

**BEFORE A HEARINGS PANEL OF THE GREATER WELLINGTON REGIONAL COUNCIL
AND MASTERTON DISTRICT COUNCIL**

IN THE MATTER of resource consent applications to Greater Wellington Regional Council pursuant to section 88 of the Resource Management Act 1991

AND

IN THE MATTER of a Notice of Requirement to Masterton District Council pursuant to section 168, 168A and 181 of the Resource Management Act 1991

BY Masterton District Council

FOR the proposed upgrade of the Masterton Wastewater Treatment Plant

**STATEMENT OF EVIDENCE OF CHRIS HICKEY
ON BEHALF OF MASTERTON DISTRICT COUNCIL**

Subject Area: Effects on Water Quality

1. INTRODUCTION

- 1.1** My name is Christopher Wayne Hickey. I am a scientist with the National Institute of Water and Atmospheric Research Limited (“NIWA”) based in Hamilton. I am a Senior Principal Scientist with NIWA and Director of NIWA USA (Inc).
- 1.2** I hold the degree of Doctor of Philosophy in biochemistry/microbiology from the University of Waikato. I have worked for 28 years in environmental research and consulting in the area of contaminant impacts in fresh and marine waters. My specialist areas are in water quality guidelines and environmental toxicology.
- 1.3** My research experience includes characterisation of wastewater oxidation lagoons and potential effects on receiving waters, including ammonia toxicity studies to native fish and invertebrate species. I was a contributing author to the ANZECC (2000) water quality guidelines; the New Zealand Municipal Wastewater Monitoring Guidelines (NZWWMG 2002); and Guidelines for Drinking-water Quality Management for New Zealand (2005). My ongoing studies include: routine monitoring for permit compliance, contaminant biomonitoring and sediment toxicity testing, literature reviews and government policy advice. I have authored or co-authored over 80 published scientific papers on a range of freshwater and marine environmental toxicology topics, including toxicity of chemicals to organisms, pollution impacts on benthic communities, the use of freshwater organisms for biomonitoring, and the chemical contamination of freshwater and marine sediments.
- 1.4** Acting as a consultant I have been involved with the design and implementation of aquatic toxicity assessment and biomonitoring programmes, monitoring of pollution impacts, environmental impact reports and discharge consenting applications.
- 1.5** In this matter, I have been engaged by Masterton District Council (MDC) to summarise key aspects of the proposal as they relate to the effects of the existing and proposed Masterton Wastewater Treatment Plant (MWTP) on the water quality and ecological effects in the Ruamahanga River. Specifically my brief is to discuss (i) the existing water quality in the Ruamahanga River and the effects of the existing MWTP discharge; (ii) the approaches used and the predicted water quality following the proposed upgrade; (iii) the river ecology, including algal periphyton, macroinvertebrate and fish communities, and the environmental effects caused by the current and proposed MWTP discharge; (iv) water quality guidelines that are applicable to the scheme (after reasonable mixing) and the effluent compliance guidelines and how they were derived.
- 1.6** I am familiar with the MWTP and the adjacent Makoura Stream and Ruamahanga River from having designed and participated in a number of studies to characterise the

discharge and effects. These include: (i) periphyton biomonitoring studies in 2003-2004; (ii) a pond leakage effects study; (iii) derivation of site-specific nutrient guideline for dissolved reactive phosphorus (DRP) concentration to limit nuisance periphyton growths; and (iv) dye tracer and mixing modelling studies undertaken in 2004 and 2007. These studies are summarised and referenced in the AEE (MDC 2008). In addition, since 2004 I have reviewed the annual compliance monitoring reports compiled by Beca on behalf of MDC.

1.7 I have read the Code of Conduct for Expert Witnesses issued as part of the Environment Court Practice Notes. I agree to comply with the code and am satisfied the matters I address in my evidence are within my expertise. I am not aware of any material facts that I have omitted or might alter or detract from the opinions I express in my evidence.

1.8 My evidence is structured as follows:

- (a) scope of evidence;
- (b) executive summary;
- (c) the proposal;
- (d) effects of the existing discharge on water quality;
- (e) post upgrade water quality and effects;
- (f) river ecology;
- (g) aesthetic effects;
- (h) relevant guidelines;
- (i) submitters' issues; and
- (j) conclusions.

2. SCOPE OF EVIDENCE

2.1 My evidence will address key aspects of the proposal as they relate to the effects of the existing and proposed MWTP discharge on water quality and the river ecology of the Ruamahanga River. I have based this evidence on the summer flow threshold for discharge initiation and mixing and dilutions as described by Dr Jim Cooke, and on the predicted effluent water quality as described by Mr Humphrey Archer. I have specifically included the water quality effects of pond leakage and groundwater inputs in making these assessments.

2.2 I do not specifically address the health risks posed by faecal microorganisms. The existing and predicted health risk is addressed in the evidence of Dr Andrew Ball and

John Harding. I do, however, address predicted faecal microorganism (*E. coli*) loading in relation to receiving water quality guidelines and proposed monitoring conditions.

3. EXECUTIVE SUMMARY

- 3.1** The management concept for the MWTP discharge is that no direct discharge to the river will occur for flows less than median in summer, and that a flow proportional (ie 30-fold dilution) discharge will occur at higher flows. In practice this will involve irrigation to land whenever possible, pond storage and discharge to the Ruamahanga River during flood events. This will remove the contaminants from the effluent discharge from the river during the high recreational use periods.
- 3.2** The proposed upgrade includes: (i) construction of new ponds, which will result in a significant improvement in *E.coli* concentrations; (ii) moving the discharge upstream from Wardells Bridge; (iii) installation of a discharge diffuser to improve mixing; and (iv) adoption of an intermittent discharge regime.

Catchment characteristics

- 3.3** The Ruamahanga River flows south 160 km from its headwaters in the northern part of the Tararua Ranges down to Lake Onoke, which flows into Palliser Bay. The Ruamahanga River at Makoura Stream, immediately downstream of the Masterton MWTP discharge, drains a catchment of approximately 63,346 ha and is approximately 95 km from the sea, with high production pasture comprises 67.1% of land use. A similar proportion of high production pasture occurs downstream and mean flow increases about 5-fold from Wardells Bridge to where the river meets the sea at Lake Onoke.
- 3.4** The Ruamahanga River upstream of the MWTP discharge has high water quality during low flows, but significantly declines in water quality during flood events because of diffuse contaminant inputs. The current effects of the MWTP discharge are largely limited to the partially mixed area upstream of Wardells Bridge. During low river flows this area has reduced clarity, settling of pond algae on the bed, nutrient-stimulated periphyton growths (caused by high dissolved reactive phosphorus, DRP concentrations) and elevated *E. coli* concentrations. These sometimes result in exceedance of guidelines for microbial indicators or nuisance growths, though this also occurs for the upstream site during rainfall events and in long low-flow periods (for nuisance growth development). A high frequency of flood events occur in both summer and winter in the Ruamahanga River, resulting in removal of periphyton during these events. The proposed discharge during higher flows will occur when the river is naturally turbid and minimally used for recreation.

- 3.5 Historically, the Ruamahanga River flowed through Lake Wairarapa and wastewater nutrient loads from all of the municipal discharges would have contributed to the eutrophication of the lake. However, since the completion of the Lower Wairarapa Valley Development Scheme (LWVDS) in 1983, the Ruamahanga River flows directly to the sea at Lake Onoke. The rapid flushing of the small Lake Onoke during flood events means that lake effects of nutrients are not relevant to this discharge. The elimination of nutrient discharges for summer flows less than median will improve water quality in Lake Onoke during the key summer period. (See the evidence of Dr Jim Cooke.)

Monitoring results and the impact of the current discharges

- 3.6 The effluent (treated wastewater) from the MWTP is currently discharged to the Makoura Stream, which is a tributary of the Ruamahanga River. The confluence of the Ruamahanga River and Makoura Stream is 200-300 m upstream of Wardells Bridge. At Wardells Bridge the effluent is not currently fully mixed with the river flow and there are therefore more noticeable effects from the discharge at Wardells Bridge, particularly at low river flows, compared with the situation further downstream once the effluent is fully mixed with the river flow.
- 3.7 Key conclusions from the 2005/2006 Annual Monitoring Report for the impact of the treated wastewater discharge on the Makoura Stream and Ruamahanga River:

Makoura Stream

- (a) The discharge caused a conspicuous change in water clarity at the downstream;
- (b) The discharge caused a significant increase in the concentrations of ammonia-nitrogen, and the ANZECC (2000) toxicity guideline for aquatic ecosystems was often exceeded downstream;
- (c) The discharge had negligible effects on pH, *E.coli*, nitrate-nitrogen and temperature;
- (d) Dissolved oxygen was typically lower than 80% saturation downstream.

Ruamahanga River

- (a) The discharge caused a 'conspicuous change' in water clarity at the partially-mixed downstream monitoring site at Wardells Bridge ('Rua2');

- (b) The discharge did not cause a 'conspicuous change' in colour of the Ruamahanga River;
- (c) At the Wardells Bridge location, the clarity of the river did not meet the MfE (1994) recreational guideline on 9 out of 12 sampling occasions. However, four of these occasions were also below the clarity guideline for the upstream site;
- (d) The water quality up and down stream of the discharge met the ANZECC (2000) guidelines for nutrients in livestock drinking water;
- (e) The Ruamahanga River downstream of the MWTP discharge exceeded the MfE (1994) microbiological bathing water quality guidelines 'alert' level on eight occasions. Five of these occasions were also above the 'action' level. Of these eight occasions, alert levels were also exceeded upstream of the discharge point on five of those and action levels were exceeded on two of those;
- (f) The periphyton levels were acceptable (no nuisance levels).

3.8 In summary, the existing discharge, after partial mixing, does not have significant adverse effects on the receiving water quality in the Ruamahanga River and generally complies with the relevant guidelines in the Regional Freshwater Plan for the Wellington Region (WRFP). Nevertheless, it is apparent from field observations and the monitoring programme that at lower flows, the direct discharge does have somewhat greater effects on water quality, particularly in terms of colour, clarity, nutrients and pathogens. The poor mixing of the discharge at Wardells Bridge results in a plume which hugs the right bank, with degradation of water quality being most marked at low flows.

Proposed upgrade water quality and effects

3.9 An integrated assessment was undertaken for potential pond discharge effects for all constituents on the water quality in the Ruamahanga River. However, the primary focus is: clarity, *E. coli* and dissolved reactive phosphorus (DRP) effects on nuisance growths.

3.10 The management concept for the MWTP discharge is that no direct discharge to the river will occur for flows less than median in summer, and that a flow proportional (ie 30-fold dilution) discharge will occur at higher flows. Therefore, the analysis of potential effects considers two situations:

- (a) Below median flows, where cumulative effects will be restricted to such limited pond leakage as occurs and groundwater return flows, since there will be no direct discharge; and
- (b) Above median flows, where cumulative effects of all three sources (direct discharge, leakage and groundwater return flow) will occur. The potential for

effects is greatest for this scenario in the 'threshold flow range', which are the flows just above median flow when the direct discharge is initiated and where upstream water quality may remain high for a short time.

- 3.11** Assessment of potential effects for the threshold flow region were made after reasonable mixing, corresponding to a 20-fold dilution occurring 300 m downstream of the discharge. The concentrations of potentially toxic ammonia is maximally 34% of the water quality guideline, and other constituents were also below the guidelines used to establish the receiving water targets. Because both clarity and *E.coli* concentrations are affected by river flow, and may naturally exceed guidelines, a Monte-Carlo modelling approach was used to predict the effects of the MWTP discharge. These results showed a median clarity decrease of -15% and *E.coli* increase of +6.5% in the threshold flow range.
- 3.12** In conclusion, this analysis of summer data has shown that the predicted impact after reasonable mixing (at 300 m) and at Wardells Bridge for *E.coli* and clarity will be no change or negligible change as a result of discharges from the proposed upgraded ponds. The nutrient parameters (nitrogen and phosphorus) which increase at high flows are intermittent in nature and occur at times when the river conditions prevent the stimulation of attached growths (ie scour and turbidity). The elimination of discharge at below median flows removes all effects at these flows which coincide with higher recreational use.

River ecology

- 3.13** The effects of the MWTP discharge on river algae, macroinvertebrates and fish populations were assessed. The key findings are:
- (a) **River periphyton growths** respond to added nutrients but nuisance growth levels are limited in the Ruamahanga River by the high flood frequency. Although growths downstream of the MWTP discharge are generally (ie >95% of time) not at nuisance levels, it does have some minor impacts on the recreational and aesthetic values of this section of the river. Elimination of discharge below median flow and discharge during high flow periods (river freshes) is predicted to be sufficient to scour the river bed and in doing so will limit undesirable growths;
 - (b) **River macroinvertebrate communities** in the Makoura Stream will improve with removal of the discharge. The proposed upgrade will assist in decreasing the proportion of species associated with algal growths (snails, midge larvae)

in the Ruamahanga River at Wardells Bridge, and will therefore result in an improvement to macro-invertebrate indices reflecting pollution sensitive species (eg mayflies);

- (c) **Native fish and trout** species diversity was greatest in the Upper Ruamahanga. In summer, low flows and associated elevated water temperatures are considered the main factor restricting distribution of fish species in the middle to lower Ruamahanga River. The existing discharge does not show any noticeable adverse effect on the fish life in the Ruamahanga, and the proposed change to an intermittent discharge regime is not expected to have any adverse effects on fish habitat or migration. The removal of the discharge from the Makoura Stream will result in a significant improvement in water quality which will have beneficial effects on fish communities.

Proposed Receiving Water Quality Targets

- 3.14** The WRFPP contains no specific guidelines on allowable nutrient loadings to the Ruamahanga River – the only reference is to a discharge not causing undesirable biological growths in the river, which is of little assistance as undesirable or nuisance levels of attached algae seldom occur with the existing discharge.
- 3.15** Water quality guidelines from MfE, ANZECC (2000) and a site-specific guideline DRP have been used to derive proposed receiving water targets (RWT) for pond constituents. The DRP guideline is based on the site-specific study carried out by NIWA, and is applicable to assessment of potential nuisance growth development under low flow conditions from diffuse nutrient inputs from the proposed scheme.
- 3.16** Compliance assessments were made with the proposed receiving water target and section 107 RMA standards after reasonable mixing. The discharge will readily meet the minimum standards set out in section 107 of the Act. However, because of the nature of the proposed upgrade, with discharge triggered by elevated river flows, the analysis and future compliance monitoring of effects requires a different approach from what would be used for a full time discharge. Predominantly this relates to assessing effects against the natural decline in river water quality which occurs during flood events. Compliance assessment would be primarily based on effluent monitoring.

Submitters

- 3.17 Responses to submitters' concerns are addressed in relation to potential effects on receiving water quality.

4. THE PROPOSAL

- 4.1 In terms of surface water quality, the key components of the proposed upgrade of the existing wastewater treatment and disposal system are as follows:

- (a) construction of new oxidation ponds, comprising two primary ponds operating in parallel and five maturation ponds operating in series, which will improve treatment efficiency (particularly for faecal microorganisms) and significantly reduce leaching to groundwater;
- (b) effluent will be discharged to the land whenever possible. Discharge to the river will take place in summer only when the flow is > median (12.3 m³/sec) and in winter when the flow is > half median. At these flows nutrients in the effluent cannot effectively stimulate algal growths in the river and upstream water quality is usually affected by rural runoff. The receiving water would be more likely to already naturally exceed the relevant guidelines upstream of the MWTP (in terms of clarity and microbiological quality);
- (c) whenever there is a discharge to the river, the river flow will be at least 30 times greater than the discharge rate of effluent (i.e. a minimum dilution of 30x);
- (d) the discharge will only commence when flows are predicted to exceed the trigger flow for more than 6 hours;
- (e) the location of the discharge will be moved upstream and discharged through a diffuser to improve river mixing, thus eliminating existing aesthetic effects and ensuring full mixing before the flow reaches Wardells Bridge;
- (f) there will be no discharge of effluent directly to the Makoura Stream, leading to a significant improvement of water quality in the lower reaches of that stream; and
- (g) the discharge will occur at times when there is little (if any) primary contact recreation and little secondary contact recreation.

4.2 In my opinion, the upgrade will result in a marked improvement in water quality in the Ruamahanga River at Wardells Bridge and will also result in downstream improvements. At below median flows in summer and below half-median flows in winter, no direct discharge will occur, and at these flows, the residual indirect discharge from the minimal leakage from the new ponds will have little or no environmental effect on receiving water quality. The upgrade will also result in significant improvements at other flows, particularly in terms of pathogen levels (the net result of pond improvements and mixing, though with lower dilution when discharge occurs).

4.3 The key improvements during low flows when there is no direct discharge to the river and minimal pond leakage will be:

- (a) No green colouring in the water from pond algae;
- (b) No change to river water clarity;
- (c) No nutrients directly discharged to the river that would encourage undesirable biological growths (periphyton/slime) on the bed of the river;
- (d) No discharge of effluent directly to the river (ie reduced bacterial and pathogen loads in the river) when the river is most attractive for swimming and other forms of contact recreation; and
- (e) Residual discharge via leakage from the new ponds will have little if any effect on the water quality in the river, or the natural biological communities present.

4.4 The key improvements at higher flows, when there is a direct discharge to the river will be:

- (a) Improved water microbiological quality of the residual discharge to the Ruamahanga River;
- (b) Reduced mixing zone due to improved mixing as a result of the diffuser;
- (c) Moving of the mixing zone upstream, as a result of the diffuser and new upstream discharge point, so that full mixing will occur upstream of Wardells Bridge (currently full mixing occurs downstream of Wardells Bridge);

- (d) The discharges into the Ruamahanga River will generally occur when the river water quality is already of a lower quality due to diffuse upstream sources, resulting in negligible downstream aesthetic effects;
- (e) There will be a considerable reduction in phosphorus loads to the river and to Lake Onoke during low flow conditions; and
- (f) Discharge will occur at times when little (if any) primary contact recreation occurs.

5. EXISTING WATER QUALITY AND EFFECTS OF THE EXISTING DISCHARGE

Catchment characteristics

5.1 The Ruamahanga River flows south 160 km from its headwaters in the northern part of the Tararua Ranges down to Lake Onoke, which flows into Palliser Bay. The Ruamahanga River at Makoura Stream, immediately downstream of the Masterton MWTP discharge, drains a catchment of approximately 63,346 ha and is approximately 95 km from the sea. Although the headwaters of the Ruamahanga River pass through bush and scrub, most of the River above Homebush meanders through pastureland as shown in Figure 1, with a marked increase in high production pasture as the river flows closer to Homebush. In the area around Double Bridges high production pasture comprises 25.5% of land use, while in the vicinity of Te Ore Ore, just upstream of the MWTP discharge, high production pasture comprises 67.1% of land use. A similar proportion of high production pasture occurs at the most downstream monitoring site at Waihenga, where the catchment area has increased by about 4-fold compared to Wardells Bridge (Table 1). The Ruamahanga River mean flow increases 4.7-fold from 26.1 m³/s at Wardells Bridge to 122.5 m³/s where the river meets the sea at Lake Onoke (Table 1).

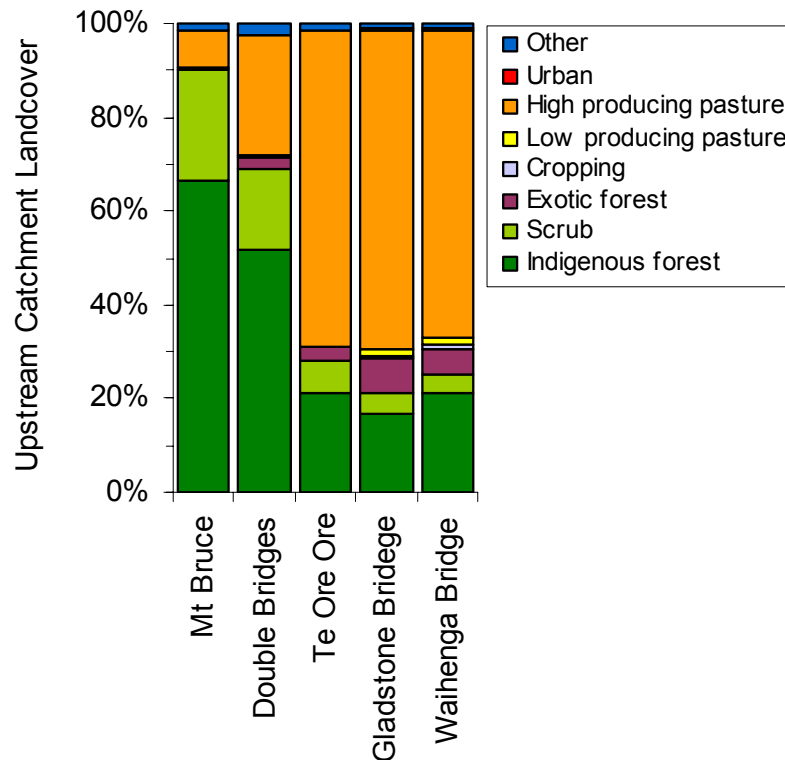


Figure 1 Major landcover types in the catchment area (Figure 9 in AEE and Appendix B for location map)

5.2 The intensification of land use as the Ruamahanga River flows from its headwaters results in increasing inputs of pollutants from diffuse sources (particularly increased sediment, nutrients and faecal material) into the Ruamahanga River¹, thereby affecting key water quality characteristics, such as a reduction in water clarity, before the River reaches the Homebush vicinity. These diffuse source inputs are most pronounced during rain events, while the existing MWTP discharge occurs over all river flows. These water quality changes have been monitored both as part of the Greater Wellington Regional State of the Environment (RSoE) programme (3 upstream sites) and immediately upstream of the MWTP discharge as MDC monitoring programme for effects assessment.

