The impact of the closure and decommissioning of the Wainuiomata Waste Water Treatment Plant on the water quality of the Wainuiomata River.

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ABSTRACT

The quality of the Wainuiomata River (particularly downstream of the Wainuiomata Waste Water Treatment Plant) has been affected over the years (e.g. eutrophication) by a number of contaminants, such as nutrients and faecal bacteria. The main source of these contaminants has been the treated effluent discharged into the river from the Wainuiomata Waste Water Treatment Plant (WWTP). The WWTP has been discharging treated effluent into the river since the 1950's. This sewage treatment plant was decommissioned in November 2001 and is now used solely as a pumping station. Sewage from Wainuiomata is now piped over to the new sewage treatment plant in Seaview. This research project aimed to examine the impact of the WWTP closure on the water quality of the Wainuiomata River.

Water samples were collected from a number of selected sites over a period of three months: January 2003 to March 2003, above and below the WWTP site. For this particular study, the microbiological, chemical (nutrients) and biological parameters were assessed as follows: *Escherichia coli* and total coliforms (microbiological) dissolved reactive phosphorus (DRP), nitrate nitrogen and ammoniacal nitrogen (chemical) and periphyton (biological) for biomass and taxa identification. The results for each of the above parameters sites were compared with historical data obtained from Greater Wellington Regional Council (2003).

Overall this research has shown that the closure of the WWTP has impacted on the J5 site (Golf Course), which is downstream of the WWTP, in a number of ways. The chemical indicator levels (NO_3-N, NH_4-N and DRP) have dropped significantly; periphyton was still in abundance at site J5 (no real improvement seen) and the median level of the microbiological indicator, *E.coli* has reduced. However, site J5 on a number of occasions, did not comply with the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). Sites sampled upstream of the WWTP, particularly the tributary sites (Black Creek and Wainuiomata Stream), also did not comply with the guidelines on a number of occasions. This is a concern, as the public are known to swim near where these tributaries enter the Wainuiomata River. The effects of storm water or land runoff may have affected the results on two occasions (when there had been rainfall) however, on all other occasions where high *E.coli* levels

were observed, the effects of storm water and runoff would have been minimal, as there had been very little rain.

The Wainuiomata River is used for recreational activities such as swimming, canoeing and fishing; therefore an important resource. Any water quality concerns (namely, *E.coli* levels and periphyton proliferation), therefore need to be monitored by the Greater Wellington Regional Council and actions taken to eliminate these concerns.

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DEDICATION

I dedicate this thesis to my children, Katherine, Michelle, Vanessa and Daniel (who have put up with all my years of study), my husband Chris and my parents Pat and Albert Sheppard and family for their love and support. I would like to finally dedicate this thesis to my special friend and helper Our Lord Jesus Christ, who believed in me.

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"everything will live where the river goes"

Ezekiel, 47:9

CHAPTER ONE: INTRODUCTION

1.1 Water Quality

1.1.1 <u>New Zealand Rivers</u>

Many of New Zealand's rivers and streams are swift and are strewn with boulders. The high rainfall, mountainous terrain and the long narrowness of the Island often give rise to such rivers and streams. When rivers course towards the sea they contain a mass of material known as their 'load'. This mass can be made up of chemicals in solution and solid matter. The solid matter may be deposited along its length creating alluvial flats, or be carried out to sea (Parkinson & Cox, 1990). The chemicals in solution and solid matter could be pollutants, which have been discharged from industries, farmland, storm water pipes, and much more. Not only does anthropogenic pollution (man-made) affect our rivers; the introduction of grazing herbivores, such as cattle and sheep into forest areas or the clearing of trees for farmland in steep unstable areas can cause erosion. In some case this can be extensive. This erosion will allow vast amounts of sediment to pour unchecked into the rivers and then carried to the sea. This unchecked sediment, as it travels along the river, can fill in river pools destroying both animal/plants and habitat (Parkinson & Cox 1990, p.8 &15).

Many rivers, streams and lakes within New Zealand are relatively healthy when compared to other parts of the world. However, in many parts of New Zealand waterways have deteriorated significantly since bush and forests were cleared and converted to farmland. Clearing of riparian forests has also played a major role in the deterioration of water quality in waterways. Forests canopies are important for the collection and absorption of rainfall. When forests are cleared and grassland is introduced, the absorption of rainfall is reduced, resulting in increased runoff (MfE, 1999).

The quality of water in New Zealand is a concern because many people may use a particular water body for recreational purposes (e.g. swimming and fishing). If polluted, this can greatly compromise the use of this particular resource. Many aquatic ecosystems are also affected by pollution. The most common factors, which limit water quality, are microbiological and nutrient contamination (Foster & Young, 1986).

Point source pollution such as sewage treatment plant effluent, even if treated, can have the potential to significantly reduce water quality such as: microbiological contamination, and/or nutrient enrichment. Abundance of nitrogen and phosphorus (often referred to as nutrient enrichment) can fuel excessive plant and algal growth in rivers and estuaries; often referred to as eutrophication (MfE, 1997a). Eutrophication may degrade surface waters by making them aesthetically unpleasant, by depleting the water of oxygen, by changing the quantity and type of food available for fish and birds, and by altering the habitat for fish and invertebrates. Dissolved reactive phosphorus and dissolved inorganic nitrogen, which includes nitrate nitrogen and ammoniacal nitrogen, are most likely to cause excessive algal growths in waterways (MfE, 1997a).

There are a number of rivers and lakes in New Zealand that have been affected by sewage effluent as well as non-point sources such as land runoff and storm water discharge. Specific examples are Lake Rotorua, Horowhenua Lake and the Wainuiomata River (Menon & Perkins, 1995). In Lake Rotorua the accelerated eutrophication that has occurred has been caused by both domestic and industrial sewage disposals from Rotorua City, together with nutrient laden runoff from the surrounding catchment (MfE, 1997a). All three New Zealand water bodies have all had major algae blooms due to the high nutrient loading.

The increased use of fertilizers could be a major contributor to the increase in nutrient loading of waterways. By the late 1990's cattle numbers had increased throughout New Zealand to 9.3 million. This rise has increased the use of nitrogen fertiliser to boost grass growth. In the period 1994-1999, farmers were on average applying 25-100kg of nitrogen as fertiliser per hectare each year with some applications as high as 200kg/hectare (MfE, 1999). This increase in the use of fertiliser will increase the likelihood of it reaching waterways. To improve farm operation most farmers constructed drains to remove runoff from the land. This practice is of concern as runoff water may also contain contaminants such as pesticides, herbicides, bacteria (faecal bacteria), nutrients and sediments all of which will inevitably be transported to larger water systems such as river and lakes (MfE, 1999).

The effects of clearing riparian forest from a waterway can e seen with the Wainuiomata River situated in the Wellington Region (New Zealand). Figures 1.1 – 1.4 are photographs taken of the different sampling sites along the Wainuiomata River, which represent the different environments that exist. In the upper reaches of the river, which is in the closed Catchment area, there is abundant aquatic life and plant life (see Figure 1.1), but as the river enters the urban

Figure 1.1: Manuka Track - Closed Catchment

There is abundant aquatic life and the water was very clear.

area, the environment changes dramatically. Grasses and low lying scrub replace the riparian forest, and the water no longer has that clear crystalline appearance, which is seen in the upper reaches. The surrounding environment is often littered with rubbish (see Figure 1.2).

Figure 1.2: Leonard Wood Park - Semi-urban area

Low-lying scrub, bushes and grass are apparent on the riverbanks. Rubbish can be seen littered along the riverbank.

As the River flows down through the rural domain the landscape becomes even more barren, farmland is predominant with scattered patches of gorse bush throughout (see Figure 1.3 & 1.4).

Figure 1.3: Golf Course - rural

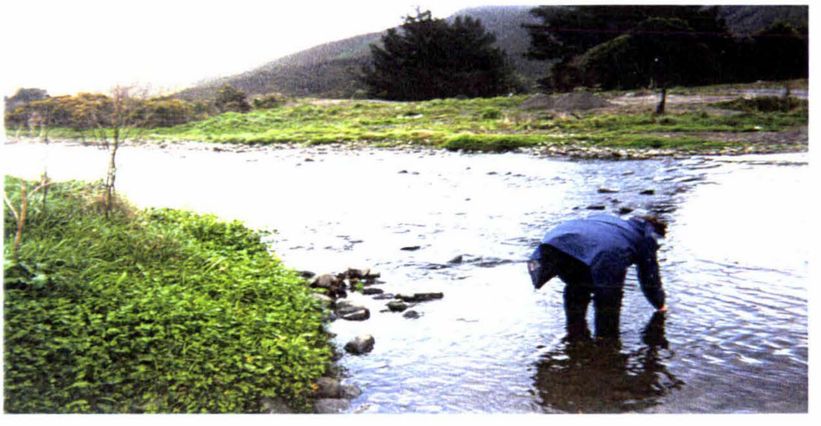


Figure 1.4: Coast Road Bridge - Rural area

Riparian forest at both these sites, have been replaced by gorse, low lying scrub and grasses.

Figures 1.3 and 1.4 show there is very little vegetation by the river to sustain aquatic life such as the native fish, which require overhanging native vegetation for shelter and nourishment (Parkinson & Cox, 1990). All of New Zealand's native fish are predators and are reliant on adequate supply of invertebrates and other fish species for their survival (MfE, 1999). Where the river flows through cleared farmlands that are away from the forested areas, only bully and eels are encountered (Parkinson & Cox, 1990). Most native fish can adapt to changes in their food supply due to changes in the riparian vegetation, but the large fish such as the giant Kokopu and Banded Kokopu are dependant on native forest for their breeding habitat (Parkinson & Cox, 1990).

Rivers and lakes polluted with human faecal material may pose a public health and animal health risk. This faecal material could be a source of bacteria; viruses and protozoa, which if ingested can cause serious illness. The appearance of pathogenic organisms is particularly important if the public bathe or come in contact with the river water. Sewage treatment plants are a source of faecal material. The Wainuiomata Wastewater Plant (WWTP) was decommissioned in November 2001 because of the affects its operation was having on the water quality of the Wainuiomata River. Even though the effluent from the WWTP was of a reasonably good quality for the age and type of plant, it still contained high levels of bacteria, phosphorus and nitrogen (Hutt City Council 1998a).

A focus group study was carried out in 2002 to determine the perceptions of Wainuiomata residents in relation to the water quality of the Wainuiomata River, following the WWTP closure (de Silva, 2002). The perception of the Maori representative of this focus group was that the water quality of the Wainuiomata River will be greatly improved along with the "Mauri" (refer section 1.1.2 for definition) and that the WWTP when operating was greatly offensive to Maori, because of the human wastes that polluted the river. Along with the public health concerns the effluent discharged from the plant was greatly offensive to Maori. The Maori perspective on the discharge of effluent to natural waterways, are discussed in the following section.

1.1.2 Maori Perspective on Resources such as Fresh Water

Maori have strong ties to the waterways and land. This connection can be traced back in history to before settlers arrived. The water was and still is a traditional source of foods for Maori, including tuna (eels), whitebait and watercress, therefore the quality and quantity of freshwater is important to the life and traditional food sources of Maori (MfE, 2002).

Tangata whenua, like the wider community, share a number of concerns about the state of the environment, such as the water quality of water bodies (Greater Wellington Regional Council (GWRC, 1997a). The Maori perception of land and water is quite different or distinct from that of New Zealanders with European background. The Maori have a holistic approach to how they view life, place and environment and do not separate spiritual aspects from the physical practices of resource management. Instead Maori see that all elements of the natural environment (including peoples) possessing a mauri or life force and that all forms of life are related. In the Maori worldview, all natural and physical elements of the world are related through whakapapa (genealogy) and each is safeguarded and protected by spiritual beings (MfE, 2002).

Changes or alterations to waterways can affect the relationship of Maori with these resources, as Maori are identified as "tiaki" (guardians) of these natural resources (MfE, 2002). It is important to Maori that waterways have a healthy mauri so as to sustain healthy ecosystems, therefore supporting flora and fauna. When wastewater is discharged into rivers or streams it can degrade the river or stream it is received into. This degradation puts the food supply in jeopardy, which is contrary to the Maori perception of a healthy environment and as well the degradation of the water may also offend the mana of different iwi who hold traditional rights and responsibilities with respect to the different waterways (MfE, 2002). It is important to restore degraded waterways, especially waterways that are a resource of high ecological or cultural value (MfE, 2002).

This research project examines the impact of the Wainuiomata Waste Water Treatment Plant (WWTP) closure on the water quality of the Wainuiomata River, namely the sites downstream of the WWTP. The sites downstream of the WWTP have been monitored by Greater Wellington Regional Council for many years and will be used to determine any impact. This research project also examines the compliance of sites selected with the relevant guidelines. Environmental indicators selected for this research were as follows Microbiological (E.coli), Chemical (nitrate nitrogen, ammoniacal nitrogen and dissolved reactive phosphorus) and Biological (periphyton). This research project is the first comprehensive study of its kind to investigate the effects of removing this major source of contamination. The following section (1.1.3) gives a background to the water quality problems and issues faced by the Wainuiomata River.

1.1.3 History of the Wainuiomata River

The Wainuiomata Township is situated approximately 23km northeast of Wellington and has a population of 17,000. The township is situated in a valley surrounded by the Rimutaka Ranges. Within this valley is the Wainuiomata Catchment, which lies between Wellington Harbour and the southern part of the Rimutaka Range. Many streams drain the side slopes of the Wainuiomata Catchment, which are tributaries of the Wainuiomata River (GWRC, 1998).

The forests in the Water Collection Area include rata, podocarp, subtropical emergent forest, which is above a canopy of hinau, kamahi, rewa rewa and tree ferns. Black Beech can be found on drier sites and Silver Beech on the high ridge tops (GWRC, 2002a) The Landuse Map (Figure 1.5), illustrates clearly the different land use, including the vegetation that exists within this catchment. The dark green areas show the indigenous forest and as you go further down the catchment towards Baring Head (the mouth of the Wainuiomata River) the indigenous forest diminishes and scrubland is more prevalent. The pink areas in Figure 1.5, highlights where there is livestock and in these areas there is mainly scattered bush and grasses. The animals present in this catchment are the Kaka, fantails, parrots, pig, red deer, possums, stoats, and rabbits (GWRC, 1998). Entry to the catchment area beyond the Water Treatment Plant is carefully controlled to avoid contamination of the water supply area within the catchment, especially by disease causing organisms such as *Giardia* and *Cryptosporidium*. The only public, which are allowed access to the Water Collection Area, are outdoor groups or environmental interest groups at different times throughout the year, by way of guided tours (GWRC, 2002a).

The Wainuiomata River, which is some 30 kilometres long, is a relatively stable, slow moving and mature river. The river runs through a native forest catchment area before entering the rural and urban areas. The river passes through the urban catchment for most of its journey to the sea. The mouth of the Wainuiomata River is located between Baring Head and Turakirae Head (see Figure 1.5) (Hutt City Council, 1998b).

Figure 1.5: Wainuiomata Catchment – Land Use (Hutt City Council, 1998a)

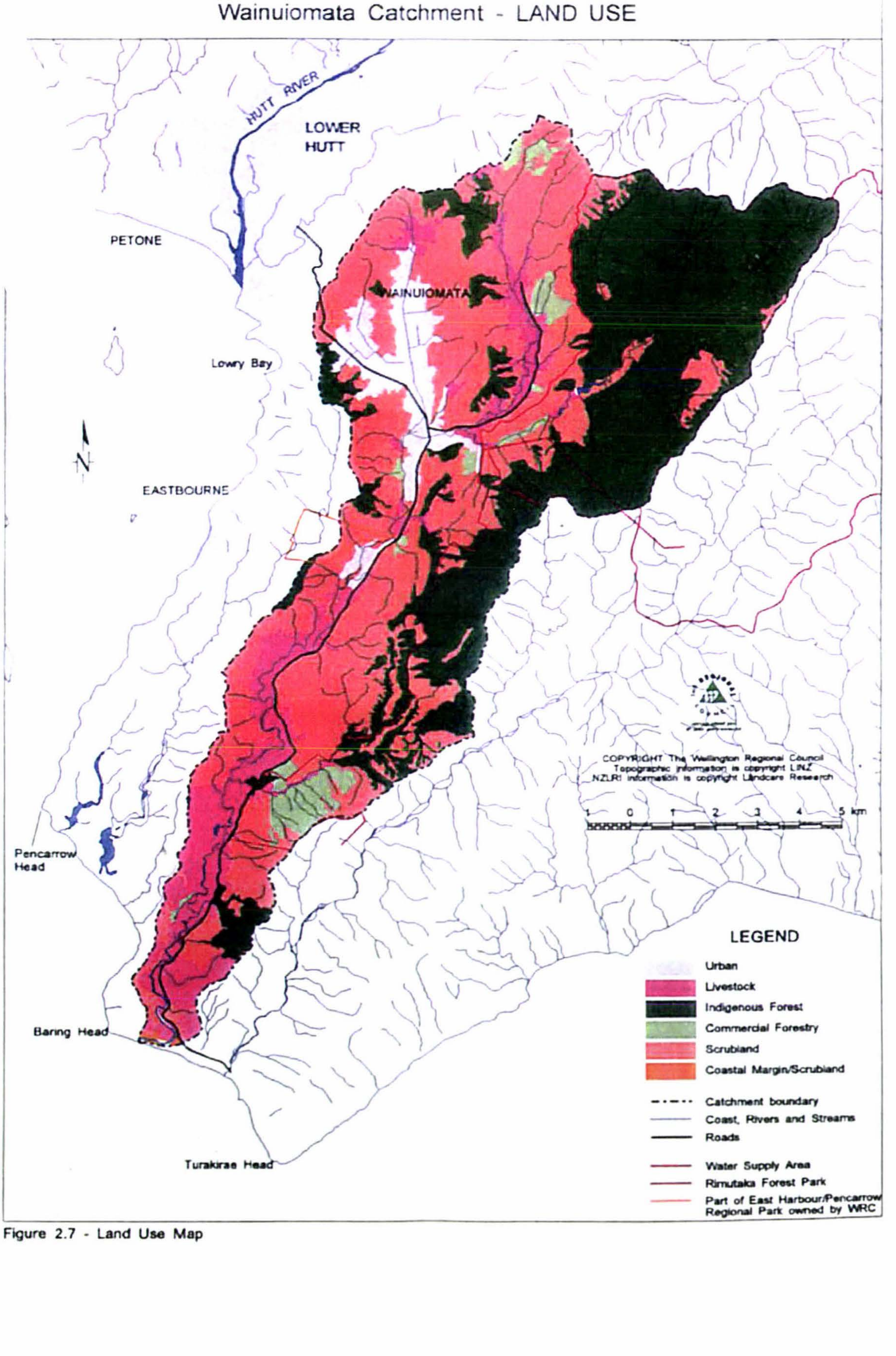


Figure 2.7 - Land Use Map

The main headwater tributaries divide into three separate Catchment areas as follows: (Hutt City Council, December 1998b)

1) The heavily forested water supply catchment, drained by Skull Gully Stream and Wainuiomata River-east and west branches
2) The Moores Valley Catchment, drained by the Wainuiomata Stream
3) The urban Wainuiomata Catchment is drained by Black Creek.

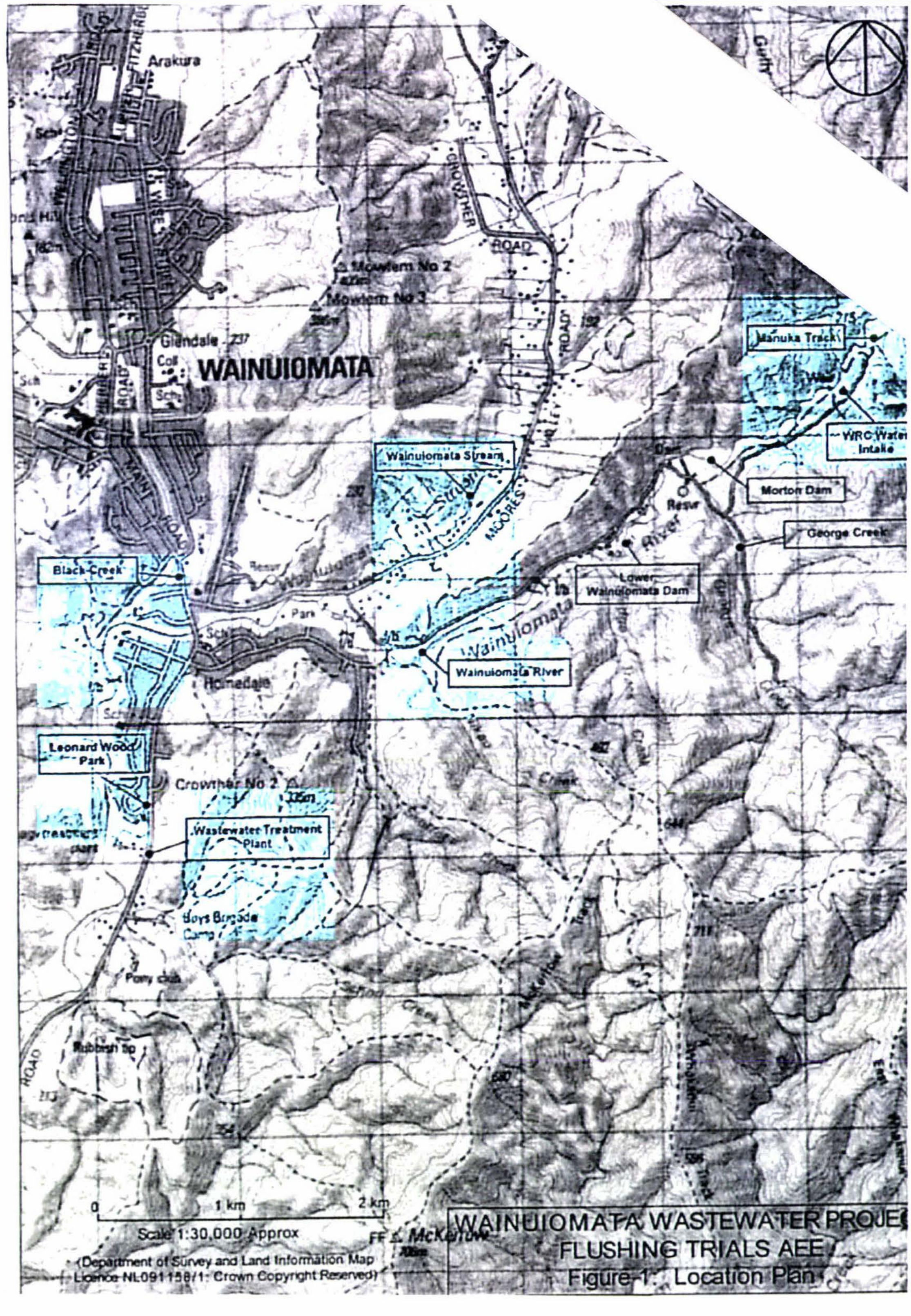
The Wainuiomata River is an important water body as there is found within it a number of native fish, especially in the upstream-forested areas. There have been fourteen fish species noted, of which thirteen are native fish and twelve of the native fish are migratory. The Catchpool Stream, which joins the river 19 km below Morton Dam, drains a catchment of mixed native and exotic forest and is known to be a trout-spawning stream of considerable importance to the fishery of the Lower River (see Figure 1.6) (Hutt City Council, 1998a).

Within the Catchment are situated a landfill and water treatment plant. Resource consents allow water to be taken directly from weirs (shallow dam) in both the Wainuiomata and Orongorongo Catchments. The water from the Orongorongo and Wainuiomata River and George Creek (tributary) are fully treated at the Wainuiomata Water Treatment Plant.

The Waste Water Treatment Plant (WWTP) was located adjacent to Ngaturi Park and Coast Road (see Figure 1.6) and was opened in 1956. The effluent treated from this sewage treatment plant was discharged into the Wainuiomata River, downstream from the extraction source of the water treatment plant (Hutt City Council, 1998a). Sludge that remained was dried out in drying beds then taken to the local landfill (see Figure1.6 rubbish tip). The closure of the sewage treatment plant (November 2001) was principally due to the effects effluent discharges were having on the water quality of the Wainuiomata River (Hutt City Council, 1998a).

The public swim at certain sites along the river, but more commonly upstream of the WWTP. Below the Water Treatment Plant there is a recreational area, which is popular in the summer months. The area also includes swimming holes, a small recreational forest, walking tracks, picnicking, horse riding and tramping.

Figure 1.6: Department of Survey and Land I rmation Map (Hutt City Council, 1998b)



Sites of interest are highlighted in blue.

The flood plain of the middle and lower Wainuiomata Valley used to be extensively farmed, but now it has reverted to scrub and gorse and the number of stock farmed has reduced. Livestock have access to the river and it is therefore an important water source for farming (Hutt City Council, 1990).

Before the closure of the WWTP, there were a number of fresh water bodies identified by Greater Wellington Regional Council that, were considered of concern because of their poor water quality. Both the Wainuiomata River and the Waiwhetu stream were included. A Hutt City Council report (1996), revealed an increase in faecal coliforms (FC) downstream of the WWTP, and it was this, that was deemed responsible for the deterioration in the water quality of the river. The FC levels observed exceeded the ANZECC Guidelines (2000) for stock drinking. Faecal contamination of the Wainuiomata River is a concern as it poses a risk to the public as well as to the stock that drink at the river.

The Hutt City Council's 1990 report also noted that a number of areas along the river revealed poor water quality. A significant finding of this report was that dissolved reactive phosphorus (DRP) levels increased between the Leonard Wood Park site (0.3km upstream of the WWTP) and the Golf Course site downstream of the WWTP and the ANZECC Guidelines (2000) were exceeded for aquatic ecosystems (i.e. prolific algae growth)

Hutt City Council (1998b), have suggested, that this increased algal mass was probably due to nutrient loading (particularly high levels of dissolved reactive phosphorus). The main source of this nutrient loading was identified as being the sewage treatment plants effluent in conjunction with other factors, which included unshaded riverbeds, warm water and stable flow conditions in the river. This build up of periphyton/algae caused adverse effects on the water quality. Increased algal density can deplete water of oxygen causing eutrophication to occur, therefore posing a threat to aquatic life, this occurred downstream of the WWTP. The aesthetic values of the middle and lower reaches of the river were also affected. Prolific algae or periphyton growth in a water body can deter people from utilising it for recreational purposes and as well is a nuisance for anglers (Hutt City Council, 1990).

Even though there had been subsequent improvement to the WWTP, during low summer flow periods, there was insufficient dilution for the river to properly assimilate the discharge (Hutt City Council, 1990). A number of studies and reports have also highlighted other problems, including low dissolved oxygen levels, pH fluctuations, prolific algae growth and altered invertebrate communities (Hutt City Council, 1990, Hutt City Council, 1996, Hutt City Council, 1998a, & Hutt City Council, 1998b).

The Hutt City Council in discussion with consultants proposed a number of options to resolve those concerns relating to the water quality of the River, particularly downstream of the WWTP. The options that were discussed were as follows:

1. Treatment at Wainuiomata (including nutrient stripping) and disposal to Wainuiomata River.
2. Treatment at Wainuiomata and disposal to land
3. Treatment at Wainuiomata, discharging at Pencarrow outfall
4. Treatment at Seaview, discharge at Pencarrow

The fourth option was chosen, which was to treat the sewage at the new milli-screen plant in Seaview. This involved diverting the untreated Waiuiomata Sewage through reticulation to the Seaview treatment plant (Kashler, 2002).

