Zealand agriculture, and farm management practices which counteract it.* Retrieved 1 June, 2007, from http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/land-management/erosion-risks/erosiona.htm

Hicks, D. L. (2000). *Threshold Rainfalls for Landslides*. Masterton: Wellington Regional Council Internal Report.

Hicks, S. R., & Woodward, D. J. (1978). Gravity Models of the Wairarapa Region, New Zealand. *New Zealand Journal of Geology and Geophysics, 21*(5), 539-544.

Historic Places Act, (1993).

Holmes, J. (2005). *Landscape Objectives* (No. 08/01). Wellington: Greater Wellington Regional Council.

Holmes, J. (2006). *Landscape and Heritage Evaluation Report* (No. 403584). Wellington: Greater Wellington Regional Council.

Horizons MW. (2007). *Proposed One Plan - Water*.

Hutchins, G. (2006). *High Water: Floods in New Zealand*. Wellington: Grantham House Publishing.

Ibbitt, R., Woods, R., & McKerchar, A. (1997). Hydrological Processes of Extreme Events. In M. P. Mosley & C. P. Pearson (Eds.), *Floods and Droughts: the New Zealand Experience*. Wellington: New Zealand Hydrological Society.

Institute of Geological and Nuclear Sciences (Cartographer). (n.d.). *QMAP - Digital geological maps of New Zealand (1:250 000)*

Jones, A., & Baker, T. (2005). *Groundwater Monitoring Technical Report*: Greater Wellington Regional Council.

Jones, A., & Gyopari, M. (2005). *Regional conceptual and numerical modelling of the Wairarapa groundwater basin* (No. WGN_DOCS-#376797-V2): Greater Wellington Regional Council.

Jowett, I. G., & Richardson, J. (1996). Distribution and abundance of freshwater fish in New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research, 30*, 239-255.

Jowett, I. G., & Richardson, J. (2003). Fish communities in New Zealand rivers and their relationship to environmental variables. *New Zealand Journal of Marine and Freshwater Research, 37*, 347-366.

Joy, M. (2002 unpublished). *Freshwater fish survey of the Wellington Region.* Palmerston North: Massey University.

Joy, M. K., & Death, R. G. (2004a). Predictive modelling and spatial mapping of freshwater fish and decapod assemblages using GIS and neural networks. *Freshwater Biology, 49*, 1036-1052.

Joy, M. K., & Death, R. G. (2004b). Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. *Environmental Management, 34*(3), 415-428.

Kenny, J. A., & Hayward, B. W. (Eds.). (1996). *Inventory and maps of important geological sites and landforms in the Manawatu and Wellington Regions*. Lower Hutt: Joint Earth Science Societies' Working Group on the New Zealand Geopreservation Inventory.

Kereama-Royal, I., & Ashton, L. (2000). One more river to cross. *Mana, 35*, 32-43.

Kerehi, J. (2005). *Nga wahi tapu o Ngati Hamua: Sacred sites of Ngati Hamua – Paramount hapu of Rangitane o Wairarapa.* Paper presented at the Indigenous Knowledges Conference 22-25 June, Victoria University, Wellington.

Kingma, J. T. (Cartographer). (1967). *Sheet 12 Wellington Geological Map of New Zealand. (Scale 1: 250000)*

Landcare Research. (2007). *S Map Project.* Retrieved 23 May, 2007, from http://www.landcareresearch.co.nz/databases/smap.asp

Larned, S., Scarsbrook, M., Snelder, T., & Norton, N. (2005). *Nationwide and regional state and trends in river water quality 1996-2002.* Christchurch: NIWA (Prepared for Ministry for the Environment).

Lewis, J. (1996). Turbidity-controlled suspended sediment sampling for runoff-event load estimation. *Water Resources Research, 32*(7), 2299-2310.

LINZ. (2005). *Geographic Information Systems Layer of Land Tenure in New Zealand*, from Greater Wellington Regional Council GIS Department

Livestock Improvement. (1999). *Regional Dairy Statistics 1998/99.* Retrieved 20 June, 2007, from http://www.lic.co.nz/pdf/dairy_stats/3_regional_dairy_statistics.pdf

Livestock Improvement. (2006). *Regional Dairy Statistics 2005/2006.* Retrieved 20 June, 2007, from http://www.lic.co.nz/pdf/dairy_stats/2006_STATISTICSc.pdf

Maasdam, R., & Smith, D. G. (1994). New Zealand's National River Water Quality Network 2. Relationships between physico-chemical data and environmental factors. *New Zealand Journal of Marine and Freshwater Research, 28*, 37-54.

Masterton District Council. (2007). *Planning Reports - Combined District Plan.* Retrieved 20 July, 2007, from http://www.mstn.govt.nz/combinedplan/index.htm

Masterton District Library and Wairarapa Archive. (2006a). *Papawai - the centre of the Maori Parliament.* Retrieved 13 November, 2006, from http://library.mstn.govt.nz/history/papawai.html

Masterton District Library and Wairarapa Archive. (2006b). *Wairarapa History Stories.* Retrieved 14 November, 2006, from http://library.mstn.govt.nz/history/index.html

Masterton Tourism. (2005). *Henley Lake.* Retrieved 24 July, 2007, from http://www.masterton.co.nz/events/index2.php?content=event_venues/henley.php

McClean, R. (2005). *Wellington Region SER Historic Heritage Technical Report.* Wellington: New Zealand Historic Places Trust.

McDowall, R. M. (2001). *Freshwater Fishes of New Zealand.* Auckland: Reed.

McEwen, W. M. (Ed.). (1987). *Ecological regions and districts of New Zealand.* Wellington, New Zealand: Jirah Services Ltd.

McFadgen. (2003). *Archaeology of the Wellington Conservancy: Wairarapa. A study in tectonic archaeology.* Wellington: Department of Conservation.

McIntyre, R. (2002). *The Canoes of Kupe: A History of Martinborough District.* Wellington: Victoria University Press.

McLea, M. (1995). *Freshwater for the future.* Wellington: Wellington Regional Council.

Mills, C. (2002). *Healthy River, Healthy People? A strategic overview of the Ruamahanga river catchment from a public health perspective*: Wairarapa District Health Board.

Milne, J. (2005). *Recreational water quality monitoring technical report.* (No. GW\RINV-T-05/89). Wellington: Greater Wellington Regional Council.

Milne, J. (2007). *On the beaches 2006/07. Annual recreational water quality monitoring report for the Wellington region.* Wellington: Greater Wellington Regional Council.

Milne, J., & Perrie, A. (2006). *Freshwater quality monitoring technical report.* Wellington: Greater Wellington Regional Council.

Milne, J., & Wyatt, K. (2006). *Will I get sick if I swim?* Wellington: Greater Wellington Regional Council.

Ministry for the Environment. (1997). *The State of New Zealand's Environment 1997.* Wellington: Ministry of Environment. GP Publications.

Ministry for the Environment. (2000). *New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams.* Wellington: Ministry for the Environment.

Ministry for the Environment. (2001). *Managing Waterways on Farms. A guide to sustainable water and riparian management in rural New Zealand.* Wellington: Ministry for the Environment.

Ministry for the Environment. (2004). *Water Bodies of National Importance: Potential Water Bodies of National Importance for Recreation Value.* Wellinton: Ministry for the Environment.

Ministry for the Environment. (2006). *Using the Cultural Health Index: How to assess the health of streams and waterways.* Wellington: Ministry for the Environment.

Ministry for the Environment. (n.d). *Microbiological Water Quality Guidelines frequently asked questions (FAQs)*. Retrieved 27 April, 2007, from http://www.mfe.govt.nz/issues/water/water-quality-faqs.html

Ministry for the Environment, & Ministry for Health. (2003). *Microbiological water quality guidelines for marine and freshwater recreation areas*. Wellington: Ministry for the Environment.

Ministry of Agriculture and Forestry. (2006). *Situation and Outlook for New Zealand Agriculture and Forestry: An update to the December 2005 SONZAF*. Retrieved 25 June, 2007, from http://www.maf.govt.nz/mafnet/rural-nz/statistics-and-forecasts/sonzaf/2006/index.htm

Ministry of Works and Development. (1979). *Our Land Resources - a bulletin to accompany New Zealand Land Resource Inventory Worksheets*. Wellington: National Water and Soil Conservation Organisation; Water and Soil Division, Ministry of Works and Development.

Molloy, L. (1993). *Soils of the New Zealand Landscape: The Living Mantle* (1st ed.). Lincoln: New Zealand Society of Soil Science.

Molloy, L. (1998). *Soils of the New Zealand Landscape: The Living Mantle* (2nd ed.). Lincoln: New Zealand Society of Soil Science.

Morgan, M. (2000). *Water Resources and Allocation in the Wairarapa* (No. 00/15): Wellington Regional Council.

Morgan, M., & Hughes, B. (2001). Wellington. In M. R. Rosen & P. A. White (Eds.), *Groundwaters of New Zealand* (pp. 397-410). Wellington: New Zealand Hydrological Society Inc.

Morgenstern, U. (2005). *Wairarapa Valley Groundwater - Residence time, flow pattern, and hydrochemistry trends* (No. 2005/33): Institute of Geological and Nuclear Sciences Limited.

Mosley, M. P., & Pearson, C. P. (1997a). Introduction: hydrological extremes and climate in New Zealand. In M. P. Mosley & C. P. Pearson (Eds.), *Floods and Droughts: the New Zealand Experience*. Wellington: New Zealand Hydrological Society.

Mosley, M. P., & Pearson, C. P. (Eds.). (1997b). *Floods and Droughts: the New Zealand Experience*. Wellington: New Zealand Hydrological Society.

Naiman, R., Decamps, H., & McClain, M. (2005). *Riparia. Ecology, Conservation, and Management of Streamside Communities*. London: Elsevier Academic Press.

National Water Conservation (Lake Wairarapa) Order, (1989).

Nature Reviews. (2004). *Nature Reviews Glossary*. Retrieved 31 January, 2006, from http://www.nature.com/nrm/journal/v5/n9/glossary/nrm1451_glossary.html

New Zealand Archaeology Association. (2007). *Site Recording Scheme*. Retrieved 17 August, 2007

New Zealand Archaeology Association. (n.d.). *Site Recording Scheme*. Retrieved 4 August, 2007, from http://www.nzarchaeology.org/recording.htm

New Zealand Government. (2005). *Local and Regional Councils*. Retrieved 25 October, 2006, from http://newzealand.govt.nz/record?recordid=1921

New Zealand Historic Places Trust. (2001). *New Zealand Historic Places Trust*. Retrieved 3 August, 2007, from http://www.historic.org.nz/

New Zealand Ministry of Health. (2005). *Drinking Water Standards for New Zealand 2005*. Wellington, New Zealand: New Zealand Ministry of Health.

New Zealand Travel Infocus Ltd. (2006). *Wairarapa History*. Retrieved 1 November, 2006, from http://www.destination.co.nz/wairarapa/history.asp

Newsome, P. F. J., Wilde, R. H., & Willoughby, E. J. (2000). *Land Resources Information System Spatial Data Layers. Volume 1: 'Label Format'*. Palmerston North: Landcare Research New Zealand Ltd.