5.3 We have summarised the RSoE data for key water quality parameters in the AEE to quantify downstream trends and the 2 downstream sites and have used the MDC dataset to quantify more local water quality changes². This monitoring data was complemented with NIWA collected National River Quality Monitoring Network (NRQMN) data from 3 sites on the Ruamahanga River (upstream at Mt Bruce (SH2); immediately downstream at Wardells Bridge; and about 53 km downstream at Waihenga) which have monthly monitoring for nuisance periphyton growths since 1989

¹ Diffuse source pollution is that arising from land use activities that is dispersed across a catchment. In rural catchments it is usually a much greater source of contaminants to waterways than point source discharges of wastewater.

² AEE, Appendix B, Figure B1.4.

and annual macroinvertebrate and water quality monitoring³. Together, these provide a comprehensive spatial and temporal monitoring dataset for the Ruamahanga River.

- 5.4** The nature of the receiving water downstream of a riverine discharge affects the potential for adverse effects on the aquatic environment. Thus while shallow rivers respond primarily to dissolved nutrients (which stimulate bed-attached growths of algae) and sediments (which may settle and smother the bed) there are different concerns for lakes.
- 5.5** The eutrophication of lakes occurs because of an increase in total nutrient loads. The settling nature of lakes combined with a long residence time results in potentially high growth of algal biomass in surface waters and deoxygenation of deeper waters – a process which exacerbates algal blooms by internal nutrient cycling.
- 5.6** Historically, the Ruamahanga River flowed through Lake Wairarapa and wastewater nutrient loads from all of the municipal discharges would have contributed to the eutrophication of the lake. However, since the completion of the Lower Wairarapa Valley Development Scheme (LWVDS) in 1983, inflows have been restricted to Tauherenikau River and several small streams along the western shores, and potentially under flood conditions, from the Ruamahanga River via the Oporua Floodway. Normally, the Ruamahanga River flows directly to the sea at Lake Onoke.
- 5.7** Lake Onoke is a 650 ha brackish lagoon at the mouth of the Ruamahanga River. It is separated from Palliser Bay by a 3 km long shingle spit, which is naturally breached by rising lake levels or, now more commonly, cut artificially to reduce the danger of flooding nearby farmland. For long periods the lake is tidal, but in southerly conditions with a low river flow the exit to the sea becomes blocked. The range in stage height for Lake Onoke was 3.06 m in 2008. Lake Onoke is relatively small (3 km by 2 km) and shallow (maximum depth about 2.5 m) and is therefore well flushed by the Ruamahanga River flows. There is no routine water quality monitoring programme in place for Lake Onoke.

³ AEE, Table B1.1 and Figure B1.5.

5.8 Lake Wairarapa is a large (80 km²), isothermal, shallow lake (maximum depth about 2.5 m) which had its catchment reduced by 80% as a result of the LWVDS diversion implemented in 1974. Wetlands surrounding Lake Wairarapa are considered of high value by the Department of Conservation and various administrative authorities and interest groups (DOC 2000). The lake has been routinely monitored since 1994 as part of Greater Wellington Regional Council's Freshwater State of the Environment monitoring programme. The most recent report (Perrie 2005) classifies the lake as "supertrophic" and states:

"High levels of total nitrogen, total phosphorus, algal biomass and low water clarity are all suggestive of a highly modified, eutrophied system... There is some indication of a slight improvement in water quality since monitoring began, with decreases in total nitrogen and increases in secchi depth occurring.... Increases in conductivity were observed and are a result of increased salinity caused by back flow from Lake Onoke. Increases in salinity may adversely affect the lake ecosystem and also have implications for agricultural uses in the region."

5.9 The isolation of Lake Wairarapa from the Ruamahanga River means that the currently proposed improvements to the Masterton wastewater discharge are not relevant to the water quality in this lake.

Table 1 Summary of Ruamahanga River catchment and flow characteristics downstream of Masterton

Site	Distance to sea (km)	Elevation (m)	Catchment area (km ²)	Mean flow (m ³ /s)	Mean annual low flow (m ³ /s)
Wardells	99.8	91.5	634	26.1	4.05
Waihenga	52	16.8	2361	98.6	16.6
Lake Onoke	3.4	0.5	3311	122.5	20.8

Source: NIWA River Environment Classification database

5.10 Hydrology is another significant influence on river water quality. This is particularly the case for parameters responsive to runoff such as *E.coli*, clarity and nutrients. Notably, the Ruamahanga River has a highly variable flow during both summer and winter. The record shows that there are frequent minor floods ('freshes') where river flow rises rapidly to a peak flow well above the median river flow of 12.3 m³/s. Similarly in winter, the flow record displays a far greater trend of frequent short, sharp 'freshes' in the river.

This characteristic of frequent freshes is particularly relevant to the proposed discharge regime, as discussed later in my evidence.

- 5.11 The hydrology of the Ruamahanga River is addressed in more detail, together with flow-related water quality for faecal indicator bacteria (*E. coli*) is addressed in the evidence of Dr Jim Cooke (see Figure 7). I address below the existing water quality conditions upstream and downstream of the MWTP, together with predicted changes following the system upgrade.

Monitoring results and the impact of the current discharges

- 5.12 The effluent (treated wastewater) from the MWTP is currently discharged to the Makoura Stream, which is a tributary of the Ruamahanga River. The confluence of the Ruamahanga River and Makoura Stream is 200-300 m upstream of Wardells Bridge. At Wardells Bridge the effluent is not currently fully mixed with the river flow and there are therefore more noticeable effects from the discharge at Wardells Bridge, particularly at low river flows, compared with the situation further downstream once the effluent is fully mixed with the river flow.

- 5.13 The 'Interim Consent' conditions required the compiling and supply of an annual monitoring report to Greater Wellington describing the effects of the existing discharge on the water quality of the Makoura Stream and the Ruamahanga River. The existing compliance conditions apply to the Makoura Stream, while the Ruamahanga River monitoring occurs at the partially mixed downstream site at Wardells Bridge and a fully mixed site upstream of the Waingawa River confluence. Data from all sites are compared with water quality guidelines and time series plots are provided in the monitoring reports. The results from the 2004-2005 and 2005-2006 reports are summarised below as provided in the AEE. The receiving water monitoring programme was undertaken monthly, but with weekly *E.coli* monitoring in summer (1 December to 31 March) in the Makoura Stream, upstream and downstream of the discharge, and in the Ruamahanga River at an upstream reference site and two sites downstream of the Makoura Stream confluence. A single annual macroinvertebrate and periphyton sampling is undertaken in late summer. This data provides robust upstream/downstream comparisons and representative annual data for the upstream river conditions. It is, however, limited for periphyton nuisance growth assessment to the single annual sampling occasion.

- 5.14 Table 2 below shows the effect of the existing discharge on the Ruamahanga River in terms of median values of various parameters upstream and downstream of the discharge point for 2004-2005 monitoring (Beca 2005). The following overall

conclusions can be drawn about the 2004-2005 environmental quality of the Ruamahanga River:

- (a) The MWTP discharge did not cause a 'conspicuous change' in median water clarity or water colour in the mixing zone (as measured at 'Rua2' just downstream of Wardells Bridge). Notably, at 'Rua4' further downstream (measured just upstream of the Waingawa confluence) the water colour was similar to that upstream of the discharge, while the clarity is slightly reduced;
- (b) The algal mat cover was largely absent upstream and increased downstream of the MWTP discharge, though to less than 'nuisance' thresholds in the 2005 annual sampling. This increased algal abundance in the partially mixed region upstream of Wardells Bridge would have contributed to the observed aesthetic effects of the MWTP discharge;
- (c) There was an increase in ammonia-nitrogen, nitrite-nitrogen and nitrate-nitrogen concentrations downstream of the MWTP discharge. However the river complied with the ANZECC (2000) aquatic ecosystem toxicity guidelines for all the parameters on all monitoring occasions;
- (d) The total phosphorus and dissolved reactive phosphorus concentrations increased 10-fold downstream of the MWTP discharge in the partially mixed zone above Wardells Bridge (Rua2);
- (e) The discharge had a negligible effect on temperature, pH and dissolved oxygen; and
- (f) The median downstream increase in *E.coli* concentration was 2-fold for these occasions in the partially mixed zone above Wardells Bridge (Rua2).

Table 2 Water Quality of Ruamahanga River Upstream and Downstream of Makoura Stream Confluence, and above Waingawa River Confluence (Monthly sampling, 4 May 2004–16 May 2005) (Table 19 in the AEE)

Parameter	Rua 1 (2.1 km upstream of Makoura Stream) Median	Rua 2 (0.4 km downstream from Makoura Stream – partially mixed) Median	Rua 4 (1.1 km downstream of Makoura Stream; upstream from Waingawa River) Median	Rua 1 to Rua 2 Increase
pH	7.31	7.14	7.26	-2%
Conductivity ($\mu\text{S}/\text{cm}$)	124	113	110	-9%
Dissolved Oxygen (g/m^3)	9.5	10.3	11.1	9%
Dissolved Oxygen % saturation (%)	96	92	98	-4%
Black Disc (m)	1.4	1.17	1.15	-16%
Colour - Hue (Munsell points)	37.5	35	37.5	2.5 points change
<i>E.coli</i> (cfu/100mL)	56	130	50	2.5 fold
Ammonia-N (g/m^3)	0.02	0.17	0.02	9 fold
Nitrate-N (g/m^3)	0.549	0.95	0.693	73%
Nitrite-N (g/m^3)	0.003	0.019	0.004	6 fold
Total Kjeldahl Nitrogen (g/m^3)	0.2	0.45	0.15	2 fold
Total Nitrogen (g/m^3)	0.7	1.45	0.9	2 fold
Total Phosphorus (g/m^3)	0.012	0.121	0.025	10 fold
Dissolved Reactive Phosphorus (g/m^3)	0.010	0.099	0.012	10 fold
Turbidity (NTU)	0.72	5.19	3.56	7 fold
Total Organic Carbon (g/m^3)	2.65	3.8	3.65	38%

5.15 Under the Regional Freshwater Plan for the Wellington Region (WRF 1999a), the reach of the Ruamahanga River where the MWTP is located is managed for contact recreation purposes. The WRF (Appendix 8) provides guidelines for resource consents and monitoring in relation to the management purpose. These guidelines are predominantly the narrative standards of the Act and include some water quality standards (e.g., pH & dissolved oxygen saturation). The discharge from the MWTP is fully mixed with the Makoura Stream which in turn has a long plume, which, at low flows, hugs the right bank of the Ruamahanga River until downstream of Wardells Bridge. Field inspections at low river flows have noted the settling of pond algae on the cobble river-bed downstream of the Makoura confluence, affecting the observed algal mat cover and apparent river colour when observed from Wardells Bridge (NIWA 2003). The partially mixed downstream site in the Ruamahanga River has been used for assessment with a suite of water quality guidelines, including MfE for microbiological and colour and clarity, WRF and ANZECC (2000).

5.16 Key conclusions from the 2005/2006 Annual Monitoring Report (Beca 2006) for the impact of the treated wastewater discharge on the Makoura Stream and Ruamahanga River are summarised below:

Makoura Stream

- (a) The discharge caused a conspicuous change in water clarity at the down stream monitoring location;
- (b) The water quality upstream and downstream of the discharge met the ANZECC (2000) guideline for nutrients in livestock drinking water;
- (c) The discharge caused a significant increase in the concentrations of ammonia-nitrogen, and the ANZECC (2000) toxicity guideline for aquatic ecosystems was often exceeded downstream of the discharge;
- (d) The stream complied with the ANZECC (2000) nitrate-nitrogen guideline for the aquatic ecosystems both upstream and downstream of the discharge;
- (e) The discharge had negligible effects on pH, *E.coli*, nitrate-nitrogen and temperature; and
- (f) Dissolved oxygen was typically lower than 80% saturation downstream approximately half of the time.

Ruamahanga River

- (a) The discharge caused a 'conspicuous change' in water clarity at 'Rua2'. However, at 'Rua4' further downstream the water clarity was similar to that upstream of the discharge;
- (b) The discharge did not cause a 'conspicuous change' in colour of the Ruamahanga River;
- (c) At the Wardells Bridge location, the clarity of the river did not meet the MfE (1994) recreational guideline on 9 out of 12 sampling occasions. However, four of these occasions were also below the clarity guideline for the upstream site. The greatest reduction in clarity occurred during the January and February low flows;

- (d) The water quality up and down stream of the discharge met the ANZECC (2000) guidelines for nutrients in livestock drinking water;
- (e) There was generally an increase in ammonia-nitrogen, nitrite-nitrogen and nitrate-nitrogen downstream of the MWTP discharge. However the river complied with the ANZECC (2000) aquatic ecosystem toxicity guidelines for all the parameters on all monitoring occasions;
- (f) The discharge had a negligible effect on temperature, pH and dissolved oxygen;
- (g) The Ruamahanga River downstream of the MWTP discharge exceeded the MfE (1994) microbiological bathing water quality guidelines 'alert' level on eight occasions. Five of these occasions were also above the 'action' level. Of these eight occasions, alert levels were also exceeded upstream of the discharge point on five of those and action levels were exceeded on two of those. Summer low flow periods show the greatest increase in *E. coli* levels, particularly at the partially mixed site at Wardells Bridge (Rua2); and
- (h) The periphyton levels were acceptable (no nuisance levels).

Effects of the existing discharge on aesthetic values

- 5.17** During low river flows in summer, the algae in the current treatment process results in a discernible bright green plume from the discharge while mixing with the river water. There is also a reduction in clarity for some distance downstream of the discharge. The visual effect of the discharge plume before it becomes fully mixed has a negative impact on the aesthetic and amenity values of the Ruamahanga.
- 5.18** The effect of the added nutrients on the stimulation of periphyton (algae) growths on the river bed also has a minor effect on the aesthetic value of the river, particularly at times when the river is most valued for recreational use (at times of lower flows in warm summer periods).
- 5.19** With regard to colour, oxidation ponds have a characteristic yellow green colour as a result of the algae in the wastewater. During lower river flows the pond algae can settle on the riverbed, and this gives the appearance of a green plume. This is currently the situation in the Ruamahanga River, primarily because at the confluence with the Makoura Stream the river flow is frequently low enough to allow algae to settle. The

settled pond algae are a negative impact for recreational users of the river, and on its aesthetic appearance.

5.20 The measure of colour is the Munsell Scale. The actual colour of the river upstream of the confluence is yellow-green (upstream 'Rua1' typically Munsell hue 10GY(40)8/2 in summer) and has a colour similar to the wastewater (Beca, 2006). Therefore, even in the summer when there is more green colour from the algae, the discharge typically changes the river colour by only 2.5 Munsell points (downstream 'Rua2' typically 7.5 GY(37.5)7/6). This is lower than the 10-point guideline in MfE Water Quality Guidelines N° 2 (1994), Guideline 2 (Appendix B3 of the AEE).

5.21 In summary, the existing discharge, after partial mixing, does not have significant adverse effects on the receiving water quality in the Ruamahanga River and generally complies with the relevant guidelines in the WRF. Nevertheless, it is apparent from field observations and the monitoring programme that at lower flows, the direct discharge does have somewhat greater effects on water quality, particularly in terms of colour, clarity, nutrients and pathogens. The poor mixing of the discharge at Wardells Bridge results in a plume which hugs the right bank, with degradation of water quality being most marked at low flows. As discussed by Andrew Ball, although the existing discharge meets contact recreation guidelines, there is a residual health risk, particularly at lower flows.

6. POST UPGRADE WATER QUALITY AND EFFECTS

6.1 This section provides a comparison of upstream water quality (ie upstream of the MWTP) with predicted water quality downstream following the proposed upgrade. This analysis provides an integrated assessment for the potential for all pond constituents on water quality in the Ruamahanga River. However, the primary focus is on pond discharge effects on water quality are on: clarity, *E. coli* and DRP effects on nuisance growths.

6.2 The management concept for the MWTP discharge is that no direct discharge to the river will occur for flows less than median in summer, and that a flow proportional (ie 30-fold dilution) discharge will occur at higher flows. Therefore, the analysis of potential effects considers two situations:

- (a) Below median flows, where cumulative effects will be restricted to such limited pond leakage as occurs and groundwater return flows, since there will be no direct discharge; and

- (b) Above median flows, where cumulative effects of all three sources (direct discharge, leakage and groundwater return flow) will occur. The potential for effects is greatest for this scenario in the 'threshold flow range', which are the flows just above median flow when the direct discharge is initiated and where upstream water quality may remain high for a short time.

6.3 The construction of new oxidation ponds, comprising two primary ponds operating in parallel and five maturation ponds operating in series, will improve treatment efficiency and is described in section 6 of the AEE. The specific water quality improvements will result from:

- (a) 400 mm of silty clay lining to markedly reduce pond leakage from the base of the ponds to groundwater (AEE section 6.3.6);
- (b) the use of five maturation ponds, with four additional aerators/mixers, will improve disinfection (from natural sunlight) and is expected to reduce *E.coli* from the summer geometric mean of 485/100mL currently to a predicted target of 200/100mL (AEE section 6.3.3); and
- (c) the concentrations of other constituents are expected to be minimally changed and the data from the existing ponds provides the basis for effects predictions.

6.4 The principal potential environmental effect relates to dissolved phosphorus and periphyton growth attached to the river bed. Periphyton is only an issue in the Ruamahanga during summer months, so the analysis can be further reduced to the summer period of 1 November to 30 April. The proliferation of periphyton to nuisance levels can only occur when river conditions are suitable for growth (ie high light and nutrients and minimum scour of the bed).

6.5 The analysis focuses on concentrations of DRP, as this has been determined to be the growth-limiting nutrient (NIWA 2003), and as dissolved nutrients are the form which stimulate attached algal growths in rivers. However, for completeness, we have included mass load calculations for total nutrient loads. Such information is relevant to the assessment of total catchment loads of nutrients.

6.6 The pond and river monitoring data from March 1994 to October 2005 forms the basis of the water quality effects assessment and predictions for future water quality with inclusion of a reduced leakage rate and the consent *E.coli* value. The proposed effluent quality compliance *E.coli* value (geometric mean 300 cfu/100 mL, Median 330 cfu/100 mL; AEE Table 54) are used for model predictions for surface water discharges to

provide a conservative assessment of potential downstream effects. Additional analyses have been included in this evidence on the frequency of occurrence of nuisance periphyton growths for data from March 1989 to February 2008.

- 6.7** The comparison is presented for summer (1 November to 30 April) and winter (1 May – 31 October) periods, in order to account for the different proposed discharge regimes for these periods, and provides monitoring results for concentrations of key parameters upstream of the MWTP and predictions for locations downstream of the effluent discharge point allowing for mixing and dilution.
- 6.8** We have used two approaches to make predictions of downstream water quality following the pond upgrade:
- (a) for constituents which have relatively low upstream concentrations (ie Biochemical Oxygen Demand (BOD), soluble BOD (sBOD)⁴, ammoniacal-nitrogen (NH₄-N), nitrite-nitrogen (NO₂-N), nitrate-nitrogen (NO₃-N), and dissolved reactive phosphorus (DRP)) a median upstream concentration is used with addition of a 95 percentile (95thile) effluent concentration allowing for an appropriate dilution; and
 - (b) for constituents with a strong upstream flow variability, and sometimes high upstream concentrations (ie clarity & *E. coli*), a statistical modelling approach, termed Monte-Carlo (described below), has been used to predict concentration changes.
- 6.9** The relationships between these variables and river flow in the Ruamahanga River upstream of the discharge have been described by Dr Jim Cooke in his evidence (see Figures 6 & 7). Together these two methods provide a robust and conservative approach to predict in stream concentrations in the 'threshold flow region' (ie the flows just above 12.3 m³/s where the discharge will be initiated).
- 6.10** The contribution of the pond leakage is calculated using the highest anticipated leaching rate of 8.7 L/s (750 m³/d) which gives a dilution of 1414x at median flow. Median upstream concentrations and the median effluent concentrations, including predicted target *E.coli* concentrations, have been used as representative leachate values. The median effluent concentrations are used as the groundwater percolation is relatively slow and contaminant concentrations would be expected to be represented by 'average' effluent conditions. The predicted river concentrations allow for a conservative leakage

dilution based on leakage volume measurements as described by Dr Jim Cooke in his evidence.

- 6.11** The post-upgrade effluent concentrations are conservatively based on the existing effluent distributions for all constituents except for *E. coli*. The proposed target effluent quality for *E. coli* is a summer geometric mean of 200 cfu/100 mL (ie a 58% reduction from existing) and no change for winter values (Table 25 of AEE). However, as noted earlier, the proposed consent compliance *E.coli* concentrations (geometric mean 300 cfu/100 mL) are used as a conservative basis for the predictive modelling. The predicted improvements in effluent quality have been described in the evidence of Mr Humphrey Archer.