The Wainuiomata sewage that is pumped to the old WWTP site and then on to Seaview, under certain adverse conditions, such as excessive infiltration caused by heavy rain is discharged into the Waiuiomata River (Kashler, 2002). Untreated sewage discharged into the river during winter months may not pose a serious risk to the public because of the time of year, as there is less water sport. However, if heavy rain occurs in summer months and sewage is discharged untreated into the river (which may have occurred recently in the February 2004 floods), then there could be an increased level of risk due to higher public use of the river in the summer months.

1.2 Wainuiomata River Pollution Sources

1.2.1 <u>Effluent Discharged from WWTP</u>

There are a number of non-point [1]and point[2] sources of pollution that contributed to the overall water quality of the river. Previous reports (Hutt City Council 1990, Hutt City Council, 1999a &1999b) have identified a number of sources of pollution that were contributing to the rivers poor water quality, which included effluent from the WWTP, landfill leachate, discharge from storm water reticulation and rural runoff. This poor water quality was also having an indirect effect on invertebrates by way of stimulating algal growth due to pH, and DO (dissolved oxygen) fluctuations and altering substrate conditions (Hutt City Council, 1998a).

The treated sewage effluent has been a source of faecal coliforms, which has been a main cause for the deterioration of the river water quality (Hutt City Council, 1998a). In the ANZECC Guidelines (1992) it states that, "even with the most stringent effluent limits set and strict waste minimisation in place, effluents can be of a poorer quality than the receiving water quality objectives". This was the case for the effluent from the WWTP. It was of a reasonably good quality for the type of technology in use, yet still contained high bacterial counts and phosphorous and nitrogen concentrations (Hutt City Council 1998a). Studies and reports have also identified the tributaries Wainuiomata Stream and Black Creek, which flow into the Wainuiomata River as another source of faecal coliforms (Hutt City Council, 1996 & Hutt City Council, 1998b).

Background information regarding the operation of the Wainuiomata Waste Water Treatment Plant over the last few years as well as the present situation is outlined in the next section (1.2.1.1).

1.2.1.1 WWTP Operation

In 1958 the first stage of the WWTP commenced with the construction of a low-rate filter plant to serve a population of 8000 people (Daley, 1978). The Wainuiomata

[1] Non-point pollution source: Non-point source (NPS) pollution comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water.

Sewage Plant became operative in 1959, which provided full primary and secondary treatment. This sewage treatment plant used a low rate biological trickling filter process and sedimentation to remove the majority of the solids and organic matter in the wastewater stream (Hutt City Council, 1996). The treated effluent was then discharged into the river after passing through a retention pond river chlorinated with a 20 minute contact time. Even though the effluent was of a reasonably good quality for the age and type of plant, it still contained high levels of bacteria, phosphorous and nitrogen (Hutt City Council 1998a) and could not meet the present day criteria required to sustain the health of the river. The Sludge from the wastewater stream was digested, dewatered and air dried in exposed drying beds, before disposal at the local landfill (Hutt City Council, 1998a).

In 1967 a high rate plant was added to the existing plant to increase the treatment capacity to serve a population of 20,000. In 1976, the safety of the Wainuiomata River was raised in the media, due to concern over public bathing in the river near the effluent outfall area (Hutt News, 1976). Attempts were also made to improve the effluent quality, which included the addition of a Pasveer oxidation plant. This was not successful and the process discontinued. Some more acceptable solutions were investigated other than direct river discharge, which included spraying effluent on scrub surrounding the river. These too were unsuccessful. Improvement and upgrading of the treatment plant was another option seriously considered (Hutt City Council, 1998b), but eventually it was decided to divert the Wainuiomata sewerage to the new milli-screen plant in Seaview (Kashler, 2002).

The WWTP operation ceased its service in November 2001 (Kashler, 2002) and the site is now used as a pumping station. The sewage from the Wainuiomata community is now pumped to the new upgraded plant in Seaview. The sewage from Wainuiomata is collected in three zones in Wainuiomata as follows:

- The sewage from the Parkway zone is pumped to the Wise Park pumping station.

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[2] Point source pollution. Point sources of pollution come from a known source such as sewage treatment plant or an industry.

- The sewage from the Arakura area is pumped to the Wellington Road pumping station. This sewage together with the sewage from The Strand, is pumped to the Wainuiomata pump station (old WWTP site).
- This sewage is then pumped through a newly constructed reticulation system to the upgraded Seaview Wastewater Treatment Plant (George, 2002).

An overflow storage tank was to be constructed in case of overflows due to high rainfall (Kashler, 2002). The Resource Consent for the Wainuiomata Pumping station requires that when there are excessive flows then sewage must be screened and the solids removed. These solids are then disposed of at the local landfill, while the effluent must be retained until excessive flows diminish. It is required that there is provision for 2 hrs settling. When the conditions are such that the storage capacity is not sufficient, a restricted discharge into the river four times a year is permitted only (Kashler, 2002).

The decommissioning of the sewage treatment plant may have had an impact on the quality of the water. In the Hutt News (2000) it stated that 'the removal of the treatment plant is expected to improve the water quality of the Wainuiomata River and eliminate odour problems'. The perception of the focus group carried out in 2002 (refer section 1.1.1 p.5) was that the water quality of the Wainuiomata River should show some improvement. However, this has still not been evaluated or confirmed and the impact of the decommissioning of the sewage treatment plant is a major part of this research project.

1.2.2 Other Pollution Sources Affecting the Wainuiomata River

In a study carried out by Hutt City Council (1998a), it was identified that the discharge from the Wainuiomata urban area (Black Creek - non-point), main drains, and the landfill were having significant adverse effects on the water quality, which ultimately affected the ecosystem, particularly the invertebrate communities. Agricultural runoff and possibly runoff from poorly maintained and antiquated septic tank system and drainage fields are also know to affect the quality of rivers and streams (George, 2002).

The Wainuiomata River flows through rural areas where there is livestock and there is the use of septic tanks for sewage disposal. The river also flows through urban areas where storm water drains discharge into the river. Untreated storm water during peak flows can contain concentrations of contaminants that can be worse than secondary treated sewage (Whipple *et al*, 1974). If sewerage systems are flooded, untreated sewage can escape. In Auckland, storm water can amount to 75% of the total quantity of sewage effluent (MfE, 1997). The leachate from the landfill was pumped to the WWTP and treated. A small stream that is diverted around the Landfill carries runoff from the tip to the river. This runoff may carry some low-level contaminants, which also may affect the water quality (Hutt City Council, 1998a). Landfills are a point source of pollution, especially if they are not managed effectively (Whipple *et al*, 1974). The leachate from the landfill may also be a source of heavy metals and microorganisms.

The Wainuiomata Water Treatment Plant, located upstream from the former WWTP, may also be a potential point source of pollution. The treatment plant discharged supernatant into the Wainuiomata River under certain conditions, one being when the turbidity of the raw water entering the treatment plant exceeds 4 NTU (MOH, 2000). This supernatant could possibly contain high concentrations of *Giardia* and *Cryptosporidium* (a single celled animal, i.e., a protozoa which causes diarrhoea if ingested) therefore a possible health concern for those who use the river for swimming. Usually the supernatant, which is extracted from decanted scum and filter backwash flow, is recycled back into the plant inlet at a controlled rate (de Silva, 2000). However, in 1998 the plant became contaminated as concentrations of *Giardia* in the water supply were at a maximum of 68 cysts per litre (normal range 0 to 5 cysts/L). It was strongly suspected that the recycling of scum supernatant mainly caused this contamination. As a result of this the backwash recovery plant was optimized to decrease the likelihood of contamination reoccurring (de Silva, 2000).

1.3 Pollution Effects on Water Quality Indicators (Fresh water)

Non-point (e.g. agricultural runoff) and point (e.g. sewage treatment plant effluent) source pollution entering waterways such as rivers and lakes provide a nutrient source to generate algae proliferation, leading to the water body's deterioration. Rivers and streams are required under the Resource Management Act (RMA) (1991) to be monitored regularly to ensure pollution problems are identified. Environmental indicators are used to do this. For this project, which was to assess the water quality of the Wainuiomata River, the environmental indicators that were selected were as follows: microbiological (*E. coli* and total coliforms), chemical (Nitrate Nitrogen, Ammoniacal Nitrogen & Dissolved Reactive Phosphorus) and biological (Periphyton). These indicators were selected and based on what the Wellington City Council currently uses to monitor the water quality of the Wainuiomata River.

Sections 1.3.1 to 1.3.3 evaluate the microbiological, chemical and biological environmental indicators selected for this project and their relevance in being pollution indicators.

1.3.1 Pollution Effects on Faecal Indicator Bacterial Populations

Bacteria, such as *Escherichia coli (E.coli)* and *enterococcus* are useful indicators of faecal contamination of potable or fresh water. *Escherichia coli* is the predominant coliform in faeces and the only member of the coliform (and thermotolerant coliform) group exclusively associated with faeces (Internet, 2004a). The ability of total coliforms to indicate the presence of faecal pollution is less reliable. However, because of its superior survival characteristics, the total coliform group is preferred as an indicator of the adequacy of treatment (Internet, 2004a) (see Chapter 1.5 for information on the characteristics of the environmental indicators selected for this study).

A number of studies have found that contamination of water by sewage or excreta have been associated with public health, affects such as gastroenteritis and respiratory health effects. For example a study to assess the exposure of swimmers to microbiological contaminants in fresh waters in the Netherlands, Medema *et al* (1998) found that the risk of an intestinal infection correlates with the concentration of thermotolerant coliforms (faecal coliforms) and *E.coli.* Some of the sites assessed for this study have been also been affected by sewage effluents and agricultural run-off (Medema *et al*, 1998). Even though these illnesses are minor and short lived, there is the potential to contract a more serious disease such as Hepatitis A, Giardiasis, Cryptosporidiosis, Camplyobacteriosis and Salmonellosis (MfE, 2001a).

A recent chemical and microbiological study was carried out on the Dongjiang River in Hong Kong to determine the cause for the deterioration of the water quality of the River. The research found that the deterioration of water quality was associated with increased domestic sewage discharges and non-point-source pollution such as agricultural chemicals (Ho, 2003). In Sweden during the period 1980-1995, a total of 90 outbreaks of waterborne diseases were reported, involving about 50,000 sick people and two deaths. Unknown agents caused approximately 80% of the outbreaks that occurred. *Campylobacter* was detected in some of the outbreaks. Between 1980 and 1995, eleven Campylobacteriosis outbreaks were reported. For three of these outbreaks, 1,000-3,000 sick people were involved (Anderson, 2001).

A comprehensive study carried out in New Zealand revealed that three out of every five popular swimming spots in New Zealand's rivers and lakes are infected with *Campylobacter*. Animal wastes and effluent washed into the waterways were one of the causes of the contamination of rivers and lakes (NZ Herald, 2003).

In the Wainuiomata River, high bacteria levels were found from Leonard Wood Park (0.3km above WWTP), down to where the Catchpool Stream enters the main stream (9km below WWTP), posing a health risk to swimmers (Hutt City Council, 1998a) Swimmers, especially children are known to swim at the Leonard Wood Park site (Taylor, 2003).

Water recreational illnesses, are spread by ingesting, breathing, or having contact with contaminated water from swimming pools, spas, lakes, rivers, or oceans. Recreational water illnesses can cause a wide variety of symptoms, including skin, ear, respiratory, eye, and wound infections. The most commonly reported water recreational illness is diarrhoea, which can be caused by pathogens such as *Cryptospordium*, *Giardia*, *Shigella* and *E.coli* O157H (MOH, 1998).

Even though *E.coli* is the recommended indicator of faecal pollution of freshwater, a Microbiological Programme undertaken in New Zealand 1998-2000, found that *E.coli* concentrations alone are not sufficient enough to enable the health risk from recreational use of fresh waters to be assessed (McBride *et al*, 2002). The programme's objective was to quantify the relationship between pathogens and indicators leading to improved guidelines for recreational waters (McBride *et al*, 2002).

1.3.2 <u>Pollution Effects on Chemical Indicators (Nitrate Nitrogen, Dissolved Reactive Phosphorus & Ammoniacal Nitrogen)</u>

The measurement of nitrogen, ammonia and phosphorus (as nitrate nitrogen, ammoniacal nitrogen and dissolved reactive phosphorus) can determine the nutrient loading of a particular waterway. The growth of all organisms depends on the availability of mineral nutrients with nitrogen being one of the most important of all the minerals. Nitrogen is required in large amounts as it is an essential component of proteins, nucleic acids and other cellular constituents. The availability of nitrogen is therefore essential to the health of an aquatic environment (University of Edinburgh, 2002).

Overseas studies have also indicated that nutrient loading can compromise the water quality of a water body. A study was carried out on the Nile River because of the serious pollution problems it was facing. The pollution of the river was due to modern developments (e.g. sewage plant operation), which has lead to eutrophication caused by nutrient enrichment of water causing blooming of the alga and zooplankton (Gamila, 2000). The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes (including birds and fish) and discharges from car exhausts (Internet, 2004).

Nitrogen-containing compounds act as nutrients in streams and rivers. Nitrate reactions [NO_3^-] in fresh water can cause oxygen depletion, thus, aquatic organisms depending on the supply of oxygen in the stream could die. Bacteria in water can also quickly convert nitrites [NO_2^-] to nitrates [NO_3^-] (Internet, 2004). The primary health hazard from drinking water with nitrate-nitrogen occurs when bacteria in the digestive system transforms nitrate to nitrite. The nitrite oxidizes iron in the haemoglobin of red blood cells to form methemoglobin, which lacks the oxygen-carrying ability of haemoglobin. This creates the condition known as methemoglobinemia (sometimes referred to as "blue baby syndrome"), in which blood lacks the ability to carry sufficient oxygen to the individual body cells (NebGuide, 1998).

Dissolved reactive phosphorus (DRP), nitrate-nitrogen (NO_3-N) and ammoniacal nitrogen (NH_4-N) are most likely to cause excessive algal growths in waterways if found in excessive amounts (MfE, 1999a). The combined nitrogen load from nitrates and ammonia is referred to as dissolved inorganic nitrogen (DIN). Although direct measurements of DIN are not available, nitrate nitrogen concentrations alone can determine whether a river is at risk of developing nuisance algae (MfE, 1997a). Nitrate nitrogen or nitrate at high levels can be toxic to humans and other animals that drink contaminated water (MfE, 1999a). Ammonia can be found in urine (Hoare & Rowe, 1992) and at sustained high levels in fresh water can be toxic to fish. This affect of ammonia on fish is dependent on the water's temperature and its pH, as well as the dissolved oxygen and carbon dioxide levels. Levels of ammonia greater than 0.1 mg/L usually indicate pollution of waters. Dissolved reactive phosphorus at certain levels (15-30 mg/L) can facilitate algae growth (MfE, 1997a).

1.3.3 Pollution Effects on Indicator Periphyton Communities

The analysis of periphyton in relation to water quality is a biological approach. The basis for this approach is that different species vary in their tolerance to environmental stressors (Kroeger *et al*, 1999). Determining the relative abundance (e.g. Chlorophyll *a*) and identifying the taxa of a periphyton community can reveal how well a body of water supports aquatic life. For example elevated chlorophyll *a* (determines periphyton mass) levels can indicate a pollution problem (usually due to high nutrient loading). In a biological bio-assessment in Florida, elevated chlorophyll *a* was determined from samples of periphyton. This elevated chlorophyll *a* indicated that the floral community imbalance was due to pollution (Kroeger *et al*, 1999). This makes periphyton a very good indicator of pollution.

In certain conditions such as high nutrient and temperature levels and low flows, algal communities can become prolific growth causing water resource management problems such as degrading aesthetic, recreational and bio-diversity values (Biggs, 2000a). Excessive nutrient loading can be due to point or non-point sources of pollution such as sewage effluent or land runoff. The eutrophication of the Rotorua Lakes has been caused by both domestic and industrial sewage disposals from Rotorua City together with nutrient laden runoff from the surrounding catchment (Biggs, 2000a).

Excessive algal growth observed by a number of studies carried out on the Wainuiomata River could be attributed to the high dissolved reactive phosphorus (found in sewage effluent) in conjunction with other factors such as unshaded riverbeds, warm water and stable flow conditions in the River. These conditions can also create a nuisance for anglers as when they fish their lines often become tangled in the algae or weed growth (Hutt City Council, 1998a).

Water can become toxic to animals if tainted with prolific algae. It is a requirement under the Resource Management Act, 1991 (RMA) that local councils ensure that nuisance growth of organisms is kept under control (Biggs, 2000a). In the Wainuiomata River there has been prolific growth of periphyton downstream of the now demised sewage treatment plant, causing eutrophication. Flushing trials to be carried out by the Council were proposed to try and solve this problem. Water was to be stored in a dam and released regularly to ensure periphyton is flushed of river substrate. With the closure of the treatment plant these flushing trials have not been carried out (Hutt City Council, 1998b). In Lake Taupo the improved treatment and the removal of all sewage effluent discharges from the lake improved the eutrophication condition that occurred there (Menon & Perkins, 1995, pp. 28). It is important therefore to continue to monitor the water quality of freshwater bodies such as the Wainuiomata River to minimise the risk of infection from contaminated water. There is legislation and guidelines within New Zealand, which helps local councils for the management and the sustainability of freshwater resources (see section 1.4).

1.4 Monitoring of Water Quality

1.4.1 Legislation and Guidelines

There have been a number of legislative changes that have occurred over the last 50 years in regard to the environment. The Soil Conservation Act of 1941 primarily was concerned with stemming erosion, sedimentation and flooding. In 1967 the Water &

Soil Conservation Act was introduced that emphasised the water quality and allocations, and in 1983 there was a Wild & Scenic Rivers amendment to this Act, which had a particular focus on the aesthetic and recreational aspects of rivers in their natural state (MfE, 1999b)

In 1991 the Resource Management Act (RMA) was enacted, replacing all the above legislation of 1941, 1967 &1983. This legislation now considers the intrinsic values of ecosystems, including the bio-diversity and life supporting capacity that must be considered when managing waters. The RMA (1991) now places a greater emphasis on environmentally sustainable management, instead of the multiple-use management approach previously used (MfE, 1999b).

The Department of Conservation, Ministry of Fisheries, and the Games Council have statutory roles relating to the following: protected areas, fish & bird life and indigenous species associated with water. The Ministries of Agriculture, Health and Commerce also have an interest in water resource management. The National Institute of Water and Atmospheric Research (NIWA) role is one of research (MfE, 1999b). Other legislation and guidelines that regulates and enforces anything in regard to natural water bodies are the Health Act 1956, Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003) and the ANZECC Guidelines (2000) (MfE, 1999b).

The role of the Medical Officer of Health is to ensure under the Health Act, that proper steps are taken by local authorities to protect public health. Guidelines provide the necessary processes for Councils when investigating public health nuisances (e.g. pollution of waterways). However, they do not provide the means for Councils to remove the nuisance. To remove or abate a nuisance is a Health Act requirement and it is an RMA requirement to remedy and mitigate the nuisance (MfE, 1996b).

The Ministry of the Environment and Ministry of Health has jointly released recently, the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). These new guidelines will assist councils and other agencies to better inform their communities of the risks related to swimming at bathing beaches. With the new guidelines there have been amendments to the freshwater guideline values (see

Table 1.1). Greater Wellington Regional Council's main responsibility in regard to Fresh Water is to manage the use of water and to resolve any difficulties that may arise from its use. The Hutt City Council is responsible for the treatment and disposal of wastewater in a manner, which complies with the discharge consents issued by Greater Wellington Regional Council (Hutt City Council, 1996b).

To enable an assessment of the water quality of the Wainuiomata River, the Microbiological Water Quality Guidelines for Marine and Fresh Water Recreational Areas (2003) were used to determine the compliance of the microbiological parameters. The ANZECC Guidelines (2000) were used to determine the compliance of the chemical parameters tested.

1.4.1.1 Microbiological Water Quality Guidelines for Marine & Fresh Water Recreational Areas (2003)

These new guidelines completely replace the existing Microbiological Water Quality Guidelines, and all previous microbiological and bacteriological water quality guidelines (MfE, 2003). These new guidelines cover the following categories of water use:

- Marine bathing and other contact recreational activities
- Freshwater bathing and other contact recreational activities
- Recreational Shellfish Gathering in marine waters

These guidelines were released in June 2003 marking the end of a four year multi-agency development programme led by Ministry for the Environment and the Ministry of Health with extensive contributions by the regional councils, territorial authorities and public health agencies.

The purpose of the Microbiological Research Program was to develop more robust guidelines that would assist in monitoring and reporting of recreational waters, primarily by Regional Councils, Local Councils, District Health Boards and Medical Officers of Health (MfE, 2003). The programme, aimed to determine appropriate microbiological health–risk indicators should there be a change in the current choice i.e. *E.coli* levels to a more appropriate indicator (McBride *et al*, 2002). As mentioned previously, the findings from this programme overall revealed that *E.coli* levels alone are not sufficient to enable the health risk from recreational use of fresh waters to be assessed. Factors such as turbidity and catchment type had to be examined as well (McBride *et al*. 2002).

The new guidelines therefore, move away from the sole use of guideline values of faecal indicator counts to assess the risk of the public health using particular recreational water. Instead it uses a combination of a qualitative risk grading of the catchment supported by the direct measurement of appropriate faecal indicators (MfE, 2003)

To measure the suitability of a recreational beach (beach refers to either freshwater or marine site) single-sample results are compared against guideline values (MfE, 2003) (see Table 1.1).

Table: 1.1 Surveillance, Alert, and Action levels for Freshwater

1) Acceptable Green Mode: No single sample greater than 260 *E.coli*/100ml
- Continue routine (e.g. weekly) monitoring

2) Alert /Amber Mode: Single sample greater than 260 *E.coli*/100ml
- Increase sampling to daily (initial samples will be used to confirm if a problem exists).
- Consult the CAC to assist in identifying possible location of sources of faecal contamination
- Undertake a sanitary survey report on sources of contamination

3) Action / Red Mode: Single sample greater than 550 *E.coli*/100ml
- Increase sampling to daily (initial samples will be used to confirm if a problem exists)
- Consult the CAC to assist in identifying possible location of sources of faecal contamination
- Undertake a sanitary survey report on sources of contamination
- Erect warning signs
- Inform public through the media, that a public health problem exists

1.4.1.2 Australian and New Zealand Environment and Conservation Council (ANZECC, 2000)

The purpose of the ANZECC Guidelines (2000), are to assist those involved with managing water resources to ensure that slight, moderate and highly disturbed ecosystems are adequately protected. There are two types of chemical stressors that directly affect aquatic life:

1) those that are directly toxic to biota and
2) those that, while not directly toxic, can result in adverse changes to aquatic ecosystems

Chemical or physical stressors can cause serious degradation of aquatic ecosystems when ambient values are too high. Examples of chemical stressors are nutrients, biodegradable organic matter and pH. Table 1.2 shows the ANZECC Guideline (2000) trigger values, for limiting excessive aquatic plant growth and the ANZECC Guidelines (2000) threshold levels, for Recreational Water Quality and Aesthetics, which determine suitability for particular uses.

Table 1.2 ANZECC Guidelines (2000) Default Trigger Values (for slightly disturbed ecosystems) and Threshold Levels for Recreational Water Quality and Aesthetics.

Chemical Stressor	Default Trigger Value (g/m^3)	Recreational Water Quality and Aesthetics (g/m^3)
Nitrate Nitrogen (NO_3-N)	0.44	10 (human consumption)
Dissolved Reactive Phosphorus (DRP)	0.01	0.015 - 0.030 (contact recreation and aesthetics)
Ammoniacal Nitrogen (NH_4-N)	0.021	Toxicity to fish is dependant on level and pH and temperature

In a document published by the Ministry for the Environment (State of NZ Waters), it stated that for ammonia levels to become toxic, a four day average concentration of 1.15 g/m^3 would be required (Ministry for the Environment, 1997a).

The existing ecosystem of the Wainuiomata River is considered under the ANZECC Guidelines (2000) to be moderately disturbed; therefore to improve the situation the trigger values for ecosystems that are slightly disturbed are required. The ANZECC Guidelines for Recreational Water Quality and Aesthetics (2000) are for aesthetics, human consumption and contact recreation.

Nutrients are an example of a non-toxic direct effect stressor as it can result in excessive algal growth and cyanobacterial blooms (ANZECC, 2000) (see Table 1.2 for trigger values). Trigger values are used to assess risk of adverse effects due to these chemical or physical stressors. The ANZECC Guidelines (2000) define trigger values as the concentrations of the key performance indicators, below which there is a low risk that adverse biological effects will occur. The trigger values are mean't to be used in conjunction with professional judgement, to provide an initial assessment of the state of a water body in relation to the issue in question. The trigger values of toxic stressors are generally determined from laboratory exotoxicity tests conducted on a range of sensitive aquatic plants and animal species (ANZECC, 2000).

1.4.1.3 ANZECC Guidelines (2000) for Recreational Water Quality and Aesthetics

The chemical indicator results were compared with the Guidelines for Recreational Water Quality and Aesthetics (2000) values. These guidelines are necessary to protect waters for recreational activities, such as swimming and boating, and to preserve their aesthetic appeal. Factors considered include: (Australian Government, 2000)

- microbiological characteristics;
- nuisance organisms (macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches); and
- physical and chemical characteristics (pH, temperature, toxic chemicals and surface films).

Recreational guidelines accommodate two categories of sporting activity:

- sports such as swimming in which the user comes into frequent direct contact with water, either as part of the activity or accidentally (primary contact); and
- sports such as boating or fishing that generally involve less-frequent body contact with the water (secondary contact).

Swimming is not frequent downstream of the Wainuiomata Waste Water Treatment Plant site due to access restraints to the river (Hutt City Council, 1998a). These guidelines were used, as 95% of fishing effort is concentrated in the middle and lower reaches of the Wainuiomata River. Canoeing below the WWTP site is not that frequent due to the slow moving water and high weed growth.

To determine the state/or to monitor a particular environment, such as the Wainuiomata River it is necessary to use indicators. The definition of an indicator, as given by MfE, (1997) is the "quantitative measure against which some aspects of policy performance can be assessed". The New Zealand environment has undergone a significant change only in a short time due to the constant pressure of human activity. To ensure that such a situation does not become out of control, environmental indicators are used to measure regularly any trends or sudden changes in a natural environment such as rivers. This means that the environmental indicator can determine if improvement or degradation over time is occurring. Ultimately environmental indicators can assist in achieving better environmental outcomes i.e. are signposts for sustainability (MfE, 1997).

The ANZECC Guidelines (1992) identifies three types of indicators of environmental quality

§ those that are normally present in the water and that can be usefully monitored for a change in concentration, quality or quantity, some or all of which can be linked to a change in the environmental value

§ those that are not normally present, but if detected in certain concentrations or quantities can be used to identify a change in or effect on an environmental value

§ indicators that are normally present but the absence of which reflects a change in an environment value

When selecting indicators for environmental protection the following attributes are desirable:

- readily identifiable and can be sampled with ease
- associated with abundant autecological data
- economic importance as a resource or nuisance or pest species
- a pollutant that readily accumulates and is easily analysed in laboratories and has low variability

It is also important when choosing an indicator to first determine the question of what is to be indicated (Hellawell, 1986). To give an example, when analysing drinking water one of the parameters that may be of interest would be chlorine, while in natural waters this would not be the case (Hach Company's University, 2002). Another example given by Hoare (1992) suggests that in a lake or river with eutrophic conditions, the nitrogen and phosphorous levels would be of higher importance than the levels of heavy metals. The water quality of the Wainuiomata River was assessed for this research project using the indicators; *E.coli*, total coliforms (microbiological), nitrate nitrogen, ammoniacal nitrogen, dissolved reactive phosphorous (chemical) and periphyton (biological). These indicators were selected, as they are the most appropriate for the particular problem at hand, therefore providing the information needed to make an assessment.