NIWA. (2007a). *New Zealand Freshwater Fish Database*. Retrieved 28 June, 2007, from http://www.niwascience.co.nz/services/nzffd/

NIWA. (2007b). *River Environment Classification for management purposes*. Retrieved 2007, 11 May, from http://www.niwascience.co.nz/ncwr/rec/

NIWA and GNS. (n.d.). *Natural Hazards Centre*. Retrieved 9 July, 2007, from http://www.naturalhazards.net.nz/

O'Keefe, T., & Hoffmann, L. (2005). *Roaring Fork Watershed Inventory*. Basalt, Colorado: Roaring Fork Conservancy.

Oxenham, S. (1993). *Waiohine*. Carterton: Lamb-Peters Print.

Oxford English Dictionary. (2007). *Oxford English Dictionary*. Retrieved 3 August, 2007, from http://www.askoxford.com/concise_oed/heritage?view=uk

Packman, J. J., Comings, K. J., & Booth, D. B. (1999). *Using turbidity to determine total suspended solids in urbanizing streams in the Puget Lowlands: in Confronting Uncertainty: Managing Change in Water Resources and the Environment,*. Paper presented at the Canadian Water Resources Association Annual Meeting, Vancouver, BC, 27-29 October 1999., Vancouver, BC,.

Park, G. N. (1983). *Protected Natural Areas for New Zealand: Report of a Scientific Working Party convened by the Biological Resources Centre (DSIR) - 14 - 17 December, 1982, Wellington*. Wellington, New Zealand: Biological Resources Centre (DSIR).

Parliamentary Commissioner for the Environment. (2000). 1.2.6 Urban water systems and tikanga Maori. In *Ageing pipes and murky waters: Urban water system issues for the 21st century*. Parliamentary Commissioner for the Environment: Wellington.

Pearson, C. P. (1992). Analysis of Floods and Low Flows. In M. P. Mosley (Ed.), *Waters of New Zealand*. Wellington: New Zealand Hydrological Society.

Pearson, C. P., & Davies, T. (1997). Stochastic Methods. In M. P. Mosley & C. P. Pearson (Eds.), *Floods and Droughts: The New Zealand Experience*. Wellington: New Zealand Hydrological Society.

Perrie, A. (2005). *Lake Wairarapa Water Quality Monitoring Technical Report*. Wellington: Greater Wellington Regional Council.

Pollok, J. A., Neall, V. E., & De Rose, R. (1994). *A field description of the soils and geology of Riverside Farm : a window on the Northern Wairarapa Valley*. Palmerston North: Massey University.

Poole, A. L. (1983). *Catchment Control in New Zealand* (Vol. 48). Wellington: Water and Soil Miscellaneous Publication.

Porteous, A., Reid, S., Thompson, C. S., Burgess, S., Copeland, J., & Sansom, J. (1999). *Meteorological Hazards Relevant to Wairarapa Engineering Lifelines* (No. Client Report WLG99/59). Wellington: NIWA.

Purchas, C. (1998). *Landfills in the Wellington Region* (No. WRC/RINV-T-98/47). Wellington: Greater Wellington Regional Council.

Queen Elizabeth II National Trust. (n.d.). *About QEII*. Retrieved 4 August, 2007, from http://www.qe2.org.nz/

Quinn, J., Cooper, A. B., Davies-Colley, R. J., Rutherford, J. C., & Williamson, R. B. (1997). Land use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill-country streams. *New Zealand Journal of Marine and Freshwater Research, 31*, 579-597.

Rangitaane o Wairarapa, & Greater Wellington Regional Council. (2005). *Ngati Hamua Environmental Education Sheets*. Greytown: Lamb-Peters Print.

Reid, S. J., Turner, R. W., & Wratt, D. S. (2000). *Wairarapa windstorms - a supplement to the report: Meteorological hazards relevant to Wairarapa Engineering Lifelines* (No. Client Report WLG2000/40). Wellington: NIWA.

Resource Management Act, (1991).

Richardson, J., Williams, E. K., & Hickey, C. W. (2001). Avoidance behaviour of freshwater fish and shrimp exposed to ammonia and low dissolved oxygen separately and in combination. *New Zealand Journal of Marine and Freshwater Research, 35*, 625-633.

Rosen, M. R. (2001). Hydrochemsitry of New Zealand's Aquifers. In M. R. Rosen & P. A. White (Eds.), *Groundwaters of New Zealand*. Wellington North: New Zealand Hydrological Society Inc.

Roskruge, N. (2007). *Maori Resource and Environmental Management - Freshwater Study Guide - Module One*. Palmerston North: Massey University.

Rowe, D. K., Chisnall, B. L., Dean, T. L., & Richardson, J. (1999). Effects of land use on native fish communities in east coast streams of the North Island of New Zealand. *New Zealand Journal of Marine and Freshwater Research, 33*, 141-151.

Salinger, M. J. (2004). *Factors affecting rainfall trends in the Wellington Region*: Prepared for Resource Investigations, Greater Wellington Regional Council.

Saunders, W. (2000). *Wairarapa storm events 1880-1998*. Masterton: Greater Wellington Regional Council.

Scarsbrook, M., & McBride, G. B. (2004). *Levels of E. coli in New Zealand rivers* (No. NIWA Client Report: HAM2004-157). Hamilton: NIWA (Prepared for Ministry for the Environment).

Schrader, B. (2007). *Wairarapa lakes, Te Ara - the Encyclopedia of New Zealand*. Retrieved 31 July, 2007, from http://www.teara.govt.nz/Places/Wairarapa/WairarapaPlaces/11/en

Sinton, L. W. (2001). Microbial contamination of New Zealand's aquifers. In M. R. Rosen & P. A. White (Eds.), *Groundwaters of New Zealand* (pp. 221-251). Wellington: New Zealand Hydrological Society Inc.

Smith, D. G., & Maasdam, R. (1994). New Zealand's National River Water Quality Network 1. Design and physico-chemical characterisation. *New Zealand Journal of Marine and Freshwater Research, 28*, 19-35.

Smith, D. G., McBride, G. B., Bryers, G. G., Wisse, J., & Mink, D. F. J. (1996). Trends in New Zealand's National River Water Quality Network. *New Zealand Journal of Marine and Freshwater Research, 30*, 485-500.

Snelder, T., Biggs, B., & Weatherhead, M. (2004). *New Zealand River Environment Classification Guide*. Wellington: Ministry for the Environment.

Snelder, T., Biggs, B., Weatherhead, M., & Niven, K. (n.d). *A brief overview of New Zealand's River Environment Classification*. Christchurch: NIWA.

Snelder, T., & Scarsbrook, M. (2005). *Spatial patterns in state and trends of environmental quality in New Zealand rivers: an analysis for State of Environment reporting*. Wellington: Ministry for the Environment.

Stansfield, B. (1996). *Lake Wairarapa water quality monitoring programme.* (No. 95/16). Masterton: Wellington Regional Council.

Stansfield, B. (1999). *Lake Wairarapa water quality monitoring programme* (No. 99/2). Masterton: Wellington Regional Council.

Stark, J. D. (1985). *A macroinvertebrate community index of water quality for stony streams*. Wellington: National Water and Soil Conservation Authority.

Stark, J. D. (1993). Performance of the Macroinvertebrate Community Index: effects of sampling method, sample replication, water depth, current velocity, and substratum on index values. *New Zealand Journal of Marine and Freshwater Research, 27*, 463-478.

Statistics New Zealand. (2006). *2006 Census Data*. Retrieved 25 June, 2007, from http://www.stats.govt.nz/census/2006-census-data/regional-summary-tables.htm

Statistics New Zealand. (2007a). *Agricultural Production Statistics*. Retrieved 25 June, 2007, from http://www.stats.govt.nz/economy/primary-production/agriculture.htm

Statistics New Zealand. (2007b). *Directory of Environmental Databases and Collections: New Zealand Geopreservation Inventory*. Retrieved 13 July, 2007, from http://www2.stats.govt.nz/domino/external/web/catv2.nsf/9930f7a8283198954c2563f1002c10d1/36041e39dc1557934c256632000191ef?OpenDocument

Statistics New Zealand. (2007c). *Glossary Term - Meshblock*. Retrieved 23 July, 2007, from http://www2.stats.govt.nz/domino/external/omni/omni.nsf/23f076d733ded7e74c256570001d92b4/0e2ddb61dc0e30eacc25722f0079847a?OpenDocument

Statistics New Zealand. (2007d). *Statistics New Zealand Glossary*. Retrieved 25 June, 2007, from http://www2.stats.govt.nz/domino/external/omni/omni.nsf/

Strickland, R., & Quarterman, A. (2001). *Review of the freshwater fish in the Wellington Region* (No. WRC/RP-T-01/58). Nelson: Cawthron Institute.

Stronge, J. (2000). *An Investigation into the Taratahi and Carrington Water Races, Carterton, Wairarapa.* Unpublished Honours Thesis, Massey University, Palmerston North.

Tait, A., Bell, R., Burgess, S., Gorman, R., Gray, W., Larsen, H., Mullan, B., Reid, S.,Sansom, J., Thompson, C., Wratt, D and Harkness, M.,. (2002). *Meteorological Hazards and the Potential Impacts of Climate Change in Wellington Region – A scoping study. NIWA Client Report WLG2002/19.* (No. WRC/RP-T-02/16): Greater Wellington Regional Council.

Te Ara - The Encyclopedia of New Zealand. (1966 updated 2006). *Wairarapa Region*. Retrieved 13 November, 2006, from http://www.TeAra.govt.nz/1966/W/WairarapaRegion/en

Tech History. (2006). *Aerial Fertiliser*. Retrieved 14 November, 2006, from http://www.techhistory.co.nz/OntheLand/aerial_top-dressing.htm

The Soil Conservation and Rivers Control Council. (1957). *Floods in New Zealand 1920-53*. Wellington: The Soil Conservation and Rivers Control Council.

Thompson, C. S. (1982). *The Weather and Climate of the Wairarapa Region*. Wellington: New Zealand Meteorological Service.

Tipa, G. (1999). *Environmental Performance Indicators. Maori Indicators Case Study. Taieri River Case Study* (No. Technical Paper 58): Ministry for the Environment.

Tipa, G. (2001). The Maori perspective: Customary and traditional freshwater and riparian values. In *Managing Waterways on farms: A guide to sustainable water and riparian management in rural New Zealand* (pp. 7-12). Wellington: Ministry for the Environment.

Tipa, G., & Teirney, L. (2003). *A Cultural Health Index for Streams and Waterways Indicators for recognising and expressing Maori values*. Wellington: Ministry for the Environment.

Truhlar, J. F. (1978). Determining suspended sediment loads from turbidity records. *Hydrological Sciences Bulletin, 23*(4).

Tweed Forum. (n.d.). *Tweed Forum*. Retrieved 17 October, 2006, from http://www.tweedforum.com/home

Uhrich, M. A., & Bragg, H. M. (2003). *Monitoring Instream Turbidity to Estimate Continuous Suspended-Sediment Loads and Yields and Clay-Water Volumes in the Upper North Santiam River Basin, Oregon, 1998–2000* (No. Water-Resources Investigations Report 03–4098). Portland, Oregon: U.S.Department of the Interior and U.S. Geological Survey.

Unwin, M., & Image, K. (2003). *Angler usage of lake and river fisheries managed by Fish and Game New Zealand: results from the 2001/02 National Angling Survey.* (No. NIWA Client Report CHC 2003-114). Christchurch: National Institute of Water and Atmospheric Research Ltd.

Wairarapa Engineering Lifelines Association. (2003). *Wairarapa Engineering Lifelines Project - Risk to lifelines from natural hazards*. Masterton.