Summer Discharge Regime

- 6.12** A specific modelling approach was used for the assessment of *E.coli* and clarity effects with results presented later in this section. The Monte-Carlo modelling approach was used to statistically combine the upstream river and pond effluent distributions for these parameters and then to predict a downstream concentration after mixing. This is a recognised statistical technique that is used to combine variable distributions, and produce an output for the mixed product. This statistical approach was required to provide a predictive model appropriate for existing and upgraded pond contaminant concentrations. This model was calibrated on summer river data for a data range around median flow, and for pond data for these constituents (after reducing the existing pond geometric mean *E. coli* to the proposed consent compliance effluent quality value) in order to provide predictions relevant to the threshold flow range where the discharge is initiated.
- 6.13** The tables below provide the in-river predictions for the effluent and leakage, and leakage alone. Table 3 and Table 4 are based on Tables 32 and 33 in the AEE (pages 135 & 136) and provide predicted contaminant concentrations within the partially mixed region downstream of the multiport discharge diffuser. The proportion of river mixing with distance downstream is based on the modelled data from Table 31 (p130) of the AEE, with full hydraulic mixing occurring at about 800 m downstream and 'reasonable mixing' regarded as occurring at about 300 m, as described in the evidence of Dr Jim Cooke. The predicted in-river contaminant concentrations downstream reflect the likely worst-case (95th percentile) effluent discharge conditions. The predicted river concentrations are compared with the 'Receiving Water Target' (RWT) values, which are numeric guideline values as summarised in Table 25 (Table 30 of the AEE p124). The RWT values are consistent with the relevant guidelines in the Regional Freshwater

Plan for the Wellington Region (WRF 1999a, Appendix 8) and are appropriate for ecosystem and recreational use classifications.

- 6.14** The predicted receiving water concentrations of effluent and leakage after reasonable mixing (ie at 300 m) are shown in Table 3. All downstream values are well within guidelines at 300 m, with the nominal exception of the site-specific DRP guideline which is not applicable to high river flow situations and is addressed further below. The ammoniacal-N concentrations maximally reach about 35% of the toxicity guideline value. The effects of *E. coli* and clarity are addressed in the following section.
- 6.15** Phosphorus predictions are included for the effluent and leakage scenario. However, the additional phosphorus concentration input at the time of flows above median will not be expected to contribute to increased algal growths. This is because the hydraulic bed scouring during the flood/fresh events, combined with the intermittent nature of the discharge and increased turbidity and depth at high flows, will prevent algal growths occurring.
- 6.16** In the current situation under summer conditions (< median flow) with direct discharge to the river (including pond leakage), I consider the effects on periphyton growth to be only minor in relation to the development of nuisance growths (see sections of evidence in relation to nuisance growths (section 7) and DRP guideline derivation (section 8)). Therefore, taking out direct discharge (the major source of DRP) to the river during this period will further reduce this effect. The significant reduction in pond leakage will also have a beneficial effect.

Table 3 Predicted Concentrations of Key Parameters for Effluent Discharges at Just Above Median River Flow (Table 32 of AEE). Note that the site-specific DRP guideline is not applicable to high river flow conditions – therefore the nominal exceedance values are bracketed as ‘not applicable’ [N/A]

Parameter	Concentrations (g/m ³)				Distance downstream of outfall (m)					
	Median Upstream	95%ile Effluent	Median Leakage	Receiving Water Target	200 (g/m ³)	300 (g/m ³)	300 %RWT	400 (g/m ³)	800 and Wardells Bridge(g/m ³)	800 %RWT
fBOD	0.3	28	5	2.00	1.89	1.64	82%	1.43	1.24	62%
NH ₄ -N(S)	0.01	11.3	1.1	1.61	0.65	0.55	34%	0.46	0.39	24%
NH ₄ -N(W)	0.01	11.1	6.7	1.61	0.65	0.55	34%	0.46	0.38	24%
NO ₂ -N	0.002	2.01	0.14	9.00	0.12	0.10	1%	0.08	0.07	1%
NO ₃ -N	0.5	4.29	0.84	7.20	0.74	0.71	10%	0.67	0.64	9%
DRP	0.01	3.3	2.7	0.030	0.20	0.17	[N/A]	0.14	0.12	[N/A]

□ Table updated from NIWA (2007). Uses upstream background concentrations with conservative new pond leakage (750 m³/d; 1414x dilution to median flow). Receiving water targets provided in Table 25 (Table 30 of AEE).

RWT = receiving water target; S = Summer; W = Winter.

Leakage only (summer contribution calculated for half-median flow)

Table 4 Predicted Concentrations of Key Parameters for River Flow at Just Below Median Flow (no direct discharge in summer) (Table 33 in AEE)

Parameter	Concentrations (g/m ³)				Distance downstream of outfall (m)					
	Median Upstream	95%ile Effluent	Median Leakage	Receiving Water Target	200	300	300 %RWT	400	800 and Wardells Bridge	800 %RWT
fBOD	0.30	0	5	2.00	0.31	0.31	16%	0.31	0.31	15%
NH ₄ -N(S)	0.01	0	1.1	1.61	0.013	0.012	1%	0.012	0.012	1%
NH ₄ -N(W)	0.01	0	6.7	1.61	0.026	0.024	1%	0.021	0.019	1%
NO ₂ -N	0.002	0	0.14	9.00	0.002	0.002	0%	0.002	0.002	0%
NO ₃ -N	0.5	0	0.84	7.20	0.50	0.50	7%	0.50	0.50	7%
<i>E.coli</i> (S)	103	0	200	130	103	103	80%	103	103	79%
<i>E.coli</i> (W)	49	0	260	130	50	50	38%	49	49	38%
DRP	0.010	0	2.7	0.030	0.016	0.015	52%	0.015	0.014	46%

Notes: Modified Table from NIWA (2008); Upstream Background with Leakage (750 m³/d; 707x dilution) to Half-Median River Flow, with (s) = summer; (w) = winter. RWT= Receiving Water Target. Receiving water targets provided in Table 25 (Table 30 of AEE).

Scenario for proposed effluent compliance standards (Table 54 of AEE)

Table 5 Mixing region scenario: Uses upstream median, leakage median and proposed effluent compliance values (from AEE Table 54). Median river flow (12.33 m³/s) with effluent dilution (30X) + leakage dilution (1414X). Note that the site-specific DRP guideline is not applicable to high river flow conditions – therefore the nominal exceedance values are bracketed as ‘not applicable’ [N/A]

Parameter	Concentrations (g/m ³)				Distance downstream of outfall (m)					
	Median Upstream	90%ile Effluent percentile compliance standard	Median Leakage	Receiving Water Target	200	300	300 %RWT	400	800	800 %RWT
fBOD	0.3	28	5	2.00	1.89	1.64	82%	1.43	1.24	62%
BOD	1	43	17	5*	3.45	3.06	61%	2.74	2.45	49%
NH ₄ -N(S)	0.010	11	1.1	1.61	0.63	0.53	33%	0.45	0.38	23%
NH ₄ -N(W)	0.010	11	6.7	1.61	0.64	0.54	34%	0.46	0.38	24%
NO ₂ -N	0.002	1	0.14	9.00	0.06	0.05	0.6%	0.04	0.04	0.4%
NO ₃ -N	0.50	7.5	0.84	7.20	0.92	0.86	12%	0.80	0.75	10%
SS	1	91	23	10*	6.17	5.36	54%	4.67	4.05	40%
DRP	0.010	3	2.7	0.030	0.18	0.16	[N/A]	0.13	0.11	[N/A]

- * = default receiving water criteria values from: Hickey, C.W.; Quinn, J.M.; Davies-Colley, R.J. (1989). *Effluent characteristics of domestic sewage oxidation ponds and their potential impacts on rivers*. *New Zealand Journal of Marine and Freshwater Research* 23: 585-600.
- Receiving water targets provided in Table 25 (Table 30 of AEE).
- RWT = receiving water target; S = Summer; W = Winter.

6.17 Ammoniacal-nitrogen is the major potential toxicant of concern in the oxidation pond treated discharge. The predictions for the potential pond discharge effects are conservatively based on the measured summer and winter 95%ile values, which are maximally 40% of the guideline value at 200 m downstream (55% mixed), declining to 24% of the guideline at 800 m (fully mixed). Therefore, in my opinion the effects of ammoniacal nitrogen will be no more than minor. The risk to receiving water organisms is further reduced by:

- (a) The intermittent nature of the discharge;
- (b) Use of the 95%ile effluent ammoniacal-nitrogen concentration (note the summer median value is 10x lower as used for leakage inputs (Table 3); and
- (c) Application of the chronic ANZECC (2000) guideline value to this assessment. Studies with New Zealand native fish and macroinvertebrate species have indicated that compliance with the chronic ANZECC guideline would provide good protection for most species (Hickey et al 1999, Hickey 2000).

- 6.18** Table 4 presents the results for the scenario for half-median flow in summer when there is no effluent discharge, but there is leakage from the base of the new clay lined ponds. The values were conservatively calculated based on the dilution available at half-median flow in the river and the maximum anticipated leakage rate. These predicted values are based on the highest anticipated leakage rate (750 m³/d, 707x dilution; as discussed in the evidence of Mr Humphrey Archer) for conditions of maximum pond retention. Average leakage is expected to be less than this.
- 6.19** Table 4 indicates that the DRP value at 300 m downstream may approach about half the NIWA-developed site-specific guideline, and that all other parameters are markedly below guideline values both within and downstream of the reasonable mixing zone. The DRP increase within the area of reasonable mixing may slightly increase periphyton growth (as compared to upstream) but nuisance growth will not occur as a result of the discharge. There should be a noticeable reduction in periphyton growth as compared to the current situation with much higher pond leakage and with continuous direct discharge.
- 6.20** Table 5 provides predictions of receiving water concentrations at median flow for effluent and leakage after reasonable mixing for the proposed 90%ile monitoring compliance standards with RWT values. These comparisons show all constituents will be substantially below the RWT, with the nominal exception of DRP which is not applicable to high river flow situations when river conditions will not allow periphyton growth (ie high turbidity and scour conditions).

Cumulative effect of pond seepage, land disposal and direct river discharge

- 6.21** The following section provides an analysis of the DRP concentration from the three major sources (direct discharge, leakage and groundwater return flow). As noted earlier, the concentration of DRP in the river is of major importance since it is the limiting nutrient for algal growth. However, for completeness, we have included mass load calculations for total nutrient loads. Such information is relevant to the assessment of total catchment nutrient loads.
- 6.22** Groundwater modelling provides seasonal groundwater concentrations for the irrigation scheme (PDP 2008) and this has been used to determine the combined effects on the river from direct discharge, pond leachate and groundwater inflows. The cumulative effects assessment is based upon the following worst case DRP loads: (i) effluent to the Ruamahanga River (using 95 percentile nutrient concentrations in the discharge); (ii) upper bound pond leakage volume; and (iii) long-term (after 28 years) groundwater from irrigation return flow; at just above median flow are summarised in Table 6 below.

- 6.23** This confirms that at just above median flow, direct discharge is by far the major contributor (97%) of DRP contributed by the MWTP, and that by removing the discharge (as will be the case below median flow in summer) there will a large reduction in river DRP concentration. This will reduce the 'minor' effects of DRP on periphyton growths noted with the current discharge regime.
- 6.24** From Table 6 and Table 7, the conservative assessments of the increase in DRP as a result of pond leakage and long term irrigation groundwater is to increase DRP concentrations in the river by 0.003 g/m^3 which is less than the scheme with the existing ponds at 0.0065 g/m^3 . With background DRP concentrations of 0.010 g/m^3 , total DRP is predicted to increase to 0.013 g/m^3 downstream of the ponds as a result of pond leakage and irrigation groundwater. This is significantly lower than the site-specific guideline value of 0.030 g/m^3 (Table 25).
- 6.25** The analysis was also carried out for the situation during low river flow. Table 8 provides the DRP mass loads and concentrations for the potential irrigation scheme on all of the MDC land at the maximum irrigation rates, and at a 5 percentile low river flow of $2.7 \text{ m}^3/\text{s}$. While MDC is not applying for discharge consents to apply effluent to the western portion of the 107 ha site at this stage, the modelling has been carried out on a very conservative basis to identify the potential future effects. This approach also supports the designation of the full area for land treatment of pond effluent in the future.
- 6.26** Table 8 shows that at low river flows, the predicted in-river DRP concentration increases by 0.012 g/m^3 as a result of pond leakage and groundwater return. At sustained low river flows, upstream DRP concentrations also become very low. This is consistent with the findings in other rivers, that as flow decreases, DRP concentration decreases e.g. Manawatu River catchments (McBride & Quinn, 1993). During the low river flows from December 2007 to April 2008, DRP in the Ruamahanga River upstream of the oxidation ponds dropped to below the detection limit of 0.004 g/m^3 . Therefore DRP concentrations downstream of the ponds, will be less than 0.016 g/m^3 during low flow conditions, which is significantly less than the DRP guideline value of 0.030 g/m^3 (Table 25).
- 6.27** We have also considered the potential for greater DRP leakage from the existing and new ponds during the initial decommissioning phase. Maximally, the DRP from the existing pond leakage (Table 7) would be added to the total from the new pond and irrigation (Table 8). The total additional leakage for this period might maximally increase to 65% of the site-specific guideline value, however, this would still be

expected to be less than the guideline when added to the river background DRP downstream of the ponds.

Table 6 Predicted worst case DRP discharge to River from direct discharge, pond leakage and groundwater (irrigation return flow) at just above median flow (AEE Table 37)

Component	DRP mass (kg/day)	Change in fully mixed River DRP concentration (g/m ³)
Direct discharge	117	0.11
Pond leakage	2.0	0.002
Groundwater (from irrigation)	0.82	0.001
TOTAL	120	0.113

Table 7 Original Scheme; Predicted worst case DRP discharge to river from direct discharge, pond leakage and groundwater (irrigation return flow) at just above median flow in the river (AEE Table 38)

Component	DRP mass (kg/day)	Change in fully mixed river DRP concentration (g/m ³)
Direct discharge	117	0.11
Existing Pond leakage	6.5	0.0065
Groundwater (from irrigation)	0.5	0.00048
TOTAL	124	0.117

Table 8 Updated Scheme (new ponds) predicted worst case DRP discharge to River from pond leakage and groundwater (irrigation return flow) at 2.7 m³/s low flow (AEE Table 39)

Component	DRP mass (kg/day)	Change in fully mixed River DRP concentration (g/m ³)
Direct discharge	0	0
Pond leakage (new ponds)	2.0	0.0090
Groundwater (from irrigation)	0.82	0.0030
TOTAL	2.82	0.012

6.28 In summary, in my opinion the proposed discharge regime will ensure that any effects on attached algal growth downstream of the discharge will be minor. Although the current discharge is generally not causing nuisance algal growth levels at Wardells Bridge, it does stimulate algal growth particularly at low flows when upstream nutrient concentrations are high and river conditions are clear. The effects are most evident in the partially mixed area on the right bank side. I consider that removing the discharge from the river at flows below median in summer, will markedly reduce algal build-up downstream of the discharge as compared to the present situation.

Comparison of Upstream and Downstream *E.coli* and Clarity Concentrations

6.29 Upstream *E.coli* and clarity values vary significantly with flow. In addition, the concentrations of *E.coli* and clarity in the effluent will typically be variable. In view of this

inherent variability, the approach used to determine *E.coli* and clarity impacts of the discharge, was to undertake a Monte-Carlo simulation.

- 6.30** This is a recognised statistical technique that is used to combine variable distributions, and produce an output for the mixed product. Taking *E.coli* as the example, the approach used was to select a threshold flow range of 12.3 m³/s to 14 m³/s (just after discharge commences in summer) and combine the upstream *E.coli* concentrations (based on monitored data), with the predicted distribution of *E.coli* in the effluent from the upgraded oxidation ponds adjusted to the proposed consent compliance (ie geometric mean 300 cfu/100 mL, median 330 cfu/100mL; AEE Table 54). The output is a distribution of *E.coli* in the receiving water (Ruamahanga River) downstream of the treatment plant. The same approach was taken with clarity. The results of this procedure are outlined below for *E.coli* with details provided in NIWA (2006).
- 6.31** The Monte-Carlo simulation modelling used 16 *E.coli* data available for the Ruamahanga River for flows >10-<20 m³/s to define the probability distribution. An inverse-gaussian distribution provided a good fit to log-transformed distribution of the upstream data. The observed and predicted statistics are shown in Table 9. This model is considered to provide an acceptable fit to the river data given that only 16 measurements were available. The model-predicted median was slightly lower than the observed river median (-19%) and predicted upper percentiles ranged from +14% to -42% when compared with the observed values. This level of accuracy is considered acceptable in that the mass load of discharge *E.coli* and predicted increment magnitude is the major issue addressed in this simulation.
- 6.32** There were 68 data available from pond discharge *E.coli* using summer data from 2000 to 2005. A Beta-General model provided a good fit to a log-transformed distribution of the summer data. The observed and predicted statistics for the existing effluent distributions are shown in Table 10. This model is considered to provide a good fit to the effluent data for the 68 available measurements. The model-predicted median was slightly lower than the observed pond median (-11%), and predicted upper percentiles ranged from +30% to -1% when compared with the observed pond values. The slight over-predictions of the model for the 90%ile and 95%ile values for the pond effluent will increase the conservatism of the modelled river predictions. The predicted improvements in the effluent treatment were incorporated into the model simulations by reducing the effluent distribution median by a factor (-57%) to provide a predictive model for the proposed consent limit (ie median of 330/100mL; effluent median of 763 → 330 = -57%). The resulting distribution was used in the Monte Carlo simulation.

6.33 A Monte Carlo simulation was run using @Risk software to combine the upstream and diluted effluent *E.coli* distributions predict downstream water *E.coli* concentration for a predicted 30-fold effluent dilution (ie fully mixed discharge at above median flow) and dilutions appropriate to partial mixing. 20000 iterations were used for simulation runs to predict river concentrations. The simulation result for the maximum predicted upstream *E.coli* distribution and the results of a 30-fold dilution of the upgraded effluent together with the downstream predictions are given in Table 11. These show a median downstream increase in *E. coli* number of 4.3% for the upgraded fully mixed discharge at 800m. This can be compared with a predicted 6.5% increase in *E.coli* for the existing discharge at river flows just above median.

6.34 Inspection of this modelled data (Table 11) shows that the river naturally exceeds the MfE ‘Alert’ level (260/100mL) for about 20% of the time and the MfE ‘Action’ level for (550/100mL) for 5 to 10% of the time during the threshold flow period. Addition of the effluent will not result in the river being in these conditions for greater periods of time.

Table 9 Upstream (RUA1) summer *E.coli* data summary statistics for observed and model-predicted distributions (from NIWA 2006)

Summary of <i>E.coli</i> @ RUA1 (Log model) Sel RUA1:sum:>10- Cases selected by: <20m3/s			
	Observed	Predicted	Pred/Obs (Δ%)
Count	16		
Mean	261		
Median	103	83	-19
StdDev	540		
Min	10		
Max	2220		
Upper 75th %tile	187	214	14
Upper 90th %tile	532	529	-1
Upper 95th %tile	1722	998	-42

Table 10 Pond effluent summer *E.coli* data summary statistics observed, existing and upgraded model-predicted distributions (from NIWA 2006). Upgrade model for consent limit median *E.coli* of 330/100mL.

Summary of Cases selected by:	Effluent <i>E.coli</i> (Log model) Summer selector		Existing model		Upgrade model
	Observed	Predicted	Pred/Obs ($\Delta\%$)	Predicted	
Count	68				
Mean	1204				
Median	763	677	-11	339	
StdDev	1312				
Min	13				
Max	7000				
Upper 75th %tile	1750	1732	-1	866	
Upper 90th %tile	2884	3346	16	1673	
Upper 95th %tile	3415	4446	30	2246	

Table 11 Predicted *E.coli* changes for a 30-fold dilution of effluent with median *E.coli* of 330/100mL. Orange shading for exceedance of MfE 'Alert' level (260/100mL); bold white-face for exceedance of MfE 'Action' level (550/100mL). where: Q_u = upstream river flow; C_d = downstream *E.coli* (/100mL); C_{eff} = effluent *E.coli*; C_u = upstream *E.coli*; = dilution. (from NIWA 2006)

alpha = 30 for upstream 10-20 m3/s				Antilog data			Downstream increase (%)	
Name	C_d	Q_u	C_{eff}	C_u	C_d	C_{eff}	C_u	
Minimum	0.4117748	10.00018	0.707664	0.3258171	2.58	5	2	21.9
Maximum	4.947583	14.19963	3.627762	5.017554	88630.46	4244	104125	-14.9
Mean	1.990662	12.1	2.482163	1.974279	97.87	304	94	
Std Deviation	0.5706454	1.212495	0.582056	0.5893742	3.72	3.82	3.88	
Variance	0.3256361	1.470144	0.3387891	0.3473619	2.12	2.18	2.23	
Skewness	0.5469801	3.35E-06	-0.337281	0.5474707	3.52	0.46	3.53	
Kurtosis	3.482887	1.799997	2.437715	3.482127	3040.09	273.98	3034.78	
Errors Calculated	0	0	0	0	1.00	1.00	1.00	
Mode	1.794454	12.24699	2.683879	1.799727	62.30	482.92	63.06	
5% Perc	1.14941	10.20983	1.448347	1.103935	14	28	13	11.0
10% Perc	1.29992	10.41969	1.667961	1.263271	20	47	18	8.8
15% Perc	1.411174	10.62999	1.826732	1.377013	26	67	24	8.2
20% Perc	1.505306	10.83967	1.95759	1.471442	32	91	30	8.1
25% Perc	1.584339	11.04975	2.071729	1.555122	38	118	36	7.0
30% Perc	1.660659	11.2598	2.174867	1.632705	46	150	43	6.6
35% Perc	1.731079	11.46971	2.270368	1.706482	54	186	51	5.8
40% Perc	1.799941	11.6796	2.360379	1.778303	63	229	60	5.1
45% Perc	1.870835	11.88976	2.44647	1.849457	74	280	71	5.0
50% Perc	1.939221	12.09995	2.529728	1.921135	87	339	83	4.3
55% Perc	2.010409	12.30969	2.611253	1.994501	102	409	99	3.7
60% Perc	2.085307	12.51982	2.691784	2.070899	122	492	118	3.4
65% Perc	2.163614	12.72961	2.772369	2.151689	146	592	142	2.8
70% Perc	2.244412	12.93975	2.853809	2.238913	176	714	173	1.3
75% Perc	2.340402	13.14961	2.937439	2.335447	219	866	216	1.1
80% Perc	2.445663	13.35972	3.024825	2.446001	279	1059	279	-0.1
85% Perc	2.578439	13.56964	3.118429	2.579283	379	1313	380	-0.2
90% Perc	2.746028	13.77968	3.22339	2.753285	557	1673	567	-1.7
95% Perc	3.005923	13.98972	3.351498	3.025153	1014	2246	1060	-4.3

Table 12 Summer *E.coli* and Clarity in Ruamahanga River upstream of discharge, in relation to River Flow (Table 34 in the AEE)

	<i>E.coli</i> (cfu/100 mL)	Clarity (visibility of Black Disc in metres)
Flow category [1]	Median (5 – 95%ile)	Median (5 – 95%ile)
< Half-median	29 (7 – 87)	3.4 (1.1 – 5.8)
Half-median to Median	40 (4 – 219)	2.0 (0.22 – 4.3)
Threshold flow range [2]	83 (13 – 1058)	1.0 (0.17 – 4.6)
High flow	207 (16 – 2909)	0.34 (0.09 – 1.92)

Notes: [1] Flow ranges are: <Half-median = < 6.15 m³/s; Half-median to Median = 6.15 – 12.3 m³/s; Threshold flow range = 12.3 – 14.0 m³/s; High flow = >14 m³/s.