1.5 Water Quality Indicators

The characteristics of the environmental indicators selected for this research project (*E.coli* - microbiological, DRP, NO_3-N, NH_4-N - chemical and periphyton - biological) for determining the state of the water quality of the Wainuiomata River, are outlined in Sections 1.5.1 - 1.5.3.

1.5.1 *Escherichia coli* (microbiological)

The *Escherichia coli* are a faecal coliform and are part of the total coliform group. The coliform group consists of several genera of bacteria belonging to the family Enterobacteriaceae. The historical definition of the group has been based on the method used for detection, which is lactose fermentation (EPA, 2002a). *Escherichia coli* are defined as coliform bacteria and a number of *E.coli* strains are β-glucuronidase negative (including pathogenic strains such as O157:H7), which can cleave the fluorogenic substrate 4-methylumbelliferyl-β-glucuronide (MUG) at 44.5°C within 49 hr. *E. coli* is associated exclusively with the faeces of warm-blooded animals, including humans (one person excretes daily 125-400 billion of these bacteria) and is itself non-pathogenic (the serotype *E. coli* 0157:H7 found in contaminated meat is deadly, but is not found in water). *E.coli* is a specific indicator of faecal contamination of water and its presence may indicate the presence of enteric pathogens (Queens College, 2003).

Enteric pathogens are aerobes, which ferment a wide range of carbohydrates and whose natural habitat is the intestinal tract of man and animals for example Shigella and Salmonella. These gram-negative bacteria produce endotoxins with have a wide range of pathological effects (Jawetz et al, 1970).

To measure all the different pathogens within a water body is not practical for a number of reasons; pathogens may have been diluted in receiving waters, therefore detection is difficult and the isolation and identification of the pathogen may involve a number of tests, therefore can be expensive and time consuming. The detection of indicator organisms such as *E.coli* is more practical for signalling potential presence of pathogens, which may cause gastrointestinal disease (Abbott 2001). If pathogenic organisms such as viruses, bacteria, and protozoa enter waterways they can pose a health hazard to those who use the water for recreational purposes such as swimming and other "high contact" water sports. If contaminated water is swallowed, inhaled or come in contact with ears, nasal passages mucous membranes and cuts in the skin, can allow the pathogens to enter the body (Abbott 2001).

Some Regional Councils within New Zealand have investigated using faecal *streptococci* to assist in identifying pollution sources. In spite of a world investigation into this indicator, faecal *streptococci* failed to fulfil their potential as faecal source indicators (Sinton *et al*, 1993). Another reason *E.coli* are such a good indicator, is their quick response to organic enrichment or toxic substances. This is because the generation time of bacteria is very rapid. The methods and techniques for the isolation and examination of bacteria of faecal origin are extremely well developed (Hellawell, 1986).

1.5.2 Dissolved Reactive Phosphorus, Nitrate Nitrogen and Ammoniacal Nitrogen (Chemical)

Nutrients are substances or elements that aquatic plants need to sustain their growth (Hoare & Rowe, 1992). All organisms depend on the availability of mineral nutrients. Nitrogen and Phosphorus are the most important of all the minerals. Nitrogen is required in large amounts as it is an essential component of proteins, nucleic acids and other cellular constituents (University of Edinburgh, 2002). The Nitrogen (N) and Phosphorus (P) concentrations are expressed as mg/m^3 of the element N or P respectively (Hoare and Rowe, 1992).

Nitrogen is made available by a number of processes. The earth's atmosphere supplies nearly 79% of nitrogen in the form of nitrogen gas, but is unable to be used in this form for growth. In order for nitrogen to be used for plant growth, it needs to become "fixed" or "combined" in the form of ammonium (NH_4) or nitrate (NO_3) ions (University of Edinburgh, 2002). Nitrate is the most common form found in water. Most laboratories report nitrate as nitrate-nitrogen (NO_3N), which is the amount of nitrogen in the nitrate form (NebGuide, 1998). The weathering of rocks releases these ions, but the process is so slow that it has very little effect on the availability of fixed nitrogen. The lack of fixed nitrogen can be a limiting factor for growth in an environment even when there is suitable climate and the availability of water to support life. The availability of nitrogen is therefore essential to the health of an aquatic environment (University of Edinburgh, 2002).

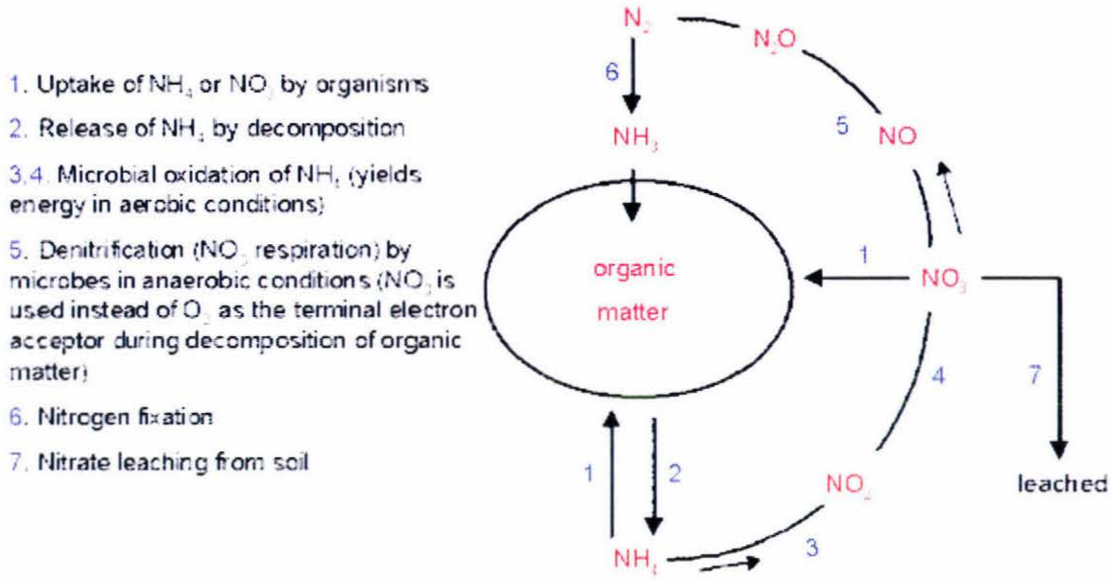
Microorganisms play a key role in nearly all aspects of nitrogen availability and therefore life supporting the earth. Some bacteria convert nitrogen into ammonia by the process, nitrogen fixation. Some of these bacteria live independently of other organisms (e.g. *Aztobacter* - aerobic), also known as 'free-living nitrogen fixing bacteria. Some bacteria live in a symbiotic relationship with plants or other organisms (e.g. protozoa), while other bacteria bring about the transformation of ammonia to nitrate, and of nitrate to $N_{2(g)}$ or other nitrogen based gases. Many bacteria and fungi also degrade organic matter, therefore providing another source of fixed nitrogen (University of Edinburgh, 2002).

Phosphorus is an essential element that is naturally present in water at low concentrations, ~ 10 ppb (parts per billion or 10 ug/L). Natural phosphorus compounds are non-volatile and generally exist as compounds not highly soluble in water. The main geochemical reservoir of phosphorus is calcium phosphate $Ca_3(PO_4)_2$, in sedimentary rocks. Phosphorous can also be found in sewage (Hoare & Rowe, 1992). There are many forms of phosphorous in freshwater and its measurement can be carried out by a variety of means. Often these are loosely known as 'phosphates'. DRP is the dissolved form, and therefore can be readily taken up by plants (Hoare & Rowe, 1992). Fertilizer use and runoff is not a major source of dissolved phosphates, however since this phosphate is readily fixed as slightly soluble aluminium and iron compounds it will predominantly exist in the suspended sediment load and end up buried. If in a less soluble form it won't have the same bioavailability as a soluble form and uptake by aquatic plants will be limited (Hoare & Rowe, 1992).

Ammonia naturally occurs in the environment through the action of bacteria on proteins and urea; this relationship can be seen in the Nitrogen Cycle (see Figure 1.7 for Nitrogen Cycle). Ammonia (NH_3) is made up of one nitrogen and three hydrogen atoms, is a very good source of nitrogen and is therefore a good fertilizer (University of Edinburgh, 2002)

When there are excessive amounts of these nutrients, eutrophication can occur, i.e. the excess amounts of fuel causes enhanced plant and algal growth (MfE, 1999a).

Figure 1.7: Nitrogen Cycle (University of Edinburgh, 2002).



1.5.3 Periphyton (Biological)

Periphyton are an attached framework of communities or they can be described as benthic or attached algae i.e. they attach themselves to surfaces such as rocks, wood, or larger plants when growing and also known as bottom-dwelling algae (U.S. Environmental Protection A, 2002a). Periphyton, which is made up of slime and algae, are essential for ecosystems to function. The community can be recognised by giving the substrate (e.g. rocks), a brown or brown-green colouring. Periphyton communities contribute most to aquatic life, as they are transducers of light energy. The algae convert the sunlight via their chlorophyll molecules; absorb CO_2 and other nutrients, therefore providing food for other aquatic life (Bold, 1985). Periphyton absorbs nutrients such as phosphorous and nitrogen from the surrounding environment, organic carbon is then synthesised causing enlarged cells.

Unlike plankton, which often does not respond well to pollution effects, the periphyton show dramatic responses (in enhanced growth) immediately below pollution sources and therefore is an excellent biological indicator to determine the presence of pollution (The United State Protection Agency, 2002c).

Research has shown that as algae biomass increases, the internal cycling of nutrients also increases and fewer nutrients are taken up from the stream water for growth. The assemblage of the periphyton serves as a good biological indicator for the following reasons: (Brightbill & Bilger, 1998)

1) Periphyton species naturally occur in high numbers.
2) The response time of periphyton (i.e. the amount of growth) to both exposure and recovery is quite rapid.
3) Experienced biologists can carry out identification to the periphyton species level.
4) Many species of this algae are quite tolerant or sensitive to any changes in the environment condition

To perform a rapid bioassessment protocol for periphyton it could include, but is not limited to, assessment of biomass species composition and biological condition of the periphyton assemblage (Brightbill & Bilger, 1998). The algal biomass could therefore be used as a measure of water quality. The algal biomass indicators commonly measured are chlorophyll *a*, chlorophyll *b* and ash free dry mass. As mentioned previously a quick assessment of biomass could be carried out using a method such as the Periphyton Abundance Scale as explained in Quinn & McFarlane (1985). These measurements can help establish baseline conditions used to determine the effects of nutrient reduction goals in a long term monitoring program. For the purpose of this research project, the methods that were used for the selection, detection and enumeration of the bacteriological, chemical and biological indicators are discussed in section 1.5.4.

1.5.4 Methods for Selection, Detection and Enumeration of the Microbiological, Chemical and Biological Indicators

There are a number of methods available for detecting and enumerating the environmental indicators selected for this work. Criteria for method selection involved the following:

- Reviewing of methods in use in New Zealand and overseas
- Selection of the most widely used
- Simplicity of use
- Cost effectiveness

The methods used for the enumeration and detection of *E.coli* and total coliform in freshwater are the multiple tube fermentation and membrane filtration (MF) techniques and have been used for some years to monitor water quality. These methods determine the most probable number (MPN) (McGrady, 1915). Both MF and MPN are labour intensive, complicated and require a minimum of 48-72 hour incubation before results can be obtained (Abbott, 2001).

The Colilert® Method was used instead over other traditional methods (e.g. MPN & MF) to detect *E.coli* and total coliforms in the Wainuiomata River. This was because the Colilert® Method was less expensive (20-50% less) than traditional methods, took less than one-minute hands on per sample, detected *E.coli* and total coliforms within 24 hours or less and has been internationally approved for compliance (INDEXX Laboratories, Westbrook, Maine & United States). The Ministry for the Environment has used this method and this method has been used in the development of the Microbiological Guidelines (MfE, 2003).

The HACH DR/2000 Spectrophotometer method (a screening method) was used for the detection of nitrate nitrogen, ammoniacal nitrogen and DRP due to ease of use in the field and availability. Samples for interlaboratory calibration were sent to an IANZ certified laboratory, Environmental Laboratory Services, Seaview (ELS). The HACH method was simple to use and results were obtained within a short time. This method can be also used in the field providing a rapid evaluation of samples on site and was of sufficient sensitivity for this research project.

The visual assessment of periphyton abundance for this work was carried out using the Periphyton Abundance Scale, which is a quick assessment of periphyton abundance and has been used in other studies such as the study investigating the effects of the discharge of sewage effluent on the Wainuiomata River (Hutt City Council, 1990). Each site was allocated a score depending on the amount of periphyton growth visible on substrate (e.g. rocks) within the river. The score ranged between 0-5; zero being no periphyton visible and 5 indicating periphyton covered the riverbed. The determination of the relative abundance of periphyton using the visual assessment scale, should equate to the rapid assessment method used by Greater Wellington Regional Council. Their method focuses on measuring the cover of a particular stone by periphyton using a quadrate.

This is specifically designed for assessing compliance with the periphyton guidelines for cover to protect the aesthetic, recreational and fishing values (Taylor, 2003).

Although there are many different methods used internationally for periphyton research and monitoring, the Stream Periphyton Monitoring Manual (2000b) was selected for this research project, as it was more applicable to the stream habitats found in New Zealand. The Stream Periphyton Monitoring Manual (2000b), produced for the New Zealand Ministry for the Environment reviews periphyton in regard to their importance in the management of water resources. In addition it provides a standard set of methods for Regional Councils to collect and analyse data on periphyton for resource surveys, and impact assessments/monitoring (Biggs & Kilroy, 2000b) and for this research.

The periphyton taxa for this study, was identified to the Genera using the semi-quantitative method (one of two methods) described in chapter 8 of the Stream Periphyton Monitoring Manual (2000b). This semi-quantitative method assesses which taxon is principally contributing to the overall community biomass. The second method (fully quantitative) involves a detailed count of the number of individuals of each taxon. This particular method is time consuming, as an average analysis may take as much as 2 hours; together with the potential occupational overuse injuries that can result. The semi-quantitative method is used more widely in New Zealand (Biggs & Kilroy, 2000b) therefore, for these reasons the semi-quantitative method was used in this research.

1.6 Objectives and Approaches

The aim of this research was to study the water quality of the Wainuiomata River and to assess whether the Wainuiomata Waste Water Treatment Plant closure, has had any effect on the water quality of the river. This involved examining the microbiological, chemical and biological indicators at various sites along the Wainuiomata River as follows: J1, J2, J3a, J3b, J4, J5, J6, J7, B1 and B2 (see Figure 2.1 Chapter 2 for site map).

1.6.1 Objectives of the Research Project

The objectives were as follows:

1) Establish levels of E.coli indicator organisms with sites J4 and J5.
2) Establish levels of nitrogen, phosphorus and nitrate as site J1, J4 and J5
3) Establish levels of periphyton using the semi-quantitative Periphyton Abundance Scale.
4) Compare *E.coli*, Nitrogen, phosphorus and nitrate values at sites J4 and J5 with historical data for same WRC surveys
5) Establish water quality compliance by comparing data yielded at sites J1 - J7, B1 and B2 with Microbiological Guidelines and ANZECC Guidelines.

1.6.2 Approaches to the Research Project

To determine the impact the closing of the WWTP has had on the microbiological quality of the Wainuiomata River samples were collected from sites upstream and downstream of the WWTP. The following sites were selected for collection of water samples: J1, J2, J3a, J3b, J4, J5, J6, J7, B1 and B2 (see Figure 2.1 in Chapter 2 for site map). The site of particular interest (impact site) was J5 as it is downstream of the WWTP. Site J5, has been monitored for many years by Greater Wellington Regional Council, before and after closure of the treatment plant, so there was ample data to make an impact assessment.

Evaluation of an impact assessment was carried out using the median of the indicator values determined for both this research project and the GWRC data. Both the mean and median are good locations of the centre of a distribution of measurement however; the median is less sensitive to extreme values (Mendenhall & Beaver, 1991) such as those that can be associated with rainfall events and variation during normal base flow conditions. Calculating the median would eliminate these extreme values. Median faecal coliform concentrations therefore provide the most reliable measure of centrality for comparison between sites (Rodgers *et al*, 2003).

The Greater Wellington Regional Council used faecal coliforms as their indicator to monitor the water quality of the Wainuiomata River, and the data was expressed as faecal coliform/100 ml. In this research project *E.coli* was the microbiological indicator used, and data was expressed as *E.coli*/100 ml. Even though the indicators are different, data can be compared as both these indicators are used for the detection of faecal pollution; therefore the presence of faecal coliforms is relative to the presence of *E.coli*.

To determine the impact (microbiological) the closure of the WWTP has had on site J5, other confounding factors, which may be exerting some influence on this site, were taken into account. For example other faecal pollution sources such as the tributaries Black Creek and the Wainuiomata stream, which enter the Wainuiomata River upstream of the WWTP and the J5 site. Storm water discharge and land runoff may also have a confounding effect on this assessment. Samples for microbiological analysis were therefore collected for this work from specific sites along Black Creek and the Wainuiomata stream, as well as from specific sites along the Wainuiomata River, upstream and downstream of storm water outlets. Samples were also collected downstream of the local landfill (downstream of the WWTP site) and near the mouth of the river (J6 & J7 respectively). Collection of water samples from all these sites would enable a far better impact assessment than if sites immediately upstream and downstream of the WWTP were sampled only.

Escherichia coli detected at sites were measured against the microbiological guidelines for compliance (see Table 1.1). As some of these sites were popular swimming areas it was important to measure their level of compliance because of potential risk to public health.

Chemical analysis was carried out on samples collected from selected sites (J4, J5 & J7). The analysis of the chemical indicators was to determine the level of nutrient loading. Samples for chemical analysis were collected on only four occasions from the selected sites; this decision was based on low levels of chemicals observed in the Greater Wellington Regional Council recent data (2002-2003) for sites J4, J5 & J7. Site J4, the control site (upstream of WWTP), was compared with site J5, J6 and J7 for impact assessment. The HACH DR/2000 Spectrophotometer method was preferred over standard methods because of its ease of use and as well only a general picture of the level of nutrients was required.

Clesceri *et al* (1959) suggests that samples of periphyton for analysis should be collected at selected sites upstream and downstream of the suspected source of pollution of the intended study area. As the WWTP effluent was the major source of pollution samples of periphyton were scraped from rocks and collected into plastic containers from site J5 (Golf Course) downstream of the WWTP site and also J4 (Leonard Wood Park) upstream of the WWTP site. Samples were also taken from near Coast Road Bridge (J7), where there may be affects from agricultural runoff. Samples were scanned and the dominant taxon was identified to the genus level. Determining the taxa that comprise a periphyton community is recommended in most periphyton studies as it helps in the interpretation and evaluation in any pollution monitoring investigation (Biggs, 2000a), and this was performed at the sites J4, J5 and J7.

The following chapters in this thesis entail; methods used for sample collection, analysis of samples, results, conclusions and recommendations as an outcome for this research project. Chapter two relates in detail the methodology of collection of the samples. Chapters 3, 4 & 5, outlines the results and discussion for the microbiological, chemical and biological parameters analysed respectively. Chapter 6 is the overall conclusion and recommendations of the water quality of the Wainuiomata River and the impact the closure of the WWTP has had on the river.

CHAPTER TWO: METHODOLOGY

2.1 Collection of Samples

Samples were collected at a number of sites along the Wainuiomata River and also from two tributaries Wainuiomata Stream and the Black Creek (See Figure 2.1 for site map). During the sampling period rainfall for 72, 48 and 24 hours were recorded before collection of samples (see Appendix I for rainfall and flow rate data). Flow rate was also recorded on the day of sampling from the GWRC's Reporting System, (2003). Rainfall was recorded at Skull Gully and flow rates at Manuka Track. The Manuka Track is the principal flow station used for hydrological analysis (Hutt City Council, 1998b).

2.1.1 Wainuiomata Sampling Sites

In 2002, in consultation with a water quality scientist Stevenson (2003) of the Greater Wellington Regional Council, a number of sites were selected to assess the water quality of the Wainuiomata River. The following sites were selected for collection of water samples: J1, J2, J3a, J3b, J4, J5, J6, J7, B1 and B2 (see Figure 2.1 for site map). These sites represent the various environments that exist, through which the river flows (see Table 2.1 for description of each site). As mentioned in previous sections, the environments through which the Wainuiomata River flows vary considerably. This can be seen more clearly in the Wainuiomata Catchment Land Use Map (see Figure 1.5) and in Figures 1.1-1.4. The river first flows through a closed catchment area, where there is abundant aquatic life, but as the river winds itself into the urban area the environment changes dramatically from riparian forest to mainly grasses and low lying scrub with a clear degradation of the water from visual observation. The surrounding environment also differs in that littered rubbish is visible. As the river flows down through the rural domain the landscape becomes dominated mainly by low-lying pasture and gorse, which are completely surrounded by steep scrub and bush covered hills. This part of the catchment is predominantly drained by Black Creek (GWRC, 1998). In addition to farming and a limited amount of commercial forestry, the area provides opportunities for rural-residential living in Moores Valley Road and along the Coast Road, and for a variety of recreational activities such as tramping, fishing and swimming (GWRC, 1998).

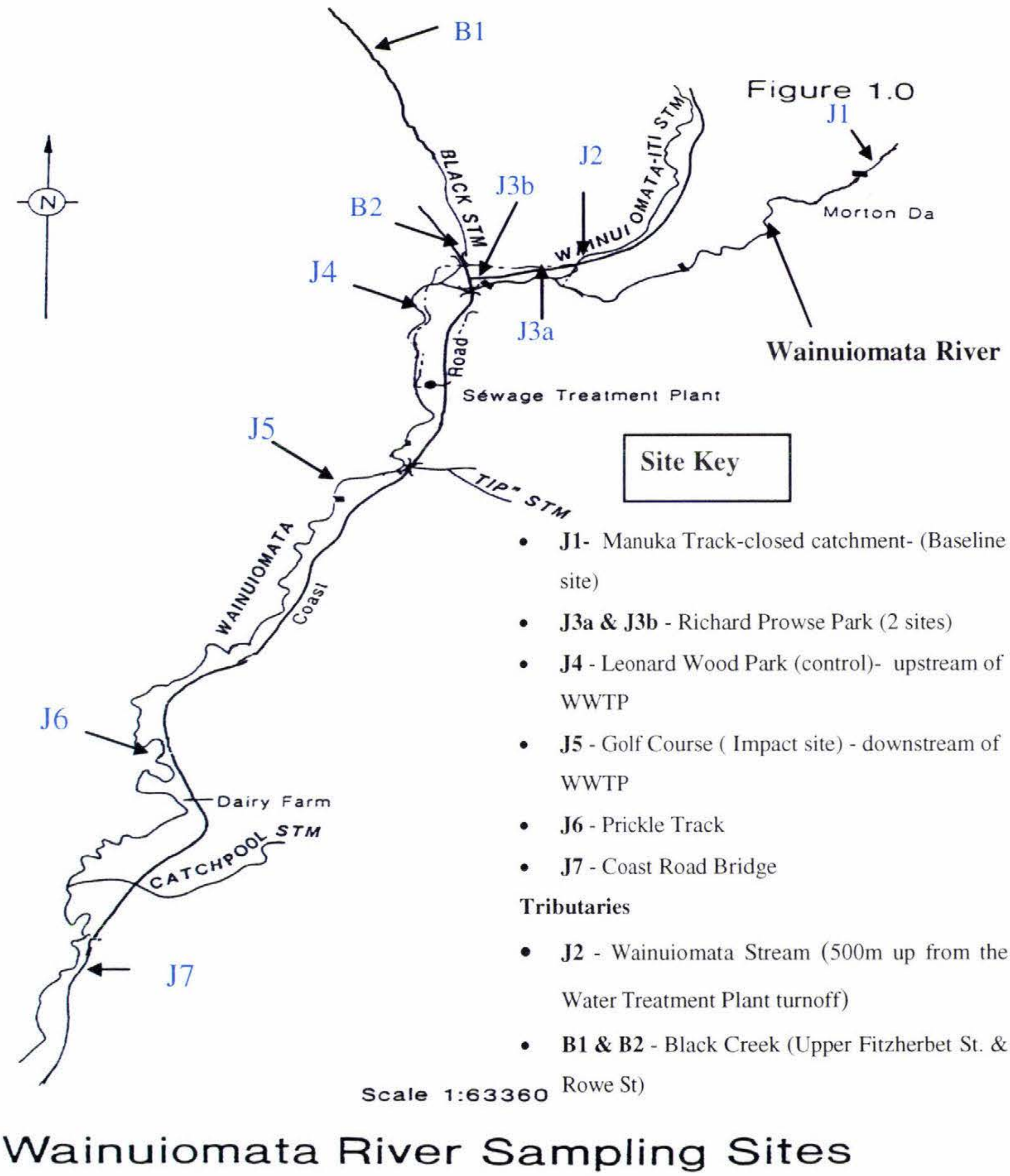


Figure 2.1: Site Map

Adapted: Hutt City Council, 1990

Site	Land Use	Co-ordinates: * Easting (E) Northing (N)
J1. Manuka Track – Riparian forest/ abundant aquatic life	Closed catchment. Water abstraction for water supply	E – 2678265 N – 5992349
J2. Wainuiomata Stream - Stream flows through rural land before entering the Wainui. River. 500m upstream from the Water Treatment Plant turnoff. Site accessed through 191 Moores Valley Road.	Semi-rural - Properties are on septic tanks	E – 2675297.6 N – 5991191.7
J3a Richard Prowse Park - 40m downstream from where Wainuiomata Stream enters the river, near sport clubrooms at park. **J3b** Richard Prowse Park - Below Village Bridge	River flows through a popular park used for sports as well swimming. Site is upstream of the urban sector. No storm water outlets. Urban area. Storm water enters at this site.	E – 2674310.1 N – 5990780.64
J4. Leonard Wood Park - About 0.3km upstream of WWTP.	Semi-urban/rural. Contains pollutants from, Black Creek and Wainuiomata Stream.	E – 2673083 N – 5989567
J5. Golf Course. 2.4km downstream of WWTP.	Coast Road. Rural - Properties on septic tanks	E – 2672107 N – 5987363
J6 Prickle Track - Before Catchpool Stream. 7 km below WWTP	Coast Road. Rural - Properties on septic tanks	
J7 Coast Road Bridge. 50m downstream of white bridge	Rural - Properties on septic tanks	E – 2667340 N – 5977436
B1 Black Creek. Top-end of Fitzherbet Road. Site is near little bend in road and is near a fence line. **B2** Black Creek - before it enters the river. Access site through Motel at end of Rowe St.	Rural area. - Properties on septic tanks Suburban area.	E – 2673351.3 N- 5995565.4 E – 2673408.5 N – 5990538.6

* The Easting and Northing co-ordinates have been obtained form New Zealand Map Grid Reference

Tnble 2.1: Site Description

2.1.2 Fresh Water Samples for Microbiological Testing (*Escherichia coli* and Total Coliforms)

Materials

500 ml sterile glass bottles with a screw lid (Schott Corporation, New York, USA)
Mighty Gripper (Mighty Gripper CO., Whangarei, NZ)
Latex Gloves (disposable)
Chilly bin with ice and ice trays
Gumboots
Clipboard
Field data sheets
First-aid kit

Method

Fresh water samples were collected every 7 days at all sites (see section 2.1.1) starting on the 6^{th} January 2003 and ending on 25^{th} March 2003 (over bathing season as recommended by Water Quality Guidelines, 2003) giving a total of 114 samples for microbiological analysis. Samples were collected on the same day between 0800 and 1200 hrs every week whether it was raining or not, therefore reflecting the condition of the river at the time of sampling. In contrast Greater Wellington Regional Council samples monthly for its monitoring programme (Taylor, 2003). At each site visit the following were recorded: weather conditions, air and water temperatures, pH and water observations (i.e. water clarity).