Wairarapa Outdoor Pursuits. (2002). *Wairarapa Outdoor Pursuits*. Retrieved 24 July, 2007, from http://wairarapa.co.nz/outdoor-pursuits/index.html

Wairarapa Regional Development Council. (1978). *Wairarapa: Resources of a Region*. Masterton: Wairarapa Regional Development Council.

Waitangi Tribunal. (2007). *Wairarapa Ki Tararua Introduction*. Retrieved 1 August, 2007, from http://www.waitangi-tribunal.govt.nz/inquiries/wairarapa_inq/default.asp

Warr, S. (2002). *Rivers State of the Environment Monitoring Review* (No. WGN-DOCS-#407703). Wellington: Greater Wellington Regional Council.

Waste Management Wairarapa. (2006). *Refuse Figures*, from http://www.waiwaste.org.nz/Policy&reports/refuse%20figures.htm

Watts, L. (2001). *Wairarapa Municipal Oxidation Ponds. Water Quality Monitoring Report. July 1999-June 2001* (No. 01/10): Greater Wellington Regional Council.

Watts, L. (2004). *The 15-16 February 2004 storm in the Wellington Region: hydrology and meteorology.* (No. GW/RINV-G-04/91). Wellington: Greater Wellington Regional Council.

Watts, L. (2005). *Hydrological monitoring technical report.* (No. GW\RINV-T-05/88). Wellington: Greater Wellington Regional Council.

Watts, L., & Gordon, M. (2006). *The 4 - 7 July 2006 storms in the Wellington region: hydrology and meteorology.* (No. WGN_DOCS-#352907-V1). Wellington: Greater Wellington Regional Council.

Watts, L., & Perrie, A. (2007). *Lower Ruamahanga Instream Flow Assessment. Stage 1: Instream flow issues report*. Wellington: Greater Wellington Regional Council.

Waugh, J., Freestone, H., & Lew, D. (1997). Historic floods and droughts in New Zealand. In M. P. Mosley & C. P. Pearson (Eds.), *Floods and Droughts: the New Zealand Experience*. Wellington: New Zealand Hydrological Society.

Weingartner, R., & Pearson, C. (2001). A Comparison of the Hydrology of the Swiss Alps and the Southern Alps of New Zealand. *Mountain Research and Development, 21*(4), 370-381.

Wellington City Council. (2005). *Assessment of Water and Sanitary Services*. Retrieved 25 June, 2007, from http://www.wellington.govt.nz/plans/policies/watersanitary/pdfs/5-5watersan.pdf

Wild, M., Hicks, M., & Merrilees, R. (2006). *Suspended sediment monitoring in the Motueka catchment: data report to 1 May 2006* (No. NIWA Client Report: CHC2006-087). Christchurch: NIWA.

18. Appendicies

1. Geological Time Scale including Geological Units indentified in Wairarapa. (Begg et al, 2005)

Geological Time Scale				Age (Ma)	Corresponding Geological Unit
CENOZOIC			Holocene	0.01	
	Quaternary		Pleistocene	1.8	UNIT 4 & UNIT 5
	Tertiary	Neogene	Pliocene	5.3	UNIT 3
			Miocene	23.8	25 Ma – 2.3 Ma
			Oligocene	33.7	UNIT 2
			Eocene	54.8	100 – 25 Ma
			Paleocene	65.0	
			Cretaceous	142	
MESOZOIC			Jurassic	206	UNIT 1
			Triassic	248	230 – 120 Ma
PALEOZOIC			Permian	290	

2. Geological Subdivision of Lithological Units 4 and 5 arranged in stratigraphic order, from youngest to oldest. (Begg et al, 2005, p. 10)

Unit	Relative age	Material	Name	Depositional environment	Symbol	Absolute age (ka)
5	Holocene	Mud & silt		Estuarine, lacustrine	Q1m Q1s	0-7
5	Holocene	Gravel & sand		Alluvial	Q1a	0-10
5	Late Otiran	Gravel & sand	Waiohine	Alluvial	Q2a	10-25
5	Middle Otiran	Gravel & sand	Ramsley	Alluvial	Q3a	50-25
5	Early Otiran	Gravel & sand	Waipoua	Alluvial	Q4a	70-50
5	Kaihinu Interglacial	Mud, silt, sand & minor gravel	Francis Line	Swamp, lacustrine	Q5m	125-70
5	Kaihinu Interglacial	Sand, some gravel	Eparaima	Marginal marine	Q5b	125-70
4	Waimea Glacial	Gravel & sand		Alluvial	Q6a	186-125
4	Middle Quaternary	Gravel, sand, silt, loess, tephra	Ahiaruhe	Alluvial, swamp	mQa	500-186
4	Early Quaternary	Gravel, sand, silt, loess, tephra	Te Muna	Alluvial, swamp	eQa	c. 1000-500

3. Sub classification of the Land Cover Database 2 (LCDB2)

1st Order Class	Area (km^2)	%	LCDB2 Class	Area (Km^2)	%
Artificial Surfaces	22.9	0.64	Built up area	17	0.5
			Urban Parkland	5.6	0.16
			Surface Mine	0.17	0.005
			Dump	0.07	0.002
			Transport Infrastructure	0.06	0.002
Bare or lightly vegetated surfaces	176.8	4.92	River/lakeshore gravel	14.98	0.44
			Landslide	0.81	0.023
			Alpine Rock and gravel	0.71	0.021
			Alpine grass and herbfield	0.07	0.002
Water Bodies	93.9	2.62	Lake and pond	82.6	2.41
			River	11.35	0.33
Cropland	33.9	0.94	Short-rotation cropland	19.73	0.57
			Vineyard	10.66	0.31
			Orchard and other perennial crops	3.54	0.10
Grassland	2156.8	60.1	High producing grassland	2081	60.6
			Low producing grassland	32.6	0.95
			Tall tussock grassland	32.8	0.96
			Herbaceous freshwater vegetation	10.3	0.3
Scrub and Shrubland	366.3	10.2	Gorse and Broom	59.2	1.72
			Manuka and Kanuka	101.25	2.95
			Broadleaved indigenous hardwoods	159.7	4.65
			Sub alpine shrubland	46.1	1.34
			Mixed exotic shrubland	0.09	0.003
			Grey scrub	0.06	0.002
Forest	153.6	4.28	Major Shelterbelts	1.9	0.06
			Afforestation	16	0.46
			Forest – Harvested	5.3	0.15
			Pine Forest (Open Canopy)	36.57	1.07
			Pine Forest (Closed Canopy)	73.9	2.15
			Other Exotic Forest	3.4	0.1
			Deciduous hardwoods	16.4	0.48
Indigenous Forest	586.3	16.3	Indigenous Forest	586.3	17.1

4. Selected Rainfall and Climate Stations operating in the Ruamahanga Catchment

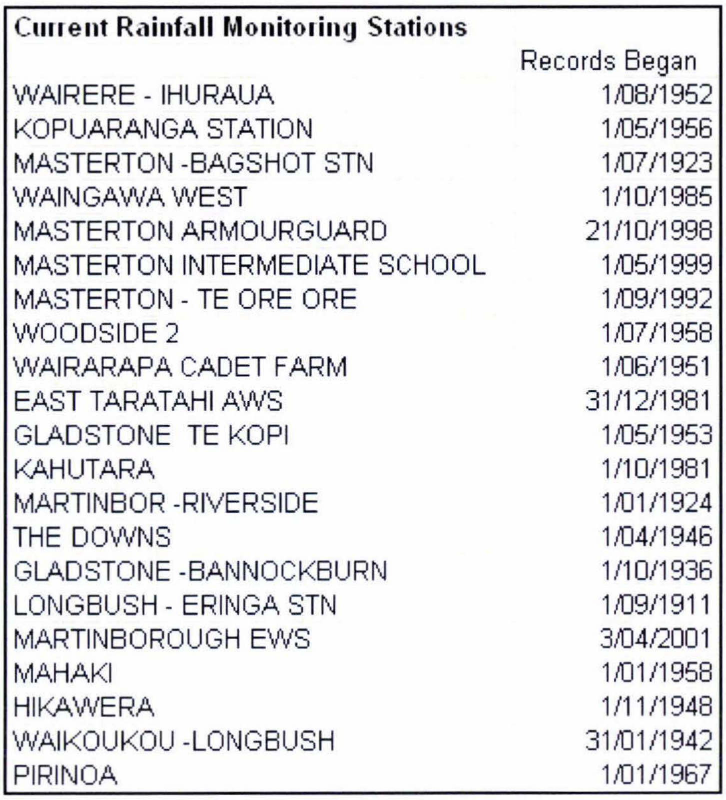
RAINFALL STATIONS

Station Name	Station No.	Catchment	Alt (m)	Start Date	Telemetry
GREATER WELLINGTON REGIONAL COUNCIL STATIONS					
Bannister Basin	57511	Head of Ruamahanga	1000	30/09/1974	N
Mt Bruce	57514	Ruamahanga (foothills)	300	30/07/1984	N
Castlehill	57958	Head of Taueru	240	10/04/1991	Y
Angle Knob	58403	Head of Atiwhakatu	1200	27/12/1974	Y
Carkeek	58411	Head of Waiohine	1158	30/09/1974	N
Waingawa	58582	Waingawa (river level)	240	09/05/1994	Y
Waihi	58737	Whangaehu	175	10/01/2001	Y
Bull Mound	59310	Head of Tauherenikau	1000	23/03/1974	Y
Valley Hill (aka. Mangatarere)	59445	Mangatarere (foothills)	483	21/04/1997	Y
Te Weraiti	59795	Taueru	80	09/09/1997	Y
Phelps	150303	Lower Waiohine	?	02/01/1974	N
Iraia	153387	Huangaroa		09/04/1969	N
MET SERVICE STATIONS					
East Taratahi	150302				D15062
PRIVATE STATIONS					
Bagshot	D05872	Whangaehu		02/07/1923	N
Bannockburn	D15161	Whangaehu/Huangarua		01/10/1936	N
Waiorongmai	152101 (D15211)	Lower Ruamahanga		01/11/1928	N

CLIMATE STATIONS

Station Name	Station No.	Catchment	Alt (m)	Start Date	Telemetry
GREATER WELLINGTON REGIONAL COUNCIL STATIONS					
Masterton Office	596461	Ruamahanga	120	18/08/2000	
Alloa	1513501	Tauherenikau	40	01/03/1963	

5. NIWA's current rainfall stations in the Ruamahanga Catchment



Current Rainfall Monitoring Stations

	Records Began
WAIRERE - IHURAUA	1/08/1952
KOPUARANGA STATION	1/05/1956
MASTERTON -BAGSHOT STN	1/07/1923
WAINGAWA WEST	1/10/1985
MASTERTON ARMOURGUARD	21/10/1998
MASTERTON INTERMEDIATE SCHOOL	1/05/1999
MASTERTON - TE ORE ORE	1/09/1992
WOODSIDE 2	1/07/1958
WAIRARAPA CADET FARM	1/06/1951
EAST TARATAHI AWS	31/12/1981
GLADSTONE TE KOPI	1/05/1953
KAHUTARA	1/10/1981
MARTINBOR -RIVERSIDE	1/01/1924
THE DOWNS	1/04/1946
GLADSTONE -BANNOCKBURN	1/10/1936
LONGBUSH - ERINGA STN	1/09/1911
MARTINBOROUGH EWS	3/04/2001
MAHAKI	1/01/1958
HIKAWERA	1/11/1948
WAIKOUKOU -LONGBUSH	31/01/1942
PIRINOA	1/01/1967