[2] The analysis uses actual data (between 21 and 36 data points) for each flow range except for the threshold flow range, which is based on modelled values derived from the Monte-Carlo simulation (this is discussed below).

[3] “Threshold flow range” is the flow region where the discharge is initiated and prior to higher flows where upstream quality is poorer. This range occurs approximately 4% of the time and 13% of the time when discharging (see Figure 33 of AEE; evidence of Dr Jim Cooke)

6.35 As can be seen from Table 12, as flow increases there is a general tendency of higher *E. coli* values and a marked reduction in river clarity. Notably, for flows above half-median the upstream *E. coli* values may at times exceed the microbial guidelines (130 cfu/100 mL for contact recreation or 100 cfu/100 mL for livestock drinking; see Table 25), while the clarity may at times be less than the guideline value (1.6 m horizontal Black disc visibility) in all flow classes. However, at flows below median, the river upstream of the discharge is generally relatively clear and has low *E. coli* levels. In these situations the existing discharge causes an appreciable deterioration in water quality, particularly in the partially mixed region between Makoura Stream and Wardells Bridge. Accordingly, the removal of the direct discharge from the river at flows below median will have a considerable benefit in terms of water quality.

6.36 At higher flows, the discharge will not have a significant effect on water quality, which is already relatively poor. Discharge above median flow has considerably less impact than discharge at lower flows because of the poorer upstream water quality and higher dilution available for the discharge. Furthermore, at flows above median there is little use made of the river for contact recreation (particularly primary contact recreation).

6.37 The modelling indicates that reduction in median clarity values caused by the proposed discharge at threshold flows was 15% at 300 m and a reduction of 11% at 800 m (the range was 0-50% reduction and 0-42% reduction Table 13 & Table 14 respectively). The “No change” indicated for these predictions refers to flow periods where the discharge is not occurring, with “Negligible change” indicating that the magnitude of change would be very small at higher flows. I consider that a clarity change of at least

50% (after reasonable mixing) would be required to result in a conspicuous change in this shallow river, where the bed generally dominates the perceived clarity and colour. Notably, flows in this threshold range only occur for 4% of the time (see evidence of Dr Jim Cooke) in summer and thus any aesthetic impacts will be minimal. Clarity impacts will decline at higher river flows as a result of higher background levels and greater available receiving water dilution.

6.38 The predictions for *E. coli* are based on a proposed upgraded consent compliance geometric mean value of 300 cfu/100mL (which equates to a median value of 330 cfu/100mL). Actual quality is expected to be closer to 200 cfu/100mL as a geometric mean (AEE Table 25) so this modelling is conservative. The upstream median *E. coli* at threshold flows was 83 cfu/100 mL (Table 12) and is predicted to show slight increases for median *E.coli* values (<6.5% for 300 m, Table 13; & <4.3% for 800 m, Table 14). Notably, the upper 95%ile *E. coli* values are markedly elevated in the threshold flow region as a result of the high natural variability, with the predicted increase indicating a negligible change as a result of effluent addition.

6.39 In conclusion, this analysis of summer data has shown that the predicted impact after reasonable mixing (at 300 m) and at Wardells Bridge for *E.coli* and clarity will be no change or negligible change as a result of discharges from the proposed upgraded ponds. The elimination of discharge at below median flows removes all effects at these flows which coincide with higher recreational use.

Table 13 Predicted Summer *E.coli* and Clarity at 300m Downstream of Discharge in relation to River Flow. Bracketed value [] is percent change from existing summer median (Table 12). (Table 35 in the AEE)

Flow category [1]	<i>E.coli</i> (cfu/100 mL)	Clarity (visibility of Black Disc in metres)
	Median (5 – 95%ile)	Median (5 – 95%ile)
< Half-median	No change	No change
Half-median to Median	No change	No change
Threshold flow range [2]	89 (15 – 1012) [+6.5%]	0.85 (0.17 – 2.3) [-15%]
High flow	Negligible change	Negligible change

Notes: 'No change' refers to distribution values given in Table 12 (Table 34 of AEE).

[1] See Table 12 (Table 34 of AEE) footnotes;

[2] Model predicted values for *E.coli* is based on a median effluent concentration of 330 /100mL added to upstream distribution.

Table 14 Predicted Summer *E.coli* and Clarity at Wardells Bridge in relation to River Flow. Bracketed value [] is percent change from existing summer median (Table 12). (Table 36 in the AEE)

Flow category [1]	<i>E.coli</i> (cfu/100 mL)	Clarity (visibility of Black Disc in metres)
	Median (5 – 95%ile)	Median (5 – 95%ile)
< Half-median	No change	No change
Half-median to Median	No change	No change
Threshold flow range [2]	87 (14 – 1014) [+4.3%]	0.89 (0.17 – 2.67) [-11%]
High flow	Negligible change	Negligible change

Notes: ‘No change’ refers to distribution values upstream as given in Table 12 (Table 34 in AEE). ‘Negligible change’ indicating that the magnitude of change would be very small.

[1] See Table 12 (from Table 34 in AEE) footnotes;

[2] Model predicted values for *E.coli* is based on a median effluent concentration of 330 /100mL added to upstream distribution.

Winter Discharge Regime

6.40 With regard to the winter discharge regime (1 May to 31 October) there are two significant differences (compared to a summer discharge of effluent) that apply to the assessment of impacts of a discharge of effluent just above and just below the half-median river flow (the winter trigger flow). These are:

- (a) Much less contact recreation in the river due to unfavourable river and climatic conditions; and
- (b) River and climatic conditions that do not promote rapid growth of algae (ie cold water, low light conditions).

6.41 Insufficient river water quality data was available on which to base a robust numerical analysis (the main focus of monitoring of river water quality had been during the summer season when recreational use of the river is greatest). The approach taken to analyse the impacts of the winter discharge of effluent has been to prepare a comparative assessment as set out in Table 16 and Table 17 below.

Table 15 Winter *E.coli* and Clarity in Upstream Ruamahanga River in relation to River Flow (Table 40 in the AEE)

Flow category [1]	<i>E.coli</i> (cfu/100 mL)	Clarity (visibility of Black Disc in metres)
	Median (5 – 95%ile)	Median (5 – 95%ile)
< Half-median	6 (2 – 10)	3.6 (0.3 – 7.1)
Threshold flow range [2]	ND	3.0 (0.7 – 5.2)
High flow [3]	50 (5 – 291)	0.6 (0.084 – 3.6)

Notes: ND = No Data available.

[1] Clarity data for <Half-median flows comprises 8 data points; *E coli* data for <Half-median flows comprises 2 data points

[2] A 'threshold flow range' of 5 to 8 m³/s was used to summarise data in the range where the effluent discharge commences; 9 data points available for clarity;

[3] Clarity data for high flows (>6.15 m³/s) comprises 16 data points; 32 data points for *E. coli* (range 3 – 493 cfu/100 mL).

Table 16 Winter *E.coli* and Clarity at 300m Downstream of Discharge in relation to River Flow (Table 41 in the AEE)

Flow category [1]	<i>E.coli</i> (cfu/100 mL)	Clarity (visibility of Black Disc in metres)
	Median (5 – 95%ile)	Median-
< Half-median	No change	No change
Threshold flow range	Negligible change	2.5 [a]
High flow	Negligible change	Negligible change

[a] Estimated value based on a 17% reduction predicted for Monte-Carlo modelling of summer discharge.

Table 17 Predicted Winter *E.coli* and Clarity at Wardells Bridge in relation to River Flows (Table 42 in the AEE)

Flow category [1]	<i>E.coli</i> (cfu/100 mL)	Clarity (visibility of Black Disc in metres)
	Median (5 – 95%ile)	Median-
< Half-median	No change	No change
Threshold flow range	Negligible change	2.6 [a]
High flow	Negligible change	Negligible change

Notes; [a] Estimated value based on a 13% reduction predicted for Monte-Carlo modelling of summer discharge.

Notes: 'No change' refers to distribution values upstream as given in Table 34 of AEE. 'Negligible change' indicating that the magnitude of change would be very small.

[1] See Table 12 (Table 34 in AEE) footnotes;

- 6.42** Because of the lack of data, winter 'predictions' are not based on modelling, but rather an expert view based on the summer data and winter conditions (eg ponds generally clearer, high variability in *E coli* and clarity upstream).
- 6.43** Table 15, Table 16 and Table 17 summarise the available *E. coli* concentrations in relation to river flow, though only the >half-median flow category provides a reasonable number of data points (n = 58). The predicted change for flows above half-median is either no change to the upstream water quality or negligible change as a result of the discharge during the winter period.
- 6.44** With regard to winter clarity conditions, the upstream value for the low flow and threshold flow scenarios indicates a good clarity (median of 3.6 m and 3.0 m respectively) which does not change significantly following the onset of a discharge. I predict that the plume will be inconspicuous (ie <50% change in clarity) once reasonable mixing has occurred (ie after 300-500m). By Wardells Bridge the discharge will be fully mixed and will have negligible effect on colour and clarity.

Comparison with Existing Water Quality

- 6.45** A comparison of Ruamahanga River summer water quality is summarised for flows below and above median, for before and after the proposed upgrade for the downstream site at Wardells Bridge (Table 18). The highlighted values indicate marked (>50%) improvements from the existing conditions that will occur for water quality at Wardells Bridge under low flow (< median) conditions, particularly for increased clarity and reduced *E coli* and nutrients. Marked improvements will also occur above median flow for ammoniacal-nitrogen and nitrite-nitrogen.
- 6.46** The predicted improvements in downstream water quality at low flows are a result of elimination of the discharge during this period. At high flows (> median) the improvements are the result of the combination of three major factors:
- (a) pond treatment upgrade to reduce *E.coli* concentrations;
 - (b) full mixing occurring upstream of Wardells as a result of a change in discharge location and installation of diffusers; and
 - (c) use of a flow-proportional (ie constant 30x dilution) relationship.

- 6.47** The first two factors will result in a decrease in *E. coli* concentrations at Wardells Bridge, while the third will increase concentrations around the threshold flow region once the discharge is initiated.

The monitored downstream median *E. coli* for high river flows (ie 300 cfu/100 mL)

- 6.48** Table 18 represents the upstream river contribution plus the partially mixed existing ponds and upstream Makoura Stream contributions. The improvement in Wardells Bridge median *E. coli* value is estimated to be about a 34% reduction at river flows above median when compared with the existing situation. This level of reduction is expected as a result of the combined improvements detailed above. The dominance of highly variable upstream *E.coli* concentrations at high river flows will result in considerable variability in the measured *E.coli* concentrations at Wardells Bridge.
- 6.49** The reason for the predicted 41% increase in river DRP concentration post-upgrade is simply that, on days when discharge can occur, there will be at least 410 L/s of treated effluent (1:30 ratio at >median flow) compared with the current average discharge rate of 180 L/s.

Predicted effects of the new discharge regime on aesthetic values

- 6.50** The Ruamahanga River at Wardells Bridge will show a significant improvement in clarity as a result of the elimination of the summer discharge for flows below median (see Table 18).
- 6.51** Initiation of the discharge at median flow will not result in a conspicuous reduction in clarity, either during the threshold flow period when the discharge is initiated, or at higher flows when the river clarity naturally declines. The shifting of the discharge point upstream and the use of a mixing diffuser will eliminate the highly visual partial mixing zone which currently exists below the Makoura Stream inflow. The combined result will be a significant improvement in river clarity during high use recreational periods.
- 6.52** The ponds have a lower algal production in winter with a consequent reduction in suspended solids and increased clarity compared to summer (median suspended solids 38% lower and black disk clarity >2-fold higher than summer). Flows in the Ruamahanga River are higher in winter (Figure 34 AEE) and clarity shows a marked reduction with increasing flow, with generally good, though highly variable, clarity at below half-median flow (Table 15). The predicted improvements in clarity will be high for below half-median flow when the discharge does not occur (this is 7.5% of the time) and

a predicted 'negligible change' for higher flows (Table 16 & Table 17). Even at threshold flows it is predicted that the plume will be inconspicuous (ie <50% change in clarity) once reasonable mixing has occurred.

6.53 The impact of the discharge on perceived colour will be markedly reduced following the proposed upgrade for the following reasons:

- (a) There will be no algae settling on the bed below median flows (summer) because there will be no discharge; (this is currently a problem at times of low flow with periods where there is conspicuous colour change for a distance of up to 200-300m below the current discharge (ie Makoura confluence))
- (b) Moving the discharge point from the Makoura Stream to the main stem of the Ruamahanga River and discharging via a diffuser will result in better mixing and less visual impact; and
- (c) The discharge occurs only during flows above median, when the river is naturally discoloured. This will result in a lesser ability to perceive any colour changes.

6.54 The future colour-related effects on the receiving water will therefore be minor and significantly less than the existing situation.

6.55 The proposed quality of effluent and the intermittent effluent discharge as a result of the proposed effluent discharge regime during summer low flows will eliminate the discernible green plume from the discharge mixing with the river water and will significantly improve the clarity of the river downstream of the discharge.

6.56 There will be no conspicuous change to colour and clarity at below median flow in summer and half-median flow in winter (no direct discharge) and no conspicuous change to colour and clarity after reasonable mixing (conservatively taken as being 300m) when discharge does occur. The reasonable mixing and full mixing zones will be moved upstream of Wardells Bridge.

6.57 In summary, the elimination of the discharge from the river at low flows will result in greatly improved water quality, especially clarity and faecal contaminants, and improve the receiving environment for the higher recreational use occurring during this period. The nutrient parameters (nitrogen and phosphorus) which increase at high flows are intermittent in nature and occur at times when the river conditions prevent the stimulation of attached growths (ie scour and turbidity).

Table 18 Comparison of Water Quality at Wardells Bridge in Summer before and after Upgrade (Table 43 in the AEE)

Parameter	< Median flow			> Median flow		
	Before Median	After Median	Change (%)	Before Median	After Median	Change (%)
Flow (m ³ /s)	5.6			19.4		
pH	7.4	7.5	1%	7.3	7.2	-1%
Conductivity (µS/cm)	152	134	-12%	112	106	-5%
Dissolved Oxygen (g/m ³)	9.4	9.6	2%	9.8	9.9	1%
Dissolved Oxygen % saturation (%)	97.3	98.3	NC	95.9	95.4	NC
Black Disc (m)	1.34	3.6	170%	1.21	1.3	7%
Colour - Hue (Munsell points)	32.5	35	8%	33.8	37.5	11%
<i>E.coli</i> (cfu/100mL)	93.5	34	-63%	300	198	-34%
Ammonia-N (g/m ³)	0.11	0.012	-89%	0.12	0.053	-56%
Nitrate-N (g/m ³)	0.81	0.50	-38%	0.54	0.41	-24%
Nitrite-N (g/m ³)	0.029	0.002	-93%	0.023	0.0077	-67%
Total Kjeldahl Nitrogen (g/m ³)	0.57	0.18	-68%	0.41	0.53	29%
Total Nitrogen (g/m ³)	1.48	0.70	-53%	1	0.91	-9%
Total Phosphorus (g/m ³)	0.24	0.028	-88%	0.12	0.14	17%
Dissolved Reactive Phosphorus (g/m ³)	0.19	0.014	-93%	0.071	0.100	41%
Turbidity (NTU)	2.55	0.85	-67%	6.42	5.11	-20%
Total Suspended Solids (g/m ³)	3	0.94	-69%	17.5	11.9	-32%
Total Organic Carbon (g/m ³)	4.2	ND	NC	3.8	ND	NC

Notes: [1] NC = No Change; ND = No Data. [2] Monitoring data from March 1994 to October 2005 for <Median flow (12.3 m³/s; n = 57) and > Median flow (n = 31). [3] Rua 2 concentrations are measured values before upgrade and calculated after using: <Median - using Rua 1 values with addition of summer median effluent data to estimate leachate (diluted 707x); and (ii) >Median flow have effluent (diluted 30x) + leachate (diluted 1414x). [4] *E.coli* concentrations use the proposed consent compliance upgrade median of 330 /100mL.

Existing and predicted median, mean and maximum nutrient loads

6.58 The total quantity of nutrients, or mass load, is an environmentally relevant measure for eutrophication of lakes and for integrated catchment load calculations. As noted earlier, the diversion of the Ruamahanga River from Lake Wairarapa and the rapid flushing of the small Lake Onoke means that lake effects are not relevant to this discharge. Mass load calculations are, however, a useful measure of the expected seasonal and annual efficacy of the integrated land management scheme. Mass loads of the effluent discharge may be calculated from the measured concentration multiplied by the volume of discharge.

6.59 The MWTP contributes a small proportion of the total annual nutrient load to the final discharge of the Ruamahanga River to Lake Onoke. This nutrient load information is presented in the evidence of Dr Jim Cooke. However, as the river flows decrease in summer the importance of the existing continuous effluent discharge increases, with the potential for greater downstream proliferation of nuisance growths. The proposed change from continuous to intermittent discharge will largely eliminate the potential for riverine algal proliferation.

6.60 The existing median, mean and maximum (95%ile) nutrient concentrations in the discharge were calculated from the compliance monitoring record (May 03 □ Jun 07). This data is presented in Table 19 below, together with the number of observations from which the statistics were calculated.

Table 19 P and N Statistics of Effluent (from Compliance Records) – all g/m³ (Table Q22.1 in FIR)

	Mean	Median	95%ile	n
TP	3.0	2.9	4.0	53
TN	10.6	10.9	16.8	55

6.61 Daily loads (Table 20 below) were calculated from the product of the above table with corresponding flow statistics (a mean of 13,944 m³/day, a median of 12,361 m³/day, and a maximum 74,937 m³/day). While this is not strictly correct in the case of 95%ile load, it serves to illustrate a worst case.

Table 20 Estimated P, and N loads (existing in kg/day) (from Table Q22.2 in FIR)

	Mean	Median	95%ile
TP	42	35	300
TN	148	134	1258

6.62 Predicted daily loads at just above median flow (Table 21 below) were calculated using the same concentration data (no change expected from existing quality – refer to Table 25 AEE), but assuming that when discharge is occurring, it is at a rate of at least 410 L/s (allowing for a minimum 30x dilution).

Table 21 Predicted P, and N loads at just over median flow (kg/day) (from Table Q22.3 in FIR)

	Mean	Median	95%ile
TP	106	100	140
TN	371	381	588

6.63 The worst case maximum discharge (Table Q22.4 below) was calculated using the maximum possible discharge rate (1200 L/s) equivalent to 103,680 m³/day).

Table 22 Predicted Maximum P and N loads (kg/day) (from Table Q22.4)

	Mean	Median	95%ile
TP	314	296	415
TN	1100	1130	1741

6.64 In order to calculate the mass load of nutrients discharged over a typical year (Table 23 below), the simulations of average daily discharge (Table 27 AEE) was multiplied by the average (mean) TP and TN concentration given in the Table above (3.03 and 10.6 g/m³, respectively). This gives an average daily load discharged to the river for each month from which an average annual load can be estimated. In order to compare with the 'before upgrade' situation we used this same data (Table 27 AEE) but assumed that the effluent load entering the river would be the sum of land and river discharges.

6.65 Table 23 shows the mass load of nutrients discharged over a typical year. The reduction in nutrient load is, however, distributed unequally throughout the year, with greater reductions in summer (when effluent is dominantly irrigated). Figure 2 and Figure 3 below illustrate the 'average' monthly TP and TN loads before and after the upgrade. The average load reduction for TP and TN is about 25% with up to 50% in summer months.