Water samples were collected using the grab sample method. A grab sample is a sample collected at a particular time or place, which can only represent the composition of the source at that time and place. A grab sample is taken in the middle of the stream at mid-depth. Other methods can be used such as integrated sampling, however the process is a complicated and specialised process (Clesceri *et al,* 1989). Samples were collected in 500 ml labelled sterile glass bottles from the middle of the river at mid-depth, using the Mighty Gripper sampling device (see Figure 2.2). Bottles were rinsed 2 or 3 times in the water to be collected before collecting the sample (Clesceri, 1989). When collecting samples gloves and aseptic techniques were used to avoid contamination. The samples were stored in a chilly bin and when all samples were collected they were taken to the laboratory for testing (Rump, 1992). All samples were tested for *E.coli* and total coliforms within an hour of reaching the laboratory. Method of detection was the Colilert® Method (see section 2.2.1).

Figure 2.2: Mighty Gripper being used at site J5 to collect water samples

2.1.3 Fresh water samples for chemical analysis (nitrate nitrogen, ammoniacal nitrogen and dissolved reactive phosphorus)

Materials

30 ml plastic vile with a blue top screw lid (Biolab Scientific LBS 3570))
0.45um Whatman filters (Whatman International Ltd. Maidstone England)
30ml syringes (Terumo (Australia) PTY.LTD. Melbourne)
Mighty Gripper (Mighty Gripper CO., Whangarei, NZ)
Adhesive labels
Latex gloves (disposable)
Chilly bin with ice and ice trays
Gumboots
Clipboard
Field data sheets

Method

The method used for the collection of samples for chemical analysis was based on the method used by Greater Wellington Regional Council, and demonstrated by Jane Taylor (GWRC Laboratory).

Samples for chemical analyses were collected on 4 occasions (January 2003 - March 2003) from 3 selected sites J4, J5 & J7 (refer to site map 2.1). On one occasion a sample was collected from the baseline site J1, giving a total of 13 samples (see my comments in 1.6.2 for reason for sample number).

The samples to be analysed were collected using 30 ml sterile syringes on-site and then filtered through a 0.45 um filter into a 30 ml plastic discardable container (non-sterile). Samples not filtered on-site were filtered immediately on reaching the laboratory. Samples were stored in a chilly bin until they reached the laboratory. All filtered samples were preserved by freezing (-18^{o}C); this is only if samples were not analysed within 24hrs (Taylor, 2003). When required, samples were thawed and analysed for the following chemical indicators: Nitrate-nitrogen, ammoniacal-nitrogen and dissolved reactive phosphorus (DRP).

2.1.3 Collection of Samples for Biological Analysis (Periphyton)

Material

- 400 ml clear rigid plastic containers with a screw lid (Biolab Scientific, Labserv Division, East-Tamaki. Batch nos. A8083)
- Syringes (Terumo (Australia) PTY. LTD. Melbourne)
- Scalpel
- Measuring tape
- Small scrubbing brush
- Squirt bottle for river water
- A ring of appropriate size - used to define a sampling circle on each stone (e.g.- top of container lid)
- Deep sided laboratory tray or container (e.g. ice-cream container)
- Adhesive labels

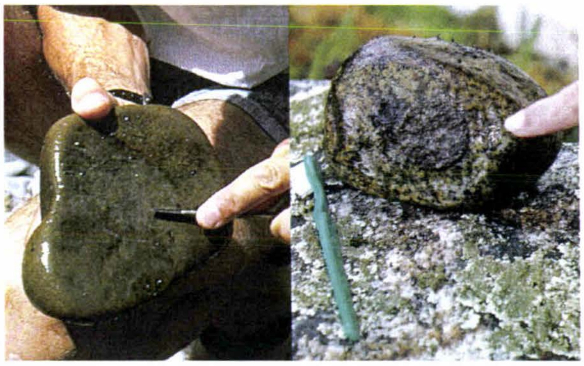
- Latex gloves (disposable)
- Chilly bin with ice and ice trays
- Clipboard
- Field data sheets

Method

Samples were collected on 4 occasions (January 2003 - March 2003) from 3 selected sites J4, J5 and J7 (refer Figure 2.1 for site location). Periphyton samples were collected from stones using the method from the Stream Periphyton Monitoring Manual (Biggs & Kilroy, 2000).

At each site a stone was selected and all periphyton was removed from the top of the stone using a scalpel from a known area of 32 cm^2 and placed in a 400 ml rigid plastic container together with any residue. The area of 32 cm^2 was determined by using a ring of appropriate size that defined the sample circle on each stone (see Figure 2.3 for a visual description).

Figure 2.3 Sampling periphyton from a defined area on surface of stone.



Any residue was rinsed from the rock into a container using a small amount of river water. Periphyton samples were chilled until sampling was finished. Periphyton samples on reaching the laboratory were frozen (-18°C) until ready for analysis (Biggs & Kilroy 2000).

2.2 Sample Analysis

After collection of water samples from the many sites along the Wainuiomata River and from tributaries (see Figure 2.1 for site map), samples were either analysed straight away or frozen for future analysis. Samples were analysed for the following water quality parameters: Microbiological (section 2.2.1), Chemical (section 2.2.2) and Biological (section 2.2.3).

2.2.1 Detection and Enumeration of *E.coli* and Total Coliforms

Materials

- 97 Quanti-trays/2000 -- counts up to 2,419 (IDEXX Laboratories)
- 250 ml sterile glass bottles (Schott
- Colilert reagents (IDEXX Laboratories)
- Controls
  - *Klebsiella pneumoniae on* nutrient agar plates - negative control
  - *E.coli* on nutrient agar plates - positive control

§ 37^{0}C incubator

§ UV light - 365 nm wavelength (De Saga)

§ Quanti-Tray Sealer (IDEXX Laboratories)

§ Bunsen Burner

Method

The Colilert® method was used to detect and enumerate total coliforms and *E.coli* from the water sample collected and was performed as described in the manufacturer's instruction guide (IDEXX Laboratories).

Figure 2.4 Overview of Colilert Method

Fresh water samples were first shaken and then 100 ml of the sample was poured into a 250 ml sterile glass bottle. Colilert reagent (IDEXX Laboratories) was added to the sample, which was then mixed by swirling and poured into Quanti-Tray/2000 (see Figure 2.4). The Quanti-Tray/2000 and sample was then sealed using the Quanti-Tray Sealer and incubated at 35^0C for 18 hours (see Figure 2.5).

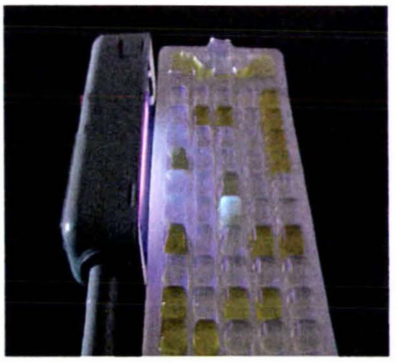
Figure 2.5

The Quanti-Tray is then sealed. incubated at 37^oC for 24 hours

To detect total coliforms the Quanti-Tray/2000 after incubation was viewed in normal light for yellow wells. Any yellow well denoted positive for total coliforms. For the detection of *E.coli* the Quanti-Tray/2000 was then placed under an UV light (365nm) in a darkened room. Yellow and Blue Fluorescence wells denoted positive for *E.coli.* Wells showing no yellow or blue fluorescence was designated as negative for *E.coli* and total coliforms (see Figure 2.6).

Figure 2.6

Following incubation the yellow wells (Total coliforms) and fluorescent wells (*E.coli*) were counted.



The most probable number (MPN), based on a number of positive wells counted (for Total coliform and *E.coli),* and were determined by using the Standard Methods for Water and Wastewater MPN Tables (1989). The MPN was written as *E.coli*/total coliform present per 100 ml.

The positive and negative controls used were *E.coli* and *Klebsiella pneumoniae*. These controls (*E.coli* & *Klebsiella pneumoniae*) were not included with every sampling analysis. Controls were run once in January 2003, February 2003 and March 2003. These controls helped to ensure validation of results (Colilert ® Method (IDEXX).

2.2.2 Evaluation of Chemicals (DRP, Nitrate-N & Ammonia-N)

Materials

- Hach DR/ 2000 Spectrophotometer Handbook
- Hach Kit Reagents (DR/2000)
- Glass Cells
- Volumetric flasks - 50ml, 10ml, 250ml (To make up Standards)
- 25ml graduated cylinders
- Automated pipettes - 100ml & 200ml (OXYF)
- Distilled water in a squirt bottle
- Tissues
- 1ml calibrated dropper

Method

Once freshwater samples were thawed they were analysed for nitrate nitrogen, ammonia nitrogen and dissolved reactive phosphorus using the HACH DR/2000 spectrophotometer method (Hach DR/2000 Spectrophotometer Handbook). Three individual 100 ml samples from the different sites were sent to the Environmental Laboratory Services (ELS) Seaview (reference laboratory) to ensure validity of the Hach Kit method (See Appendix X for results) .

To ensure familiarity of the Hach method for chemical analysis a series of pre-tests were carried out on samples (freshwater) with known values. These samples were obtained from the referee laboratory (ELS). Each sample run included a blank, a standard (diluted as directed in manual for each analysis) and a quality control sample.

Nitrate nitrogen was determined using the Cadmium Reduction Method (Range 0 to 4.5 mg/L NO_3^--N), Ammoniacal Nitrogen was determined using the Salicylate Method (Range 0 to 0.50 mg/l NH_3-N) and Dissolved Reactive Phosphorus (DRP) was determined using the Ascorbic Acid Method (Range 0 to 2.2 mg/L PO_4^{3-}). All of these methods are outlined in detail in the Hach DR/2000 Spectrophotometer Handbook.

These three chemical methods that were used to analyse the chemical indicators of water samples collected from the Wainuiomata River were very similar. Each test had a stored number, which was entered into the spectrophotometer before analysis of sample and the appropriate wavelength was set. A sample cell was then filled with 25 ml of sample and the appropriate reagent (e.g. powder pillow for nitrate nitrogen etc.) for colorimetric determination was added. Each test required a blank. Once the reagent was added to each cell and stoppered, a timer started and a reaction time began (the reaction time varied for each chemical analysed). Sample cells were then shaken for the required time. The blank was placed into the cell holder and the light shield was closed. ZERO was pressed and the result read as x mg/L for the appropriate analyte. The blank was replaced by the prepared sample and the result read as y mg/L. The concentration of the analyte being measured was determined by the difference in the two concentrations.

2.2.3 Biological Analysis (Periphyton)

A biological analysis was carried out on periphyton samples that were collected from river stones at sites J4, J5 and J7 between January and February 2003 (see section 2.1.4 for site location). Periphyton abundance (see section 2.2.3.1) and taxa identification was carried out on the collected samples (see section 2.2.3.2).

2.2.3.1 Rapid Assessment of Periphyton Biomass

Materials

- Periphyton abundance scale
- Field sheets for recording assessment of periphyton abundance.
- Periphyton field identification chart

Method

An assessment of periphyton abundance was carried out on sites J4, J5 & J7 over a period of 11 weeks using the periphyton abundance scale (Table 2.2). On each sampling visit an assessment on the amount of periphyton that was visible was carried out. River stones and the riverbed were visually studied and a score between 0, no periphyton and 5, highly abundant (covering riverbed), was noted on the field sheet for that particular site. The visual abundance scale used to assign a score to each site is shown in Table 2.2.

Table 2.2 Periphyton Abundance Scale

Score	Visual Description
0	Not visible on hand held boulders
1	Visible on hand held boulders
2	Present as clearly visible colonies on bed
3	Covering many surfaces
4	Covering most surfaces
5	Covering bed

2.2.3.2 Taxa Identification

Materials

Glass slides

Pasteur pipettes

Inverted microscope - Olympus CKX41 microscope

Method

When frozen samples were thawed they were homogenised (mixed well using a blender). A sub-sample (2 ml) was taken from the homogenised sample and placed in a small plastic vial and labelled. This sub-sample was used for taxa identification to the Genera level. A couple of drops from the sub-sample were placed on a glass slide with a coverslip and identification of taxa was made using an Olympus CKX41 microscope (inverted). Duplicate slides were prepared from each subsample for taxa identification. This was to ensure consistent results (Biggs & Kilroy, 2000).

The slides containing periphyton sample were then scanned at a low power (about 100X's) and the dominant taxa seen were identified. Slides were scanned again at a higher power (400x-700x) to confirm identification. All other non-dominant taxa were identified and Diatoms were also noted. For those taxa that were dominant, a 'D' for dominant was noted for each sub-sample (Biggs & Kilroy, 2000b). Wood (2003) provided expert assistance in the identification and verification of taxa and also with the use of the Identification Guide to Common Periphyton (Biggs & Kilroy, 2000b).

CHAPTER 3.0 Microbiological Results & Discussion

3.1 Introduction

As mentioned previously, a research project to assess the water quality of the Wainuiomata River was carried out over a 3-month period, January 2003 to March 2003 (bathing season). Samples collected (see section 2.1.2) were assessed for *E.coli* levels and total coliforms using the Colilert® Method (see section 2.2.1). These *E.coli* levels were compared to the microbiological guidelines (see section 1.4.1.1) to determine compliance and historical data to examine the impact of the WWTP closure on water quality of the Wainuiomata River.

Correlation analysis was applied to results obtained from this research to determine whether the impact site J5 was being affected by other pollution sources such as Black Creek and the Wainuiomata Stream (known to be contaminated by faecal pollution). To determine such a correlation the correlation coefficient was calculated between selected sites. It was important to consider the correlation between sites to establish trends and patterns, which could lead to identifying contamination sources.

3.2 Results

3.2.1 Compliance of Sites with Microbiological Fresh Water Guidelines, 2003

The results obtained from the analysis of fresh water samples for the presence of *E.coli* have been expressed in the form of a histogram (Figure 3.1). The guideline values for alert/amber (>260 *E.coli*/100ml) and action red mode (>550 *E.coli*/100 ml) (refer Table 1.5) have been included in the graph to illustrate levels of compliance.

Sites presenting single samples greater than 260 *E.coli*/100ml (Alert/Amber mode) would indicate a higher frequency of sampling is required for these sites. Non-compliance strictly speaking does not occur until the count exceeds *550 E.coli/1*00ml. Single samples greater than 550 *E.coli*/100 ml (Action/Red Mode) indicate non-compliance with the Microbiological Guidelines (2003). Figure 3.1 reveals that a number of the sites over the 11 weeks of sampling did not meet the Microbiological Guidelines for either the alert/amber (blue broken line) or action/red (red broken line) modes.

Figure 3.1: Histogram of *E.coli* results for all sites for the January 2003 to March 2003 sampling period & compliance with Microbiological Guidelines (2003)

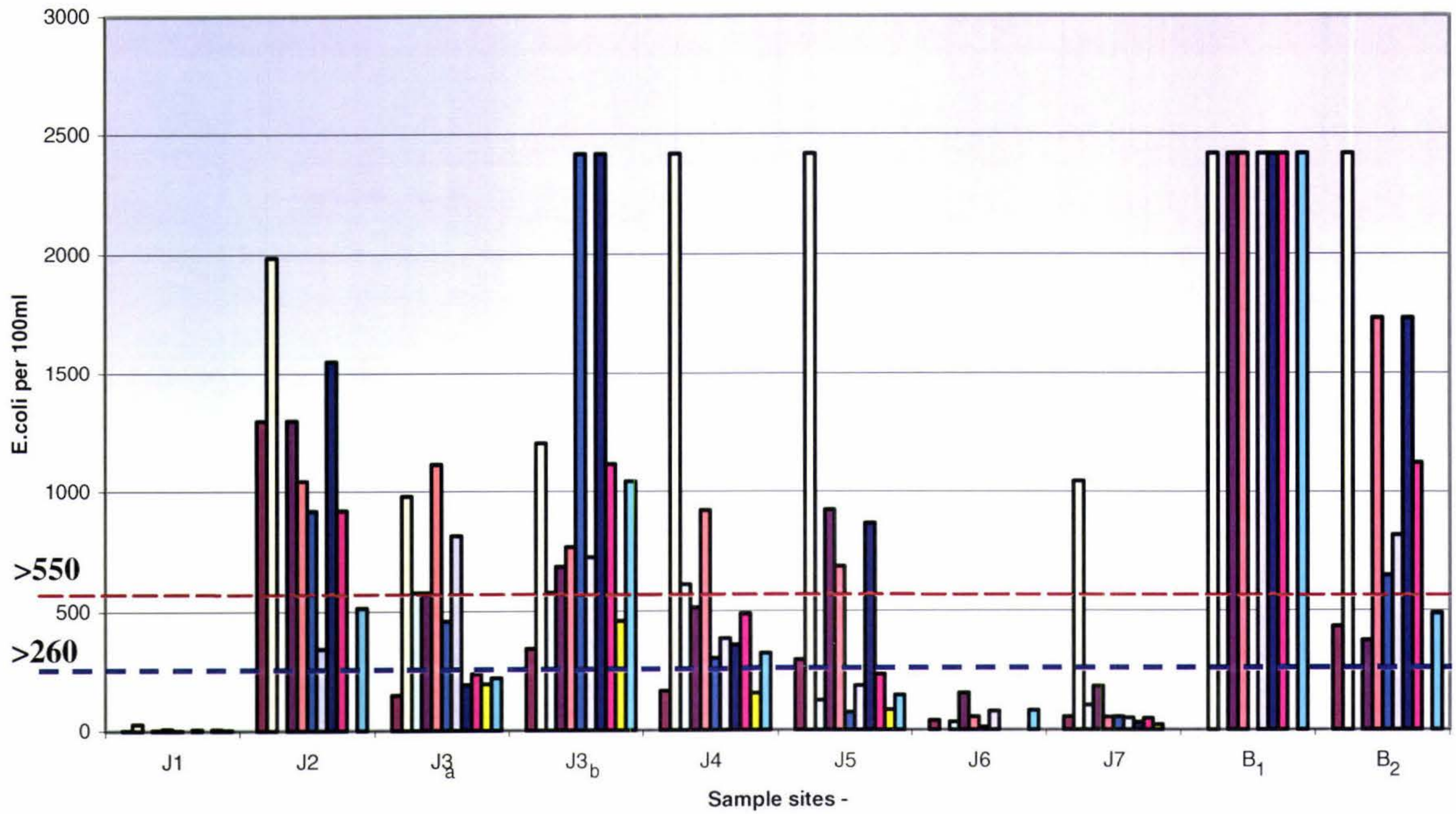


Figure 3.1 shows that sites J1 and J6 complied on all occasions to the microbiological guidelines, while all other sites did not comply on a number of occasions. Site J7 exceeded the surveillance action/red mode only once. All other sites (J2, J3a, J3b, J4, J5, B1 & B2) exceeded the microbiological guidelines for single samples (>550 *E.coli*/100ml) on a number of occasions. The control site J4 on three occasions was in the Action/Red Mode (>550 *E.coli*/100 ml) and the impact site J5 was in the Action/Red Mode on four occasions (see Table 3.1).

Table 3.1: Occasions of non-compliance of sites with the Microbiological Guidelines (2003)

Sites	Alert/Amber Mode Single sample > 260 *E.coli*/100ml	Action Red Mode Single samples > 550 *E.coli*/100ml
J1	0 (10)	0 (10)
J2	2 (9)	7 (9)
J3a	5 (11)	5 (11)
J3b	2 (11)	9 (11)
J4	6 (11)	3 (11)
J5	1 (11)	4 (11)
J6	0 (7)	0 (7)
J7	0 (10)	1 (10)
B1	0 (8)	8 (8)
B2	3 (9)	6 (9)

Note: ( ) - Weeks sampled

It was recommended by the ANZECC Guidelines (2000) that drinking water for livestock should have a median value (MV) of less than 100 thermotolerant colifoms/100 ml or faecal coliforms/100 ml (or *E.coli*). The sites situated in rural areas (where livestock graze), that exceeded the ANZECC guidelines for stock drinking were the Wainuiomata Stream (MV 1046/100 ml), Black Creek (MV >2419/100 ml) and the Golf Course (MV 236/100 ml) (see Appendix II).

3.2.2 Impact Assessment -- Sites J4 & J5 (Leonard Wood Park and the Golf Course, respectively)

Three years of faecal coliform (FC) data were obtained from Greater Wellington Regional Council for the period January 2000 to February 2003, for sites J4 and J5 (see Appendix III for GWRC data). The median was determined to measure the central tendency (measure that locates the centre of the distribution) of the data (see Table 3.2). The median value was determined from FC/100 ml data before closure and from data after closure of the treatment plant. This allowed examination of results before and after the closing of the WWTP and assessment of the microbiological quality of the water.

The correlation coefficient (r) was calculated for results obtained for the two sites J4 and J5 (see Table 3.2) to determine if site J4 had any effect on site J5. The GWRC data for the period January 2000 - February 2003) were analysed to determine trends and patterns (see Figure 3.2). This enabled identification of factors such as seasonal variations (e.g. increased land runoff due to high rainfall would cause high FC) that may have had an affect on the water quality of the Wainuiomata River at the time of sampling.

Table 3.2: Median & Coefficient of Correlation Obtained from Historical and Current Data for Site J4 & J5 (January 2000 – March 2003

	Historical Results			Research Results (2003)		
	Site J4 **Median *FC*/100 ml**	**Site J5** **Median *FC*/100 ml**	**r***	**Site J4** **Median *E.coli*/100 ml**	**Site J5** **Median *E.coli*/100 ml**	**r***
Before closure of WWTP	410	440	0.94	No value	No value	No value
After Closure of WWTP	600	270	0.86	488	236	0.9

*** correlation coefficient**

The median for site J4 (upstream of WWTP) for the period before closure of WWTP (January 2000 – November 2001) was 410 FC/100 ml and after closure (November 2001-February 2003) was 600 FC/100 ml (the means were 737 and 677 respectively). This showed an increase in the FC median level, which may indicate that site J4 was being contaminated by faecal material from sources upstream. Site J5 had a median of 440 FC/100 ml before closure of the WWTP and after closure, 270 FC/100 ml (the means were 912 and 575 respectively). The median levels have dropped quite significantly. The median level determined for site J4 (600FC/100 ml) does not appear to have had an effect on site J5 (median - 270 FC/100ml). However, if the means were used in this assessment for sites J4 and J5, the results would indicate that site J4 was affecting site J5.

The research project results for site J5 produced a median value of 236 *E.coli*/ 100 ml, which was similar to the GWRC median value (270 FC/100ml). This indicates the closing of the WWTP has caused a decrease in faecal pollution.

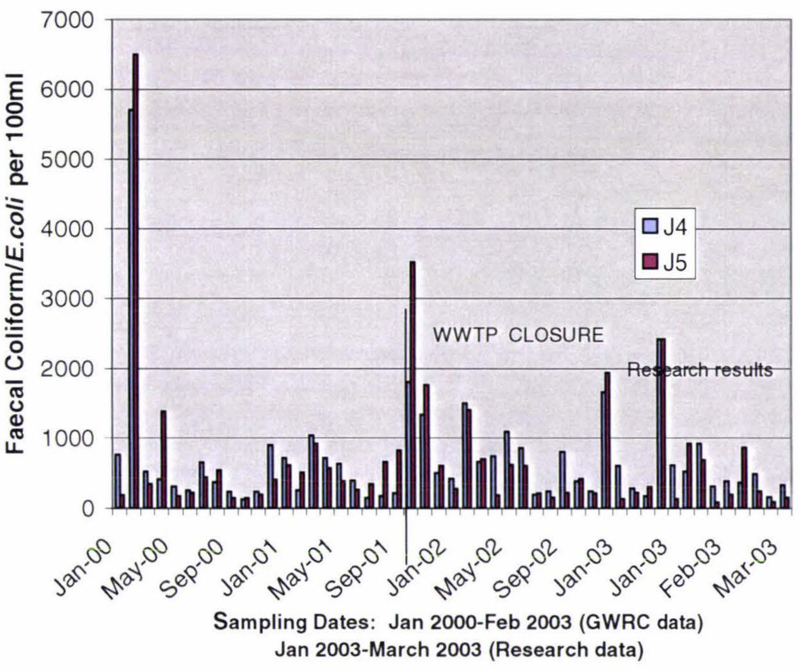
Since the closure of the WWTP, the Greater Wellington Regional Council (see appendix III) and research data for site J5 (see Table 3.1) still reveal single samples greater than 550 *E.coli*/100ml. Over the 15 months (January 2001 – February 2003) since the closure of the WWTP, the GWRC has revealed on six occasions FC levels to be in the Action/Red mode (see Appendix II & III). These results infer that other factors may be causing the continued raised levels of indicator bacteria (FC & E.coli), observed at site J5.

The GWRC historical data revealed before the closure of the WWTP, a coefficient of correlation between sites J4 and J5 of 0.94 and 0.86 after its closure, revealing a strong relationship between the two sites. For example, on the 17th February 2000 site J4 had a FC concentration of 5700/ml and J5 had a FC 6500/ml. In February 2002, after the closure of the WWTP, site J4 had a FC 1500/ml and J5 a FC 1400/ml (see Appendix III). The faecal indicator levels that were observed for sites J4 and J5 imply that the faecal contamination of the Wainuiomata River was still occurring and this contamination was having an effect on both sites, and was largely independent of the WWTP. The levels however, are not as high as was occurring before closure of WWTP.

For this research project the correlation coefficient (r) for sites J4 and J5 was 0.9 for the period January 2003 – March 2003. The "*r*" compares well with the correlation coefficient obtained from the historical data for sites J4 and J5 (0.86), indicating that there was still a strong relationship between the two sites.

Figure 3.2 demonstrates the trends for the GWRC data (January 2000-February 2003) before and after the closure of the WWTP. High peaks can be observed for both sites in February 2000, October 2001, February 2002 and December 2002. These results may be attributed to the effects of land runoff, as high rainfall was recorded at the times when these samples were taken (21,160,109 & 57mm respectively). The research data for the sampling period (January 2003-March 2003) are also plotted.

Figure 3.2: Trends for Sites J4 & J5 - before and after the closure of the WWTP (GWRC & Research Data)



GWRC data after the closure of the WWTP reveal faecal values that are still significant for site J5. For instance on 4 occasions levels of FC were greater than 1000/100ml. The trend for site J5 in relation to FC levels appears to be similar to the trend observed before the closure of the WWTP. High peaks observed for site J4 appears to be on an upward trend. The GWRC data reveals very high peaks for both sites (J4 & J5) on the 14^{th} February 2002 (1500 & 1400 *E.coli*/100ml, respectively). This high peak may have been attributed to the high rainfall experienced. There was 80 mm of rain that fell up to 24 hours prior to sampling (see Appendix V for rainfall data).