6. NIWA's historical rainfall stations in the Ruamahanga Catchment

Historical NIWA rainfall stations		
MT BRUCE	1/01/1967	31/07/1985
MAURICEVILLE EAST	1/01/1967	31/07/1968
MANGAMAHOE	1/11/1948	31/10/1971
TAKITAKI	1/11/1948	30/06/1966
TIKI TAPU	1/01/1972	31/12/1974
WAIMAPU	1/05/1956	31/05/1969
WAIRARAPA -KAITUNA	1/09/1970	31/12/1975
KAITUNA NO2	1/06/1978	30/06/1991
MAURICEVILLE EAST	1/02/1971	31/03/1981
DITTON	1/01/1907	30/04/1930
WILLOWLEA	1/03/1962	30/06/1995
BIDEFORD -MARINGI RD	1/12/1969	31/08/1987
MT HOLDSWORTH LODGE	1/05/1968	30/06/1991
MASTERTON WATERWORKS	1/10/1948	31/12/1953
MASTERTON -ESSEX ST	1/01/1884*	30/11/1942
LLANDAFF	1/01/1927	29/02/1960
MASTERTON	1/04/1945	31/08/1957
MASTERTON AERO 1	1/12/1947	30/04/1961
WAINGAWA	1/02/1926	31/03/1991
MASTERTON -COLOMBO RD	1/01/1967	30/09/1974
MASTERTON -HANSELLS	22/02/1975	31/05/1990
TE ORE ORE	1/01/1941	31/05/1968
OTAHUAO	18880801	31/12/1903
GREYTOWN P.O.	1/07/1930	31/08/1988
GREYTOWN 2	1/01/1967	30/06/1971
GREYTOWN 1	1/03/1979	31/05/1987
WAIHAKEKE	1/01/1887*	31/05/1924
WESTBOURNE	1/01/1970	30/09/1976
EAST TARATAHI	1/07/1972	31/08/1978
PAKARAKA	1/05/1978	31/10/1980
FEATHERSTON	5/31/1889*	30/11/1987
WAIPOTO	1/03/1940	30/09/1960
FEATHERSTON	11/01/1883*	10/31/1888*
TAUHERENIKAU	1/03/1963	31/03/1994
MORRISONS BUSH	1/01/1944	30/11/1966
RUAMAHANGA	1/01/1967	31/12/1970
GLADSTONE - ARAHURA	1/01/1967	31/12/1982
WAIORONGOMAI	1/11/1928	31/12/1993
TE HOPAI	1/01/1932	31/03/1969
WAIRARAPA -LAKEFIELD	1/06/1978	31/05/1992
SOUTH DOWNS	1/10/1949	31/05/1956
FEATHERSTON -PUKEO	1/08/1983	30/04/1985
MARTINBOROUGH -S.DOWNS	1/01/1967	31/12/1969
MARTINBOROUGH	1/01/1909	30/06/1943
MARTINBOROUGH	1/02/1968	31/08/1974
MARTINBOROUGH	1/01/1986	31/05/1989
MARTINBOROUGH	1/10/1986	31/01/2000
MARTINBOROUGH - DUBLIN STREET	1/10/1991	30/04/2000
MARTINBORO -PURUATANGA	31/01/1945	30/09/2002
TE MOANA	1/12/1934	31/05/1941
IRAIA	1/01/1972	31/12/1973
SHOOTING BOX	1/06/1939	30/09/1968
SUNNYSIDE STATION	1/10/1969	30/06/1978

7. Water Quality Variables – Definitions and Uses

as derived from (Milne & Perrie, 2006), (Watts, 2001), Environment Waikato (Environment Waikato, 2006), and Christchurch City Council (Christchurch City Council, 2008)

Dissolved Oxygen (DO) – (g/m^3)

The presence of DO is essential for aquatic life. Water bodies should be more than 80 percent saturated with DO for aquatic plants and animals to live in it. Lower levels of DO can be attributed to the presence of sewage (organic pollution) where bacteria utilize the DO as they mineralize the organic matter. DO concentrations can also indicate photosynthesis.

Temperature (°C)

Water temperature can impact on how aquatic ecosystems function. The temperature is important for fish spawning and aquatic life. Temperatures should be below 25°C to protect the health of most native fish, 20°C to protect trout health, and below 12°C for when trout are spawning. Temperature can also influence DO concentrations.

pH

pH measures the acidity or alkalinity of water. A pH which is either very acidic or very alkaline can impact directly on ecosystem health. Alkaline conditions (high pH) can increase the toxicity of other pollutants (e.g. ammonia-N). Changes in pH can be indicative of industrial discharges. A pH range from 6.5 to 9 is suitable for aquatic plants and animals.

Conductivity (µS/cm)

Conductivity measures the waters ability to conduct electricity, and therefore is directly related to the concentration of dissolved ions. A high concentration of dissolved ions, and thus a high conductivity can be a result of waste water discharges.

Visual Clarity (m) and Turbidity (NTU)

Visual clarity is measured by how far away black disc can be seen through the water. It measures how clear the water is. Similarly, turbidity measures how murky the water is, reflecting the volume of sediment in the water. High levels of turbidity and low visual clarity distances can affect the ability of sight-feeding predators to locate prey, and reduce the ability of plants to photosynthesise, thus negatively impacting on the food chain. These measures also relate to aesthetic value of the water body, and can provide an indication of surrounding land use.

Colour

Colour is measured using a periscope and matching the colour with the Munsell colour cards. Colour can be used for site comparison purposes.

Biochemical Oxygen Demand (BOD_5) (g/m^3)

BOD is a measure of the amount of biodegradable organic matter present in the water, and the potential for bacteria to deplete oxygen concentrations. Measuring BOD is useful for postulating the impact of sewage or organic rich discharges on the health of the receiving water body.

Total Organic Carbon (TOC)

TOC can indicate the amount of organic carbon in the water body and allows an assessment to be made on organic contamination.

Faecal Coliforms (/100 mL)

Faecal Coliforms are present in the intestines and faeces of warm-blooded animals. Therefore their presence in a water sample indicates pollution by faecal matter. Faecal Coliform counts are useful in determining the suitability of the water for human or stock consumption, and recreational bathing.

Escherichia coli (*E.Coli*) (/100 mL)

E.Coli is the specific indicator of faecal contamination; they are a sub-group of faecal coliforms.

Nitrite Nitrogen (g/m^3)

Nitrite is an intermediate state of nitrogen and in the presence of oxygen it will readily convert into nitrate. High concentrations of nitrite thus indicate anaerobic conditions. High concentrations of nitrite-N can impact adversely on human and animal health (e.g blue baby syndrome).

Nitrate Nitrogen (g/m^3)

Nitrate is formed as a result of nitrification (conversion of ammonia into the nitrite intermediate and then to nitrate in the presence of oxygen). High nitrate concentrations can be harmful to human and livestock. Nitrate is an important nutrient for the growth of algae and other plants.

Ammonia Nitrogen (g/m^3)

Ammonia Nitrogen present at high concentrations can be harmful to aquatic life (invertebrates and fish), and is associated with sewage wastes. The toxicity of ammonia is dependent on the concentration of the undissociated form (NH_3), which can vary depending on the temperature and pH of the water solution.

Total Nitrogen (g/m^3)

Total nitrogen is the sum of all nitrogen species present in the solution (i.e. both organic and inorganic fractions of nitrogen). Nitrogen can stimulate the growth of aquatic plants which can impact negatively on water ways. High nitrogen concentrations in water solutions can be a result of runoff and leaching from agricultural land. A decrease in the concentration of Total Nitrogen can indicate an improvement in wastewater treatment in an oxidation pond system. Total Nitrogen levels above 0.5 g/m3 are thought to be undesirably nutrient-enriched.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen is the sum of organic nitrogen, ammonia (NH_3) and ammonium (NH_4^+).

Dissolved Reactive Phosphorus (DRP)

Dissolved Reactive Phosphorus is the dissolved form of phosphorus that is available for plant growth. Higher concentrations of DRP, lead to a greater chance of algae growth in waterways.

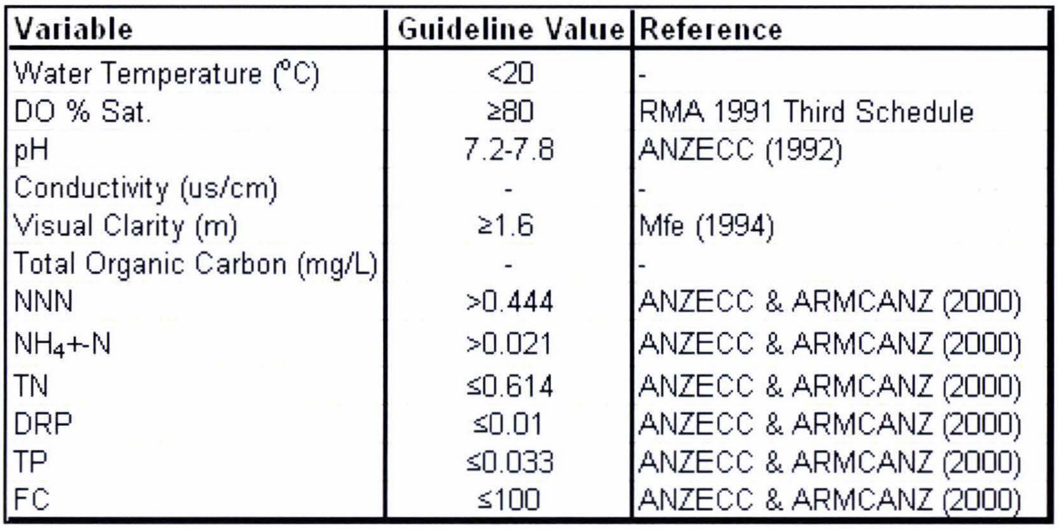
Total Phosphorus

Phosphorus can stimulate plant growth in waterways. The source of phosphorus can be either waste water discharge or runoff from agricultural land. Total phosphorus levels should be below 0.04 g/m^3 to limit the excessive growth of aquatic plants.

Periphyton Cover (%) and (% mats and filamentous cover)

Periphyton is composed of algae, diatoms, bacteria and fungi. It appears as slimy material attached to the surfaces of rocks in waterways. Periphyton is an important component in the food chain, however excessive growth can reduce aesthetic and recreational qualities, block water intakes, and impact on ecosystem values. The percentage of periphyton cover is assessed within a 1 m^2 hoop.