Table 23 Estimated average annual P and N loads discharged to the river before and after the upgrade (tonnes) (Table Q22.5 in FIR)

	Before upgrade	After upgrade
TP	16.2	12.1
TN	57	42

Note on average DIN (NH₄-N +NO₃-N +NO₂-N) is ~80% of TN and DRP is ~ 70% of TP

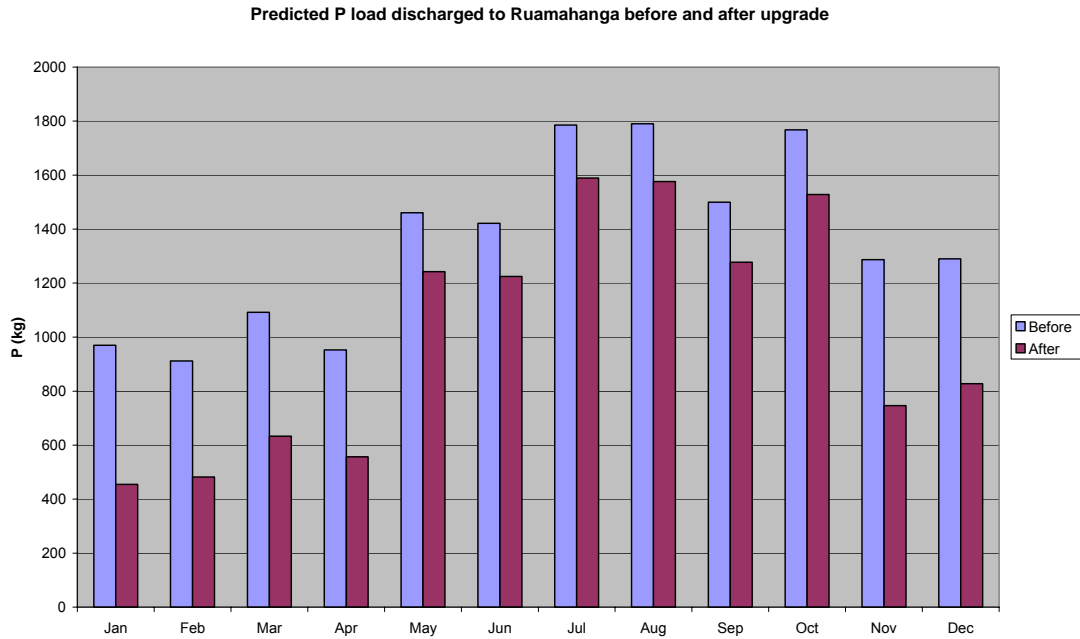


Figure 2 Predicted P Loads to River Before and After Upgrade (Figure Q22.1 in FIR)

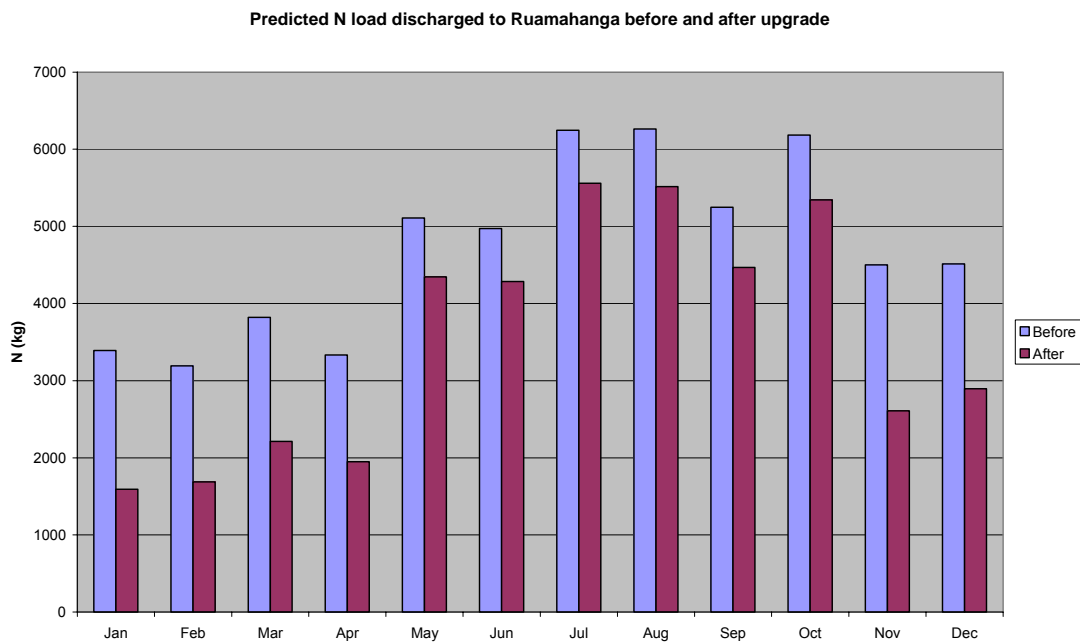


Figure 3 Predicted N Loads to River Before and After Upgrade (Figure Q22.1 in FIR)

6.66 These average monthly figures do not accurately reflect the operational regime, which will see, for example, the entire monthly phosphorus load for January discharged over 8% of the time on average (because flows over median flow only occur on average for 8% of the time).

6.67 A higher phosphorus discharge will occur when the river is greater than median flows, but under this scenario there will also be a greater phosphorus load from upstream diffuse sources, the river will be turbid, and periphyton will be stressed by low light and

hydraulic scouring. Therefore the actual impacts on the river due to the MWTP discharge will be greatly reduced compared with the before upgrade situation.

- 6.68** I do not expect that there will be any significant downstream issues with the transport of pond nutrients during the flood events. For example, travel time for the 95 km from Wardells Bridge to the sea is approximately 44 h at a flow of 12.3 m³/s, decreasing to 17 h at 75 m³/s and to 12 h at 143 m³/s, based on the velocity relationships measured at Wardells. Thus discharge to the ocean occurs rapidly and without time for river algal growths to develop.
- 6.69** The water volume of Lake Onoke is rapidly flushed during river freshes – which will prevent algal blooms occurring. The calculated flushing time for Lake Onoke at median flow in the Ruamahanga River is 1.9 d, reducing to 0.5 d for a 50 m³/s flood at Wardells Bridge. The elimination of nutrient discharges to the river at low flows will reduce the currently existing potential for algal blooms, however, the river low flow flushing time of 5.5 d (based on mean annual low flow of 4.05 m³/s at Wardells Bridge which is 20.8 m³/s at Lake Onoke inlet) is rapid and this probably controls current algal abundance.
- 6.70** The absence of major downstream lakes, together with the unfavourable conditions for periphyton growth as noted above, will therefore not result in significant downstream algal stimulation with flood discharge of pond nutrients. As noted earlier total nutrient loads will be significantly reduced as compared to present and discharges will largely occur during floods and freshes. In my opinion, the elimination of nutrient discharges for summer flows less than median will improve water quality in Lake Onoke during the key summer period.

7. RIVER ECOLOGY

- 7.1** This section reviews the effects of the MWTP discharge on river algae, macroinvertebrates and fish populations. The key findings are:
- (a) **River periphyton growths** respond to added nutrients but nuisance growth levels are limited in the Ruamahanga River by the high flood frequency. Although growths downstream of the MWTP discharge are generally (ie >95% of time) not at nuisance levels, it does have some minor impacts on the recreational and aesthetic values of this section of the river. Elimination of discharge below median flow and discharge during high flow periods (river freshes) is predicted to be sufficient to scour the river bed and in doing so will limit undesirable growths;

- (b) **River macroinvertebrate communities** in the Makoura Stream will improve with removal of the discharge. The proposed upgrade will assist in decreasing the proportion of species associated with algal growths (snails, midge larvae) in the Ruamahanga River at Wardells Bridge, and will therefore result in an improvement to macro-invertebrate indices reflecting pollution sensitive species (eg mayflies);
- (c) **Native fish and trout** species diversity was greatest in the Upper Ruamahanga. In summer, low flows and associated elevated water temperatures are considered the main factor restricting distribution of fish species in the middle to lower Ruamahanga River. The existing discharge does not show any noticeable adverse effect on the fish life in the Ruamahanga, and the proposed change to an intermittent discharge regime is not expected to have any adverse effects on fish habitat or migration. The removal of the discharge from the Makoura Stream will result in a significant improvement in water quality which will have beneficial effects on fish communities.

7.2 The presence/absence and relative abundance of biological communities (invertebrate, fish, algae and macrophytes) in a river system is a good indicator of habitat condition and suitability. The suitability of a particular river reach to support a particular species, community or ecosystem is dependent on a number of factors including substrate, hydrology and water quality. The resident sessile (non-mobile) communities (macro-invertebrates and periphyton, and macrophytes) are 'integrators' of all these factors, responding directly according to their environmental conditions. In comparison, fish, being mobile, can 'avoid' reaches that do not provide the optimum habitat; nevertheless fish are also impacted by the same environmental factors.

7.3 The Ruamahanga River has a generally rocky bed (largely cobble), with a range of hydraulic habitats (ie pool, run, riffles). This means within the main stem of the river at least there are no major differences in substrate that would result in differences in biological communities. Rainfall runoff in the headwaters (Taraia Ranges) is the dominant hydrological driver and therefore broadly similar hydrological responses will be expected along the main stem of the Ruamahanga (although the headwater channel gradients and tributary inflows would also have an effect). Therefore, it is reasonable to conclude if there are significant differences in biological communities along the length of the Ruamahanga, these differences are due to differences in water quality.

7.4 Microscopic algae are always present in aquatic ecosystems. As with terrestrial plants, the factors that govern their growth are light, temperature and nutrients, but with additional hydrological and physical habitat factors. In shallow river ecosystems, free-

floating algae rarely reach levels where they are noticeable. However, some species of algae (termed 'periphyton'⁵) can attach to the riverbed, submerged debris, or rooted plants.

- 7.5** Given suitable habitat conditions (suitable attachment substrate, hydraulic and light conditions), periphyton respond to increased nutrient inputs and elevated temperature by rapidly increasing their growth rates. In turn, a high abundance of periphyton may result in adverse ecological effects and aesthetic concerns. Major controllers of algal abundance are grazing by benthic invertebrates, scouring by floods and reduced light (for example, through turbidity and shading).

Effects of the existing discharge on algal growth

- 7.6** Ministry for the Environment guidelines for the protection of aesthetic and contact recreation values define a "nuisance growth" for rivers as either greater than 30% of its bed covered by filamentous periphyton (> 2 cm length) or greater than 60% matt cover, to be applied during periods when recreational use is likely.⁶ Intermittent algal proliferation events have been recorded at sites along the Ruamahanga River, particularly during sustained warm periods with low flow conditions.
- 7.7** There has been a low incidence of exceedance of the MfE guideline at Mt Bruce and Double Bridges (2.4% and 2.8% of monitoring occasions respectively), increasing to 7.1% at Te Ore Ore (above the MWTP discharge), but progressively decreasing downstream (Gladstone 5.7%; Waihenga 2.9%) (downstream of the MWTP discharge).⁷
- 7.8** The National Rivers Water Quality Network (NRWQN) has collected monthly periphyton monitoring data from three sites on the Ruamahanga River: upstream of the MWWTP discharge at Mt Bruce (SH2); downstream at Wardells Bridge; and distant downstream at Waihenga. The summer data from January 1989 to August 2008 is shown in Figure 4 for filamentous and matt algal abundance. Of the 120 sampling occasions, flood conditions prevented sampling on 11 occasions at Mt Bruce and Waihenga (9.2%) and 33 occasions (28%) at Wardells Bridge. No exceedances of the filamentous or matt guidelines were recorded at Mt Bruce, which were maximally 3.3% and 5.6% bed cover respectively.
- 7.9** Wardells Bridge, downstream of the discharge, exceeded the filamentous guideline on 4 occasions (3.7%, ie less than the 7.1% measured at Te Ore Ore), with a maximum average filamentous cover of 79% (8 February 1994) and 55.6% in last summer's

⁵ Periphyton is a generic term and may include bacteria and fungi living in association with the benthic algae

⁶ MFE, (2000), p91

drought (13 February 2008). The average filamentous and matt covers were 55% and 29% cover when the filamentous guideline was exceeded. The mat guideline has not been exceeded during the monitoring period. Because the GW and NWQMN periphyton monitoring sites were not sampled concurrently, we cannot determine whether the guideline exceedences at Te Ore Ore and Wardells Bridge occurred at the same time. This comparison would be necessary to establish the natural variation from that attributable solely to the MWTP discharge. Commonly the cross-section measurements at Wardells Bridge showed greater proliferations on the right-bank of the river (downstream of the Makoura Stream and MWWTP discharge) rather than uniform growths downstream of the discharge.

- 7.10** The Waihenga site exceed the filamentous guideline on 5 occasions, with a maximum filamentous cover of 50% (20 March 1989), averaging 40% filamentous and 13% matt cover for those occasions. The matt cover exceeded the guideline on only 1 occasion (6 April 1994).
- 7.11** This data indicates that the Wardells Bridge site may very occasionally (3.7% of occasions) exceed the filamentous guideline for nuisance periphyton, but this frequency of exceedence is less than an upstream site, and does not cause increased nuisance algae proliferation at distant downstream sites (Refer Appendix B of AEE for site locations). Investigations suggest that the low proliferation of nuisance growths is in large part due to the 'flashy' nature of the hydrology of the river. Frequent floods or freshes cause attached algae to slough off (NIWA 2003 and NIWA 2004a).
- 7.12** The potential for undesirable biological growths is relevant to both the intermittent effluent discharge and the leakage from the ponds. The Ruamahanga River was found to be phosphorus limited and the peak periphyton growths limited by frequent flood flows (NIWA 2003). Although there is currently a detectable impact in terms of increased biological growth downstream of the existing discharge, the extent of the biological growth generally does not reach nuisance (*undesirable*) levels.
- 7.13** In summary, the level of nutrients in the discharge, in combination with nutrient inputs from upstream, can contribute to increased algal growth on the bed of the Ruamahanga River during periods of sustained low flow in the summer. Although this build up is generally (ie >95% of time) not at nuisance levels, it does have some minor impacts on the recreational and aesthetic values of this section of the River.

⁷ Table 4.7; Milne & Perrie (2005)

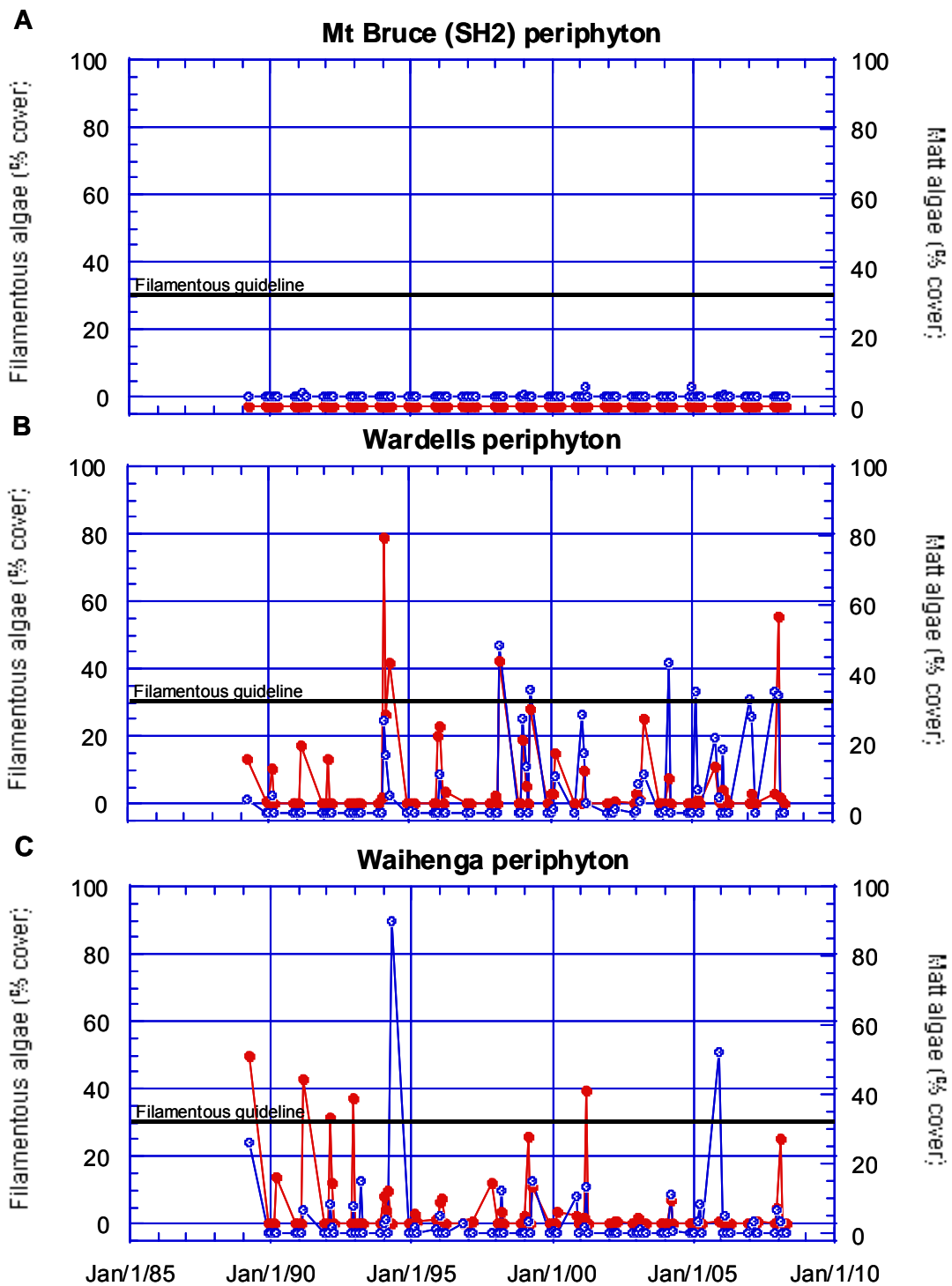


Figure 4 Ruamahanga River periphyton monthly monitoring data (summer: 1 November – 30 April) from 1989 to August 2008 (NIWA NRWQN data). Average filamentous (closed symbol) and matt (open symbol) algal abundance (\pm SD) for 10 points on cross sections. MfE (2000) nuisance growth filamentous guideline (30% cover, shown) and matt guideline (60% cover, not shown).

Predicted effects of the new discharge regime on algal growth

- 7.14** After the upgrade, five factors will reduce periphyton growths:
- (a) the cessation of direct discharge during summer at flows below median flow;
 - (b) the intermittent nature of the discharge;
 - (c) improved mixing of the effluent discharge;
 - (d) the discharge at high flows with turbid waters and high scour conditions; and
 - (e) construction of new ponds with a clay liner to reduce leakage.
- 7.15** Together, these factors will continue to avoid nuisance growths occurring and will reduce algal growth as compared to present.
- 7.16** The current leakage from the ponds is upstream of Wardells Bridge and causes some slight stimulation of periphyton growths, but not to nuisance levels. Predicted nutrient increases from the maximum leakage rate and the groundwater (from irrigation) to half-median flows will be below the site-specific DRP concentration guideline of 0.030 g/m³ (Table 18). Though some algal growth slight stimulation will occur from the leakage, the periphyton will continue to be below the nuisance guideline and the peak growths will be controlled by the macroinvertebrate grazing and the high river flood frequency.
- 7.17** In summary, I consider the proposed upgrade will result in a marked improvement (ie decrease) in nutrient status, with there being no direct effluent discharge at less than median river flow in summer (the time when biological growth is most prolific). At flows above median, the additional nutrients from the MWTP will not cause any undesirable growths because the frequency of high flow periods (river freshes) is predicted to be sufficient to scour the river bed and in doing so will limit undesirable growths.

Effects of the existing discharge on macro invertebrates and ecological health

- 7.18** The macro-invertebrate community associated with the riverbed are integrators of both the physical (for example, temperature, pH, sediment particle size, flood flows) and chemical habitat (for example, water chemistry), together with factors that affect survival and growth (for example, food supply). Thus, measurements of community parameters, together with the presence or absence of 'sensitive' species, can provide robust measures of biological impairment associated with environmental modifications.

- 7.19** The base dataset on invertebrates allows the average Ruamahanga River community characteristics to be benchmarked against other New Zealand rivers.⁸ The results of the general compliance monitoring have shown that the Wardells Bridge site has a high invertebrate density relative to the 88 rivers in the national water quality monitoring dataset (Quinn & Hickey, 1990). The results have been reported in annual monitoring reports (Beca 2003b, 2004b and 2005). The effects of the current effluent discharge on invertebrate communities is summarised in tables and figures in Appendix B of the AEE.
- 7.20** The abundance of Ephemeroptera, Plecoptera, and Trichoptera (EPT) community groups, is a good index of the degree of organic enrichment in a river system (Quinn and Hickey, 1993) with a high proportion of EPT (relative to total taxa), indicating a healthy ecosystem. The abundance of EPT species, including the predominant mayfly (*Deleatidium* sp.) shows a progressive downstream increase.⁹
- 7.21** The proportion of EPT and *Deleatidium* is high in the Ruamahanga River, with median values of 42% and 25% respectively at Wardells Bridge. The proportion of EPT and *Deleatidium* declines at Wardells Bridge compared with upstream at SH2; however, this apparent response is caused by an increase in other opportunistic species relative to the upstream site (Figure B1.5 of the AEE). Elmid beetle larvae are a major component of the macro-invertebrate community at most sites and the free-living caddis, *Aoteapsyche* sp., is a major component of the community at the upstream (SH2) site. Chironomid (midge) larvae that are tolerant of organic enrichment are a highly variable component at all sites, but the median values tend to increase downstream.
- 7.22** The mayfly *Deleatium* is at times a particularly dominant species at each of these sites, with 95%ile values of 77% at SH2, 71% at Wardells and 67% at Waihenga (Table B1.1). This finding is particularly relevant as low numbers of *Deleatium* is an indicator of potential adverse effects of contaminants such as ammonia. *Deleatium* has been found to be amongst the most sensitive of invertebrate and fish species to ammonia, being only slightly less sensitive to rainbow trout and more sensitive than all native fish species tested (Hickey 2000). Thus a high abundance of *Deleatidium* is indicative of the absence of toxic conditions occurring in the river.
- 7.23** Studies on the macro-invertebrate population in relation to the existing discharge indicated 'possible mild pollution' downstream of the discharge (Bioresearches, 2002). This conclusion was based on the reduction in the Quantitative Macroinvertebrate Community Index (QMCI) for sites downstream of the discharge (Table B1.5). Monitoring data for 2003, 2004 & 2005 have shown consistent patterns of comparable

⁸ NRWQN

⁹ Refer Table B1.1, Figure B1.5 in Appendix B.1 in AEE

or increased taxa number downstream of the discharge when compared with upstream, and a slight initial reduction in the QMCI index with a recovery at the more distant downstream site (Rua 4 at +400 m, Tables B1.10, B1.11). The Regional State of the Environment (RSoE) annual monitoring from 1999-2003 showed a marked reduction (23%) in the QMCI index in the upstream reach between Double Bridges and Te Ore Ore (Table B1.6), indicating deterioration in invertebrate quality caused by diffuse source pollution upstream of the MWTP. The QMCI index increases to Gladstone (+17%) and to Waihenga (+4.8%), indicating a downstream improvement in invertebrate quality.