The research project data also reveals some raised levels and some high peaks. On the second week of sampling, the 13th January 2003, a high peak was observed for both sites (>2419 *E.coli*/100 ml) (refer Appendix II for *E.coli* data). The 17 mm of rain that fell, 24 hours prior to sampling, may have contributed to this high peak (see Appendix V for rainfall data).

3.2.3 Other Factors That May Influence Site J5

To assess what impact the closure of the WWTP has had on the microbiological quality of the Wainuiomata River, downstream of the WWTP (particularly site J5), other factors that may have contributed to the poor water quality observed needed to be taken into account; such as contamination from tributaries like Black Creek and the Wainuiomata Stream. These have been implicated in a number of reports as being potential sources of pollution (Hutt City Council, 1990), especially faecal pollution. Black Creek and Wainuiomata Stream both enter the Wainuiomata River at different points. Black Creek (B2) enters the river near Leonard Wood Park (J4) and the Wainuiomata Stream (J2) enters the river at Richard Prowse Park (J3a) (see Figure 2.1).

Rainfall was another factor that may have had an effect on the bacteria indicator levels observed at sites J4 and J5, as well as the other sites. To determine whether there was any correlation or relationship between rainfall (mm) and the *E.coli* or faecal coliform levels detected in both sets of data (GWRC & research data) the correlation coefficient was determined (see section 3.2.2). The Greater Wellington Regional Council data for January to March 2000-2003 was used to determine any relationship (see Appendix V to show relationship).

Flow rate may be another factor that could affect *E.coli* levels observed at sites sampled. To establish if there was a linear correlation between flow rate (volume m^3/s) and *E.coli* levels for each significant site (J2, J3a, J3b, J4 & J5), the correlation coefficient was calculated (see section 3.2.6).

3.2.4 Relationships between Tributary Sites and The Wainuiomata River Sites

Samples were collected from two tributaries (J2 & B2), as well as from sites (J3a, J3b, & J4) downstream from where these tributaries meet the Wainuiomata River. The purpose of the sampling regime was to determine whether the *E.coli* levels observed at the tributary sites were having any affect on the Wainuiomata River sites. A histogram was created for each tributary and the appropriate downstream sites (see Figure 3.3 & 3.4) to reveal any observed relationship.

Figure 3.3: Histogram of Tributary site (J2) and Wainuiomata River Sites (J3a & J3b)

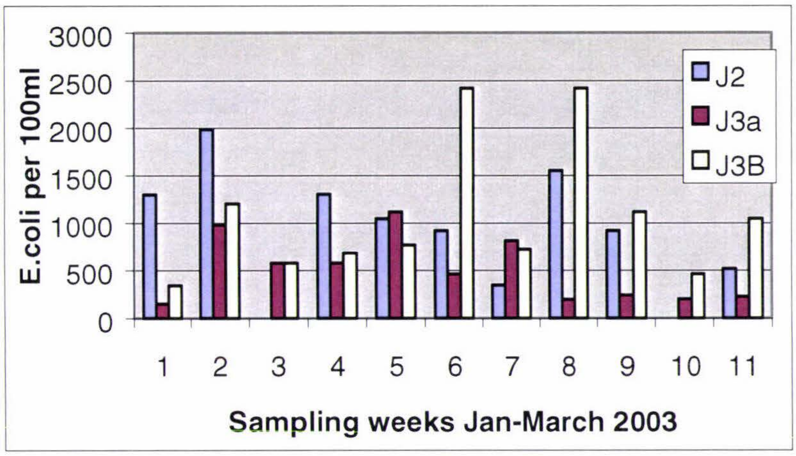


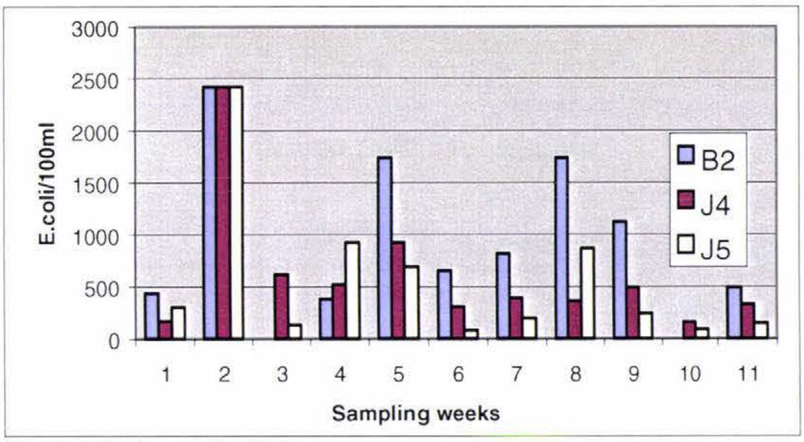
Figure 3.3 reveals the relationship between the tributary site (J2) and the Wainuiomata River site J3a and also between sites J3a and J3b. There appears to be a weak relationship between site J2 (Wainuiomata Stream, which enters the WR 40 m upstream of site J3a) and site J3a (Richard Prowse Park) (see Table 2.1 for site description). For example, in the first week of sampling, the J2 levels were over 1300 *E.coli*/100 ml and J3a were 152 *E.coli*/100 ml. No different pattern occurred for weeks 7, 8, 9 & 11. On four occasions a relationship was observed in weeks 2, 4, 5 & 6.

To determine the strength of the relationship, the correlation coefficient between sites J2 and J3a was calculated (correlation coefficient $(r) = 0.18$). The r indicates that site J2, was probably not a major source of contamination of sites J3a and J3b. The correlation coefficient between J4 and J5 was 0.18, which does not reveal any significant relationship.

This means that site J3a, was probably not having much affect on the values observed at site J3b, which was only about 300 m downstream of site J3a

Figure 3.4 reveals the relationship between the tributary site, (B2) and Wainuiomata River site, J4 and J5. Site B2 (Black Creek), which enters the Wainuiomata River approximately 100 m upstream of site J4 (Leonard Wood Park), appears to have had some effect on the *E.coli* levels observed at Leonard Wood Park (J4). This correlation coefficient between the sites, which was 0.8, supports the view that, Black Creek's poor water quality could be having some effect on the quality of water at site J4.

Figure 3.4 Histogram of Tributary Site (B2) and Wainuiomata River Sites (J4 & J5)



3.2.5 Correlation between Rainfall and *E.coli*/FC 100ml (GWRC & Research Data)

For the research project rainfall was recorded for all sites up to 72 hours before samples were collected (see Appendix I). Rainfall data was also obtained from the GWRC (for the summer months only) to enable a correlation to be determined between rainfall and the GWRC data. The correlation (r) was below 0.2 for both the GWRC and research data (see Appendix V), which indicates that the amount of rain that fell probably did not have significant effect on the *E.coli* or Faecal coliform levels detected for site J4 & J5.

3.2.6 Correlation between Flow Rate and *E.coli* Levels for Jan 2003-March 2003 Period

A weak correlation (r) between *E.coli* levels and flow rate was noted for sites J2, J3a, J4 and J5 and no correlation for site J3b (-0.22) (see Table 3.6). These results reveal that the flow rate could have had some small effect on the levels of *E.coli* detected at the above sites.

Table 3.6   *E.coli*/100ml and Flow Rate (m^3/s) for Sites J2, J3a, J3b, and J4 & J5

Weeks	J2	Flow rate	J3a	J3b	J4	J5
1	1300	0.465	152	344	167	299
2	1986	0.471	980	1203	>2419.	>2419
3		0.33	579	579	613	128
4	1303	0.33	579	687	517	921
5	1046	0.32	1120	770	920	687
6	920	0.247	461	>2419	304	76
7	345	0.25	816	727	387	190
8	1553	0.238	194	>2419	361	866
9	921	0.171	240	1120	488	236
10		0.147	197	461	157	87
11	517	0.156	225	1046	326	148
Correl.	**0.68**		**0.44**	**-0.22**	**0.57**	**0.61**

3.3 Discussion

Site J5 (Golf Course), was the most significant site to examine, if the closure of the Waste Water Treatment Plant had an impact on the water quality of the river, as it is 2.4 km downstream of the WWTP. High faecal coliforms and periphyton counts were found at this site from previous studies, with a noticeable increase in faecal coliforms downstream of the plant (Hutt City Council, 1996a).

This research and the historical data (GWRC) for site J5 (Golf Course), show that bacteria indicator levels (FC and *E.coli)* have dropped significantly since November 2001 (the closure of the WWTP). The closing of the WWTP may have been the major factor for the decline in *E.coli* and faecal coliform levels. However, there were still times at which *E.coli* levels exceeded the microbiological guidelines, therefore a public health concern. For site J5 on four occasions the *E.coli* levels were at the Action Red Mode (single samples greater than 550 *E.coli*/100 ml). Site J5 (Golf Course) is not a known bathing area so the risk to the public was minimal. People who play golf are known to enter the river to retrieve golf balls; therefore there was some public health risk. *E.coli* levels did decrease substantially further downstream of site J5, at Sites J6 and J7 (see Figure 3.1).

There was no sewage or storm water reticulation situated down the Coast Road that could affect site J5 i.e. to cause the elevated *E.coli levels* observed in the sampling period (see Figure 3.3), but there are storm water outfalls near Leonard Wood Park (see Appendix VII (d)), which may have an effect on the water quality, if there was substantial rain.

Rainfall may have been a factor on a couple of occasions where high levels of *E.coli* were observed at site J5, this is despite the fact this research showed very little correlation between rainfall and *E.coli.* In week two there had been 17 mm of rain and in week four there had been 14 mm of rain. In week two, increased levels of the indicator bacteria were observed not only for site J5, but also for all sites sampled. Site J7, which complied on all other occasions exceeded the microbiological guidelines (*E.coli* 1046/100 ml) on this day. Further investigation is needed to determine a clearer relationship between *E.coli* levels and rainfall. Investigations could include the winter months, where there is higher rainfall. A study (carried out over the summer months) by Rodger *et al* (2003), which looked at the effects of spatial and temporal bacterial quality of a lowland agricultural stream, found significant peaks at all sampling sites after the first notable rainfall spell (19.6 mm), 24 hours prior to sampling. The explanation given by Rodger *et al* (2003) for this marked increase of faecal coliforms was that faecal coliform stores from catchment land surface and streambed stones had increased over the summer due to little rainfall and low flows. When it rained the faecal coliforms were flushed into the river and due to a lower dilution factor, the levels (of faecal coliforms) were higher (Rodger *et al,* 2003).

The levels of *E.coli* observed at site J4, seemed to correlate strongly with those levels observed at site J5 (see Figure 3.4). The correlation coefficient for sites J4 and J5 was 0.8. This indicated that site J4 was contaminated by animal or human excreta from sources other than the WWTP and therefore having some impact on site J5. A Hutt City Council report (1996a) commented that other sources affecting the water quality of the Wainuiomata River might be the non-point runoff from the rural and urban sectors discharged directly into the river. These findings were also consistent with the data collected from this research project. Site J4 does receive a storm water outfall, but as sampling was carried out during the summer season, then the effect of the storm water discharge was minimised. However, as mentioned previously, on two occasions when there was significant rainfall bacteria indicator levels increased (see Appendix V).

The consistently significant levels of *E.coli* observed at site J4 (9 occasions not affected by rain) may be due to the Black Creek, which enters the river approximately 400 m upstream along with the Wainuiomata Stream (see Figure 3.1). Bother tributaries in the past, have been known to be contaminated with faecal bacteri

The Black Creek site at Upper Fitzherbet Road (B1), was in the action/red mode (>550 *E.coli* /100 ml) on all occasions (see Table 3.1). There was no sewage reticulation down this end of Fitzherbet Road (see Appendix VII (g)), which is a rural area, so most of the properties would be on septic tanks. This creek may also pose a threat to public health as the creek travels through urban areas before it enters the Wainuiomata River. Many areas along the Creek are not fenced off so it is easily accessible to the public. The Arakura Soccer grounds run up to the Creek and there is no fencing. Soccer balls fall into the Black Creek frequently and children and parents have been seen to enter the creek to retrieve the ball. The results of this research could indicate that the existing situation could be hazardous to the public.

The Black Creek site at Rowe Street (B2) was in the action/red mode on six occasions. This site could be a public health concern, as this creek flows past a motel and a popular walking track (see Appendix VII (h)). The detection of bacteria indicators such as *E.coli* in rivers and streams can signal potential presence of pathogens, such as bacteria, viruses and protozoa e.g. *Cryptosporidium* and *Giardia.* Below site B1, where the urban development is present, there are a number of storm water outlets that discharge into the Black Creek. The effect of storm water discharge on site B2 would be expected to be minimal as there had been very little rain during the sampling period (January 2003 to March 2003). However, we cannot discount such issues as cross connections (sanitary sewage being discharged into storm water drains, leaking sewerage systems, septic tank discharges and human activities such as car washing), which discharge into storm water drains and have the potential to elevate contamination levels of the river. The high levels of faecal coliforms observed at B2 could also be due to contamination of the B1 site, which is upstream of B2.

The *E.coli* levels observed at J3a and J3b sites (Richard Prowse Park) might also be having some effect on the sites J4 and J5. Site J3a on five occasions was in the action/red mode and site J3b was in the action/red mode on nine occasions (see Table 3.1).

The levels of *E.coli* observed at site J3a (Richard Prowse Park) were not affected by storm water, as the properties in this area were not connected to the storm water systems (see Appendix VII (b)). Land runoff may not of been much of an issue as there had been very little rain during the sampling period, except on two occasion, especially in the second week of sampling (17 mm) where all sites showed increased levels of *E.coli* at all sites.

This research did not reveal a significant relationship between site J2, J3a or J3b (see Figure 3.3), indicating there are other factors involved in affecting sites J3a and J3b such as other tributaries (George Creek, upstream of J3a sites) and ducks. At site J3b a number of ducks were observed on a several occasions while sampling (Duck numbers ranged 5-20). In a catchment study on the Island of Jersey (Wyer *et al*, 1995) it was shown that waterfowl such as ducks could cause a marked increased in microorganisms such as *Escherichia coli*. Further study is required to determine the cause of the high *E.coli* levels found at the Richard Prowse sites as they are at levels of public concern as it is a popular swimming area.

The levels of *E.coli* found in the Wainuiomata Stream site J2, which runs along Moores Valley Road, were also significant. On seven occasions it was in the action/red mode (>550 *E.coli*/100 ml) (refer Table 3.1). This stream runs through a number of rural properties before it flows into the Wainuiomata River at Richard Prowse Park. There was a potential health risk to homeowners, who have this stream running through their property, especially if they have small children, which may play near or in the stream. There was no sewage reticulation or storm water drains along this part of the Moores Valley, therefore the *E.coli* levels observed may include the following sources: septic tank discharges, stock effluent, agricultural activities and contributions from other tributaries that run into the stream (Appendix VII (b)).

To determine the source of contamination of the Wainuiomata Stream a sample was collected upstream of site J2 at Crowthers Road Bridge. This sample revealed *E.coli* greater than 1000/100 ml. Further upstream from this site (North end of Moores Valley Road) water samples were collected for microbiological analysis. The sample from this site complied with the guidelines for *E.coli*. These results indicated that the source of contamination could be between Crowthers Road and the North-end of Moores Valley Road, near the new housing development area. There are a couple of farms located between these sampling sites. Further investigation of this area may be able to identify the source of contamination, which if eliminated could improve the overall quality of the Wainuiomata stream, and therefore help to improve the Wainuiomata River water quality to some degree.

As studies have indicated the health risks that have been associated with contamination of water by sewage or excreta are usually gastro-enteritis and respiratory health effects (MfE, 2001). Even though these illnesses are minor and short lived, there was the potential to contract a more serious disease such as Hepatitis A, *Giardiasis, Cryptosporidiosis, Camplyobacteriosis* and *Salmonellosis* (MfE, 2001).

The high *E.coli* levels detected at various sites can also affect livestock. The sites J2, B1 and J5 did not comply with the ANZECC (2000) guidelines for stock drinking of 100-thermotolerant colifoms/100 ml of water. Surface water contaminated by animal or human faeces can cause serious illness if transmitted to livestock. Infections in livestock can have a serious economic impact by causing reduced growth, morbidity and possibly mortality. The bacteria of most concern in water supplies with unacceptable high bacteria counts are the enteric bacteria, *Escherichia coli* and *Salmonella* and to a lesser extent *Campylobacter jejuni, Yersinia enterocolitica and Y. pseudotuberculosis* (ANZECC Guidelines, 2000). Viruses and protozoa are also known to cause serious illness in livestock e.g. *Giardia.* The introduction of a high number of organisms into a herd of cattle for instance, could in turn creates a multiplier effect through the food chain such as high levels of pathogenic organisms in meat could lead to an increased risk of infection in humans (ANZECC Guidelines, 2000).

The closing of the WWTP has had some impact on the levels of indicator bacteria observed at site J5. GWRC data show that the median levels have dropped significantly. However, high levels of *E.coli* were still observed at site J5 on a number of occasions during sampling. The results indicate that the tributaries, Black Creek and the Wainuiomata Stream may be having some effect on site J5. The research results indicate that these tributaries have been contaminated by faecal material. The source of this faecal material may be from point or non-point pollution sources. Point source pollution could be discharges from failed septic tanks, or farm effluent discharged into the tributaries. Non-point source pollution could be land runoff or storm water discharge.

Many of the other sites sampled did not comply with the microbiological guidelines (2003). This is a concern, as the Wainuiomata River is an important resource to the Wainuiomata community because of its recreational value. As well there are a number of farms that water their stock at the river.

CHAPTER 4.0: CHEMICAL INDICATOR RESULTS

4.1 Introduction

Dissolved reactive phosphorus (DRP) and dissolved inorganic nitrogen (DIN), which includes nitrate-nitrogen (NO_3-N) and ammoniacal nitrogen (NH_4-N), are most likely to cause excessive algal growths in waterways if found in excessive amounts (MfE, 1999a). When there are excessive amounts of these nutrients, eutrophication can occur, i.e. the excess amounts of fuel cause excessive plant and algal growth (MfE, 1999a).

The Greater Wellington Regional Council (GWRC) data for sites J4 and J5 (from 2001 to 2002) were analysed. This was to determine if there had been any improvement in the chemical levels (nutrients) since the closure of the WWTP. Data from this research and the GWRC monitoring data (2001/2002) were compared for similar trends.

Samples were collected from sites, J1, J4, and J5 & J7 and analysed for Dissolved Reactive Phosphorus (DRP), Nitrate Nitrogen and Ammoniacal Nitrogen. These chemical indicators were selected as they had been used by the Greater Wellington Regional Council for monitoring fresh water bodies for nutrient loading within the Wellington region (including the Waiuiomata River). This facilitated comparison to the historical data collected by GWRC at site J4 and J5.

The ANZECC Guidelines (2000) provide 'Trigger Values' for the chemical indicators used in this research, i.e. nitrate nitrogen, ammoniacal nitrogen and dissolved reactive phosphorus (see Table 4.1). These trigger values limit excessive aquatic plant growth in waterways, but if they are exceeded, then an environment may be provided that could lead to adverse biological growth. It is recommended by the Guidelines (ANZECC, 2000) to use a reference site to obtain the trigger value, but as two years of monthly sampling is required to obtain such a value, the default trigger guideline has been used as alternative.

The ANZECC Guidelines (2000) for Recreational Water Quality and Aesthetics Values presented in Table 4.1 are for recreational activities such as swimming, canoeing and fishing (see section 1.4.1.3). The recreational activity most common downstream of the WWTP site is fishing. The nitrate nitrogen value of 10 g/m^3 or more detected in a waterway can be toxic to swimmers. The ammoniacal nitrogen levels greater than 0.01 g/m^3 can cause increase in algae growth making if difficult for anglers when fishing.

Table 4.1 ANZECC Guidelines (2000) Default Trigger Values (for slightly disturbed ecosystems) and Threshold Levels for Recreational Water Quality and Aesthetics.

Chemical Stressor	Default Trigger Value (g/m^3)	Guidelines for Recreational Water Quality and Aesthetics (g/m^3)
Nitrate Nitrogen	0.44	10 (human consumption)
Dissolved Reactive Phosphorus	0.01	0.015 - 0.030 (contact recreation and aesthetics)
Ammonia Nitrogen	0.021	The effects on fish suitability varies with temperature and pH)

4.2 Results

4.2.1 Comparing Chemical Indicator Levels with Guidelines

The chemical data, water temperature and pH were recorded for sites J1, J4, J5 and J7 along the Wainuiomata River are shown in Tables 4.2-4.5, respectively. Compliance of sites with the ANZECC (2000) and Guidelines for Recreational Water Quality and Aesthetics was determined. Water temperature and pH were recorded as these parameters depending on the level of ammonia detected can have a bearing on the toxicity effects of ammonia (MfE, 1997).

Table 4.2: Site J1 - Chemical indicators, Temperature and pH

Sample weeks	Date	NO_3-N (g/m^3)	DRP (g/m^3)	NH_4-N (g/m^3)	pH	Water Temp. (^oC)
1	29/01/03	0	<0.01	0.04	7.7	17
2	12/02/03	No data	No data	No data	7.8	17
3	17/03/03	0.1	0.04	0.01	7.4	18
4	25/03/03	0	0.01	0.02	7	14
Median		**0.0**	**0.01**	**0.02**		

On examination of compliance to the ANZECC Guidelines site J1 (approximately 7.5km above the WWTP) the median for each chemical stressor was either on or below the trigger value. This would be expected as this site is within the closed catchment and there would be very little nutrient input apart from what is naturally occurring e.g. the weathering of rocks. There was no sample collected on the second week of sampling due to the difficult access to the site.

Table 4.3: Site J4 - Chemical indicators, Temperature and pH

Sample weeks	Date	NO_3-N (g/m^3)	DRP (g/m^3)	NH_4-N (g/m^3)	pH	Water Temp. (^oC)
1	29/01/03	0.1	0.01	0.03	7.7	17
2	12/02/03	0	<0.01	0	7.8	17
3	17/03/03	0.1	<0.01	0.01	7.4	18
4	25/03/03	0	0.01	0.01	7	14
Median		**0.05**	**<0.01**	**0.01**		

For site J4 (0.3km upstream of the WWTP), the median value for each chemical stressor was below the trigger values (ANZECC Guidelines, 2000) and also complied with the ANZECC Guidelines (2000) values for Recreational Water Quality and Aesthetics (see Table 4.3).

Table 4.4: Site J5 – Chemical Indicators, Temperature and pH

Sample weeks	Date	NO_3-N (g/m^3)	DRP (g/m^3)	NH_4-N (g/m^3)	pH	Water Temp. (^oC)
1	29/01/03	0.1	0.03	0.02	7.7	17
2	12/02/03	0	0.08	0	7.8	17
3	17/03/03	0	0.06	0.01	7.4	18
4	25/03/03	0	0.06	0.01	7	14
Median		**0**	**0.06**	**0.01**		

For site J5 (2.4km downstream of WWTP), the impact assessment site, the median value was below the trigger value (ANZECC Guidelines, 2000) for both nitrate nitrogen and ammonia nitrogen. However, the DRP median value was above the trigger value and the Recreational Guideline value of 0.06 g/m^3 This level of DRP can trigger adverse algae growth. On each site visit moderate to high periphyton abundance was observed for this site (see Chapter 5). The NO_3-N did not exceed the water quality guidelines for recreational purposes.

Table 4.5: Site J7 – Chemical Indicators, Temperature & pH

Sample weeks	Date	NO_3-N (g/m^3)	DRP (g/m^3)	NH_4-N (g/m^3)	pH	Water Temp. (^oC)
1	29/01/03	0.4	0.10	0.17	7.7	17
2	12/02/03	0.3	0.06	0.01	7.8	17
3	17/03/03	No data	No data	No data	7.4	18
4	25/03/03	0.1	0.06	0.02	7	14
Median		**0.3**	**0.06**	**0.02**		

Table 4.5 shows, that for site J7, (approximately 13km below the WWTP) the median value for NO_3-N and NH_4-N were below the trigger value (ANZECC Guidelines, 2000) The DRP median value was above the trigger value and the Recreational Guideline value. The Nitrate Nitrogen did not exceed the recreational guidelines. The DRP value of 0.06 could trigger adverse plant growth. As with site J5, there was a moderate to high periphyton abundance, but also large amounts of algae and weed were observed for this site on most site visits.

In summary all sites sampled along the Wainuiomata River showed relatively low median values for nitrate nitrogen concentrations. Site J1 (background value) median value, did not exceed the ANZECC Guideline (2000) trigger value (0.010 g/m^3) for DRP. This is consistent with the fact that there is no or very little periphyton observed at the site. Site J4 median value did not exceed the ANZECC Guideline (2000) trigger for DRP. Site J5 DRP median value (0.06 g/m^3) was above the ANZECC Guidelines trigger value of 0.01 g/m^3. In a report by Hutt City Council (1990) it was noted that concentrations of DRP of less than 0.01 g/m^3 would be necessary to limit algal growth. Prolific alga growth was seen during the sampling regime.

Site J7 median value for DRP exceeded the ANZECC Guideline trigger value. Therefore this level of DRP would encourage algae growth. This was supported by the observation that there was significant periphyton and weed growth at this site. The NH_3--N median value for all sites sampled taking into account the prevailing pH and temperature conditions, complies with the ANZECC Guidelines (2000). On one occasion site J7 had an NH_4-N level of 0.17 g/m^3, which exceeded the ANZECC Guidelines 'trigger values' by almost 8 times.

4.2.2 Impact Assessment - Sites J4 & J5

Data for sites J4 and J5 before and after the closure of the WWTP were analysed for the period of January 2000 to December 2002 (GWRC, 2002) (see Table 4.6). Median values were obtained for each site and compliance with the guidelines was measured. Median results for site J5 before and after closure of WWTP were compared and an impact assessment evaluation made.