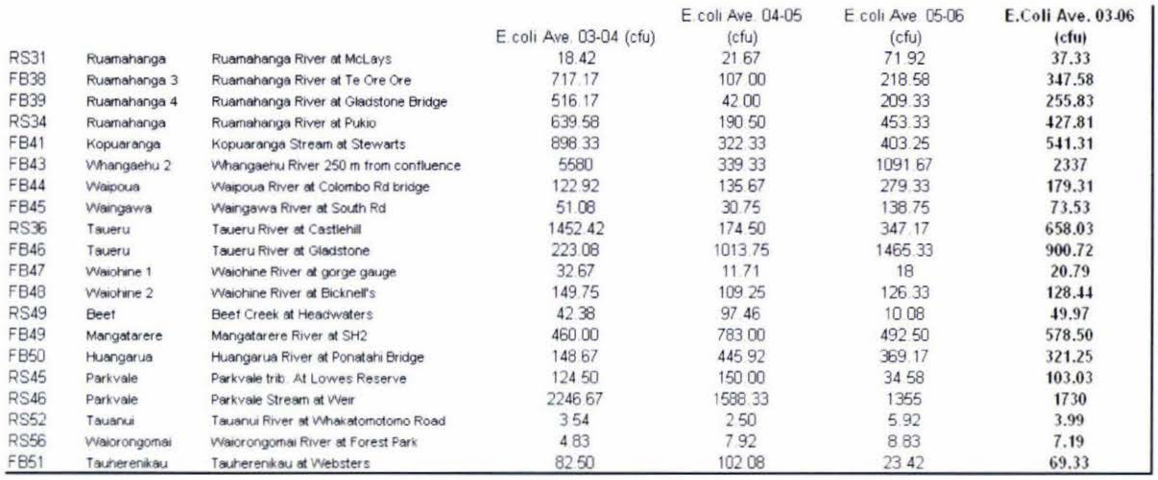
8. Source of Guideline Values (GV)



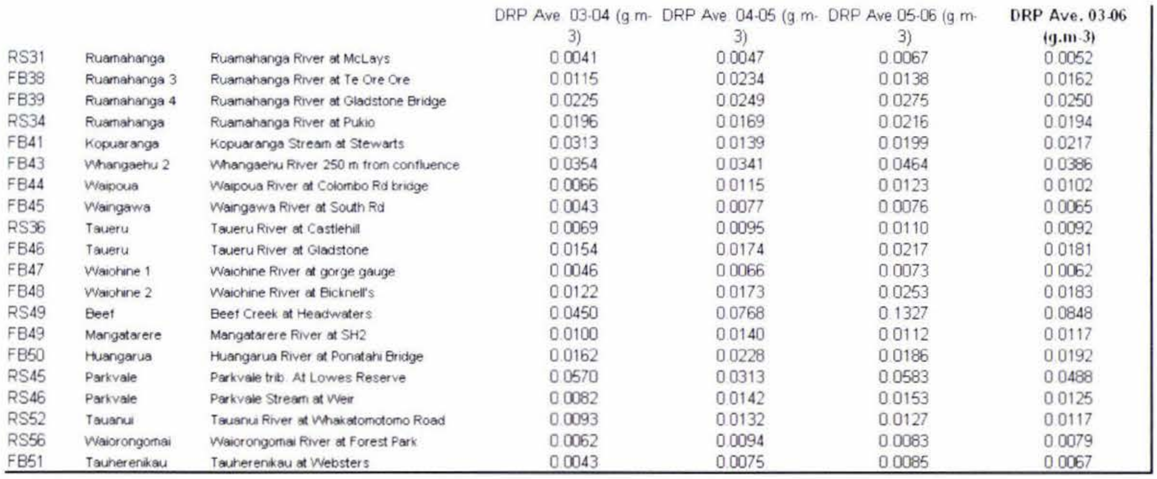
Variable	Guideline Value	Reference
Water Temperature (°C)	<20	-
DO % Sat.	≥80	RMA 1991 Third Schedule
pH	7.2-7.8	ANZECC (1992)
Conductivity (us/cm)	-	-
Visual Clarity (m)	≥1.6	Mfe (1994)
Total Organic Carbon (mg/L)	-	-
NNN	>0.444	ANZECC & ARMCANZ (2000)
NH_4+-N	>0.021	ANZECC & ARMCANZ (2000)
TN	≤0.614	ANZECC & ARMCANZ (2000)
DRP	≤0.01	ANZECC & ARMCANZ (2000)
TP	≤0.033	ANZECC & ARMCANZ (2000)
FC	≤100	ANZECC & ARMCANZ (2000)

Source (Milne & Perrie, 2006, p. 19)

9. Average concentrations of *E.Coli*, DRP, NO_3-N, TN, NH_4-N from 2003-2006



			E.coli Ave. 03-04 (cfu)	E.coli Ave. 04-05 (cfu)	E.coli Ave. 05-06 (cfu)	**E.Coli Ave. 03-06 (cfu)**
RS31	Ruamahanga	Ruamahanga River at McLays	18.42	21.67	71.92	**37.33**
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	717.17	107.00	218.58	**347.58**
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	516.17	42.00	209.33	**255.83**
RS34	Ruamahanga	Ruamahanga River at Pukio	639.58	190.50	453.33	**427.81**
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	898.33	322.33	403.25	**541.31**
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	5580	339.33	1091.67	**2337**
FB44	Waipoua	Waipoua River at Colombo Rd bridge	122.92	135.67	279.33	**179.31**
FB45	Waingawa	Waingawa River at South Rd	51.08	30.75	138.75	**73.53**
RS36	Taueru	Taueru River at Castlehill	1452.42	174.50	347.17	**658.03**
FB46	Taueru	Taueru River at Gladstone	223.08	1013.75	1465.33	**900.72**
FB47	Waiohine 1	Waiohine River at gorge gauge	32.67	11.71	18	**20.79**
FB48	Waiohine 2	Waiohine River at Bicknell's	149.75	109.25	126.33	**128.44**
RS49	Beef	Beef Creek at Headwaters	42.38	97.46	10.08	**49.97**
FB49	Mangatarere	Mangatarere River at SH2	460.00	783.00	492.50	**578.50**
FB50	Huangarua	Huangarua River at Ponatahi Bridge	148.67	445.92	369.17	**321.25**
RS45	Parkvale	Parkvale trib. At Lowes Reserve	124.50	150.00	34.58	**103.03**
RS46	Parkvale	Parkvale Stream at Weir	2246.67	1588.33	1355	**1730**
RS52	Tauanui	Tauanui River at Whakatomotomo Road	3.54	2.50	5.92	**3.99**
RS56	Waiorongomai	Waiorongomai River at Forest Park	4.83	7.92	8.83	**7.19**
FB51	Tauherenikau	Tauherenikau at Websters	82.50	102.08	23.42	**69.33**



			DRP Ave. 03-04 (g.m-3)	DRP Ave. 04-05 (g.m-3)	DRP Ave.05-06 (g.m-3)	**DRP Ave. 03-06 (g.m-3)**
RS31	Ruamahanga	Ruamahanga River at McLays	0.0041	0.0047	0.0067	0.0052
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	0.0115	0.0234	0.0138	0.0162
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	0.0225	0.0249	0.0275	0.0250
RS34	Ruamahanga	Ruamahanga River at Pukio	0.0196	0.0169	0.0216	0.0194
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	0.0313	0.0139	0.0199	0.0217
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	0.0354	0.0341	0.0464	0.0386
FB44	Waipoua	Waipoua River at Colombo Rd bridge	0.0066	0.0115	0.0123	0.0102
FB45	Waingawa	Waingawa River at South Rd	0.0043	0.0077	0.0076	0.0065
RS36	Taueru	Taueru River at Castlehill	0.0069	0.0095	0.0110	0.0092
FB46	Taueru	Taueru River at Gladstone	0.0154	0.0174	0.0217	0.0181
FB47	Waiohine 1	Waiohine River at gorge gauge	0.0046	0.0066	0.0073	0.0062
FB48	Waiohine 2	Waiohine River at Bicknell's	0.0122	0.0173	0.0253	0.0183
RS49	Beef	Beef Creek at Headwaters	0.0450	0.0768	0.1327	0.0848
FB49	Mangatarere	Mangatarere River at SH2	0.0100	0.0140	0.0112	0.0117
FB50	Huangarua	Huangarua River at Ponatahi Bridge	0.0162	0.0228	0.0186	0.0192
RS45	Parkvale	Parkvale trib. At Lowes Reserve	0.0570	0.0313	0.0583	0.0488
RS46	Parkvale	Parkvale Stream at Weir	0.0082	0.0142	0.0153	0.0125
RS52	Tauanui	Tauanui River at Whakatomotomo Road	0.0093	0.0132	0.0127	0.0117
RS56	Waiorongomai	Waiorongomai River at Forest Park	0.0062	0.0094	0.0083	0.0079
FB51	Tauherenikau	Tauherenikau at Websters	0.0043	0.0075	0.0085	0.0067

			Nitrate Nitrogen Ave 03-04 (g.m-3)	Nitrate Nitrogen Ave 04-05 (g.m-3)	Nitrate Nitrogen Ave 05-06 (g.m-3)	**Nitrate Nitrogen Ave 03-06 (g.m-3)**
RS31	Ruamahanga	Ruamahanga River at McLays	0.0268	0.0469	0.0191	**0.0309**
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	0.5530	0.4130	0.4393	**0.4684**
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	0.6932	0.5149	0.4807	**0.5629**
RS34	Ruamahanga	Ruamahanga River at Pukio	0.7098	0.4977	0.3971	**0.5349**
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	0.8779	1.0271	0.9569	**0.9540**
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	2.4533	1.1840	1.5126	**1.7166**
FB44	Waipoua	Waipoua River at Colombo Rd bridge	1.6628	1.1159	1.1602	**1.3130**
FB45	Waingawa	Waingawa River at South Rd	0.1454	0.0998	0.1372	**0.1275**
RS36	Taueru	Taueru River at Castlehill	0.2754	0.2108	0.1925	**0.2262**
FB46	Taueru	Taueru River at Gladstone	0.6154	0.6996	0.6706	**0.6619**
FB47	Waiohine 1	Waiohine River at gorge gauge	0.0385	0.0252	0.0210	**0.0282**
FB48	Waiohine 2	Waiohine River at Bicknell's	0.5073	0.3793	0.4004	**0.4290**
RS49	Beef	Beef Creek at Headwaters	0.0303	0.0322	0.0315	**0.0313**
FB49	Mangatarere	Mangatarere River at SH2	1.5658	1.4635	1.3503	**1.4599**
FB50	Huangarua	Huangarua River at Ponatahi Bridge	0.5399	0.4313	0.2858	**0.4190**
RS45	Parkvale	Parkvale trib. At Lowes Reserve	4.5206	4.5993	4.5600	**4.5600**
RS46	Parkvale	Parkvale Stream at Weir	3.3422	2.0984	1.5793	**2.3399**
RS52	Tauanui	Tauanui River at Whakatomotomo Road	0.0204	0.0148	0.0140	**0.0164**
RS56	Waiorongomai	Waiorongomai River at Forest Park	0.0291	0.0275	0.0208	**0.0258**
FB51	Tauherenikau	Tauherenikau at Websters	0.1146	0.0829	0.0830	**0.0935**

			Total Nitrogen Ave 03-04 (g.m-3)	Total Nitrogen Ave 04-05 (g.m-3)	Total Nitrogen Ave 05-06 (g.m-3)	**Total Nitrogen Ave 03-06 (g.m-3)**
RS31	Ruamahanga	Ruamahanga River at McLays	0.0819	0.0573	0.0741	**0.0711**
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	0.8709	0.5283	0.6210	**0.6734**
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	0.9833	0.6623	0.7330	**0.7929**
RS34	Ruamahanga	Ruamahanga River at Pukio	0.9717	0.6412	0.6836	**0.7655**
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	1.2279	1.2678	1.3118	**1.2692**
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	2.8842	1.6769	2.0618	**2.2076**
FB44	Waipoua	Waipoua River at Colombo Rd bridge	1.8190	1.2132	1.3293	**1.4538**
FB45	Waingawa	Waingawa River at South Rd	0.1920	0.1397	0.1649	**0.1655**
RS36	Taueru	Taueru River at Castlehill	0.6982	0.5568	0.4853	**0.5801**
FB46	Taueru	Taueru River at Gladstone	1.0726	1.3140	1.2019	**1.1962**
FB47	Waiohine 1	Waiohine River at gorge gauge	0.0863	0.0738	0.0981	**0.0861**
FB48	Waiohine 2	Waiohine River at Bicknell's	0.6421	0.4635	0.4965	**0.5340**
RS49	Beef	Beef Creek at Headwaters	0.0899	0.0842	0.0977	**0.0906**
FB49	Mangatarere	Mangatarere River at SH2	1.8892	1.7718	1.6584	**1.7731**
FB50	Huangarua	Huangarua River at Ponatahi Bridge	0.7712	0.6625	0.5791	**0.6709**
RS45	Parkvale	Parkvale trib. At Lowes Reserve	5.5900	4.8380	4.7686	**5.0655**
RS46	Parkvale	Parkvale Stream at Weir	4.1525	2.4856	2.2490	**2.9624**
RS52	Tauanui	Tauanui River at Whakatomotomo Road	0.1778	0.1470	0.0816	**0.1355**
RS56	Waiorongomai	Waiorongomai River at Forest Park	0.0837	0.1224	0.1012	**0.1024**
FB51	Tauherenikau	Tauherenikau at Websters	0.1939	0.1329	0.1703	**0.1657**