7.24 Overall, there are no marked changes or ecologically significant degradation in macro-invertebrate community structure between sites upstream and downstream of the existing MWTP discharge. Some downstream changes were apparent, which are consistent with the enhancement of communities associated with increased algal growths (ie snails, midge larvae). More distant downstream sites show changes that are consistent with the combined effects of non-point agriculture and point source discharges (ie nutrient enrichment, sediment loads) and higher summer river temperatures.

7.25 While not definitive, the overall weight of evidence from the invertebrate data is that the river is of generally good quality (compared with most NZ rivers) but that there is increasing organic enrichment with distance downstream. The upgraded discharge will not contribute to this overall enrichment during critical summer low flows and nutrients discharged during flood events will be flushed from the system, resulting in a significant reduction as compared to present.

Predicted effects of the new discharge regime on macroinvertebrates and ecological health

7.26 The proposed upgrade to an intermittent discharge, with improved downstream mixing of effluent and limitation of discharge to flows greater than median in summer (>half-median in winter) will not result in exceedance of ammonia toxicity guidelines and will improve water quality both immediately downstream of the discharge (as a result of improved mixing) and at the Wardells Bridge site.

7.27 An increase in sensitive invertebrate species, such as mayflies, will be expected in the previously poorly mixed region at Wardells Bridge which is downstream of the Makoura Stream inflow. Additionally, the removal of the discharge from the Makoura Stream will result in a significant improvement in water quality which will have beneficial effects on resident macroinvertebrate and fish communities.

7.28 The proposed changes to the discharge regime will eliminate direct summer low flow discharges, which will reduce the stimulatory effects on attached periphyton growths that currently contribute to the presently observed macro-invertebrate community effects. In conclusion, the proposed upgrade will assist in decreasing the proportion of species associated with algal growths (snails, midge larvae) and will therefore result in an improvement to macro-invertebrate indices reflecting low pollution species.

Existing effects of the discharge on native fish and trout

7.29 The range of fish species present in the Ruamahanga River system includes native and exotic species, as well as some exotic pests such as perch and tench. Diversity is greatest in the Upper Ruamahanga, and Greater Wellington's own studies have shown that low flows and associated elevated water temperatures are the main factor restricting distribution of fish species in the middle to lower Ruamahanga River (WRC 1999b). (Table 21).

7.30 Diadromous Torrent fish and Common bully are present in the Ruamahanga main stem immediately upstream of the existing MWTP discharge, while the Koaro migrates only to the headwater areas¹⁰ (Figure 5). The distribution of brown trout is largely restricted to river areas above the Waingawa River confluence (Figure 6).

¹⁰ Figures B1.5 and B1.7 in Appendix B1, and Figure B1.6 in Appendix B.1 respectively

Table 24 Fish species in 249 NZFFD records for the Ruamahanga River catchment, retrieved on 19/12/05. Wardells is about 98 km inland. (Table B1.4 of AEE).

Species		Count	Diadromous?	Above Wardells?	In Waingawa?	Max penetration (km)
<i>Aldrichetta forsteri</i>	Yelloweyed mullet	2	Y	N	N	3
<i>Mugil cephalus</i>	Grey mullet	1	Y	N	N	3
<i>Oncorhynchus tshawytscha</i>	Chinook salmon	1	Y	N	N	3
<i>Rhombosolea retiaris</i>	Black flounder	1	Y	N	N	3
<i>Galaxias postvectis</i>	Shortjaw kokopu	1	Y	N	N	9
<i>Gobiomorphus hubbsi</i>	Bluegill bully	3	Y	N	N	27
<i>Carassius auratus</i>	Goldfish	4	N	N	N	31
<i>Scardinius erythrophthalmus</i>	Rudd	8	N	N	N	36
<i>Gobiomorphus gobioides</i>	Giant bully	1	Y	N	N	37
<i>Galaxias maculatus</i>	Inanga	21	Y	N	N	80
<i>Galaxias argenteus</i>	Giant kokopu	15	Y	N	N	87
<i>Perca fluviatilis</i>	Perch	13	N	N	N	102
<i>Tinca tinca</i>	Tench	4	N	N	N	102
<i>Oncorhynchus mykiss</i>	Rainbow trout	4	N	N	N	103
<i>Retropinna retropinna</i>	Common smelt	11	Y	N	Y	106
<i>Gobiomorphus cotidianus</i>	Common bully	58	Y	Y	Y	124
<i>Gobiomorphus huttoni</i>	Redfin bully	25	Y	Y	Y	124
<i>Cheimarrichthys fosteri</i>	Torrentfish	34	Y	Y	Y	125
<i>Geotria australis</i>	Lamprey	11	Y	Y	N	131
<i>Galaxias divergens</i>	Dwarf galaxias	6	N	Y	N	131
<i>Gobiomorphus breviceps</i>	Upland bully	46	N	Y	Y	131
<i>Neochanna apoda</i>	Brown mudfish	45	N	Y	Y	131
<i>Galaxias brevipinnis</i>	Koaro	10	Y	Y	Y	149
<i>Galaxias fasciatus</i>	Banded kokopu	8	Y	Y	N	150
<i>Anguilla australis</i>	Shortfin eel	67	Y	Y	Y	165
<i>Anguilla dieffenbachii</i>	Longfin eel	129	Y	Y	Y	165
<i>Gobiomorphus basalis</i>	Crans bully	10	N	Y	N	165
<i>Salmo trutta</i>	Brown trout	84	N	Y	Y	165

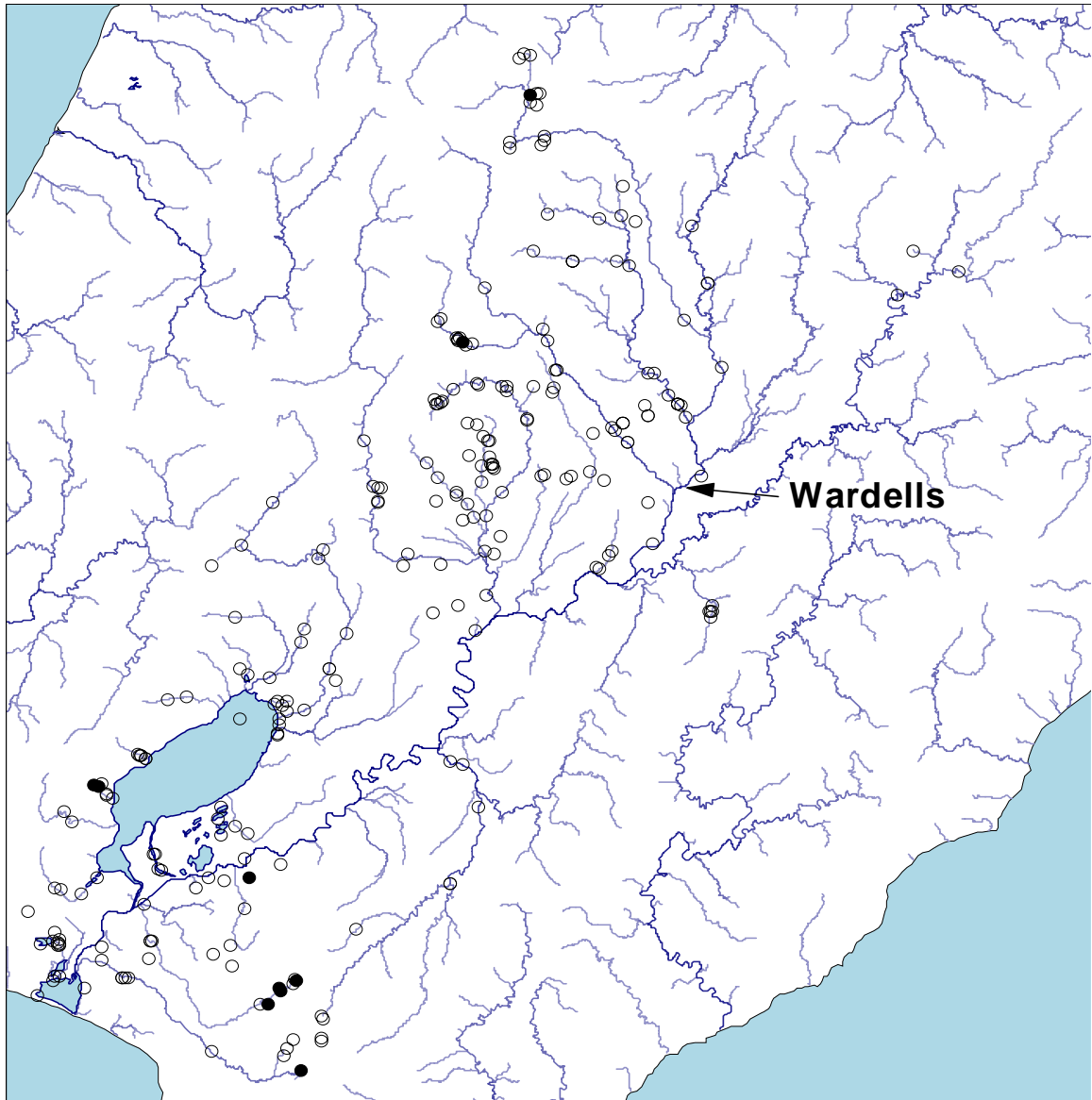


Figure 5 Distribution map for koaro *Galaxias brevipinnis* in the Ruamahanga River catchment. Open circles are sites sampled, solid circles are sites where koaro were present. (Figure B1.6 from AEE).

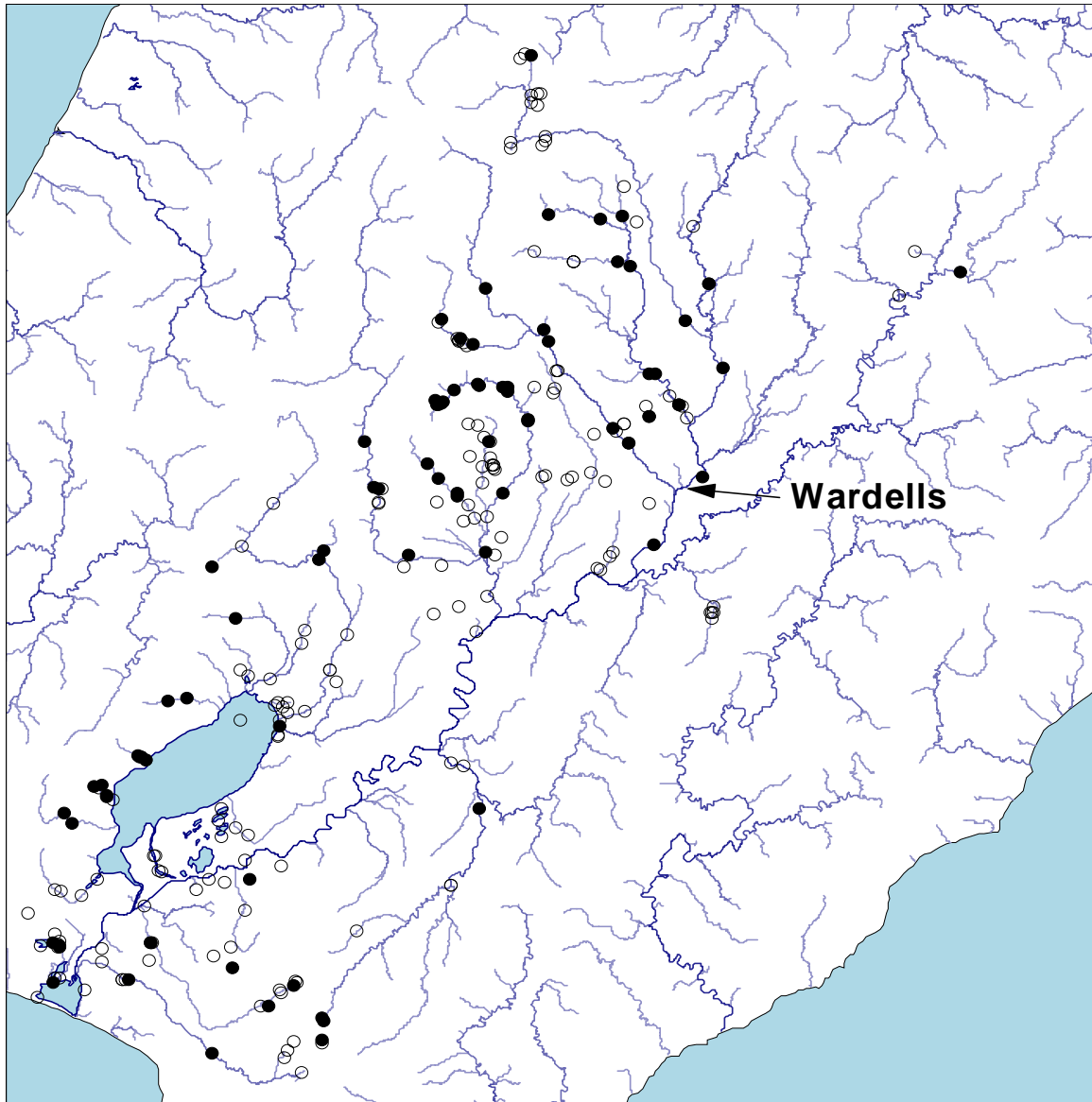


Figure 6 Distribution map for brown trout *Salmo trutta* in the Ruamahanga River catchment. Open circles are sites sampled, solid circles are sites where brown trout were present. (Figure B1.8 from AEE).

7.31 Fish species known to be present in the Ruamahanga River catchment are presented in Table 21, sorted by the maximum distance each species has been found from the mouth of the River. Distribution maps (Figures B1.5 –B1.7)¹¹ show that the diadromous torrent fish, koaro (Figure 5) and common bully are found in the upper Ruamahanga (and tributaries such as the Waingawa) and close to the mouth, but not in the middle to lower-middle reaches which are known to be impacted by low summer flows and high water temperatures.

7.32 In my opinion this shows that these species are able to pass through the main stem of Ruamahanga (including those sections most affected by the existing discharge) for both upstream and downstream migrations. A similar distribution pattern was presented for

brown trout (Figure 6), again suggesting that they avoid the lower-middle reaches in preference to areas above the Waingawa confluence, which have better habitat (through riverbank vegetation cover and cooler water temperatures).

- 7.33** The existing discharge does not show any noticeable adverse effect on the fish life.¹² Accordingly, the proposed upgrade is not expected to have an adverse effect on fish life. As noted above, the removal of the discharge from the Makoura Stream will result in a significant improvement in water quality which will have beneficial effects on fish communities.

Predicted effects of the new discharge regime on native fish and trout

- 7.34** It could be argued that the absence of fish species present in the lower-middle Ruamahanga main stem is indicative of the presence of a pollutant or pollutants. However, the data presented on invertebrate populations and densities does not support this argument. High populations (and proportion of total invertebrate populations) of EPT species (indicative of good water quality) are present at Wardells Bridge, within the mixing zone of the current discharge. In particular, the presence of high numbers of *Deleatidium* is significant because this species is very sensitive to toxic contaminants such as ammonia.¹³ Thus, the high populations of *Deleatidium* is good evidence that water quality immediately downstream of the existing discharge would not have a significant effect on either native or exotic fish populations. This supports the hypothesis that habitat conditions, low flows and high water temperatures are the most likely cause of restricted fish distribution in the middle-lower Ruamahanga main stem.
- 7.35** Bowie and Henderson (2002) studied the distribution of Short-Jawed kokopu (*Galaxias postvectis*) at 50 sites in the Mangatainoka, Makakahi, and Ruamahanga catchments of the northern Taranaki Ranges. Short-jawed kokopu were not recorded in any of the Ruamahanga sites, despite there being comparable habitat to the other two catchments surveyed. Bowie and Henderson commented that a barrier to migration in the lower catchment was the most likely reason for the apparent lack of short-jawed kokopu in the headwaters. While they suggested that “some pollutant” in the lower reaches may be responsible, this diadromous species is the only category A fish in Department of Conservation’s threatened species list,¹⁴ and it is noted that sightings have usually been made in smallish streams surrounded by unmodified broadleaf/podocarp forest, and in pools with very thick vegetation cover. High summer water temperatures and lack of cover in the lower-middle Ruamahanga are not conducive to their survival.

¹¹ Note these distribution maps constructed from records retrieved from the NZFFD December 2005, superseded similar maps prepared by Cawthron Institute for Greater Wellington in 2001.

¹² However it does appear to attract eels (an abundance of eels have been observed around outfall and in the ponds)

¹³ More so than the native fish species mentioned above - see Table 13.6 in Hickey 2000.

- 7.36** Watts and Perrie (2007) recently reported on instream flow issues as the first stage of the Lower Ruamahanga instream flow assessment. They proposed two (relevant to the MWTP Upgrade) instream flow objectives for the Lower Ruamahanga, being:
- (a) to ensure adequate water depth for migratory fish passage and recreational boating; and
 - (b) to ensure sufficient habitat is maintained for fish, in particular brown trout.
- 7.37** Watts and Perrie document the ecological values of the Lower Ruamahanga with respect to fish and note that low flows can have an indirect effect on these values due to further impairment of water quality during times of low flow. They also noted that habitat quality decreases with distance downstream in the Ruamahanga mainstem, and that there are a number of reasons for this, including a large number of point source discharges as well as non-point source (diffuse) discharges from the high degree of agricultural land use.
- 7.38** The fish experts present on a field trip organised by GW as part of the instream flow studies considered that low dissolved oxygen (DO), high water temperatures, and nutrient enrichment and its impacts on ecological value of the Lower Ruamahanga River were their key concerns (p39, Watts and Perrie 2007).
- 7.39** As Watts and Perrie note, there is no continuous DO or water temperature data. However, it should be emphasised that there is no evidence that the current discharge is directly linked with either low DO or high temperatures, and the overall contribution of the existing discharge on nutrient loads is minor compared with other sources (though major at low flows). The proposed upgrade will remove Masterton effluent-derived nutrients from the river at this time when river flows (as a source of dilution) will be at their lowest.
- 7.40** The information presented in the AEE, as well as the above supplementary information, indicate that low flows and high summer water temperature in the mid-lower main stem of the river are the main factors influencing fish distribution and habitat in the Ruamahanga and that the existing Masterton WTP discharge has minimal effect. The proposed upgrade will decrease this minimal effect by removing treated effluent from the river at times when any effect could be expected to be maximised. The existing potential for adverse toxicity effects from the discharge in the region of Wardells Bridge, caused by poor mixing and elevated ammonia and pH from the pond discharge, will be

¹⁴ Refer to <http://www.mfe.govt.nz/publications/ser/ser1997/html/chapter9.7.3.html>

eliminated by the use of a diffuser and the initiation of the discharge above median flow during fresh events. The proposed upgrade will thus remove this potential water quality impediment for fish migration in the vicinity of the discharge.

8. RELEVANT GUIDELINES

8.1 This section discusses the guideline and standards used in order to derive the water quality targets.

Wellington Regional Freshwater Plan (WRFP) 1999

8.2 This plan sets out the policies and rules relating to the sustainable management of freshwater in the Wellington Region. The WRFP identifies the need to enhance water quality at the mid and lower points of the Ruamahanga River specifically for the purpose of contact recreation. The WRFP also requires applicants for a resource consent for an activity that might compromise recreational water quality to have regard to (amongst other things):

- (a) the nature of the discharge;
- (b) the dispersal characteristics of the water body including dilution; and
- (c) consideration of alternative methods of discharge, including discharge into any other receiving environment, and the reasons for choosing the particular method of discharge.

8.3 Some guidance is provided in respect of potential nutrient thresholds needed to prevent nuisance growths of algae that may compromise contact recreation, however, these are of limited value in devising a target for discharge from the MWTP because current guidelines were not available at the time the plan was produced. Notably, the ANZECC (2000) water quality and New Zealand periphyton and microbiological guidelines were not available at the time the WRFP was published in 1999 (WRC 1999a).

ANZECC Water Quality Guidelines

8.4 The Australian and New Zealand Environment and Conservation Council (ANZECC) promulgated the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). The primary objective of these guidelines is: "*To provide an authoritative guide for setting water quality objectives required to sustain current, or likely future,*

environmental values for natural and semi-natural water resources in Australia and New Zealand." These guidelines are comprehensive and provide guidance for the protection of a range of uses for example, stock watering, as well as in-stream "protection of aquatic ecosystems".