Site J4 median value, for DRP, nitrate nitrogen and ammoniacal nitrogen obtained from the GWRC data (between January 2000 and December 2002) were below the ANZECC Guidelines trigger value. This was consistent with the research results (see Table 4.6).
For the samples taken at site J5 the median values for nitrate nitrogen, DRP, and ammonia nitrogen before the closure of the WWTP, were above the trigger value (see Table 4.7). On closure of the WWTP the median values dropped significantly e.g. nitrate levels went from 0.8 to 0.16 g/m^3, which is below the trigger value. Ammonia nitrogen levels dropped from 0.09 to 0.05 g/m^3, which is still above the trigger value of 0.021 g/m^3. The DRP later dropped significantly from 0.021 to 0.01 g/m^3, which was the same value as the trigger value (see Table 4.7)

Table 4.6 Site J4 (GWRC Data) – Chemical Indicators

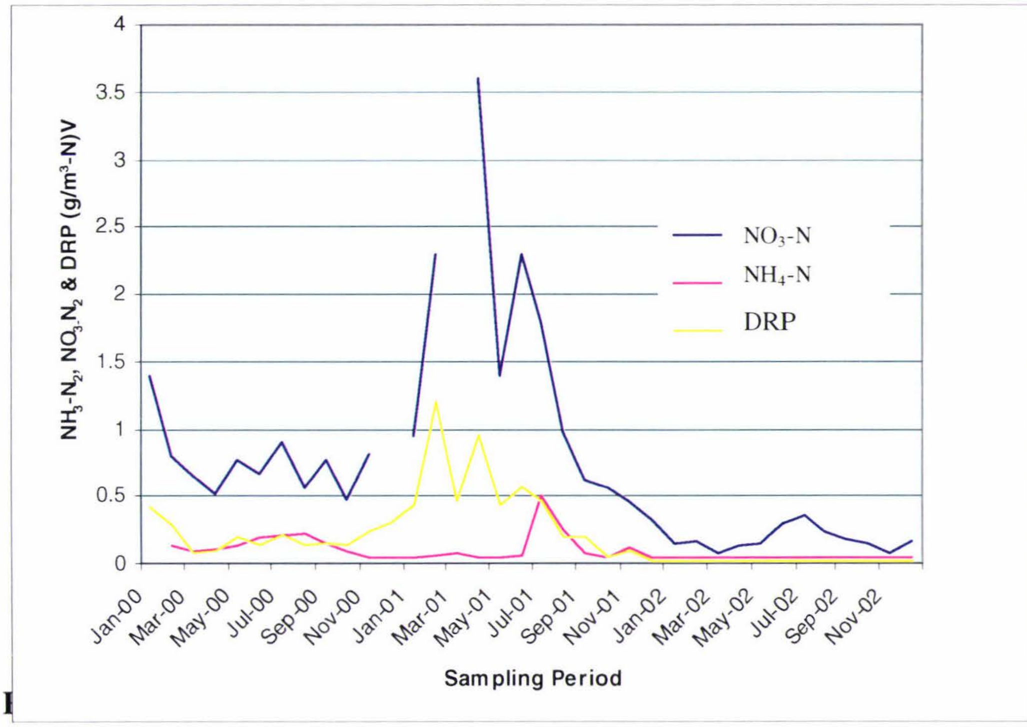
Date	Nitrate-N (g/m^3)	DRP (g/m^3)	Ammonia-N (g/m^3)
Jan-00	0.14	0.01	0.05
Feb-00	0.14	0.01	0.05
Mar-00	0.22	0.01	0.05
Apr-00	0.25	0.01	0.05
May-00	0.21	0.01	0.05
Jun-00	0.27	0.01	0.05
Jul-00	0.26	0.01	0.05
Aug-00	0.33	0.01	0.05
Sep-00	0.22	0.01	0.05
Oct-00	0.17	0.01	0.05
Nov-00	0.08	0.01	0.05
Dec-00	0.15	0.01	0.05
Jan-01	0.01	0.01	0.05
Feb-01	0.13	0.01	0.05
Mar-01	0.09	0.01	0.05
Apr-01	0.05	0.01	0.05
May-01	0.09	0.01	0.05
Jun-01	0.29	0.01	0.05
Jul-01	0.32	0.01	0.05
Aug-01	0.3	0.01	0.05
Sep-01	0.06	0.01	0.05
Oct-01	0.4	0.01	0.05
Nov-01	0.17	0.01	0.05
Dec-01	0.26	0.01	0.05
Jan-02	0.19	0.01	0.05
Feb-02	0.16	0.01	0.05
Mar-02	0.13	0.01	0.05
Apr-02	0.14	0.01	0.05
May-02	0.14	0.01	0.05
Jun-02	0.25	0.01	0.05
Jul-02	0.32	0.01	0.05
Aug-02	0.22	0.01	0.05
Sep-02	0.19	0.01	0.05
Oct-02	0.16	0.01	0.05
Nov-02	0.12	0.01	0.05
Dec-02	0.16	0.01	0.05
Median	**0.18**	**0.01**	**0.05**
Trigger value g/m^3	**0.44**	**0.021**	**0.01**

Table 4.7: Site J5 (GWRC Data) – Chemical Indicators

Date	Nitrate-N (g/m^3)	DRP (g/m^3)	Ammonia-N (g/m^3)
Jan-00	1.4	0.42	0.05
Feb-00	0.8	0.28	0.14
Mar-00	0.65	0.08	0.09
Apr-00	0.52	0.09	0.11
May-00	0.77	0.2	0.13
Jun-00	0.67	0.13	0.19
Jul-00	0.91	0.21	0.21
Aug-00	0.56	0.13	0.22
Sep-00	0.77	0.15	0.15
Oct-00	0.48	0.14	0.09
Nov-00	0.82	0.24	0.05
Dec-00		0.3	0.05
Jan-01	0.95	0.43	0.05
Feb-01	2.3	1.2	0.06
Mar-01		0.46	0.07
Apr-01	3.6	0.95	0.05
May-01	1.4	0.43	0.05
Jun-01	2.3	0.56	0.06
Jul-01	1.8	0.46	0.51
Aug-01	0.98	0.2	0.25
Sep-01	0.62	0.2	0.08
Oct-01	0.56	0.04	0.05
Nov-01 - **WWTP closed**	0.46	0.09	0.12
Dec-01	0.32	0.01	0.05
Jan-02	0.15	0.01	0.05
Feb-02	0.16	0.01	0.05
Mar-02	0.08	0.01	0.05
Apr-02	0.14	0.01	0.05
May-02	0.15	0.01	0.05
Jun-02	0.3	0.01	0.05
Jul-02	0.36	0.01	0.05
Aug-02	0.24	0.01	0.05
Sep-02	0.18	0.01	0.05
Oct-02	0.15	0.01	0.05
Nov-02	0.07	0.01	0.05
Dec-02	0.17	0.01	0.05
Median before Closure of WWTP	**0.8**	**0.21**	**0.09**
Median after Closure of WWTP	**0.16**	**0.01**	**0.05**
Trigger value g/m^3	0.44	0.021	0.01

To clearly illustrate how the closure of the WWTP had impacted on the level of nutrients at site J5, historical data was plotted using a line graph for the following chemical parameters: nitrate nitrogen, dissolved reactive phosphorus and ammoniacal nitrogen (See Figure 4.8)

Figure 4.8: Chemical Indicators: NH_4-N, NO_3-N & DRP (GWRC Data) Jan 2000 - December 2002



This graph reveals clearly how nitrate nitrogen (NO_3-N) and DRP levels have dramatically improved since the closure of the WWTP in November 2001.

4.3 Discussion

A number of studies overseas (e.g. Gamilia, 2000) have indicated through their research that nutrient loading can affect the water quality of a water body by causing an increase in algae growth. Research in New Zealand (MfE, 1997a & Mosley, 1992); have also shown a similar trend. Point sources of pollution, such as sewage treatment plants and industries, have the potential to affect the water quality of receiving waters. A study carried out in New Zealand to investigate the state of our waters, found that many small lakes particularly in the North Island were found to have eutrophic conditions (MfE, 1997) .It was suggested that these conditions were mainly due to high algae growth, causing a depletion of dissolve oxygen, which is necessary for the existence of aquatic animals. The water quality problems of these small lakes were the result of drainage, groundwater seepage, large duck populations, and in two cases, urban treated sewage (Lake Rotorua and Lake Horowhenua).

High levels of nutrients have also affected the water quality of the Wainuiomata River for many years. The main point source being the treated sewage effluent discharged from the Wainuiomata Waste Water Treatment Plant. This sewage effluent was a major source of nutrients such as nitrogen and phosphorus (see section 1.2). Several studies (Hutt City Council 1996, Hutt City Council 1998a & 1990), revealed high levels of phosphorous, nitrate and ammonia at different site along the Wainuiomata River, which may have been responsible for the prolific algae experienced in the past (see section 1.1.3).

Key nutrients; dissolved reactive phosphorus (DRP) and dissolved inorganic nitrogen (DIN), which includes nitrate-nitrogen (NO_3-N) and ammoniacal nitrogen (NH_4-N), are most likely to cause excessive algae growths in waterways (MfE, 1999a). Although nutrient concentrations are responsible (together with other factors) for stimulating growth it is the total load of the key nutrients in the ecosystem that control the final biomass of aquatic plants (ANZECC, 2000, pp. 68).

The ANZECC Guidelines trigger values for chemical indicators such as nitrate nitrogen (NO_3-N), DRP and ammoniacal nitrogen (NH_4-N) enable one to assess whether the nutrient levels detected may cause the risk of adverse affects such as increased algae growth. The trigger values outlined in the guidelines are values only applicable to New Zealand. The trigger approach is an early warning mechanism to alert the resource manager of the potential or emerging change and should be followed up.

It was demonstrated from the GWRC data at the impact sire, site J5 (Golf Course), that the nutrient levels downstream of the WWTP site, have dropped significantly since its closure. The highest nitrate nitrogen levels recorded at this site, was 2.3 g/m^3, which was in the summers of 2000 and 2001. The highest level recorded since the WWTP closure was 0.16 g/m^3 over the same period. The levels are well below the trigger value (0.44 g/m^3).

The highest ammoniacal nitrogen levels recorded between January - March 2000 was 0.14 g/m^3. The highest ammoniacal nitrogen level recorded in 2002 over the same period was 0.05 g/m^3, a significant reduction since the WWTP closure. The median level is at present 0.05 g/m^3, which is still above the trigger value (0.021 g/m^3). This ammoniacal nitrogen level may be still providing a nitrogen source for aquatic plant life, hence continued observance of moderate to high periphyton abundance. For ammonia levels to become toxic, a four-day average concentration of 1.15 g/m^3 would be required (MfE, 1997a). The higher the temperature and pH, the more toxic ammonia becomes and when there is little dissolved oxygen or carbon dioxide then the fish are aquatic life are greatly affected (HACH Company's University, 2002). In this research, the ammonia levels were well below the toxicity level for aquatic life.

The GWRC recorded the highest DRP level in the summer of 2000 and 2001 for site J5 of 1.2 g/m^3, which was above the ANZECC Guidelines (2000) trigger value of 0.01 g/m^3. Since the closure of the WWTP, the highest level of DRP recorded over the 2002 summer period was 0.01 g/m^3, which is the same as the trigger value, therefore a much improved level. Dissolved Reactive Phosphorus concentrations should be below approximately 0.015-0.03 g/m^3 to reduce the effect on periphyton biomass in flowing waters (Hutt City Council, 1998a). For the research a median of 0.06 g/m^3 for DRP was determined for sites J5 and J7. These levels did not compare well with the GWRC median of 0.01 g/m^3 for the 2002 period. There may be a number of factors that may have caused this discrepancy in results, such as sampling or analysis error or there may have been some land runoff due to rainfall, which could off caused fertilizer to be washed into the river elevating phosphorus levels.

Overall the research and GWRC median values for the chemical indicators (dissolved reactive phosphorus, nitrate nitrogen and ammoniacal nitrogen) have decreased significantly at sites J4 and J5 since the closing of the WWTP.

CHAPTER 5.0: BIOLOGICAL INDICATOR RESULTS AND DISCUSSION (Periphyton)

5.1 Introduction

The biological indicator, periphyton, was of special interest in this study as in a number of studies it has shown to be a very effective and quick indicator of pollution. Quinn, (2001) states that a number of studies carried out on New Zealand Rivers have revealed changes in obvious periphyton cover between upstream (typically "baseline") sites and downstream of "impact" sites. This indicates there are catchment activities, particularly human activity, such as municipal (previously a main point source of pollution for the Wainuiomata River) and industrial discharges. This can frequently result in increased periphyton cover, often to "nuisance" levels (>40% cover) at least once a year (Quinn, 2001). Studies reveal that the lower reaches of the river, particularly downstream of the WWTP have shown to have nuisance levels of periphyton (Hutt City Council, 1998a)

For this research project the abundance of periphyton was measured in the field for sites J4, J5 and J7 using the Visual Assessment Abundance Scale (see section 2.2.3 for method). This scale is a rapid determination and has been used in a number of studies including a study into the effects of sewage effluent on the Wainuiomata River (Hutt City Council, 1990). The taxa of the periphyton were identified using the method from the stream periphyton-monitoring manual (see section 2.1.4 for method)

Periphyton data obtained from GWRC for the past few years were analysed for the sites of interest (J4 & J5) and an impact assessment made. Results were compared with the research results.

5.2 Results

5.2.1 Periphyton Visual Assessment

On each of the 11 sampling runs between January 2003 and March 2004, a periphyton visual assessment was made at sites J4, J5 & J7 (site J4 (reference site) is upstream and J5 and J7 are downstream of the WWTP) using the Periphyton Abundance Scale. This assessment determined the relative abundance of periphyton at each site. Table 5.1 represents the results for this assessment.

Table 5.1: Periphyton Abundance Assessment (Sites J4, J5 & J7)

Sample nos.	Date	Site J4	J5	J7
1	6/1/03	3	4	No value due to poor visibility
2	13/1/03	4	Periphyton not visible due to high flows	No assessment
3	20/1/03	No assessment	4	No value due to poor visibility
4	27/1/03	4	4	4
5	3/2/03	5	5	4
6	10/2/03	3	3	4
7	12/2/03	4	4	4
8	17/2/03	4	4	4
9	24/2/03	4	4	3
10	10/3/03	4	4	3
11	17/3/03	4	4	3
12	24/3/03	4	4	Not sampled
13	26/3/03	*4*	*4*	*0*

Periphyton abundance was generally high at the upstream (J4) and downstream sites J5 and J7 (see Figure 5.1). The score assigned to sites J4, J5 & J7 ranged between 3 and 5. The score of 3 indicates that periphyton was covering many surfaces and the score of 5; periphyton was covering the bed, which indicated that the periphyton community in the Wainuiomata River was highly productive. The warm, relatively dry weather and low flows at this time of the year may have produced these algal blooms. For site J7 on most occasions there was a moderate abundance of periphyton (see Figure 5.1).

Figure 5.1: Long filamentous Periphyton on rock at site J7

Long-filamentous periphyton is visible on the rock.

5.2.2 Taxa Identification

Periphyton samples were collected on four occasions at sites J4 and J5 and one sample was collected from J7. Samples were scraped from a defined area on a selected rock from each site. Taxa identification was performed (see section 2.2.3.2 for method). The species of algae (taxa) that were dominant for each sample were noted and a 'D' denoted beside the taxa identified. Other species such as diatoms were noted and if possible, identified (see Table 5.2 for taxa identification). The purpose of the taxa identification was to determine whether the algae present were those that are present in polluted waters or whether they are the algae present in unpolluted waters.

Table 5.2: Taxa Identification

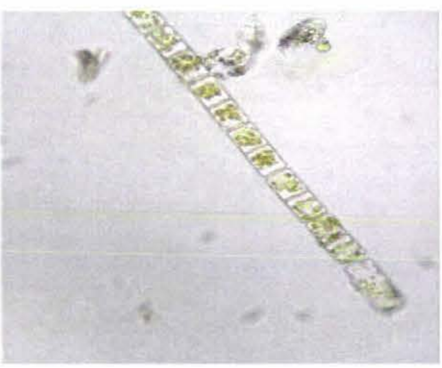
Sample nos.	Site	Date	Taxa	Rank
1	**J4**	**12/2/03**	Melosira Diatoms	Dominant
2	**J5**	"	Melosira Mougeotia Diatoms	Dominant Occasional
3	**J7**	"	Mougeotia Melosira Diatoms	Dominant Occasional
4	**J4**	**24/2/03**	Melosira Frustulia (Diatom) Other Diatoms	Dominant
5	**J5**	"	Melosira Mougeotia Frustulia Mougeotia	Dominant Occasional
6	**J4**	**24/3/03**	Melosira Diatoms	Dominant
7	**J5**	"	Melosira Cosmarium (single celled green algae) Other Diatoms	Dominant
8	**J4**	**26/3/03**	Melosira Navicula (Diatom) Other Diatoms	Dominant
	J5	"	Mougeotia Navicula Other diatoms	Dominant

The taxa identified for each site are shown in Table 5.2. Photographs of the taxa identified in Table 5.2 were taken and these clearly show the algae present for each site (See Figure 5.2 a-d)

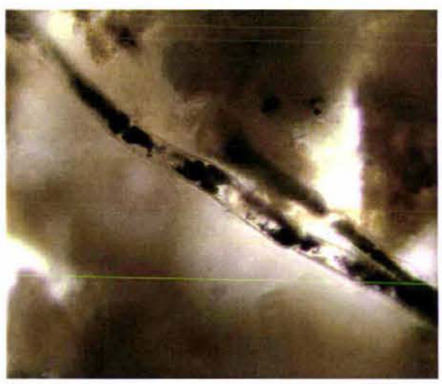
The unbranched filamentous diatom *Melosira* was the most dominant species at all sites (see Table 5.2 and Figure 5.2a). *Melosira* is found throughout the country in slow to medium flowing open lowland streams. It can dominate the periphyton community in moderately enriched situations. It is reported as both a 'clean water species' and 'moderately polluted water species'. The unbranched filamentous algae *Mougeotia* (commonly known as green algae) (see Figure 5.2b) and *Cosmarium*, single celled (non-diatom) (see Figure 5.2c) was also found at site J5. *Mougeotia* is typically found in moderately to highly enriched and slow flowing streams. *Cosmarium* is most abundant in lakes and wetland areas. However, the occurrence of some *Cosmarium* species in the periphyton communities of streams and rivers can be common (Biggs & Kilroy, 2000b).

Figure 5.2: Taxa Identification Photographs for Sites J4, J5 and J7

a) Melosira - unbranched filament or or single cells (Diatoms)



b) Mougeotia - unbranched filaments



c) Cosmarium - single cells (non-diatom)

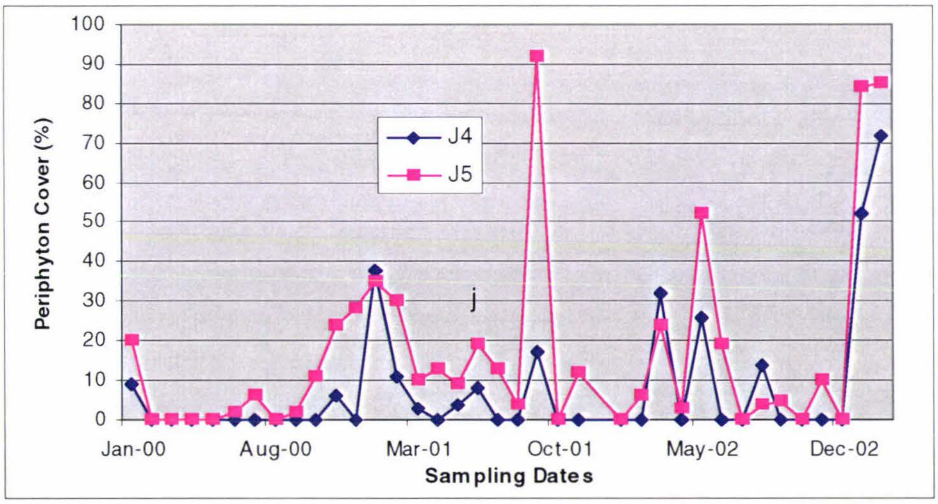
d) Frustulia - single cells (diatoms)

Frustulia (See Figure 5.2d) an unbranched diatom was observed for sites J4 and J5. *Frustulia* can be found in periphyton samples over a range of conditions and is quite common Navicula a small, slender diatom with capitated ends was observed on one occasion, at sites J4 and J5. Navicula is widespread and relatively common and occasionally dominates periphyton communities in relatively clean streams (Biggs & Kilroy, 2000b, pp.175)

5.2.3 Impact Assessment (GWRC Data) - Percent Periphyton Cover

The GWRC periphyton data (percent cover) for sites J4 and J5 (January 2000 to February 003) was analysed and an impact assessment made (see Appendix IX). This was achieved by analysing the percent periphyton cover before and after closure of WWTP. The data for the percent periphyton cover is represented graphically in Figure 5.3

Figure 5.3: Periphyton Cover (%) for Sites J4 & J5



On a number of occasions the periphyton communities exceeded the maximum suggested levels recommended in the New Zealand Periphyton Guidelines (2000) for percent cover (>30%) for aesthetic/recreational, trout habitat and angling. Before the WWTP closure (summer months) the percent cover was between 0 and 68% and since its closure the levels have ranged between 0 and 85%. Further sampling is needed to determine whether this level of periphyton cover will continue. In January and February 2003, the percent cover was 84 and 85%, which is relatively high.

5.3 Discussion

The analysis of periphyton in relation to water quality is a biological approach based on the theory that different species vary in their tolerance to environmental stressors (Kroeger *et al*, 1999). By determining the relative abundance or other attributes of species comprising a community and by knowing how a particular environment influences a species we can determine how well a body of water supports aquatic life. Water can become toxic to animals if tainted with prolific algae. It is a requirement under the Resource Management Act (1991) that local councils ensure that nuisance growth of organisms is kept under control (Biggs, 2000a). In the Wainuiomata River there has been prolific growth of periphyton downstream of the now demised sewage treatment plant, causing eutrophication for a number of years.

Periphyton is essential for ecosystems to function and contribute most to aquatic life, as they are transducers of light energy. The algae convert the sunlight via their chlorophyll molecules; absorb CO_2 and other nutrients providing food for other aquatic life (Bold, 1985). The nutrients that are absorbed (such as phosphorous and nitrogen) from the surrounding environment, when synthesized can cause enlarged cells increasing the biomass of the periphyton community.

There are many organisms in rivers/streams that are sensitive to not only the magnitude of stress created by factors such as periphyton proliferation, but also the duration of such events. Therefore the length of time that a stream or river contains moderate to high periphyton biomass will also be important factor to consider in relation to whether high periphyton biomass is likely to have an adverse effect on fish communities. If the duration of the periphyton is short lived then the affect on the aquatic life will be minimal. However, during low flows where the periphyton biomass is very high then direct lethal effects may occur on fish. This occurs through changes in water quality as a result of photosynthetic and respiration activity of the periphyton (Biggs, 2000a)

Studies have shown that as algae biomass increases, the internal cycling of nutrients also increases and fewer nutrients are taken up from the stream water for growth. As periphyton by its mass can indicate there are problems with a particular waterway they are very useful pollution indicators (Kroeger *et al*, 1999).

When looking at the GWRC historical data for site J5, the levels of periphyton did not remain at high levels for long periods; therefore there would have been a minimal affect on the fish community. The algae, *Melosira* and *Mougeotia* identified in the recent research are usually present in moderately enriched situations, therefore their presence could indicate, that there are still significant levels of nutrients present in the river bed. Sites downstream of the Wainuiomata Waste Water Treatment Plant site, particularly, the Golf Course (J5) are still revealing moderate to high periphyton productivity, even though nutrient levels have decreased significantly since the closure of the WWTP (see Figure 5.4).

Figure 5.4: Periphyton (brown/matt) visible on rock at site J5)

Other factors causing the abundant growth of the periphyton community need to be addressed. It is usually certain conditions such as high nutrient and water temperature levels and low flows that can cause prolific algae growth (Biggs, 2000a). Even with the low flows that occurred during sampling, the high level of periphyton observed at site J5 was surprising when taking into account the relatively low chemical indicator levels present and the normal water temperatures (see Chapter 4). Biggs (2000a) states that nutrients in the riverbed may be a food source for the periphyton community. Fish feeding on the riverbed may disturb the nutrients, which then can be assimilated by the periphyton. The continued periphyton productivity experienced at site J5 may also be due to nutrients in the riverbed been disturbed.

CHAPTER 6: OVERALL CONCLUSION & RECOMMENDATIONS

6.1 CONCLUSION

This research project, which investigated the water quality of the Wainuiomata River, in particular those sites that have been affected by the now decommissioned Wainuiomata Waste Water Treatment (WWTP), has revealed some interesting results. Studies have shown that the major source of pollution of the Wainuiomata River until recently has been the effluent from the Wainuiomata Waste Water Treatment Plant. Even though the effluent was of a reasonable good quality, it still contained high bacterial counts and there were high concentrations of phosphorous and nitrogen (Hutt City Council 1998a).

This section will summarise the results of each water quality indicator for the Wainuiomata River as investigated and conclusions will be drawn. The water quality indicators selected for this study were, *E.coli (*microbiological), DRP, nitrate nitrogen (NO_3-N), ammoniacal nitrogen NH_4-N (chemical) and periphyton (biological). These results were assessed in relation to impact (closing of the WWTP) and the compliance with the appropriate guidelines (see Chapters 2, 3 and 4).

6.1.1 *E.coli*

This research project has revealed that the level of faecal indicators (*E.coli* and faecal coliforms) observed at site J5 (impact site) since November 2001 (closing of the WWTP), have significantly dropped in relation to FC/*E.coli*/100 ml. However, the levels observed at this site since the treatment plants closure on many occasions has not complied with the Microbiological Guidelines (2003).

This research also revealed that a number of the sites sampled along the Wainuiomata River, including two tributaries (Black Creek and Wainuiomata Stream) did not comply on number of occasions with the microbiological guidelines for single samples greater than 550 *E.coli*/100 ml. The sites that did not comply were as follows: J2, J3a, J3b, J4, J5, B1 & B2 (see section 3.0). Sites J2, J5 & B1 did not meet the ANZECC Guidelines (2000) for stock watering.

When determining the source of faecal contamination of those sites that did not comply with the guidelines, the effects of flow rate, storm water and rainfall were taken into account and the relationship between sites was also assessed. The research revealed that there was some correlation between some sites in regard to *E.coli* levels, but the strongest relationship observed was between sites J4 & J5 and between B2 and J4. The relationship between sites J4 (upstream of WWTP) and J5 (downstream of WWTP) was observed both before and after the closure of the WWTP. This relationship seen, indicates that the Leonard Wood Park site (J4), which flows into site J5, may be contaminated with faecal pollution from sources such as septic tank, farm effluent and storm water. As there is also a strong correlation between site B2 and J4 this indicates that the Black Creek is having some effect on the Leonard Wood Park site. This may explain why significant levels of faecal indicators, *E.coli* and FC, are still occurring at site J5 even after the closure of the WWTP. The faecal indicator levels decrease further downstream of site J5 i.e. at sites J6 (Prickle Track) and J7 (Coast Road Bridge). These sites show less significance levels of *E.coli*.

As mentioned previously the B2 site seems to have some affect on site J4, as there is a strong correlation ($r = 0.8$). This is probably due to the high levels of *E.coli* that was observed at site B1 on all sampling occasions. The faecal pollution levels observed on a number of occasions at site J4 (Leonard Wood Park), therefore may have been due to the tributaries Black Creek and also to some extent the Wainuiomata Stream (see Figure 3.1). This research project and other studies (refer Hutt City Council, 1990) have found that these tributaries are potential sources of faecal pollution. The high *E.coli* levels observed, particularly Black Creek (B1) and the Wainuiomata Stream (J2), could be due to septic tank failure, land runoff or stock effluent making its way into the stream, as there is no sewage reticulation service or storm water outlets affecting these sites. These waterways are still contaminated and will continue to have an effect on the water quality of the Wainuiomata River.

As the research was carried out over the summer months there had been very little rainfall recorded apart from two occasions (see Appendix I for rainfall data). On the two occasions where there was significant rain, 72 hours before sampling, an increase in *E.coli* levels was observed at all sites. On the other occasions where high *E.coli* levels were observed and no rain effects, other factors must be involved. Even though this research indicates that land runoff (due to significant rainfall) had little effect on results, this was because the rainfall was minimal and not sufficient to cause runoff. The correlation observed between flow rate and *E.coli* levels was weak, indicating that flow rate has had a small affect on the *E.coli* levels, but was not the main factor.