			Ammoniacal-N Ave 03-04 (g.m-3)	Ammoniacal-N Ave 04-05 (g.m-3)	Ammoniacal-N Ave 05-06 (g.m-3)	**Ammoniacal-N Ave 03-06 (g.m-3)**
RS31	Ruamahanga	Ruamahanga River at McLays				
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	0.0117	0.0153	0.0058	**0.0109**
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	0.0158	0.0098	0.0098	**0.0118**
RS34	Ruamahanga	Ruamahanga River at Pukio	0.0350	0.0200	0.0232	**0.0261**
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	0.0250	0.0104	0.0170	**0.0175**
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	0.0300	0.0084	0.0166	**0.0183**
FB44	Waipoua	Waipoua River at Colombo Rd bridge	0.0383	0.0205	0.0181	**0.0256**
FB45	Waingawa	Waingawa River at South Rd	0.0267	0.0095	0.0086	**0.0149**
RS36	Taueru	Taueru River at Castlehill	0.0054	0.0054	0.0054	**0.0054**
FB46	Taueru	Taueru River at Gladstone	0.0258	0.0129	0.0145	**0.0178**
FB47	Waiohine 1	Waiohine River at gorge gauge	0.0296	0.0299	0.0286	**0.0294**
FB48	Waiohine 2	Waiohine River at Bicknell's	0.0088	0.0068	0.0058	**0.0071**
RS49	Beef	Beef Creek at Headwaters	0.0150	0.0087	0.0163	**0.0134**
FB49	Mangatarere	Mangatarere River at SH2	0.0050	0.0050	0.0083	**0.0061**
FB50	Huangarua	Huangarua River at Ponatahi Bridge	0.0625	0.0873	0.0725	**0.0741**
RS45	Parkvale	Parkvale trib. At Lowes Reserve	0.0113	0.0117	0.0125	**0.0118**
RS46	Parkvale	Parkvale Stream at Weir	0.0429	0.0065	0.0073	**0.0189**
RS52	Tauanui	Tauanui River at Whakatomotomo Road	0.0783	0.0185	0.0404	**0.0458**
RS56	Waiorongomai	Waiorongomai River at Forest Park	0.0067	0.0057	0.0095	**0.0073**
FB51	Tauherenikau	Tauherenikau at Websters	0.0500	0.0108	0.0079	**0.0229**
			0.0083	0.0132	0.0338	**0.0184**

10. Average concentrations, loads and losses per hectare of DRP, NO_3-N, TN, NH_4-N from 2003-2006

Site No.	Site Name	Site Description	Area (m^2)	Accum. Rain (m^3)	Accum. Evap. (m^3)	Accum. Runoff (m^3)	Av. Flow (m^3.sec-1)	Av. DRP 03-06 (g.m-3)	DRP Load (g.year-1)	DRP/ha (g.ha-1)
RS31	Ruamahanga	Ruamahanga River at McLays	7.11E+07	2.28E+08	3.56E+07	1.92E+08	6.10	0.0052	991831.69	139.42
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	3.08E+08	5.58E+08	1.54E+08	4.04E+08	12.81	0.0162	6548760.02	212.67
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	1.34E+09	1.99E+09	6.69E+08	1.32E+09	41.90	0.0250	32996416.53	246.73
RS34	Ruamahanga	Ruamahanga River at Pukio	2.46E+09	3.93E+09	1.23E+09	2.70E+09	85.56	0.0194	52243039.24	212.37
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	1.66E+08	2.32E+08	8.31E+07	1.49E+08	4.72	0.0217	3234758.81	194.66
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	1.45E+08	1.70E+08	7.25E+07	9.75E+07	3.09	0.0386	3768738.31	260.05
FB44	Waipoua	Waipoua River at Colombo Rd bridge	1.74E+08	2.51E+08	8.69E+07	1.64E+08	5.20	0.0102	1666313.61	95.90
FB45	Waingawa	Waingawa River at South Rd	1.44E+08	3.75E+08	7.18E+07	3.03E+08	9.61	0.0065	1974945.29	137.51
RS36	Taueru	Taueru River at Castlehill	1.76E+07	2.41E+07	8.78E+06	1.53E+07	0.49	0.0092	140200.23	79.89
FB46	Taueru	Taueru River at Gladstone	4.48E+08	5.11E+08	2.24E+08	2.87E+08	9.09	0.0181	5199194.84	116.10
FB47	Waiohine 1	Waiohine River at gorge gauge	1.82E+08	7.61E+08	9.12E+07	6.70E+08	21.24	0.0062	4130568.61	226.51
FB48	Waiohine 2	Waiohine River at Bicknell's	3.91E+08	1.09E+09	1.96E+08	8.94E+08	28.36	0.0183	16323430.43	417.34
FB49	Mangatarere	Mangatarere River at SH2	1.19E+08	2.01E+08	5.93E+07	1.42E+08	4.49	0.0848	12015945.16	1012.95
FB50	Huangarua	Huangarua River at Ponatahi Bridge	3.09E+08	3.98E+08	1.55E+08	2.43E+08	7.72	0.0117	2849109.77	92.11
RS45	Parkvale	Parkvale trib. At Lowes Reserve	1.08E+06	1.20E+06	5.41E+05	6.56E+05	0.02	0.0192	12591.74	116.40
RS46	Parkvale	Parkvale Stream at Weir	5.05E+07	5.94E+07	2.53E+07	3.42E+07	1.08	0.0488	1669237.74	330.50
RS49	Beef	Beef Creek at Headwaters	3.00E+06	5.71E+06	1.50E+06	4.21E+06	0.13	0.0125	52811.40	176.27
RS52	Tauanui	Tauanui River at Whakatomotomo Road	2.61E+07	4.32E+07	1.30E+07	3.01E+07	0.96	0.0117	352835.23	135.24
RS56	Waiorongomai	Waiorongomai River at Forest Park	1.87E+07	5.80E+07	9.33E+06	4.87E+07	1.54	0.0079	386781.85	207.21
FB51	Tauherenikau	Tauherenikau at Websters	1.44E+08	3.90E+08	7.21E+07	3.18E+08	10.09	0.0067	2147165.14	148.89

Site No.	Site Name	Site Description	Area (m^2)	Accum. Rain (m^3)	Accum. Evap. (m^3)	Accum. Runoff (m^3)	Av. Flow (m^3.sec-1)	Av. Nitrate 03-06 (g.m-3)	Nitrate Load (g.year-1)	Nitrate/ha (g.ha-1)
RS31	Ruamahanga	Ruamahanga River at McLays	7.11E+07	2.28E+08	3.56E+07	1.92E+08	6.10	0.0309	5950990.12	836.53
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	3.08E+08	5.58E+08	1.54E+08	4.04E+08	12.81	0.4684	189268704.37	6146.55
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	1.34E+09	1.99E+09	6.69E+08	1.32E+09	41.90	0.5629	743795752.00	5561.71
RS34	Ruamahanga	Ruamahanga River at Pukio	2.46E+09	3.93E+09	1.23E+09	2.70E+09	85.56	0.5349	1443242066.82	5866.81
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	1.66E+08	2.32E+08	8.31E+07	1.49E+08	4.72	0.9540	142060513.99	8549.08
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	1.45E+08	1.70E+08	7.25E+07	9.75E+07	3.09	1.7166	167436562.63	11553.32
FB44	Waipoua	Waipoua River at Colombo Rd bridge	1.74E+08	2.51E+08	8.69E+07	1.64E+08	5.20	1.3130	215490137.46	12402.15
FB45	Waingawa	Waingawa River at South Rd	1.44E+08	3.75E+08	7.18E+07	3.03E+08	9.61	0.1275	38648289.80	2691.01
RS36	Taueru	Taueru River at Castlehill	1.76E+07	2.41E+07	8.78E+06	1.53E+07	0.49	0.2262	3465222.17	1974.49
FB46	Taueru	Taueru River at Gladstone	4.48E+08	5.11E+08	2.24E+08	2.87E+08	9.09	0.6619	189710896.69	4236.45
FB47	Waiohine 1	Waiohine River at gorge gauge	1.82E+08	7.61E+08	9.12E+07	6.70E+08	21.24	0.0282	18903863.53	1036.65
FB48	Waiohine 2	Waiohine River at Bicknell's	3.91E+08	1.09E+09	1.96E+08	8.94E+08	28.36	0.4290	383687573.97	9809.70
FB49	Mangatarere	Mangatarere River at SH2	1.19E+08	2.01E+08	5.93E+07	1.42E+08	4.49	1.4599	206845069.73	17437.09
FB50	Huangarua	Huangarua River at Ponatahi Bridge	3.09E+08	3.98E+08	1.55E+08	2.43E+08	7.72	0.4190	101966360.24	3296.48
RS45	Parkvale	Parkvale trib. At Lowes Reserve	1.08E+06	1.20E+06	5.41E+05	6.56E+05	0.02	4.5600	2991384.68	27651.92
RS46	Parkvale	Parkvale Stream at Weir	5.05E+07	5.94E+07	2.53E+07	3.42E+07	1.08	2.3399	79984782.93	15836.34
RS49	Beef	Beef Creek at Headwaters	3.00E+06	5.71E+06	1.50E+06	4.21E+06	0.13	0.0313	131823.81	439.98
RS52	Tauanui	Tauanui River at Whakatomotomo Road	2.61E+07	4.32E+07	1.30E+07	3.01E+07	0.96	0.0164	493885.62	189.30
RS56	Waiorongomai	Waiorongomai River at Forest Park	1.87E+07	5.80E+07	9.33E+06	4.87E+07	1.54	0.0258	1255012.44	672.35
FB51	Tauherenikau	Tauherenikau at Websters	1.44E+08	3.90E+08	7.21E+07	3.18E+08	10.09	0.0935	29747777.85	2062.74