- 8.5 Aquatic ecosystems are classified by type and geographical region (for example, they vary between Australia and New Zealand, high country and lowland streams). The ANZECC (2000) guidelines also set out procedures whereby risk-based guidelines can be developed for a particular use or site. NIWA used this approach, in conjunction with the New Zealand Periphyton Guidelines (MfE 2000) to develop site-specific DRP guidelines downstream of the discharge. The ANZECC (2000) guidelines are freely available to download from the MfE website.¹⁵

Ministry for the Environment (2003) Microbiological Water Quality Guidelines for Marine and Freshwater Recreation Areas

- 8.6 These guidelines published jointly by MfE and Ministry of Health incorporate a risk-based approach to monitoring water quality promoted by the World Health Organisation. The guidelines presented here move away from the sole use of guideline values of faecal indicator bacteria, and instead use a combination of a qualitative risk grading of the catchment, supported by the direct measurement of appropriate faecal indicators to assess the suitability of a site for recreation. In addition, alert and action guideline levels are used for surveillance throughout the bathing season.

- 8.7 The two components used to provide a grading for an individual beach¹⁶ are, first, the Sanitary Inspection Category (SIC), which generates a measure of the susceptibility of a water body to faecal contamination, and second, historical microbiological results, which generate a Microbiological Assessment Category (MAC) and provides a measurement of the actual water quality over time. The MAC for A-grade recreational receiving water has as the standard: "sample 95%ile \leq 130 *Escherichia coli* per 100 mL." While the attainment of an A grade MAC in the Ruamahanga is unlikely (because of pollution from upstream diffuse sources), this category was selected as the target concentration upon which to assess the MWTP discharge.

- 8.8 The Guidelines for Recreational Water Quality are available from the MfE website.¹⁷

¹⁵ <http://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/>

¹⁶ Beach refers to both marine and freshwater bathing zones

¹⁷ <http://www.mfe.govt.nz/publications/water/microbiological-quality-jun03/>

Other Standards and Guidelines

- 8.9** The third schedule of the Act contains some quantitative and narrative standards applicable to different water quality classes. For example, for waters being managed for aquatic ecosystem purposes, it states, "the concentration of dissolved oxygen shall exceed 80% of saturation concentration", and, "there shall be no undesirable biological growths as a result of any discharge of a contaminant into the water".
- 8.10** The Ministry for the Environment has subsequently developed guideline documents to provide some quantitative guidance to the narrative standards. Water Quality guidelines (N^o 1) Biological Growths (1992) and Water Quality Guideline (N^o 2) Colour and Clarity (1994) are particularly relevant to this application. These guidelines are not available on the MfE website but may be interloaned from the MfE library.¹⁸

Proposed Receiving Water Quality Targets

- 8.11** To assist with the determination of an acceptable effluent quality and discharge regime a number of receiving water quality targets for the Ruamahanga River at Wardells Bridge were developed as part of the AEE investigations. All targets apply after reasonable mixing has occurred, which will be well upstream of Wardells Bridge.¹⁹
- 8.12** A starting point for these targets was WRFP guidelines, which largely rely on ANZECC (1992), MfE and RMA guidelines/standards for assessing the quality of the receiving water (the relevant guidelines are set out in Appendix 8 of WRFP 1999a). All guidelines have been applied after reasonable mixing.
- 8.13** The WRFP contains no specific guidelines on allowable nutrient loadings to the Ruamahanga River – the only reference is to a discharge not causing undesirable biological growths in the river, which is of little assistance as undesirable or nuisance levels of attached algae seldom occur with the existing discharge. The site-specific guideline suggested for DRP is based on the site-specific study carried out by NIWA.²⁰ This guideline was developed with consideration of the flood frequency of the Ruamahanga River and following the MfE (2000) guideline procedure, which is outlined below and detailed in the AEE (Section 7.1.4).

¹⁸ information@mfe.govt.nz

¹⁹ Analysis has determined that reasonable mixing would actually occur upstream from Wardells Bridge (approximately 800m downstream from the proposed discharge outlet), but for the purposes of maintaining ongoing monitoring, Wardells Bridge is a more convenient point to use.

²⁰ NIWA 2004a

- 8.14** As part of the investigations undertaken for the MWTP upgrade, a site-specific DRP target for the Ruamahanga River downstream of the proposed MWTP discharge point was derived (NIWA 2003, 2004a). The DRP target was developed in response to the WRF (WRC 1999a), which has an objective to control undesirable filamentous algal growths.
- 8.15** The studies showed that phosphorus was the nutrient limiting algal growth upstream of the discharge, but that it was the frequency of river 'freshes' that limited the accumulation of algae that attach to the bed of the river. We developed a site-specific target by developing a model that linked nutrient concentrations and flood frequency, to determine a phosphorus concentration that limited filamentous algal growths, so that they remained below a nuisance threshold of 30% cover recommended in the New Zealand Periphyton Guideline (MFE, 2000).
- 8.16** In order to determine a DRP guideline for a specific river, the periphyton guidelines use 'mean days of accrual' with an average accrual period over the whole study period (summer and winter seasons) and a river flow threshold of 3x median flow to displace algal growths from the river bed (NIWA 2003). The Ruamahanga model, however, conservatively used the average accrual period during summer when the MFE periphyton guidelines apply. Our analysis of flood frequency indicated that, on average, a 'fresh' flow in the river sufficient to displace algal growths occurred every 13 days during the summer recreation period (NIWA 2004a). Field measurements of periphyton abundance has shown floods of 3x summer median flow (6.5 m³/s) would scour and reset the algal periphyton growths (NIWA 2003). In other words, algal growths could 'accrue' for an average of 13 days before being dislodged by regular freshes. Using this accrual period, the guidelines (MFE 2000, p43) predicted that an in-river DRP concentration downstream of the discharge (after reasonable mixing) of less than 0.030 g/m³ would be appropriate.
- 8.17** The proposed application of this site-specific DRP guideline was to flows in the lower 20%ile, when recreational use was highest and nuisance growths were most likely to occur. Based on the procedure used for the Manawatu River the DRP guideline would apply to flows less than half-median (approximately the Ruamahanga summer median flow) and above the 2%ile low flow (NIWA 2004a). At flows above half-median (ie summer median) it was assumed that the river would be experiencing a fresh and that recreational use would be minimal. However, it should be noted that there is uncertainty in the data used to derive the biomass/accrual period relationship as used and acknowledged in the MfE (2000) guidelines. Both seasonal and river-specific factors will vary because of the range of factors which affect, and potentially limit the proliferation of periphyton algae to nuisance levels. A mathematical model was applied to predict

benthic algal growths in relation to river flood events, and to predict algal biomass in reaches upstream and downstream of the Masterton wastewater discharge for the summer periods for 1988 to 2002.

- 8.18** The analysis showed that nutrients are naturally present upstream and that the Ruamahanga River is generally dominated by a high frequency of significant flood events during summer periods. The conservative modelling predictions have indicated that nuisance growths may occur, but would generally be of short duration; occurring in 6 of the 15 years, with durations from 3.5 days to 35 days, with most being of around 5 days (NIWA 2004a). The frequency and duration of predicted nuisance growths would be considered low, generally occurring for only a small fraction of the summer season. Thus, while nutrient targets may be established for the Ruamahanga River and subsequently calculated for the wastewater discharge, the improvements in river condition in terms of reduction in average nuisance algal biofilm growths will be slight – since flood frequency and upstream phosphorus concentrations control growths for the majority of the time. A small increase in accrual periods would result in slightly higher attached algal biomass, both upstream and downstream of the discharge. It should also be noted that during extended periods of low flow, DRP concentrations reduce below the detection limit of 0.004 g/m³.
- 8.19** Other factors can be important to the growth of periphyton such as invertebrate grazers and shading from sunlight. The effects of invertebrate grazing in the Ruamahanga River were assessed by installing tiles in the river bed over the summer period in 2003. The experiment indicated that invertebrate grazing was very significant at times during the summer season, particularly at the upstream site. Grazing levels were lower at the site downstream of the pond discharge (NIWA 2003).
- 8.20** The site-specific DRP target was developed at an early stage of the project, when consideration was being given to having a continuous effluent discharge in summer. However, the subsequent adoption of an intermittent effluent discharge regime will result in an absence of effluent in the river during the summer (optimal growth times for algae). The site-specific guideline is not relevant to discharges of pond effluent during summer river freshes, with associated bed scouring and higher turbidity, however, it is relevant to the pond leakage and groundwater from irrigation inputs. Similarly, the guideline is not relevant to managing winter DRP, since nuisance growths are not present in the river during this period. The effects of the pond discharge (direct to river) in terms of periphyton growth are addressed via the proposed discharge regime, rather than by effluent or receiving water standards. The proposed regime is such that no purpose would be achieved by chemically reducing DRP in the pond effluent. The effects of continuous inputs to the river during summer, via groundwater movement from the area

of proposed new ponds and land treatment areas, are presented in Table 8 for river low flow, demonstrating that future contributions from the MDC site will be well below site-specific guideline value (0.030 g/m³) for in-river DRP concentrations.

- 8.21** It should be noted that the targets have been developed to confirm that the proposed discharge regime and effluent quality are appropriate. They are not intended as conditions of consent, but can be used as a basis for monitoring future performance of the scheme.

Table 25 Suggested Receiving Water Quality Targets after Reasonable Mixing (Table 30 in AEE)

Parameter	Receiving Water Target	Source Document	Water Management Purpose
Filtered BOD (g/m ³)	2.0	MfE Water Quality Guidelines N° 1 (1992), Biological growths.	To assess compliance with Minimum RMA Standard - s107(1)(c) and 3rd Schedule guideline
Visual Clarity - Black disc (m)	1.6	MfE Water Quality Guidelines N° 2 (1994), Guideline 4: For water managed for contact recreation the horizontal sighting of a 200 mm black disc should exceed 1.6 m.	Contact Recreation & to assess compliance with RMA 3rd Schedule Guideline
Visual Clarity change (%)	33% - 50% change for contact recreation	MfE Water Quality Guidelines N° 2 (1994), Guidelines for the Management of Waste Colour and Clarity; For water managed for contact recreation purposes the visual clarity should not change by more than 33% - 50% depending on site conditions	Aesthetic & to assess compliance with Minimum RMA Standard - s107(1)(d)
Colour –Hue (Munsell points)	10 points change	MfE Water Quality Guidelines N° 2 (1994), Guideline 2: The hue of the water body should not be changed by more than 10 points on the Munsell scale.	To assess compliance with Minimum RMA Standard - s107(1)(d)
Ammonia-Nitrogen (g/m ³)	1.61 ¹	ANZECC Guidelines (2000), Table 8.3.7: Effects on aquatic life for “slightly-moderately disturbed” ecosystems, for a 95% level of protection.	Aquatic Ecosystems & to assess compliance with Minimum RMA Standard - s107(1)(g)
Nitrate–Nitrogen (g/m ³)	7.2	ANZECC Guidelines (2000) recalculated value from Table 3.4.12: Effects on aquatic life for “slightly-moderately disturbed” ecosystems.	Aquatic Ecosystems & to assess compliance with Minimum RMA Standard - s107(1)(g)
Nitrite–Nitrogen (g/m ³)	9	ANZECC Guidelines (2000), Section 4.3.3.3 for livestock drinking water quality.	To assess compliance with Minimum RMA Standard - s107(1)(f)
<i>E.coli</i> (cfu/100mL) (95%ile value)	130	MfE Microbiological Water Quality Guidelines (2003): Guideline value for <0.1% risk of Campylobacter infection (from Table H2).	Contact Recreation & to assess compliance with RMA 3rd Schedule
<i>E.coli</i> (cfu/100mL) (median value)	100	ANZECC Guidelines (2000), Section 9.3.3.2 for livestock drinking water quality.	To assess compliance with Minimum RMA Standard - s107(1)(f)
Dissolved Reactive Phosphorus (g/m ³) ⁴	Not specified in WRFP Shall not cause undesirable biological growths	NZ Periphyton Guideline (MfE, 2000) (13-day accrual time) ³ . ANZECC (2000) for derivation of site-specific guidelines. NIWA (2003, 2004a) derive these site-specific guidelines.	Contact Recreation & to assess compliance with RMA 3rd Schedule

[1] At pH of 7.5 (Receiving water monitoring 1994 – 2004 shows that the mean pH upstream of the ponds is 7.5).

[2] Refer <http://www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/anzecc-nitrate-correction-sep02.html>

[3] A site-specific DRP guideline (0.030 g/m³) has been developed as part of the investigations undertaken for the project. This guideline is not relevant to the intermittent discharge of effluent, however it is relevant to the leakage through the base of the ponds. Refer to AEE sections 7.1.4 and 8.2.4 for more detail, and also NIWA, 2004a.

[4] These guidelines/standards are used for assessing compliance in terms of the Water Management Purpose. The sources of these guidelines/standards are set out in AEE Appendix B3.

Compliance with Section 107 RMA Standards

- 8.22** The following discussion addresses compliance with section 107 minimum standards following the proposed upgrade. These standards all apply after reasonable mixing.

The production of any conspicuous oil or grease films, scums or foams, or floatable or suspended materials.

- 8.23** There will be no conspicuous oil or grease films, scums or foams, or floatable or larger particulate material after the treatment process. I predict that the effluent will continue to achieve a suspended solids content of typically less than the 20 g/m³ that has been achieved following the interim upgrade, which is a very good performance. The incoming raw wastewater typically has a concentration of around 130 g/m³ (refer Table 25 AEE for tabulation of the existing effluent quality following the interim upgrade in 2003).

Any conspicuous change in the colour or visual clarity

- 8.24** MFE (1994) defines a conspicuous change in visual clarity to be 33% - 50% reduction and that the hue of a water body should not be changed by more than 10 points on the Munsell scale for contact recreation purposes (Table 25). The analysis detailed above with respect to clarity, predicts that compliance with section 107 (no conspicuous change to colour or clarity) can be achieved by 300 m downstream both in summer and winter.
- 8.25** In summer when flows are > median, the average summer clarity reduction will be 17% after 300 m with a maximum (upper 95%ile) change in clarity of 50% reduction 300 m occurring during the threshold flow period (flows 12.3 – 14.0 m³/s) just after the initiation of the discharge. This threshold flow range occurs only 4% of the time on average. The effects of the discharge on clarity will rapidly diminish with increasing flows (as flow increases upstream turbidity will begin to dominate).
- 8.26** The above discussion relates to analysis and modelling undertaken to predict effects, and is not intended to propose a region of 'reasonable mixing', which is subject to consideration of a range of factors. (Dr Cooke suggests that reasonable mixing occurs between 300-500m downstream).
- 8.27** Both colour and clarity effects will be eliminated at flows less than median in summer (<half-median in winter). The existing effects of suspended algae in the effluent contributing to poor colour and clarity will be eliminated at these times.

- 8.28** At times when discharge does occur, colour change is expected to be less at high flows than the existing measured change of 2.5 Munsell points occurring at Wardells Bridge – because of discharge occurring to a naturally discoloured river (A conspicuous change would be 10 Munsell points (Table 25)).

Any emission of objectionable odour from the discharge to water

- 8.29** The existing discharge to the river does not result in any objectionable odour in the Ruamahanga River. On this basis, plus the fact that there are specific measures to prevent the generation of odours incorporated in the design and operation of the ponds, there will be no objectionable odour as a result of the discharge to water.

Rendering of freshwater unsuitable for consumption by farm animals

- 8.30** Freshwater (in this case the Ruamahanga River) will not be rendered unsuitable for consumption by farm animals. Assessment of chemical contaminants in the pond discharge water is based on an annual sampling for heavy metals and organic contaminants and has shown these to be below ANZECC (2000) water quality guidelines after mixing. The consumption of downstream river water for livestock is not currently an issue and will continue to not be an issue. The intermittent nature of the proposed discharge will further reduce exposure of river organisms to contaminants.

- 8.31** The animal health protection guideline for drinking water protection is 100 /100mL as a median value (ANZECC 2000). The elimination of the discharge at less than median flow and the minimal increase in concentrations at higher flows will result in no additional risk for livestock as a result of the discharge.

Any significant adverse effects on aquatic life, including undesirable biological growths

- 8.32** Factors that could have an adverse impact on aquatic life include pH, dissolved oxygen, deposition of matter on the bed of the river and ammonia toxicity. The predicted changes downstream after reasonable and full mixing are summarised below in Table 26 and the guideline targets are provided in Table 25. Each of these factors is discussed below.

- 8.33** The pH of Masterton's incoming raw wastewater is an average of 7.1. The receiving water monitoring indicates an upstream median pH of about 7.3 and a partially mixed pH at Wardells Bridge of 7.1 (eg Table 2). On this basis there will not be any adverse effect due to the pH of the effluent.

- 8.34** In order for oxidation ponds to function efficiently, it is necessary for a minimum dissolved oxygen concentration to be maintained. Natural processes in the ponds will usually ensure this happens, although there may be times (these are infrequent) when the addition of additional oxygen is necessary. This is provided for by permanently installed surface aerators which can be operated as necessary to provide additional aeration, thereby boosting the concentration of dissolved oxygen in the ponds. The main function of the additional aerators/mixers being added to each of the four additional maturation cells in the proposed new ponds is to provide mixing which helps to minimise formation of blue-green algae (AEE, p93). The existing changes in dissolved oxygen concentration at Wardells Bridge are negligible and will remain negligible with the upgrade.
- 8.35** The biochemical oxygen demand guideline is based on minimizing potential bacterial growths on dissolved organic components (MFE, 1992). The guideline value will be met after reasonable mixing (Table 26).
- 8.36** The deposition of matter on the bed is a site-specific issue relating to the nature of both the discharge and the receiving water. There are inlet and outlet screens on the plant to prevent discharge and potential deposition of large material. The change to an intermittent discharge with initiation at median flow and the use of discharge diffusers to improve mixing will result in negligible deposition of organic material onto the river bed after reasonable mixing.
- 8.37** Ammoniacal-nitrogen, nitrate-nitrogen and nitrite-nitrogen each have the potential to cause toxic effects to aquatic organisms. Estimates of the downstream concentrations of these parameters have been made after reasonable mixing and based on the 95th percentile effluent values. All these parameters are markedly less than the guidelines values (Table 26), which combined with the intermittent discharge, indicates a negligible potential for toxic effects on aquatic biota.
- 8.38** Nuisance growths of attached algae, or periphyton, are stimulated by river nutrients (nitrogen & phosphorus) and are controlled by a range of factors (e.g. light, floods, grazing). The potential for nuisance growth stimulation is greatly reduced by the intermittent discharge with the median flow threshold, since periphyton growths at high river flows will be limited by scour and low light conditions. The leachate from the ponds and groundwater nutrients from irrigation provides some limited potential for stimulation of periphyton, however, calculations indicate that this will be below the site-specific guideline (maximally 53% after reasonable mixing) developed for the Ruamahanga River (Table 26). The high predicted dissolved reactive phosphorus concentrations

during periods of effluent discharge will not cause significant increases in periphyton abundance because of the controlling factors (e.g. scour, low light) operating during these intermittent discharge events. There will be no significant nuisance growths as a result of the pond discharge.

8.39 In conclusion, the discharge will readily meet the minimum standards set out in section 107 of the Act.

Table 26 Predicted Values of Water Quality Parameters after reasonable mixing (i.e. 20x dilution at 300 m downstream) and at Wardells Bridge in Summer for the Threshold Flow Region ^[a] (Table 44 in AEE)

Parameter	Receiving Water Target (RWT) [b]	Measured values (just below median flow) [c]	Predicted value: after reasonable mixing	Predicted value: Wardells Bridge
Filtered BOD (g/m ³)	2.0	0.31	1.64	1.24
Visual Clarity - Black disc (m)	1.6	1.0	0.85	0.89
Visual Clarity change (%)	33-<50% change	Nil	17%	13%
Colour –Hue (Munsell points)	10 points change	10GY(40)8/2	7.5 GY(37.5) (2.5 points change)	7.5 GY(37.5)7/6 (2.5 points change)
Ammonia-Nitrogen (g/m ³)	1.61	0.010	0.55	0.39
Nitrate–Nitrogen (g/m ³)	7.25	0.50	0.71	0.64
Nitrite–Nitrogen (g/m ³)	9	0.002	0.10	0.07
<i>E.coli</i> (cfu/100 mL) – human [livestock]	130 [100]	83	89	87
<i>E.coli</i> change (%)			6.5%	4.3%
Dissolved Reactive Phosphorus (g/m ³) - pond leakage and groundwater from irrigation area. [Bracketed value – concentration not relevant to RWT value]	0.030 [d]	0.010	0.016 [0.17] [d]	0.015 [0.12] [d]

[a] Threshold flow range = 12.3 – 14.0 m³/s. “Threshold flow range” is the flow region where the discharge is initiated. This occurs approximate 4% of the time and 13% of the time when potentially discharging (see evidence of Dr Jim Cooke; Figure 33 of AEE).

[b] See Table 25

[c] Measured upstream medians except model predicted median values for *E. coli* and clarity (from Table 13 & Table 14).

[d] A site-specific DRP guideline (0.030 g/m³) has been developed as part of the investigations undertaken for the project. This guideline is not relevant to the intermittent discharge of effluent, however it is relevant to the leakage through the base of the ponds and groundwater from irrigated area – leakage from Table 4 + groundwater from irrigated from Table 6. Refer to AEE sections 7.1.4 and 8.2.4 for more detail, and also NIWA, 2004a. Pond leakage contribution at less than median flow (AEE Table 33).

Consistency with Relevant Water Quality Guidelines and Targets

8.40 The majority of relevant guidelines have been considered in terms of the section 107 requirements and are summarised in Table 26. Because of the nature of the proposed

upgrade, with discharge triggered by elevated river flows, the analysis and future compliance monitoring of effects requires a different approach from what would be used for a full time discharge. Predominantly this relates to assessing effects against the natural decline in river water quality which occurs during flood events.