The sites J2, J3a, J3b, J4, J5, B1 and B2 that did not meet the Microbiological Guidelines, especially the sites where the public are known to swim (J3a, J3b & J4), are a concern, because of the potential harm to the public. The presence of *E.coli* is indicative of human or animal faecal pollution. This is a public health concern as the water may also contain pathogen such as *Cryptosporidium*, *Giardia* or viruses, which if ingested, may cause illness.

The Microbiological Water Quality Guidelines (2003) (Fresh Water) produced by the Ministry for the Environment, should be utilised when assessing fresh water for its microbiological aspects. It is important that we manage and monitor the condition of our freshwater resources (rivers and lakes) so as to protect the public that use these resources for recreational activities as well as livestock. It is also important to ensure our fresh water resources are sustained. The Microbiological Guidelines for Fresh Water (2004) require that popular bathing areas along rivers (such as the Wainuiomata River), streams and lakes be monitored and where single samples exceed 550 *E.coli*/100ml a number of actions need to be undertaken (See 6.2.1 for Recommendations).

6.1.2 *Nitrate-N, Ammonia-N & DRP*

The GWRC data for site J5 on analysis have revealed that the level of the chemical indicators; DRP, Nitrate Nitrogen and ammoniacal nitrogen have decreased significantly since the closure of the WWTP. However, the ammonia levels (median 0.06 g/m^3) were still above the ANZECC Guideline trigger value for ammonia (0.021g/m^3). The results from this research project when compared with the GWRC data showed a similar trend. This research project detected DRP (0.06 g/m^3) for site J5, which was at higher levels than the GWRC data (0.01) revealed for a similar period. This discrepancy may have been due to a number of factors; such as interference in the samples due to undissolved powder pillows, leading to an elevated result. If the Hach Spectrophotometer method were to be used again for future studies for the analysis of DRP in water samples, a recommendation would be, to filter samples before placing into the spectrophotometer, eliminating possible interference. Another factor that may have caused the elevated DRP at site J5 (rural area) may have been fertilizer washed from the surrounding land into the river, elevating phosphorus levels. GWRC data for site J5 show that the DRP levels have dropped from significant levels to insignificant levels since the closure of the WWTP. This drop in the chemical indicators, particularly DRP and NO_3-N at site J5 (downstream of the WWTP site), indicated there had been a significant decrease in nutrient input into the river.

6.1.3 Periphyton

Periphyton abundance is still moderate to high at site J5 (downstream of WWTP site) even though the Wainuiomata Waste Water Treatment Plant is no longer providing a continual source of nutrients into the river. The results from the chemical testing indicated that the nutrient levels at site J5 were low and at these levels, moderate to high periphyton abundance would not be expected. The high levels of periphyton observed at site J5 must be due to other factors. It has been known that sediments may release a substantial source of phosphorus (sometimes referred to as internal loading) for many years after external inputs have been minimised. Phosphorus can be released from the sediment into the river under the following conditions: (Chorus & Bartram1999)

- In shallow unstratified systems with high pH (>9.8)
- Bioturbulation caused by feeding fish and invertebrates)

The Wainuiomata River over the summer season at certain places can be quite shallow due to low rainfall. At site J5, the river is quite wide and during sampling the water level was quite low, therefore the conditions for phosphorus release from sediment as indicated by Chorus & Bartram (1999), may be why site J5 is showing periphyton growth.

The results of this research indicated that the ecosystems downstream of the WWTP site might be still under some stress during the low flow periods (summer period) because of the periphyton blooms. However, as the duration of these periphyton blooms could be relatively short (summer months only), there should be minimal affects on the aquatic life. When assessing a river's flow requirements, the degree of enrichment should be taken into account. A recent study carried out by Biggs *et al* (2003) suggested that rivers that are enriched would be more sensitive to river-flow abstraction than rivers with low flows but are not enriched. Those rivers that are more sensitive because of enrichment would require higher minimum flows to maintain river health (Biggs *et al,* 2003). The local councils under resource consent were required to ensure flow rate of the Wainuiomata River at certain points was maintained at a certain level to ensure good health of the river. However algae blooms observed in this recent study still predominate over the summer period compromising this.

Site J7, which was situated near farmland, on most occasions was not aesthetically pleasing due to the high periphyton abundance and the heavy weed growth visible. The clarity of the water was poor on most occasions. The periphyton levels observed may be due to nutrients entering the river from land runoff from neighbouring farms. Fertilizer used on the farms may invariably make its way into the river after moderate to heavy rainfall.

Under the RMA (1991), a requirement for waters being managed for aquatic ecosystem purposes is that there shall be no "undesirable biological growths" as a result of any discharge of a contaminant into water. Water can become toxic to aquatic life if tainted with prolific algae. It is a requirement under the RMA, (1991) that Regional Councils ensure that nuisance growth of organisms is kept under control (Biggs & Kilroy, 2000b). One solution that was to be undertaken by local council before the decision to close the WWTP to solve this problem was flushing trials. Water was to be stored in a dam and released regularly to ensure periphyton was flushed off river substrate. In a Hutt City Council report (1998b) it was stated that the closure of the sewage treatment should no longer require such flushing trials. In Lake Taupo the improved treatment and the removal of all sewage effluent discharge from the lake improved the eutrophication that occurred there (Menon & Perkins, 1995). Flushing of the Wainuiomata River could still be of benefit, as it would help minimise periphyton proliferation (See section 6.6.2 for recommendations).

Not only is the quality of fresh water important in terms of health and industry (that harness water i.e. manufacturing), but also in relation to Tourism. New Zealand's image of being "green" and "clean “ is a major draw card for many visitors to our country, which is important in terms of prosperity for New Zealand’s economy. People visit this country from around the world in their desire to visit unspoiled rivers and lakes. Overseas there is a growing concern in relation to maintaining our fresh water resources. In 2001, at the Stockholm Water Symposium they (scientists and environmentalists) predicted that if current trends continue, the shortage of water would extend beyond the semi arid and arid regions. The expanding demand for water would drain some of the world's largest rivers, leaving them dry throughout most of the year. Already 450 million people in 29 countries face serious shortages affecting the wealthiest and the poorest nations (NZ Herald, 2001). The state of our fresh water is therefore vital to this country, not only for the above issues but also for the future generations who will depend on these water resources in centuries to come (MfE, 1999a). It is important then that we manage and monitor the condition of our freshwater resources (rivers and lakes) to ensure their sustainability. Resource Management Act, 1991 was introduced so that these waterways are managed effectively to ensure they are sustained. The Regional Councils are responsible for ensuring that the criteria set out in the RMA, 1991 for freshwater are implemented.

Overall this research has shown that the closure of the WWTP has impacted on the J5 (Golf Course), downstream of the WWTP in a number of ways. The chemical indicator levels (NO_3-N, NH_4-N and DRP) have dropped significantly; periphyton was still in abundance at site J5 (no real improvement seen) and the median level of the microbiological indicator, *E.coli* has dropped. However, site J5 on a number of occasions did not comply with the Microbiological Guidelines (2000). A number of sites sampled upstream of the WWTP, particularly the tributary sites (Black Creek and Wainuiomata Stream) on a number of occasions did not comply with the Microbiological Guidelines (2003). This is a concern, as the public are known to swim near where these tributaries enter the Wainuiomata River. The Wainuiomata River is used for recreational activities such as swimming, canoeing and fishing so it is important, that these continuing water quality concerns (namely *E.coli* levels and periphyton proliferation) are monitored by the Greater Wellington Regional Council, and actions taken to eliminate these concerns (see Section 6.2 for recommendations). Pollution sources such as septic tanks or farm discharges may be affecting sites upstream of the WWTP.

6.2 RECOMMENDATIONS

From this research project there were a number of recommendations in relation to the microbiological (*E.coli*) and biological (periphyton) indicators as follows:

6.2.1 *E.coli*

1) The sites along the Wainuiomata River that are used for bathing should be identified and monitored in the same way Greater Wellington Regional Council monitors popular beach sites. Sites J3a, J3b, and J4, which are popular swimming areas did not comply with the microbiological guidelines, therefore the actions as recommended by the Microbiological Guidelines (2003) should be undertaken as follows:

- **Alert/Amber Mode: Single sample greater than 260 *E.coli*/100ml**

- Increase sampling to daily (initial samples will be used to confirm if a problem exists).
- Consult the CAC (Catchment Assessment Category) to assist in identifying possible location of sources of faecal contamination
- Undertake a sanitary survey report on sources of contamination

- **Action/Red Mode: Single sample greater than 550 *E.coli*/100ml**

- Increase sampling to daily (initial samples will be used to confirm if a problem exists)
- Consult the CAC to assist in identifying possible location of sources of faecal contamination
- Undertake a sanitary survey report on sources of contamination
- Erect warning signs
- Inform public through the media, that a public health problem exists

2) Further investigation into the source of contamination for the two tributaries Black Creek and Wainuiomata Stream needs to be carried out. The people who use these streams, for example eeling, recreational activities or for watering of stock, need to be informed of their potential risk to human and animal health.

3) Further research into the effects of flow rate and rainfall on *E.coli* levels in waterways such as the Wainuiomata River could be beneficial to those that manage and monitor the rivers. This information would allow for a better understanding of how water quality can be affected.

6.2.2 Periphyton

1) This study has further substantiated the usefulness of using periphyton as a pollution indicator of fresh water and it is recommended that periphyton should now be commonly used, as is *E.coli*. In most research into the water quality of fresh water bodies, chemical and microbiological parameters are more commonly used.

2) There are a number of options available to help reduce periphyton proliferation, for instance:
   a) To investigate the sediment release of phosphorus (nutrients) into the Wainuiomata River from sites where periphyton abundance was observed. One option for counteracting phosphorus release from sediment is the dredging of sediment or treatment of phosphorus in sediment. Dredging to remove phosphorus can be quite costly, therefore treatment of phosphorus would be recommended. The phosphorus can be trapped in the sediment by oxidation with insoluble iron
   b) High water velocities can prevent thick periphyton accumulation. It would be valuable to carry out field experiments on the effects of different flow variability, as flushing is a potentially useful mechanism for controlling proliferations of periphyton in rivers (MfE, 1997a).
   c) The abstraction of water from the Wainuiomata River for the Wainuiomata Water Treatment Plant may need to be reduced in the summer months (especially if there is proliferation of periphyton) or monitored carefully, too ensure plenty of water is left in the river to flush periphyton from substrate such as rocks.
   d) Implementation of riparian shading. Recent research in New Zealand and North America indicated that periphyton proliferation could be controlled with riparian shade. These studies have shown that periphyton could be reduced by up to 90% (MfE, 2000)

Overall this research has shown that the water quality of the Wainuiomata River at a number of sites is not that wonderful. The Greater Wellington Council needs to continue with the monitoring of the Wainuiomata River and to investigate a number of options to remedy and mitigate the continued effects of pollution on the water quality of this river.

APPENDIX 1 - Microbiological Data (January 2003 - March 2003)

SITE: J1 Manuka Track (Closed Catchment)

Month	Week	Time	Weather	Rainfall (mm) Day 24hr 48hr 72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100 ml	E.coli/ 100ml	Observations
Jan 6/1	1	8.30am	Cloudy/little wind	0.0 3.0 0.0 0.0	0.465	20	12	6.8	38.2	2	Water clear No visible pollution
13/1	2	10.45am	Overcast/light rain/little wind	9.0 8.0 0.0 0.0	0.471	15	18	7.8	128	28	Water clear No visible pollution
No sampling	3			0.0 0.0 0.0 0.0							
27/1	4	8.30am	Overcast/little wind/warm	5.0 9.0 8.0 0.0	0.330	15	16	7.6	178	4	
Feb 3/2	5	9.20am	Overcast/little wind/warm	9.0 0.0 0.0 8.0	0.320	17	16		187	8.5	
10/2	6	9.05am	Sunny/little wind	0.0 0.0 0.0 0.0	0.247	17	13	6.0	82.8	2.0	
No sample	7			0.0 0.0 1.0 18.0							
24/2	8	9.00	Overecast/ slight winds/light rain	2.0 0.0 0.0 1.0	0.202	12.6	11.2	7.1	62.4	5.2	
March 11/3	9	8.50	Warm/overcast	0.0 0.0 0.0 0.0	0.171	14.4	13.2	7.1	>2419.2	154.1	Sample taken below water treatment plant
18/3	10	9.00	Sunny/light winds	0.0 0.0 0.0 0.0	0.156	18.6	11.3	7.6	90.7	6.3	
25/3	11	9.15	Sunny/light winds	0.0 0.0 0.0 0.0	0.147	18.5	13.2	6.9	231	4.1	

SITE: J2 Wainuiomata Stream (Tributary)

Month	Week	Time	Weather	Rainfall(mm) Day 24hr 48hr 72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100ml	E,coli/ 100ml	Observation
Jan	1	8.30am	Cloudy/little wind	0.0 3.0 0.0 0.0	0.465	20	12	6.9	1413.6	1299.7	
	2	8.15am	Overcast/light rain/little wind	9.0 8.0 0.0 0.0	0.471	15	13	7.9	>2419.2	1986	
No sampling	3										
	4	9.40am	Overcast/little wind/warm	5.0 9.0 8.0 0.0	0.330	15	15	8	>2419.2	1303	
Feb	5	9.50am	Overcast/little wind/warm	9.0 0.0 0.0 8.0	0.320	17	16	7	>2419.2	1046	
	6	9.30am	Sunny/little wind	0.0 0.0 0.0 0.0	0.247	17	16	6.5	>2419.2	920.8	
	7	9.30am	Overcast/light winds	0.0 0.0 1.0 18.0	0.226	16.6	15	8	>2419.2	344.6	
	8	9.30	Overecast/ slight winds/light rain	2.0 0.0 0.0 1.0	0.202	12.6	13.5	7.6	>2419.2	1553.1	
March	9	9.00	Warm/overcast	0.0 0.0 0.0 0.0	0.171	14.4	14.2	7.3	>2419.2	920.8	
Not sampled	10			0.0 0.0 0.0 0.0							
	11	9.45am	Sunny/light winds	0.0 0.0 0.0 0.0	0.147	18.5	15.7	7.4	>2419.2	517	

SITE: J3a - Richard Prowse Park (50 metres downstream of Wainuiomata-Stream)

Month	Week	Time	Weather	Rainfall(mm) Day	24hr	48hr	72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100ml	E.coli/ 100ml	Observation
Jan	1		Cloudy/little wind	0.0	3.0	0.0	0.0	0.465	20	15	7.2	1986.3	151.5	Water clear
	2	11.30am	Overcast/light rain/little wind	9.0	8.0	0.0	0.0	0.471	15	15	7.5	>2419.2	980	Water clear No visible pollution
	3	9.30am	Overcast/little wind/warm	0.0	0.0	0.0	0.0	0.330		16	7.1	1986	579	
	4	8.30am	Overcast/little wind/warm	5.0	9.0	8.0	0.0	0.330	15	15	7.4	>2419.2	579	
Feb	5	10.00	Overcast/little wind/warm	9.0	0.0	0.0	8.0	0.320	17	16	7.2	>2419.2	1119.9	
	6	10.30	Sunny/little wind	0.0	0.0	0.0	0.0	0.247	17	16	6.0	>2419.2	461	
	7	11.55	Overcast/light winds	0.0	0.0	1.0	18.0	0.226	16.6	15.5	7.8	>2419.2	816.4	
	8	10.45	Overcast/ slight winds/light rain	2.0	0.0	0.0	1.0	0.202	12.6	13.4	7.5	1553.1	193.5	
March	9	10.10	Warm/overcast	0.0	0.0	0.0	0.0	0.171	14.4	14.2	7.3	>2419.2	240.1	
	10	10.25	Sunny/light winds	0.0	0.0	0.0	0.0	0.156	18.6	13.5	7.6	1732.9	196.8	
	11	10.10	Sunny/light winds	0.0	0.0	0.0	0.0	0.147	18.5	15.7	7.6	>2419.2	224.7	

SITE: J3b Prowse Park (Below village bridge 300-400m downstream of Wainuiomata -Stream)

Month	Week	Time	Weather	Rainfall(mm) Day	24hr	48hr	72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100ml	E E,coli/ 100ml	Observation
Jan	1		Cloudy/little wind	0.0	3.0	0.0	0.0	0.465	20	14	7.4	1413.6	344.1	clear
	2	11.20	Overcast/light rain/little wind	9.0	8.0	0.0	0.0	0.471	15	19	7.6	>2419.2	1203	
	3	9.40	Overcast /warn	0.0	0.0	0.0	0.0	0.330	No data	16	7.2	>2419.2	579	Periphyton visible on rocks
	4	10.00	Overcast/little wind/warm	5.0	9.0	8.0	0.0	0.330	15	16	7.7	>2419.2	687	
Feb	5	9.50	Overcast/little wind/warm	9.0	0.0	0.0	8.0	0.320	17	16	7.3	>2419.2	770	
	6	10.00	Sunny/little wind	0.0	0.0	0.0	0.0	0.247	21	16	6.0	>2419.2	>2419.2	
	7	9.55	Overcast/light winds	0.0	0.0	1.0	18.0	0.226	16.6	14.8	7.8	>2419.2	727	
	8	10.30	Overcast/ Slight winds/light rain	2.0	0.0	0.0	1.0	0.202	12.6	13.4	7.4	>2419.2	>2419.2	11-15 ducks seen in vicinity
March	9	10.00	Warm/overcast	0.0	0.0	0.0	0.0	0.171	14.4	14.4	7.4	>2419.2	1119.9	No ducks
	10	10.15	Sunny/light winds	0.0	0.0	0.0	0.0	0.156	18.6	14.2	7.7	>2419.2	461.1	
	11	10.00	Sunny/light winds	0.0	0.0	0.0	0.0	0.147	18.5	16.2	7.6	>2419.2	1046.2	

SITE: J4 Leonard Wood Park (0.3km upstream of WWTP)

Month	Week	Time Am pm	Weather	Rainfall(mm) Day	24hr	48hr	72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100ml	E.coli/ 100ml	Observation
Jan	1		Cloudy/little wind	0.0	3.0	0.0	0.0	0.465	20	14	7.4	1986	167	Clarity poor
	2	8.30	Overcast/light rain/little wind	9.0	8.0	0.0	0.0	0.471	15	12	7.1	>2419.2	>2419.2	
	3	10.15	Overcast/warn	0.0	0.0	0.0	0.0	.330	No data	17	7.3	1986	613	
	4	10.45	Overcast/little wind/warm	5.0	9.0	8.0	0.0	0.330	15	15	7.2	>2419.2	517	Periphyton visible on bed
Feb	5	10.50	Overcast/little wind/warm	9.0	0.0	0.0	8.0	0.320	17	17.6	7.2	>2419.2	920	Brown matt periphyton on
	6	10.50	Sunny/little wind	0.0	0.0	0.0	0.0	0.247	20	18	7.9	>2419.2	304.4	Filament brown periph.
	7	10.15	Overcast/light winds	0.0	0.0	1.0	18.0	0.202	16.6	15	7.8	1986.3	387	Brown filam. Periph.
	8	11.20	Overcast/ Slight winds/light rain	2.0	0.0	0.0	1.0	0.202	12.6	14.1	7.0	1986.3	360.9	
March	9	11.00	Warm/overcast	0.0	0.0	0.0	0.0	0.171	14.4	16.2	7.6	>2419.2	488.4	Poor clarity. Bubbles in water
	10	11.20	Sunny/light winds	0.0	0.0	0.0	0.0	0.156	18.6	15.7	7.7	922.8	156.5	
	11	10.35	Sunny/light winds	0.0	0.0	0.0	0.0	0.147	18.5	18.1	7.6	2419.2	325.5	

SITE: J5 Golf Course (2.4km downstream of WWTP)

Month	Week	Time	Weather	Rainfall(mm) Day 24hr 48hr 72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100ml	E.coli/ 100ml	Observation
Jan	1		Cloudy/little wind	0.0 3.0 0.0 0.0	0.465	20	16	7.9	921	299	clear
	2	8.50	Overcast/light rain/little wind	9.0 8.0 0.0 0.0	0.471	15	12	7.6	>2419.2	>2419.2	Poor clarity
	3	11.00	Overcast/warn	0.0 0.0 0.0 0.0	.330	No data	17	7.2	921	128	Periphyton visible on bed
	4	10.45	Overcast/little wind/warm	5.0 9.0 8.0 0.0	0.330	15	15	7.2	>2419.2	517	Periphyton visible on bed
Feb	5	11.10	Overcast/little wind/warm	9.0 0.0 0.0 8.0	0.320	17	17	8.0	1732.9	686.7	Filamentous periphyton
	6	11.10	Sunny/little wind	0.0 0.0 0.0 0.0	0.247	No data	18.5	7.9	>2419.2	76	Filament brown periph.
	7	10.30	Overcast/light winds	0.0 0.0 1.0 18.0	0.202	16.6	15.9	7.5	>2419.2	190	Brown filam. Periph.
	8	11.55	Overecast/ Slight winds/light rain	2.0 0.0 0.0 1.0	0.202	12.6	14.3	7.0	2419.2	866.4	
March	9	11.15	Warm/overcast	0.0 0.0 0.0 0.0	0.171	14.4	16.4	7.4	22419.2	235.9	Poor clarity. Bubbles in water
	10	11.50	Sunny/light winds	0.0 0.0 0.0 0.0	0.156	18.6	15.8	7.9	866.4	86.5	
	11	11.15	Sunny/light winds	0.0 0.0 0.0 0.0	0.147	18.5	18.4	7.4	533.5	148.3	

SITE: J6 -Prickle Track (7.0 km downstream of WWTP)

Month	Week	Time	Weather	Rainfall(mm) Day 24hr 48hr 72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100ml	E.coli/ 100ml	Observation
Jan	1		Cloudy/little wind	0.0 3.0 0.0 0.0	0.465	20	19	8.0	1986.3	41.3	clear
No sampling - Too slippery	2			9.0 8.0 0.0 0.0							
	3	11.50	Overcast/warn	0.0 0.0 0.0 0.0	.330	No data	19	7.3	1733	34	Clrar
	4	11.50	Overcast/little wind/warm	5.0 9.0 8.0 0.0	0.330	15	15	7.4	1733	158	
Feb	5	11.40	Overcast/little wind/warm	9.0 0.0 0.0 8.0	0.320	17	19	7.2	1732.9	56.5	Filamentous periphyton
	6	11.55	Sunny/little wind	0.0 0.0 0.0 0.0	0.247	20	22	8.2	1732.9	11.8	Green algae bloom
	7	11.10	Overcast/light winds	0.0 0.0 1.0 18.0	0.202	16.6	16	7.6	1553	79	Green algae bloom - prolific
No sampling	8										
March No sampling	9										
No sampling	10			0.0 0.0 0.0 0.0							
	11	11.40	Sunny/light winds	0.0 0.0 0.0 0.0	0.147	18.5	18.3	7.5	1119.9	82	

SITE: J7- Coast Road Bridge (12.0 km downstream of WWTP)

Month	Week	Time	Weather	Rainfall(mm) Day	24hr	48hr	72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ ml	E.coli/ 100ml	Observation
Jan	1		Cloudy/little wind	0.0	3.0	0.0	0.0	0.465	20	18	8.0	727	57	Poor clarity
	2	9.00	Overcast/light rain/little wind	9.0	8.0	0.0	0.0	0.471	15	14	7.5	>2419.2	1046	Weed and algae noted
	3	11.30	Overcast/warn	0.0	0.0	0.0	0.0	.330		17	7.4	1046	105	Weed and green periph
	4	11.40	Overcast/little wind/warm	5.0	9.0	8.0	0.0	0.330	15	No data	7.4	1300	186	Weed and green periph
Feb	5	11.35	Overcast/little wind/warm	9.0	0.0	0.0	8.0	0.320	17	18	7.4	461.1	55.4	Weed/matt & green filamentous
	6	11.35	Sunny/little wind	0.0	0.0	0.0	0.0	0.247	20	20	8.2	1299.7	57.3	Long Filament green periph
	7	10.50	Overcast/light winds	0.0	0.0	1.0	18.0	0.202	16.6	17.1	7.4	277.8	50.4	Filam. periph.
	8	12.20	Overcast/ slight winds/light rain	2.0	0.0	0.0	1.0	0.202	12.6	16	7.3	248.1	32.7	Long fil. Green periph.
March	9	11.40	Warm/overcast	0.0	0.0	0.0	0.0	0.171	14.4	16.1	7.5	325.5	48.2	Golden scum around river edge
	10	12.30	Sunny/light winds	0.0	0.0	0.0	0.0	0.156	18.6	17.1	7.7	139.6	22.8	
No sample taken	11			0.0	0.0	0.0	0.0							

SITE: B1- Black Creek (Upper Fitzherbet Road (Tributary)

Month	Week	Time	Weather	Rainfall(mm) Day	24hr	48hr	72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100ml	E.coli/ 100ml	Observation
Jan	1		Cloudy/little wind	0.0	3.0	0.0	0.0	0.465	20	18	6.5	>2419.2	>2419.2	Poor clarity
	2	9.55	Overcast/light rain/little wind	9.0	8.0	0.0	0.0	0.471	15	13	8.8	>2419.2	>2419.2	
Not sampled	3			0.0	0.0	0.0	0.0							
	4	11.45	Overcast/little wind/warm	5.0	9.0	8.0	0.0	0.330	15	No data	7.3	>2419.2	>2419.2	
Feb	5	12.45	Overcast/little wind/warm	9.0	0.0	0.0	8.0	0.320	17	19	7.2	>2419.2	>2419.2	
Not sampled	6			0.0	0.0	0.0	0.0							
	7	11.40	Overcast/light winds	0.0	0.0	1.0	18.0	0.202	16.6	16.4	No data	>2419.2	>2419.2	
	8	10.20	Overcast/ slight winds/light rain	2.0	0.0	0.0	1.0	0.202	12.6	14	7.3	>2419.2	>2419.2	
March	9	9.30	Warm/overcast	0.0	0.0	0.0	0.0	0.171	14.4	14.4	7.3	>2419.2	>2419.2	
Not sampled	10			0.0	0.0	0.0	0.0							
	11		Sunny/light winds	0.0	0.0	0.0	0.0	No data	18.5			>2419.2	>2419.2	

SITE: B2 Black Creek (Enters Wainui. River just before Leonard Park Site)

Month	Week	Time	Weather	Rainfall(mm) Day 24hr 48hr 72hr	Flow Rate m^3/s	Air Temp. ^0C	Water Temp. ^0C	pH	Total Coliform/ 100ml	E.coli/ 100ml	Observation
Jan	1		Cloudy/little wind	0.0 3.0 0.0 0.0	0.465	20	18	6	>2419.2	435	Very poor clarity
	2	9.40	Overcast/light rain/little wind	9.0 8.0 0.0 0.0	0.471	15	13	5.9	>2419.2	>2419.2	
Not sampled	3			0.0 0.0 0.0 0.0							
	4	12.15	Overcast/little wind/warm	5.0 9.0 8.0 0.0	0.330	15	No data	7.3	>2419.2	980	
Feb	5	12.45	Overcast/little wind/warm	9.0 0.0 0.0 8.0	0.320	17	20	6.9	>2419.2	1732.9	
	6	12.00	Sunny/little wind	0.0 0.0 0.0 0.0	0.247		23	7.4	>2419.2	648.8	
	7	11.25	Overcast/light winds	0.0 0.0 1.0 18.0	0.202	16.6	16.2	No data	>2419.2	816.4	
	8	10.10	Overcast/ Slight winds/light rain	2.0 0.0 0.0 1.0	0.202	12.6	14.4	7.3	>2419.2	1732.9	
March	9	9.50	Warm/overcast	0.0 0.0 0.0 0.0	0.171	14.4	16.6	7.3	>2419.2	1119.9	
No sample	10			0.0 0.0 0.0 0.0							
	11	1.55	Sunny/light winds	0.0 0.0 0.0 0.0	0.147	18.5	19.2	7.3	>2419.2	488.4	

APPENDIX II *E.coli* and Total Coliform Results for all Sites

E.coli: Single Sample Values (E.coli per 100ml) for Each Site

Weeks	J1	J2	J3a	J3b	J4	J5	J6	J7	B1	B2
1	2	1300	151.5	344	167	299	41	57	>2419	435
2	28	1986	980	1203	>2419	>2419		1046	>2419	>2419
3			579	579	613	128	34	105		
4	4	1303	579	687	517	921	158	186	>2419	380
5	9	1046	1120	770	920	689	57	55	>2419	1733
6	2	920	461	>2419	304	76	12	57		650
7		345	816	727	387	190	79	50	>2419	816
8	5	1553	194	>2419	361	866		33	>2419	1733
9	154*	921	240	1120	488	236		48	>2419	1120
10	6		197	461	156	87		23		
11	4	517	225	1046	326	148	82		>2419	488
N		9	11	11	11	11	7	10	8	9

The results from the analysing of fresh water for *E.coli* from all sites sample are expressed here in the form of a table.