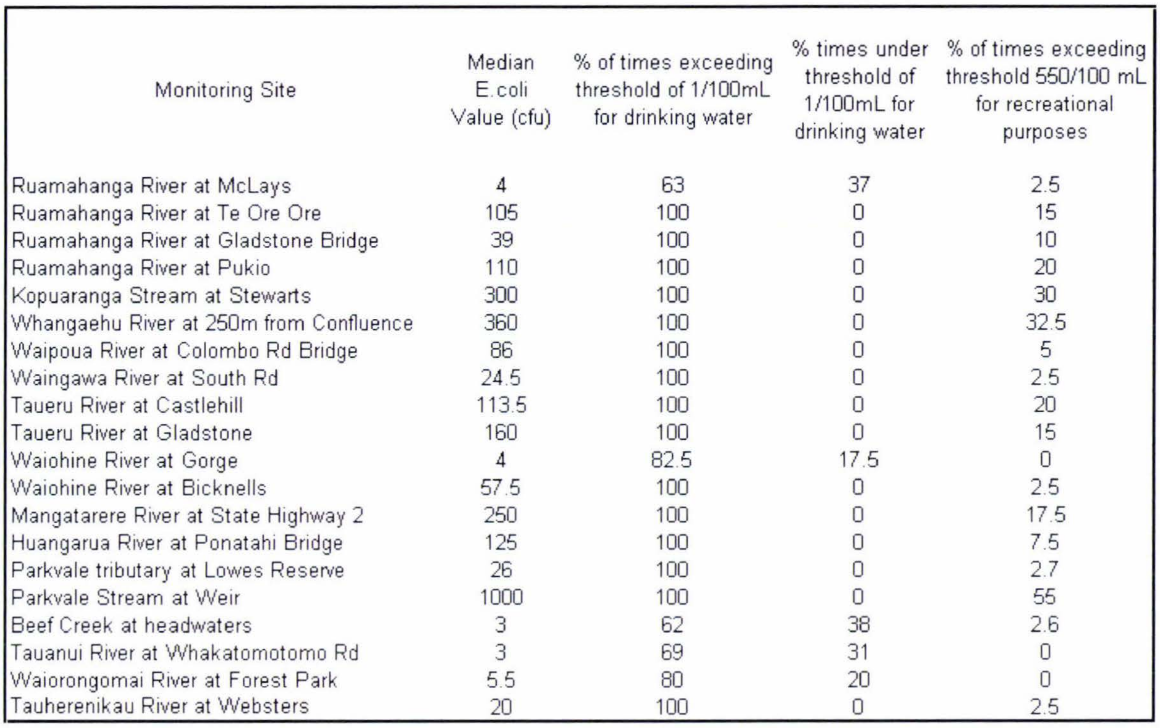
Site No.	Site Name	Site Description	Area (m^2)	Accum. Rain (m^3)	Accum. Evap. (m^3)	Accum. Runoff (m^3)	Av. Flow (m^3.sec-1)	Av. Total Nitrogen 03-06 (g.m-3)	Total Nitrogen Load (g.year-1)	Total Nitrogen/ha (g.ha-1)
RS31	Ruamahanga	Ruamahanga River at McLays	7.11E+07	2.28E+08	3.56E+07	1.92E+08	6.10	0.0711	13687811.95	1924.10
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	3.08E+08	5.58E+08	1.54E+08	4.04E+08	12.81	0.6734	272084985.77	8836.03
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	1.34E+09	1.99E+09	6.69E+08	1.32E+09	41.90	0.7929	1047663752.53	7833.88
RS34	Ruamahanga	Ruamahanga River at Pukio	2.46E+09	3.93E+09	1.23E+09	2.70E+09	85.56	0.7655	2065511380.70	8396.35
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	1.66E+08	2.32E+08	8.31E+07	1.49E+08	4.72	1.2692	189001745.47	11373.96
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	1.45E+08	1.70E+08	7.25E+07	9.75E+07	3.09	2.2076	215324736.29	14857.65
FB44	Waipoua	Waipoua River at Colombo Rd bridge	1.74E+08	2.51E+08	8.69E+07	1.64E+08	5.20	1.4538	238608814.06	13732.71
FB45	Waingawa	Waingawa River at South Rd	1.44E+08	3.75E+08	7.18E+07	3.03E+08	9.61	0.1655	50186349.73	3494.38
RS36	Taueru	Taueru River at Castlehill	1.76E+07	2.41E+07	8.78E+06	1.53E+07	0.49	0.5801	8885588.72	5063.01
FB46	Taueru	Taueru River at Gladstone	4.48E+08	5.11E+08	2.24E+08	2.87E+08	9.09	1.1962	342860227.19	7656.45
FB47	Waiohine 1	Waiohine River at gorge gauge	1.82E+08	7.61E+08	9.12E+07	6.70E+08	21.24	0.0861	57657122.05	3161.79
FB48	Waiohine 2	Waiohine River at Bicknell's	3.91E+08	1.09E+09	1.96E+08	8.94E+08	28.36	0.5340	477666443.94	12212.44
FB49	Mangatarere	Mangatarere River at SH2	1.19E+08	2.01E+08	5.93E+07	1.42E+08	4.49	1.7731	251232113.55	21178.93
FB50	Huangarua	Huangarua River at Ponatahi Bridge	3.09E+08	3.98E+08	1.55E+08	2.43E+08	7.72	0.6709	163261087.09	5278.08
RS45	Parkvale	Parkvale trib. At Lowes Reserve	1.08E+06	1.20E+06	5.41E+05	6.56E+05	0.02	5.0655	3323045.47	30717.74
RS46	Parkvale	Parkvale Stream at Weir	5.05E+07	5.94E+07	2.53E+07	3.42E+07	1.08	2.9624	101261046.97	20048.87
RS49	Beef	Beef Creek at Headwaters	3.00E+06	5.71E+06	1.50E+06	4.21E+06	0.13	0.0906	381456.46	1273.18
RS52	Tauanui	Tauanui River at Whakatomotomo Road	2.61E+07	4.32E+07	1.30E+07	3.01E+07	0.96	0.1355	4082508.74	1564.77
RS56	Waiorongomai	Waiorongomai River at Forest Park	1.87E+07	5.80E+07	9.33E+06	4.87E+07	1.54	0.1024	4986240.15	2671.30
FB51	Tauherenikau	Tauherenikau at Websters	1.44E+08	3.90E+08	7.21E+07	3.18E+08	10.09	0.1657	52717021.65	3655.45

Site No.	Site Name	Site Description	Area (m^2)	Accum. Rain (m^3)	Accum. Evap. (m^3)	Accum. Runoff (m^3)	Av. Flow (m^3.sec-1)	Av. Ammoniacal Nitrogen 03-06 (g.m-3)	Ammoniacal Nitrogen Load (g.year-1)	Ammoniacal Nitrogen/ha (g.ha-1)
RS31	Ruamahanga	Ruamahanga River at McLays	7.11E+07	2.28E+08	3.56E+07	1.92E+08	6.10	0.0109	2106639.81	296.13
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	3.08E+08	5.58E+08	1.54E+08	4.04E+08	12.81	0.0118	4769876.62	154.90
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	1.34E+09	1.99E+09	6.69E+08	1.32E+09	41.90	0.0261	34427851.73	257.43
RS34	Ruamahanga	Ruamahanga River at Pukio	2.46E+09	3.93E+09	1.23E+09	2.70E+09	85.56	0.0175	47146157.36	191.65
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	1.66E+08	2.32E+08	8.31E+07	1.49E+08	4.72	0.0183	2730103.35	164.30
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	1.45E+08	1.70E+08	7.25E+07	9.75E+07	3.09	0.0256	2500751.59	172.55
FB44	Waipoua	Waipoua River at Colombo Rd bridge	1.74E+08	2.51E+08	8.69E+07	1.64E+08	5.20	0.0149	2448181.69	140.90
FB45	Waingawa	Waingawa River at South Rd	1.44E+08	3.75E+08	7.18E+07	3.03E+08	9.61	0.0054	1642278.60	114.35
RS36	Taueru	Taueru River at Castlehill	1.76E+07	2.41E+07	8.78E+06	1.53E+07	0.49	0.0178	271890.59	154.92
FB46	Taueru	Taueru River at Gladstone	4.48E+08	5.11E+08	2.24E+08	2.87E+08	9.09	0.0294	8415848.32	187.94
FB47	Waiohine 1	Waiohine River at gorge gauge	1.82E+08	7.61E+08	9.12E+07	6.70E+08	21.24	0.0071	4778401.44	262.04
FB48	Waiohine 2	Waiohine River at Bicknell's	3.91E+08	1.09E+09	1.96E+08	8.94E+08	28.36	0.0134	11943863.30	305.37
FB49	Mangatarere	Mangatarere River at SH2	1.19E+08	2.01E+08	5.93E+07	1.42E+08	4.49	0.0741	10497806.36	884.97
FB50	Huangarua	Huangarua River at Ponatahi Bridge	3.09E+08	3.98E+08	1.55E+08	2.43E+08	7.72	0.0118	2872767.86	92.87
RS45	Parkvale	Parkvale trib. At Lowes Reserve	1.08E+06	1.20E+06	5.41E+05	6.56E+05	0.02	0.0189	12396.26	114.59
RS46	Parkvale	Parkvale Stream at Weir	5.05E+07	5.94E+07	2.53E+07	3.42E+07	1.08	0.0458	1564360.09	309.73
RS49	Beef	Beef Creek at Headwaters	3.00E+06	5.71E+06	1.50E+06	4.21E+06	0.13	0.0061	25733.13	85.89
RS52	Tauanui	Tauanui River at Whakatomotomo Road	2.61E+07	4.32E+07	1.30E+07	3.01E+07	0.96	0.0073	219775.29	84.24
RS56	Waiorongomai	Waiorongomai River at Forest Park	1.87E+07	5.80E+07	9.33E+06	4.87E+07	1.54	0.0229	1115716.88	597.73
FB51	Tauherenikau	Tauherenikau at Websters	1.44E+08	3.90E+08	7.21E+07	3.18E+08	10.09	0.0184	5869855.37	407.02

Site No.	Site Name	Site Description	DRP Load ($g.year^{-1}$)	DRP Load ($kg.year^{-1}$)	DRP Load ($T.year^{-1}$)	Nitrate Load ($g.year^{-1}$)	Nitrate Load ($kg.year^{-1}$)	Nitrate Load ($T.year^{-1}$)
RS31	Ruamahanga	Ruamahanga River at McLays	991831.69	991.83	0.99	5950990.12	5950.99	5.95
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	3234758.81	3234.76	3.23	142060513.99	142060.51	142.06
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	6548760.02	6548.76	6.55	189268704.37	189268.70	189.27
	Contribution for Reach 1			**2322.17**	**2.32**		**41257.20**	**41.26**
RS36	Taueru	Taueru River at Castlehill	140200.23	140.20	0.14	3465222.17	3465.22	3.47
FB46	Taueru	Taueru River at Gladstone	5199194.84	5199.19	5.20	189710896.69	189710.90	189.71
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	6548760.02	6548.76	6.55	189268704.37	189268.70	189.27
FB44	Waipoua	Waipoua River at Colombo Rd bridge	1666313.61	1666.31	1.67	215490137.46	215490.14	215.49
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	3768738.31	3768.74	3.77	167436562.63	167436.56	167.44
FB45	Waingawa	Waingawa River at South Rd	1974945.29	1974.95	1.97	38648289.80	38648.29	38.65
FB46	Taueru	Taueru River at Gladstone	5199194.84	5199.19	5.20	189710896.69	189710.90	189.71
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	32996416.53	32996.42	33.00	743795752.00	743795.75	743.80
	Contribution for Reach 2			**13838.46**	**13.84**		**-56758.84**	**-56.76**
RS45	Parkvale	Parkvale trib. At Lowes Reserve	12591.74	12.59	0.01	2991384.68	2991.38	2.99
RS46	Parkvale	Parkvale Stream at Weir	1669237.74	1669.24	1.67	79984782.93	79984.78	79.98
FB47	Waiohine 1	Waiohine River at gorge gauge	4130568.61	4130.57	4.13	18903863.53	18903.86	18.90
RS49	Beef	Beef Creek at Headwaters	52811.40	52.81	0.05	131823.81	131.82	0.13
FB49	Mangatarere	Mangatarere River at SH2	12015945.16	12015.95	12.02	206845069.73	206845.07	206.85
FB48	Waiohine 2	Waiohine River at Bicknell's	16323430.43	16323.43	16.32	383687573.97	383687.57	383.69
	Contribution for Reach 3			**124.11**	**0.12**		**157806.82**	**157.81**
FB48	Waiohine 2	Waiohine River at Bicknell's	16323430.43	16323.43	16.32	383687573.97	383687.57	383.69
RS46	Parkvale	Parkvale Stream at Weir	1669237.74	1669.24	1.67	79984782.93	79984.78	79.98
FB50	Huangarua	Huangarua River at Ponatahi Bridge	2849109.77	2849.11	2.85	101966360.24	101966.36	101.97
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	32996416.53	32996.42	33.00	743795752.00	743795.75	743.80
RS34	Ruamahanga	Ruamahanga River at Pukio	52243039.24	52243.04	52.24	1443242066.82	1443242.07	1443.24
	Contribution for Reach 4			**-1595.16**	**-1.60**		**133807.60**	**133.81**