- 8.41** I have addressed these by considering the ‘threshold flow region’, which examines data in the flow region where the discharge will be initiated, and the downstream mixing behaviour of the contaminants. A nominal benchmark of 300 m (20-fold dilution) has been used for ‘reasonable mixing’ and the calibrated mixing model predicts that full mixing occurs at approximately 800 m downstream of the new outfall location (the applicant suggests 400 m as the actual length of the region of reasonable mixing).
- 8.42** The majority of contaminants to be assessed relative to percentile standards are derived from existing compliance conditions and upgraded pond performance values, which can be compared with guideline targets after allowing for reasonable mixing (see Table 5). Receiving water validation requires upstream and downstream comparisons of contaminants, measuring small changes in concentrations and recognising that some parameters will already exceed guideline triggers when the river is in flood.
- 8.43** River clarity may be assessed against guidelines in terms of both “conspicuous change” and a bathing water guideline benchmark value of 1.6 m (Table 25). The analysis used for this assessment has concentrated on the change attributable to the discharge rather than the benchmark value. The reason for this approach is that the river is naturally below the benchmark value around median flow (median 1.0 m), and it is thus more appropriate to consider the additional change. The elimination of the summer discharge below median flow will remove any additional recreational impairment of use during this maximum use time.
- 8.44** The health risk from micro-organisms also warrants additional consideration. The proposed guideline targets are based on *E. coli* for both human and animal health protection (Table 25). The human health guideline is 130 /100 mL and is based on a 95%ile compliance measured “in relation to recreational use” (MFE 2003). This assessment assumes that the primary recreational use will be in summer during periods when the flow is less than median, at which time the discharge will not be occurring (which is a reasonable assumption confirmed by the survey of recreation use). Therefore the MWTP will no longer cause increased health risk from the discharge of microbial contaminants during times of high recreational use.
- 8.45** The degree of compliance with the MfE/MoH (2003) microbiological water quality guidelines for freshwater recreational areas has been calculated using the amber/alert

and action *E.coli* values (260 and 550 cfu/100 mL respectively) for both upstream and downstream of the discharge.

- 8.46** The threshold relates to a NCRL (no-calculated risk level) of one case of *Campylobacter* infection per 1000 exposures (see Table H2 MfE/MoH guidelines). The complete record has been reanalysed and the exceedances of the MfE/MoH guidelines are given in Table 27 below. This shows the level of exceedances which occur upstream, as a result of largely diffuse inputs, and the downstream increase with the existing discharge. The levels of upstream risk will continue following the proposed upgrade, while the incremental risk will be eliminated below median flow and a minimal increase at threshold flows just above the trigger flows.

Table 27 Exceedance of MfE/MoH guidelines above and at the partially mixed site below the existing discharge (December 1999-June 2007). (AEE Table 20)

Guideline	RUA1 Upstream number of exceedences n=165 (% exceedance)	RUA2 Downstream number of exceedences n=148 (% exceedance)
>130 cfu/100 mL	41 (25%)	78 (53%)
>260 cfu/100mL	25 (15%)	37 (22%)
>550 cfu/100mL	14 (8.5%)	22 (15%)

- 8.47** The animal health protection guideline for drinking water protection is 100/100mL and is based on a median value (Table 25). The elimination of the discharge at less than median flow and the minimal increase in concentrations at higher flows will result in no additional risk for livestock as a result of the discharge.
- 8.48** A suite of chemical contaminants is currently monitored annually in the pond water and compared with ANZECC (2000) water quality guidelines. It is proposed that this monitoring would continue and that the compliance would be assessed after allowing for reasonable mixing (ie 300 m corresponding to 20-fold dilution).
- 8.49** Macroinvertebrate community composition is currently monitored upstream and downstream of the discharge. Ongoing compliance monitoring of macroinvertebrate communities is proposed for both upstream and downstream (downstream at Wardells Bridge & above Waingawa River confluence) in order to measure trends in the biological response to the improved water quality conditions. The compliance with the narrative guideline would be measured for total number of taxa and abundance of key species and groups (eg mayflies).
- 8.50** The location of the upstream reference site (RUA1) is proposed to be changed to be 200-500 m further upstream. This change is proposed so that possible upstream groundwater drainage does not affect the reference monitoring site.

9. SUBMITTERS' ISSUES

Submitters Alison Elcock, Andrew Stewart, Riddlesworth Estate Ltd et al and Andrew Duncan (242568, 242620, 242514, 242612)

- 9.1** These submitters raise concerns about pollution to the Ruamahanga River and Makoura Stream, and seek that no effluent be discharged into the Makoura Stream (with no exceptions) with water quality in the Makoura Stream maintained to upstream levels.
- 9.2** In response, I note that the point source discharge to the Makoura Stream is the major factor affecting current stream health, with ammonia concentrations exceeding guidelines and depressed dissolved oxygen concentrations. These water quality issues are addressed in section 5.16 of my evidence. Removal of the MWTP discharge will eliminate these major factors affecting the stream health, though the upstream diffuse inputs will continue to reduce water quality during rain events. The irrigation and additional drainage systems will result in a predicted increase in the Makoura Stream flow where it leaves the site of 0.15 m³/s. This will result in a total summer stream flow of 0.32 m³/s (PDP 2008, pIV (4)). Some reduction in water quality will occur because of these irrigation flows, however, the water quality is not expected to exceed the appropriate guidelines and will not cause any significant adverse effects on water quality or stream ecology. Overall the health of this reach of the stream will be significantly improved as compared to the current situation.

Submitters Alexander Webster and the Department of Conservation (242572, 242577)

- 9.3** These submitters raise concerns about cumulative effects to river and associated environs, particularly as other Wairarapa towns use similar systems – uncertainty over associated effects. They seek that GWRC take responsibility for not setting high levels of control of nutrients to waterways from town effluent systems.
- 9.4** In response, I note that an integrated catchment plan for flows, water quality and land and discharge management would be a valuable document to guide best management of a complex aquatic ecosystem. Presently, no integrated plan exists for the Ruamahanga River catchment.
- 9.5** The major water quality issues for the Ruamahanga River are abstraction effects on water quantity and contaminant input (both diffuse and point source) effects on water quality. These factors combine to cause the greatest potential effects on water quality during summer low flow periods. Effects on clarity, microbial indicators and nuisance

periphyton growths at summer low flow are the key factors affected by the MWTP discharge. The potential for these effects will be eliminated during high recreational use by the proposed discharge regime (ie only discharging at greater than median river flow).

- 9.6** The water quality of the Ruamahanga River declines markedly during rainfall events, largely due to diffuse inputs of contaminants, with higher levels measured at sites more distant downstream. These inputs are dominated by agricultural sources. The high flood frequency of the Ruamahanga River in both winter and summer effectively prevents establishment of nuisance growths of periphyton. The diversion of the Ruamahanga River from Lake Wairarapa in 1983 has eliminated the upstream nutrient loadings historically contributing to eutrophication of that lake. The small brackish Lake Onoke is rapidly flushed during flood events and would be expected to benefit from all nutrient reduction measures which affect low flow periods.
- 9.7** The proposed upgrade will result in a significant improvement in water quality at the times when the river is most sensitive to the current discharge. Whilst there will be continued discharge at higher flows, in my opinion, this will not cause any more than minor adverse effects. In particular, there will be little impact on colour and clarity, little impact on periphyton production, minimal added health risk and little effect on ecological values.

Submitters Roger and Maureen Ternent (242576) and J.R. Wardell

- 9.8** These submitters raise concerns over the effect on orchard and highland cattle from water contamination (water provided by irrigation with pumping point at confluence of Ruamahanga River and Makoura Stream) (Ternent) and recreational use and swimming at their property (Wardell).
- 9.9** In response I note that the water quality will not be significantly affected at below median flow and no water quality guidelines relevant to animal health will be exceeded as a result of the discharge.
- 9.10** I note that the river naturally exceeds the ANZECC (2000) stock water guideline (100 cfu/100mL, Table 23) during flood events. I would not expect that intermittent exposure to these levels of microbial contamination would adversely affect livestock health.
- 9.11** These submitters also request clarification of the condition/quality of the river water at the relocated discharge location with respect to the use of the water for their property, and for recreational use of the river.

- 9.12** The Ternent property and stock water intake is located ~1000m and the Wardell property approximately 400-500m below the proposed new discharge location. As shown in the evidence of Dr Jim Cooke, the effluent will be 'reasonably well mixed' 300-500m below the discharge and fully mixed by 800m (see Table 1 and paragraph 4.32). The assessment of potential effects has been made after reasonable mixing occurs at a distance of 300m downstream. The river water will meet stock drinking and recreational standards except at times when the upstream quality precludes that. The discharge will not increase the frequency or duration of such times.
- 9.13** At flows less than median under during the summer there will be no discharge of effluent into the river. At slightly over median flows (the threshold for discharge) there will be a predicted increase in median *E.coli* in the threshold flow range just above median flow when the discharge is initiated is 6.5% after reasonable mixing at 300m (Table 13 of my evidence). The predicted increase in median *E.coli* after full mixing is a 4.3% (see Table 14 of my evidence). This will only cause a minor increase in health risk in terms of contact recreation beyond the background river levels at these flows. However, it should also be noted that the deteriorating bacteriological water quality during flood flows, due to sources upstream of the discharge, would not additionally compromise contact recreation even without the Masterton discharge. The river naturally exceeds the MfE 'Alert' level (260/100mL) for about 20% of the time and the MfE 'Action' level for (550/100mL) for 5 to 10% of the time during the threshold flow period. Addition of the effluent will not result in the river being in these conditions for greater periods of time (see Table 11 of my evidence). As described in my evidence and that of Mr Humphrey Archer, relocating the point of discharge is a key strategy to restore the Makoura Stream water quality and will (because of the diffuser design) result in better mixing in the Ruamahanga River. Finally, I again note that the slight elevation in health risk is only relevant at flows just above the median where some contact recreation may possibly still be occurring. Such flows only occur for a short duration and in practice it is unlikely that contact recreation would still be occurring adjoining the Ternent and Wardell properties or downstream.

Submitter Andrew Stewart (242620)

- 9.14** This submitter requests that the start of the discharge flow limit be increased to 19m³/s in summer. The submitter asks why 12m³/s is acceptable and what would be the implications for the scheme of increasing to 19m³/s.

- 9.15** In response I note that a flow trigger of 19m³/s would be reached in a matter of minutes not hours after a 12 m³/s threshold is triggered during most Ruamahanga Flood events. In practice, the delay in discharge initiation will result in a higher flow at discharge initiation.
- 9.16** The storage requirements have been recalculated as 496,700 m³ for a 19 m³/s trigger level, which is not a practical storage volume for the pond system to accommodate. The excess storage available in the current design will provide a buffer for the planned delay of discharge initiation and to allow irrigation management flexibility.
- 9.17** The effects on key water quality variables related to recreational activity (ie microbial indicators, clarity, nuisance growths) are addressed in this evidence (see section 6 of this evidence). In my opinion, increasing the threshold to 19m³/s would not have any real benefit in terms of adverse effects. Whilst it is accepted that there may be some secondary contact recreation occurring at flows between 12 and 19 m³/s, the discharge will not cause any of the relevant guidelines to be breached at these threshold flows and in particular will not pose any significant health risk (see the evidence of Andrew Ball). It should be noted that this range of flows occurs for only a short duration and accordingly exposure rates are low.
- 9.18** This submitter also requests clarification of the impact of the intermittent river discharges with respect to swimming, adverse effects on fish life, and adverse effects on downstream waters.
- 9.19** In response I note that there will be no adverse effects on fish or aquatic macroinvertebrate life caused by the initiation of the intermittent discharge. The initiation of the discharge will occur at greater than median flow (ie 12.3 m³/s) in summer when minimal recreational activity is occurring. Note that the *median summer flow* is 6.5 m³/s, which will have been markedly exceeded when this trigger flow is reached. An assessment of the key water quality effects at just above median flow has shown that the upstream water quality naturally declines and the effect of the effluent will be slight (see 6 of this evidence).
- 9.20** This submitter requests clarification of the reasons why the changing colour of the river is acceptable with respect to the RMA requirements.
- 9.21** In response I note that elimination of the low flow discharge and moving the discharge location from Makoura Stream will eliminate the existing green plume and settling of algae which is visible at low flows from Wardells Bridge. The inherent colour of the pond water and the Ruamahanga River are of similar hue and will not be changed by the

proposed discharge regime (see section 6.50 of this evidence). As discussed earlier, I am satisfied that the discharge will not cause any conspicuous change to colour or clarity of the river after reasonable mixing.

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- 9.22** These submitters are opposed to the discharge of treated effluent to water. They raise concerns about uncertainty over effects on native fish migration, and downstream effects, including Lake Onoke.
- 9.23** In response I note that the elimination of the discharge for low flows (<median in summer; <half-median in winter) will remove the potential for effects during the majority of the time during the mid-summer months and during low winter flows. Assessment of the potential for adverse effects showed that the major potential toxicant which could affect aquatic life, ammonia, was well within water quality guidelines for all discharge scenarios (see 6.17 of this evidence).
- 9.24** The potential for adverse effects on downstream Lake Onoke has been addressed. The small brackish Lake Onoke is rapidly flushed during flood events and would be expected to benefit from all nutrient reduction measures which affect low flow periods (see section 5.7, 6.63 and 6.76 of this evidence).

10. CONCLUSIONS

- 10.1** In conclusion, the water quality of the Ruamahanga River will improve markedly through the proposed upgrade, both in terms of the quality of effluent and more particularly as a result of the elimination of direct discharge into the River over summer periods of low flows.
- 10.2** The proposed upgrade will eliminate the discharge of effluent at low flows when upstream water quality is typically very good, recreation use is at its highest, and the effects of the existing discharge are most apparent. The new ponds will also significantly reduce leakage to the river. The upgrade will also improve water quality at Wardells Bridge at times when there is a discharge.
- 10.3** The significant contribution of the existing discharge to the poor condition of the Makoura Stream will be eliminated, thereby improving the environmental quality of the stream and its aquatic ecosystems.

- 10.4** The upgraded microbiological quality of the discharge and the removal of discharge at low-median summer flows will significantly reduce the MWTP's contribution to the levels of *E.coli* and pathogens in the river during high recreational use periods.
- 10.5** When the discharge occurs, the predicted concentrations for all parameters will be less than the receiving water targets by 300 m downstream of the point of discharge and there will be negligible adverse effects at Wardells Bridge or beyond as a result of the effluent discharge either in summer or winter.
- 10.6** Although the discharge will have some effect on water quality at threshold flows just above the trigger flows, any adverse effects will be minor and temporary and will not cause any breach of relevant guidelines or section 107 standards.
- 10.7** In summary, the predicted environmental improvements as a result of the upgrade are:
- (a) A significant improvement in water quality in summer for flows below median and below half-median in winter;
 - (b) No coloured plume in the Ruamahanga River downstream from the Makoura Stream to Wardells Bridge, along with enhanced clarity;
 - (c) No conspicuous change to colour and clarity after reasonable mixing;
 - (d) Elimination of the presence of settled algae from the pond in the partially mixed region downstream of the Makoura confluence and upstream of Wardells Bridge;
 - (e) An improvement in the water quality of the Ruamahanga River during summer low flows downstream of the MWTP because there will be no effluent discharged directly to the river at low river flows (below median river flow), when the river is most attractive for contact recreation (especially swimming);
 - (f) An improvement in microbiological water quality of the Ruamahanga River downstream of the MWTP at Wardells Bridge when effluent is discharged above median flow (summer) and compliance with water quality targets after reasonable mixing and at Wardells Bridge; and

- (g) The region to achieve full mixing reduces from well below Wardells Bridge to approximately 450 m upstream of Wardells Bridge.

Dr Chris Hickey
Senior Principal Scientist, NIWA
13 February 2009

References

- Beca (May 2003b). *Masterton Wastewater Treatment Plant at Homebush (WAR020074) 2002/03 Annual Monitoring Report* (Prepared for Greater Wellington Regional Council), Beca Carter Hollings & Ferner Ltd.
- Beca (May 2004b). *Masterton Wastewater Treatment Plant at Homebush (WAR020074) 2003/04 Annual Monitoring Report* (Prepared for Greater Wellington Regional Council), Beca Carter Hollings & Ferner Ltd.
- Beca (May 2005). *Masterton Wastewater Treatment Plant at Homebush (WAR020074) 2004/05 Annual Monitoring Report* (Prepared for Greater Wellington Regional Council), Beca Carter Hollings & Ferner Ltd.
- Beca (May 2006). *Masterton Wastewater Treatment Plant at Homebush (WAR020074) 2005/06 Annual Monitoring Report* (Prepared for Greater Wellington Regional Council), Beca Carter Hollings & Ferner Ltd (Beca). pp. 65.
- Bioresearches (2002). *Ruamahanga River Aquatic Biological Survey*. Bioresearches report for Masterton District Council (Beca Carter Hollings & Ferner Ltd), pp. 16+.
- Bowie, S. and Henderson, I (2002) Shortjaw kokopu (*Galaxias postvectis*) in the northern Tararua Ranges Distribution and habitat selection DOC Science Internal Series 30 21 pp.
- DOC (2000). Lake Wairarapa wetlands action plan 2000 - 2010. Department of Conservation report prepared by Sally Airey, Rachel Puentener, Aalbert Rebergen, Wellington. pp. 75.
- Hickey, C.W., (2000). *Ecotoxicology: Laboratory and Field Approaches, in New Zealand Stream Invertebrates*. In: Ecology and Implications for Management, K.C. Collier and M. Winterbourn, Editors, New Zealand Limnological Society: Christchurch, New Zealand. p. 313-343.
- Hickey, C.W.; Golding, L.A.; Martin, M.L.; Croker, G.C. (1999). Chronic toxicity of ammonia to New Zealand freshwater invertebrates: a mesocosm study. *Archives of Environmental Contamination and Toxicology* 37: 338-351.
- MDC (2008). Notice of Requirement Resource Consent Applications Assessment of Effects on the Environment: Masterton Wastewater Treatment Plant and Disposal System Long-Term Upgrade. 15 August 2008. Masterton District Council, Masterton pp. 221 +App.
- McBride G B and Quinn J M (1993). Quantifying water quality standards in the Resource Management Act, Prepared for Manawatu-Wanganui Regional Council, NIWA Ecosystems Hamilton.
- Milne, J.; Perrie, A. (2005). *Freshwater quality monitoring technical report*. Greater Wellington Regional Council, Wellington. pp.
- Ministry for the Environment (1992). *Guidelines for the Control of Undesirable Biological Growths in Water, Water Quality Guidelines No. 1*, Ministry for the Environment, Wellington.
- Ministry for the Environment (1994). *Guidelines for the Management of Water Colour and Clarity, Water Quality Guidelines No. 2*, Ministry for the Environment, Wellington.
- Ministry for the Environment (2000). Biggs, B.J.F. *New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment Of Streams*. New Zealand Ministry for the Environment, Wellington.

Ministry for the Environment (2003) *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas*. Ministry for the Environment, Wellington, New Zealand

NIWA (2003) Hickey, C.W. *Ruamahanga River: Nutrient and Algal Periphyton Monitoring in Relation to the Masterton Wastewater Discharge*. No. BCH03207; HAM2003-154. NIWA report for Beca Carter Hollings & Ferner Ltd, Wellington, Hamilton.

NIWA (2004a) Hickey, C.W.; Norton, N.; Broekhuizen, N. *Proposed dissolved reactive phosphorus guidelines for the Ruamahanga River*. No. BCH03207; HAM2004-082. NIWA report for Beca Carter Hollings & Ferner Ltd.

NIWA (2006). Hickey, C.W. Bacterial indicator (*E.coli*) effects of Masterton wastewater pond discharge on Ruamahanga River above median flow: Predictions after pond upgrades. No. BCH06201. March 2006. NIWA memorandum to Beca Carter Hollings & Ferner Ltd, Wellington. pp. 4.

NIWA (2007). Oldman, J.; Nagels, J.; Rutherford, K.; Hickey, C. Mixing and dilution studies in the Ruamahanga River below the Masterton Wastewater Treatment Plant. No. BCH07201; HAM2007-038. pp. 55.

NZWWMG (2002). Ray, D.E., (Ed) *New Zealand Municipal Wastewater Monitoring Guidelines*. New Zealand Water and Waste Association, Wellington.

.PDP (2008). *Masterton Wastewater Upgrade: Revised Groundwater Modelling*. Pattle Delamore Partners Ltd report for Masterton District Council.

Perrie, A. (2005). *Lake Wairarapa water quality monitoring technical report*. Greater Wellington Regional Council, Wellington. pp. 21.

Quinn JM, Hickey CW. (1993). *Effects of sewage stabilization lagoon effluent on stream invertebrates*. *Journal of Aquatic Ecosystem Health* 2:205-219.

Quinn, J.M.; Hickey, C.W. (1990). *Characterisation and classification of benthic invertebrate communities in 88 New Zealand rivers in relation to environmental factors*. *New Zealand Journal of Marine and Freshwater Research* 24: 387-409.

Watts, L. and Perrie, A (2007) *Lower Ruamahanga River instream flow assessment Stage 1: Instream flow issues report*. Greater Wellington Regional Council. Environmental Monitoring and Investigations Department. Report no. GW/EMI-G-07/135 53 pp

Wellington Regional Council (WRC) (1999a). *Regional Freshwater Plan for the Wellington region*. No. WRC/RP-G-99/31. Wellington Regional Council, Wellington. pp. 244.

Wellington Regional Council (WRC) (1999b). *Upper Ruamahanga River Water Allocation Plan (Draft)*. No. Wellington Regional Council, Wellington. pp. 41.