Total Coliforms; Single Sample Values for (total coliform per 100ml) each Site

Weeks	J1	J2	J3a	J3B	J4	J5	J6	J7	B1	B2
1	38	1414	1986	1553.1	1986	921	1986	727	>2419	>2419
2	128	>2419	>2419	>2419.2	>2419	>2419		>2419	>2419	>2419
3			1986	>2419.2	1986	921	1733	1046		
4	178	>2419	>2419	1732	>2419	1553	1733	1300	>2419	>2419
5	187	>2419	>2419	>2419.2	>2419	1733	1733	461	>2419	>2419
6	83	>2419	>2419	>2419.2	>2419	>2419	1733	1299		>2419
7		>2419	>2419	>2419.2	1986	>2419	1553	278	>2419	>2419
8	62	2419	1553	>2419.2	1986	2419		248	>2419	2419
9	>2419*	>2419	2419	>2419.2	>2419	2419		326	>2419	>2419
10	91		1733	>2419.2	921	866		140		
11	2	>2419	>2419	>2419.2	2419	534	1120		>2419	>2419

These results from the analysing of fresh water for total coliforms from all sites sample are expressed here in the form of a table...

*Sample was not taken from within closed catchment but below water treatment plant. Result quite different from other results so is to be excluded

APPENDIX III **GWRC Historical Data - Sites J4 & J5**

Wainuiomata River Historical Data
GWRC Historical Faecal coliform Data Jan 2000-Feb 2003

	J4	J5	
Jan-00	760	180	
Feb-00	5700	6500	
Mar-00	520	340	
Apr-00	410	1380	
May-00	310	170	
Jun-00	250	218	
Jul-00	650	440	
Aug-00	370	540	
Sep-00	230	140	
Oct-00	120	140	
Nov-00	230	189	
Dec-00	900	400	
Jan-01	710	610	
Feb-01	250	510	
Mar-01	1040	920	
Apr-01	710	570	
May-01	630	380	
Jun-01	390	260	
Jul-01	140	340	
Aug-01	170	660	
Sep-01	210	820	
Oct-01	1800	3520	
Nov-01	1330	1760	Sewage Treatment closed
Dec-01	500	600	
Jan-02	420	270	
Feb-02	1500	1400	
Mar-02	660	700	
Apr-02	740	180	
May-02	1090	620	
Jun-02	860	600	
Jul-02	190	210	
Aug-02	240	150	
Sep-02	800	220	
Oct-02	380	420	
Nov-02	240	210	
Dec-02	1660	1940	
Jan-03	600	130	
Feb-03	280	220	
	737	912	Means before closure
	677	575	Means after closure
		0.94	Correlation between J4 and J5 before closure
		0.86	Correlation between J4 and J5 after closure
	410	440	Medians before closure
	600	270	Medians after closure

APPENDIX IV: Correlation between Sites J4 and J5

Median/Mean and Correlation Coefficient for sites J4 & J5

Sampling dates	Site J4	Site J5	
Jan-03	167	299	
Jan-03	2419	2419	
Jan-03	613	128	
Jan-03	517	921	
Feb-03	920	687	
Feb-03	304	76	
Feb-03	387	190	
Feb-03	361	866	
Mar-03	488	236	
Mar-03	157	875	
Mar-03	326	148	
	605	551	Mean
		0.9	Correlation between J4 and J5
	488.4	235.9	Medians

The correlation coefficient was determined between site J4 and J5 to determine whether site J4 is having an effect on site J5 i.e. whether there is some form of relationship.

APPENDIX V: Correlation Between Rainfall and FC/100 ml (GWRC Historical Data, January 2000 - February 2003)) and Research Data, January 2003 - March 2003) for Sites J4 & J5

Site J4 - Rainfall (mm) and Faecal coliforms/100ml (GWRC data)

Sample date	Day mm	24hr	48hr	72hr	FC/100ml
20/01/00	0	0	0	0	760
17/02/00	11	10	0	0	5700
23/03/00	0	7	15	0	520
12/0101	0	13	0	0	710
15/02/01	0	0	0	15	250
15/03/01	0	10	0	0	1040
18/01/02	0	0	0	26	420
14/02/02	25	63	1	20	1500
14/03/02	3	0	0	0	660
16/01/03	0	2	16	9	600
14/02/03	18	0	0	0	280
r*		0.2	-0.178	-0.193	

r*- Correlation coefficient

Site J4 - Rainfall (mm) and *E.coli*/100ml (Research Data)

Sample date	Day	24hr	48hr	72hr	E.coli/100ml
6/1/03	0	3.0	0	0	167
13/1/03	9	8	0	0	>2419
20/1/03	0	0	0	0	613
27/1/03	5	9	5	6	517
3/2/03	9	0	0	8	920
10/2/03	0	0	0	0	304
17/2/03	0	0	1	18	387
24/2/03	2	0	0	1	361
10/3/	0	0	0	0	488
17/3/03	0	0	0	0	157
4/3/03	0	0	0	0	326
r*.		-0.119	-0.07	-0.06	

Site J5 - Rainfall and Faecal coliforms (GWRC Data)

Sample date	Day	24	48	72	FC/100ml
20/01/00	0	0	0	0	180
17/02/00	11	10	0	0	6500
23/03/00	0	7	15	0	340
12/0101	0	13	0	0	610
15/02/01	0	0	0	15	510
15/03/01	0	10	0	0	920
18/01/02	0	0	0	26	270
14/02/02	25	63	1	20	1400
14/03/02	3	0	0	0	700
16/01/03	0	2	16	9	130
14/02/03	18	0	0	0	220
r*.		0.179	0.2	-0.178	

J5 - Rainfall (mm) and E.coli/100ml (Research Data)

Sample date	Day	24hr	48hr	72hr	E.coli/100ml
6/1/03	0	3.0	0	0	299
13/1/03	9	8	0	0	>2419
20/1/03	0	0	0	0	128
27/1/03	5	9	5	6	517
3/2/03	9	0	0	8	687
10/2/03	0	0	0	0	76
17/2/03	0	0	1	18	190
24/2/03	2	0	0	1	866
10/3/03	0	0	0	0	236
17/3/03	0	0	0	0	87
24/3/03	0	0	0	0	148
r*		-0.03	-0.03	-0.10	

APPENDIX VI: Correlation between Total Coliforms and *E.coli*/100 ml

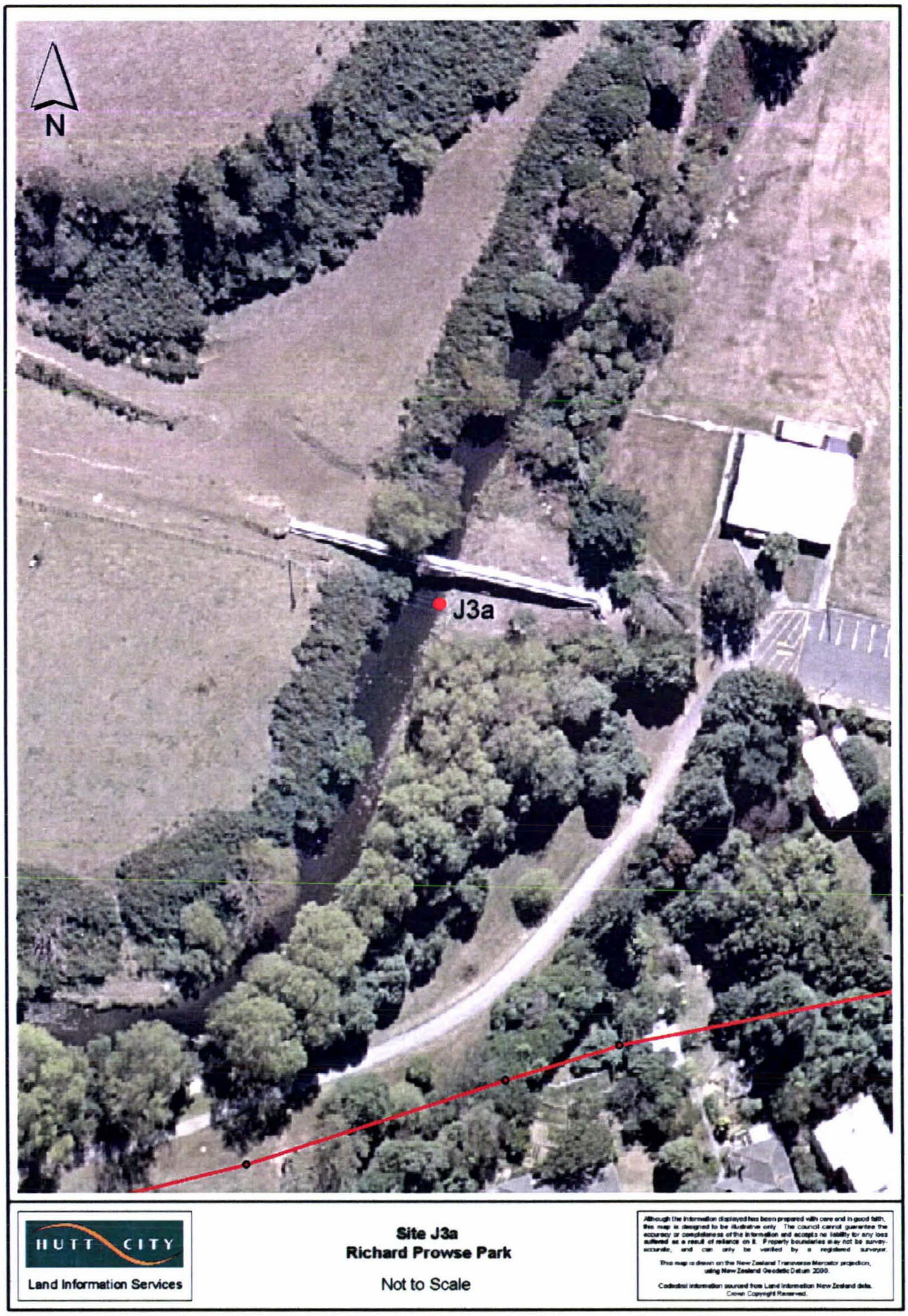
Total Coliform and *E.coli* per 100ml for Significant Sites

Weeks	J2 T.Coli	J2 E.coli	J3a T.Coli	J3a E.coli	J3b T.Coli	J3b E.coli	J4 T.Coli	J4 E.coli	J5 T.Coli	J5 E.coli
1	1414	1300	1986	151.5	1553	344	1986	167	921	299
2	>2419	1986	>2419	980	>2419	1203	>2419	>2419	>2419	2419
3			1986	579	>2419	579	1986	613	921	128
4	>2419	1303	>2419	579	1732	687	>2419	517	1553	921
5	>2419	1046	>2419	1120	>2419	770	>2419	920	1733	687
6	>2419	920	>2419	461	>2419	2419	>2419	304	>2419	76
7	>2419	345	>2419	816.4	>2419	727	1986	387	>2419	190
8	2419	1553	1553	193.5	>2419	2419	1986	361	2419	866
9	>2419	921	2419	240.1	>2419	1120	>2419	488	2419	236
10			1733	196.8	>2419	461	9218	1575	866	87
11	>2419	517	>2419	224.7	>2419	1046	2419	326	534	148

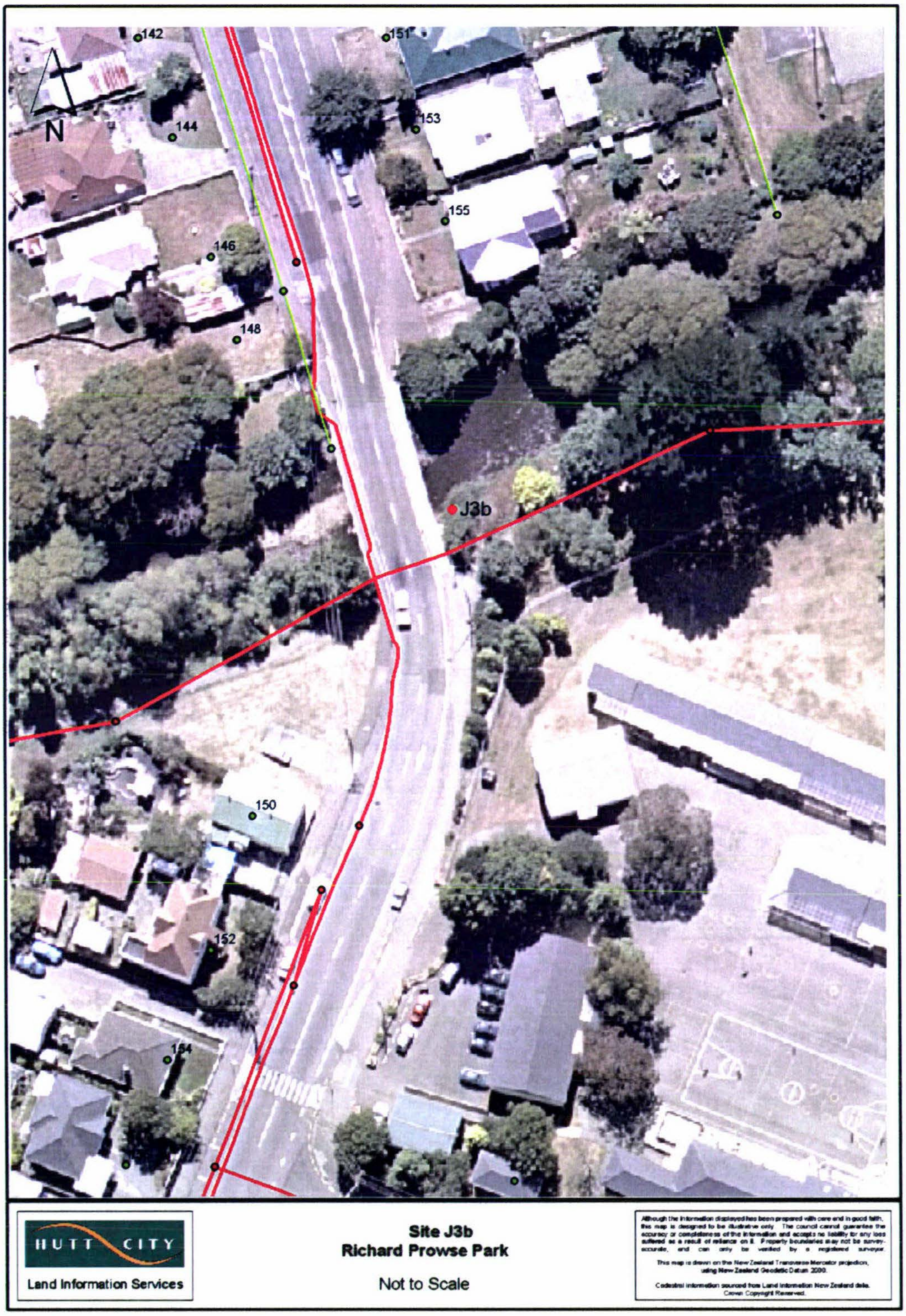
Determining the correlation between Total Coliforms and *E.coli* was not possible as the dilution of values > 2419.2 were required for an accurate assessment.

APPENDIX VII: Aerial Photographs showing the different sites sampled. The Green line represents storm water and the thick red line is the sewage reticulation. Photographs obtained from ARC GIS Systems, version software 8.3, Hutt City Council (2004), with the help of Greig Drummond.

(a) Site J2: Wainuiomata Stream – rural area. There is no storm water or sewage reticulation visible.



(b) Site J3a: Richard Prowse Park - semi urban. No storm water pipes seen.



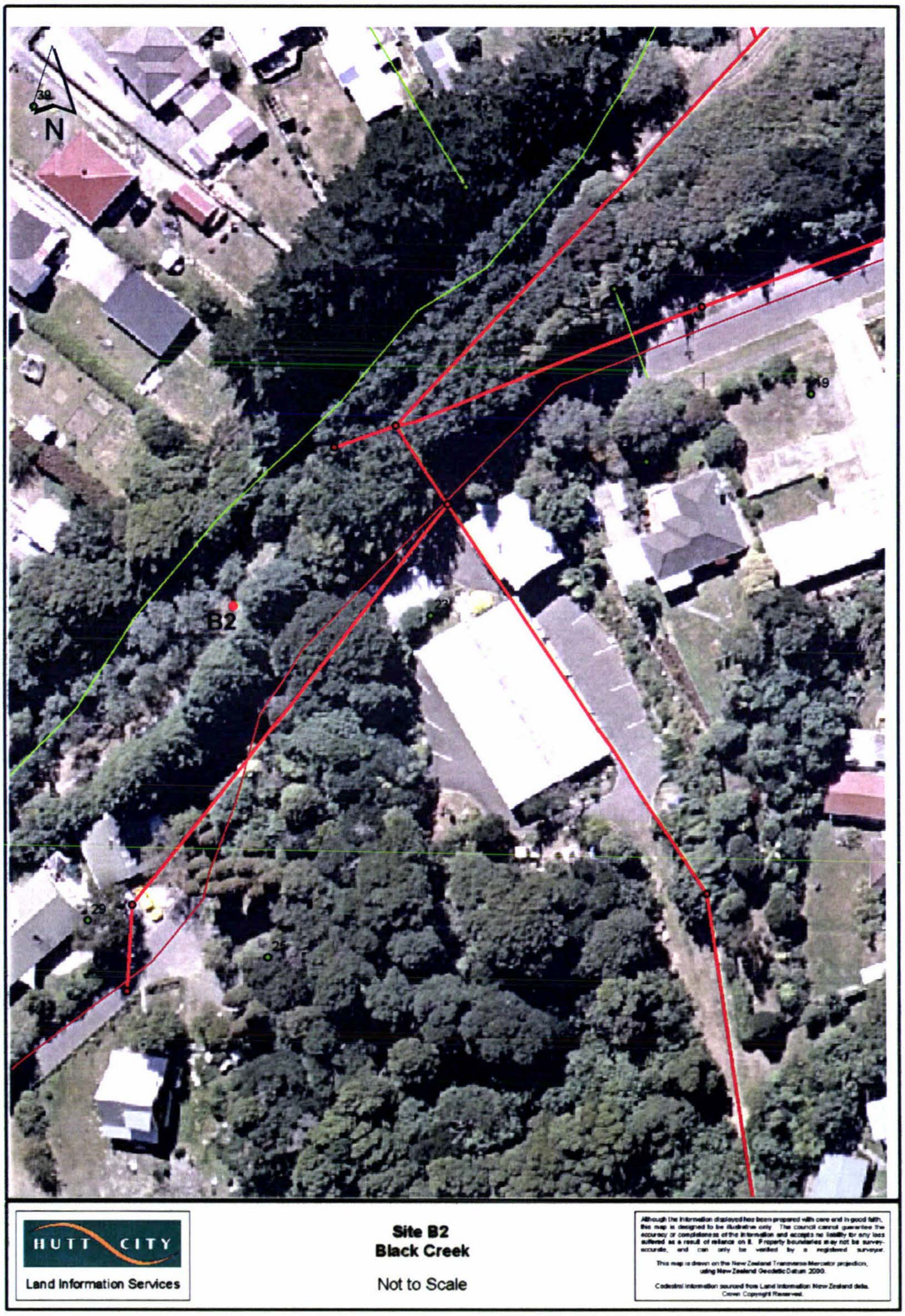
(c) Site J3b: Richard Prowse Park (under bridge) – urban area. Storm water and sewage reticulation is visible. Storm water pipes enter the Wainuiomata River, upstream of sampling site.

(d) Site J4: Leonard Wood Park – semi-urban. Storm water pipes can be seen downstream of sampling site.

(e) Site J5: Golf Course – rural. No storm water or sewage reticulation can be seen.

(f) Site J7: Coast Road Bridge – rural. Storm water and sewage reticulation cannot be seen. A culvert can be seen (small stream under bridge by way of pipe)

(g) Site B1: Black Creek (Upper Fitzherbet Road) – rural area. Storm water pipes or sewage reticulation are not visible upstream of sampling site. A couple of culverts can be seen.



(h) Site B2: Black Creek (Rowe St.) – Urban area
Storm water pipes can be seen entering creek upstream of sampling site. Sewage reticulation can also be seen.

APPENDIX VIII: Data for Periphyton Abundance Assessment and Taxa Identification for Sites J4, J5 & J7

Site J4 - Periphyton Abundance Score and Field Identification

Sample nos.	Date	Periphyton Abundance Scale	Field Identification	pH	Water Temp (°C)	Air Temp (°C)
1	**6/1/03**	3		7.4	14	20
2	**13/1/03**	4		7.1	12	15
3	**20/1/03**	No assessment		7.3	17	
4	**27/1/03**	4	Filamentous	7.2	15	15
5	**3/2/03**	5	Matt - brown	7.2	18	17
6	**10/2/03**	3	Filamentous/matt - brown	7.9	18	
7	**12/2/03**	4	Matt - brown	7.2	16	18
8	**17/2/03**	4	Filamentous - brown	7.8	15	17
9	**24/2/03**	4	Matt - brown	7.0	14	13
10	**10/3/03**	4	Matt - brown	7.6	16	14
11	**17/3/03**	4	Matt	7.7	16	19
12	**24/3/03**	4	Matt - brown	7.6	18	19
13	**26/3/03**	4	Matt - brown	7.1	14	19

Site J5 - Periphyton Abundance Score and Field Identification

Sample nos.	Date	Periphyton Abundance Scale	Field Identification	pH	Water Temp (°C)	Air Temp (°C)
1	**6/1/03**	4	Matt/Filamentous	7.9	16`	20
2	**13/1/03**	Periphyton not visible		7.6	12	15
3	**20/1/03**	4		7.2	17	17
4	**27/1/03**	4	Filamentous	7.4	16	15
5	**3/2/03**	5	Fil/Matt/ - brown	8	17	17
6	**10/2/03**	3	Filamentous	8.4	17	20
7	**12/2/03**	4	Matt - brown	7.8	17	17
8	**17/2/03**	4	Filamentous-brown	7.8	15	17
9	**24/2/03**	4	Filamentous-brown	7.0	14	13
10	**10/3/03**	4	Matt - brown	7.4	16	14
11	**17/3/03**	4	Matt	7.9	16	19
12	**24/3/03**	4	Matt - brown	7.4	18	19
13	**26/3/03**	4	Short Filamentous - brown	7.0	14	18

Site J7 - Periphyton Abundance Score and Field Identification

Sample nos.	Date	Periphyton Abundance Scale	Field Identification	pH	Water Temp (°C)	Air Temp (°C)
1	**6/1/03**	No value due to poor visibility	Long Filamentous - green. Large amount of weed.	8	18	20
2	**13/1/03**	No assessment	Weed and long filamentous algae	7.5	14	15
3	**20/1/03**	No value due to poor visibility	Weed & Long filamentous - green	7.4	17	17
4	**27/1/03**	4	Weed & Long Filamentous - green	7.4	No data	20
5	**3/2/03**	4	Matt/Long filamentous - green & Weed	7.4	18	17
6	**10/2/03**	4	Long filamentous - green	8.2	20	20
7	**12/2/03**	4	Long Filamentous - green		19	18
8	**17/2/03**	4	Short Filamentous - green	7.4	17	17
9	**24/2/03**	3	Long filamentous - green	7.3	16	13
10	**10/3/03**	3	Long filamentous - green. Golden scum observed around river edge	7.5	16	14
11	**17/3/03**	3	Filamentous - Green	7.7	17	19
12	**24/03/03**	Not sampled				
13	**26/3/03**	0	No periphyton visible			

APPENDIX IX: GWRC Periphyton Percentage Cover Data

Periphyton Percent Cover (GWRC) January 2000 - February 2003-

Sampling Dates	J4	J5	
1/20/00	9	20	
2/17/00	0	0	
3/23/00	0	0	
4/27/00	0	0	
5/25/00	0	0	
6/30/00	0	2	
7/24/00	0	6	
8/23/00	0	0	
9/21/00	0	2	
10/25/00	0	11	
11/9/00	6	24	
12/14/00	0	28	
1/12/01	38	35	
2/15/01	11	30	
3/15/01	3	10	
4/12/01	0	13	
5/10/01	4	9	
6/14/01	8	19	
7/12/01	0	13	
8/9/01	0	4	
9/13/01	17	92	
10/12/01	0	0	
11/15/01	0	12	**WWTP closure**
1/18/02	0	38	
2/14/02	0	6	
3/14/02	32	24	
4/11/02	0	3	
5/13/02	26	52	
6/13/02	0	19	
7/11/02	0	0	
8/8/02	14	4	
9/19/02	0	5	
10/10/02	0	0	
11/11/02	0	10	
12/9/02	0	0	
1/16/03	52	84	
2/14/03	72	85	

APPENDIX X

Results from selected samples sent to the Environmental Laboratory Services, Seaview for chemical analysis and comparison with test results

Sample	ELS NO_3.N mg/L	Test Hach	ELS NH_3.N mg/L	Test Hach	ELS DRP mg/L	Test Hach
J7 9/1/03	0.06	0.04	0.23	0.17	0.099	0.25
J4 12/2/03	0.02	<0.01	0.03	<0.01	<0.005	<0.01
J5 17/3/03	0.027	<0.01	0.05	0.02	0.059	0.15

The table shows that not all results obtained from the Hach/2000 Spectrophotometer method compared favourably with those obtained for standard methods used at Environmental Laboratory Services, for the same samples.

Appendix *XI:* Field Sheet used for Collection of Samples

Site Identification Guide

River name ______________________________
Catchment code
Site number ____________________
Latitude ________________
Longitude __________________
Map sheet number __________________ Elevation _____________
Access road names or numbers ____
NOTES:
Distinguishing features
____
____
____
____
______
Best access point to water
____
____
___
Photograph/Access Map

Site Data Sheet (River)

Site number ___________
Date ____________
Time ___________
Weather ____
Air temperature __________
Rain fall (before sampling) 24hr_____ 48hr_____ 72hrs_____
Rain fall (day of sampling)

Field Measurements:
Water temperature _________
D.O. ___________
pH ___________
Conductivity ___________
Flow / discharge ____________
Stage (rising / falling) ______________
Substrate type ______________________
Flow Data Measurements for Cross-Sections:

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