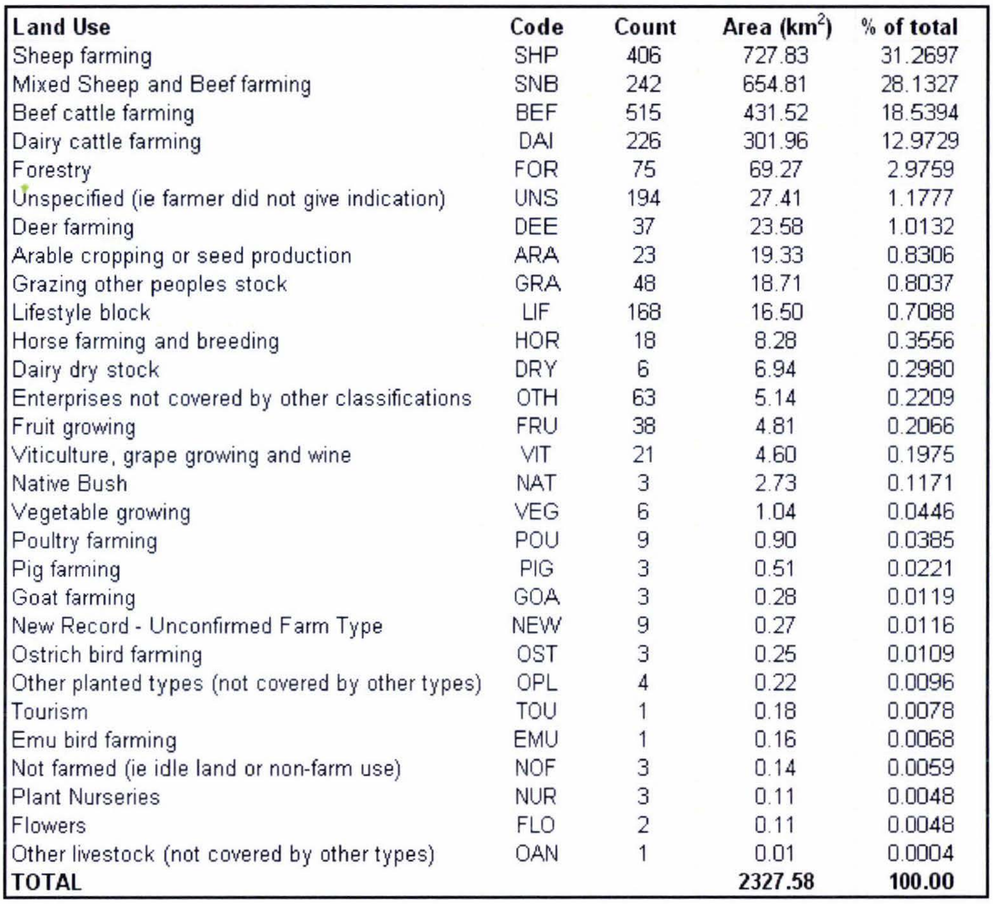
Site No.	Site Name	Site Description	Total Nitrogen Load (g.year^{-1})	Total Nitrogen Load (kg.year^{-1})	Total Nitrogen Load (T.year^{-1})	Ammoniacal Nitrogen Load (g.year^{-1})	Ammoniacal Nitrogen Load (kg.year^{-1})	Ammoniacal Nitrogen Load (T.year^{-1})
RS31	Ruamahanga	Ruamahanga River at McLays	13687811.95	13687.81	13.69	2106639.81	2106.64	2.11
FB41	Kopuaranga	Kopuaranga Stream at Stewarts	189001745.47	189001.75	189.00	2730103.35	2730.10	2.73
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	272084985.77	272084.99	272.08	4769876.62	4769.88	4.77
	Contribution for Reach 1			**69395.43**	**69.40**		**-66.87**	**-0.07**
RS36	Taueru	Taueru River at Castlehill	8885588.72	8885.59	8.89	271890.59	271.89	0.27
FB46	Taueru	Taueru River at Gladstone	342860227.19	342860.23	342.86	8415848.32	8415.85	8.42
FB38	Ruamahanga 3	Ruamahanga River at Te Ore Ore	272084985.77	272084.99	272.08	4769876.62	4769.88	4.77
FB44	Waipoua	Waipoua River at Colombo Rd bridge	238608814.06	238608.81	238.61	2448181.69	2448.18	2.45
FB43	Whangaehu 2	Whangaehu River 250 m from confluence	215324736.29	215324.74	215.32	2500751.59	2500.75	2.50
FB45	Waingawa	Waingawa River at South Rd	50186349.73	50186.35	50.19	1642278.60	1642.28	1.64
FB46	Taueru	Taueru River at Gladstone	342860227.19	342860.23	342.86	8415848.32	8415.85	8.42
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	1047663752.53	1047663.75	1047.66	34427851.73	34427.85	34.43
	Contribution for Reach 2			**-71401.36**	**-71.40**		**14650.91**	**14.65**
RS45	Parkvale	Parkvale trib. At Lowes Reserve	3323045.47	3323.05	3.32	12396.26	12.40	0.01
RS46	Parkvale	Parkvale Stream at Weir	101261046.97	101261.05	101.26	1564360.09	1564.36	1.56
FB47	Waiohine 1	Waiohine River at gorge gauge	57657122.05	57657.12	57.66	4778401.44	4778.40	4.78
RS49	Beef	Beef Creek at Headwaters	381456.46	381.46	0.38	25733.13	25.73	0.03
FB49	Mangatarere	Mangatarere River at SH2	251232113.55	251232.11	251.23	10497806.36	10497.81	10.50
FB48	Waiohine 2	Waiohine River at Bicknell's	477666443.94	477666.44	477.67	11943863.30	11943.86	11.94
	Contribution for Reach 3			**168395.75**	**168.40**		**-3358.08**	**-3.36**
FB48	Waiohine 2	Waiohine River at Bicknell's	477666443.94	477666.44	477.67	11943863.30	11943.86	11.94
RS46	Parkvale	Parkvale Stream at Weir	101261046.97	101261.05	101.26	1564360.09	1564.36	1.56
FB50	Huangarua	Huangarua River at Ponatahi Bridge	163261087.09	163261.09	163.26	2872767.86	2872.77	2.87
FB39	Ruamahanga 4	Ruamahanga River at Gladstone Bridge	1047663752.53	1047663.75	1047.66	34427851.73	34427.85	34.43
RS34	Ruamahanga	Ruamahanga River at Pukio	2065511380.70	2065511.38	2065.51	47146157.36	47146.16	47.15
	Contribution for Reach 4			**275659.05**	**275.66**		**-3662.69**	**-3.66**

12. Median *E.Coli* values and % of times exceeding threshold values for drinking water and recreational water.



Monitoring Site	Median E.coli Value (cfu)	% of times exceeding threshold of 1/100mL for drinking water	% times under threshold of 1/100mL for drinking water	% of times exceeding threshold 550/100 mL for recreational purposes
Ruamahanga River at McLays	4	63	37	2.5
Ruamahanga River at Te Ore Ore	105	100	0	15
Ruamahanga River at Gladstone Bridge	39	100	0	10
Ruamahanga River at Pukio	110	100	0	20
Kopuaranga Stream at Stewarts	300	100	0	30
Whangaehu River at 250m from Confluence	360	100	0	32.5
Waipoua River at Colombo Rd Bridge	86	100	0	5
Waingawa River at South Rd	24.5	100	0	2.5
Taueru River at Castlehill	113.5	100	0	20
Taueru River at Gladstone	160	100	0	15
Waiohine River at Gorge	4	82.5	17.5	0
Waiohine River at Bicknells	57.5	100	0	2.5
Mangatarere River at State Highway 2	250	100	0	17.5
Huangarua River at Ponatahi Bridge	125	100	0	7.5
Parkvale tributary at Lowes Reserve	26	100	0	2.7
Parkvale Stream at Weir	1000	100	0	55
Beef Creek at headwaters	3	62	38	2.6
Tauanui River at Whakatomotomo Rd	3	69	31	0
Waiorongomai River at Forest Park	5.5	80	20	0
Tauherenikau River at Websters	20	100	0	2.5

13. Land Use in the Ruamahanga Catchment derived from AgriBase (2001)



Land Use	Code	Count	Area (km^2)	% of total
Sheep farming	SHP	406	727.83	31.2697
Mixed Sheep and Beef farming	SNB	242	654.81	28.1327
Beef cattle farming	BEF	515	431.52	18.5394
Dairy cattle farming	DAI	226	301.96	12.9729
Forestry	FOR	75	69.27	2.9759
Unspecified (ie farmer did not give indication)	UNS	194	27.41	1.1777
Deer farming	DEE	37	23.58	1.0132
Arable cropping or seed production	ARA	23	19.33	0.8306
Grazing other peoples stock	GRA	48	18.71	0.8037
Lifestyle block	LIF	168	16.50	0.7088
Horse farming and breeding	HOR	18	8.28	0.3556
Dairy dry stock	DRY	6	6.94	0.2980
Enterprises not covered by other classifications	OTH	63	5.14	0.2209
Fruit growing	FRU	38	4.81	0.2066
Viticulture, grape growing and wine	VIT	21	4.60	0.1975
Native Bush	NAT	3	2.73	0.1171
Vegetable growing	VEG	6	1.04	0.0446
Poultry farming	POU	9	0.90	0.0385
Pig farming	PIG	3	0.51	0.0221
Goat farming	GOA	3	0.28	0.0119
New Record - Unconfirmed Farm Type	NEW	9	0.27	0.0116
Ostrich bird farming	OST	3	0.25	0.0109
Other planted types (not covered by other types)	OPL	4	0.22	0.0096
Tourism	TOU	1	0.18	0.0078
Emu bird farming	EMU	1	0.16	0.0068
Not farmed (ie idle land or non-farm use)	NOF	3	0.14	0.0059
Plant Nurseries	NUR	3	0.11	0.0048
Flowers	FLO	2	0.11	0.0048
Other livestock (not covered by other types)	OAN	1	0.01	0.0004
TOTAL			**2327.58**	**100.00**