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

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STATEMENT OF EVIDENCE OF ANDREW BALL
ON BEHALF OF MASTERTON DISTRICT COUNCIL

Subject Area: Public Health

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1. INTRODUCTION

1.1 My full name is Andrew Ball.

1.2 I am a Microbiologist with over 25 year's experience. Since 1995 I have been employed by the Institute of Environmental Science and Research (ESR) at Christchurch Science Centre as Consultant Water Microbiologist and I currently provide the specialist advice on issues relating to drinking and recreational water microbiology to the Ministry of Health (MoH) and the Public Health Services.

1.3 I was the project group manager of the Environmental Pathogens section, the Microbiology Research and Development section of Australian Water Technologies, in Sydney where I worked from 1992 until 1995. During this time I took part in pollution investigation surveys, an epidemiological study on waterborne disease of swimmers at Sydney beaches, and the development of pathogen testing methods for use in environmental monitoring including fresh and marine waters.

1.4 Before that I worked in and managed the State Public Health Microbiology Laboratory in Hobart for the 10 years ending 1991, which involved monitoring indicator organisms and pathogens in sewage effluent and receiving waters.

1.5 I am a member of the joint Australian and New Zealand Standards Committees for Water Microbiology Methods and Swimming Pool Quality. I am a technical assessor for National Association Testing Authorities (NATA) and International Accreditation New Zealand (IANZ).

1.6 I was a member of the steering committee of the Ministries of Environment, Health, and Agriculture and Forestry (MfE/MoH/MAF) Freshwater Microbiology Programme (FMP) to investigate the occurrence of pathogens in New Zealand rivers with the aim of developing freshwater bathing guidelines and also chaired the Microbiological Methods Committee for this project.

1.7 I have previously given advice/evidence on Resource Management Act (RMA) matters pertaining to wastewater discharges, such as the Watercare Services Ltd treatment plant at Mangere (for which I am a member of the Audit group and the Microbiology Review Group), the Titahi Bay, Napier, Hastings, Waimakariri and Gisborne ocean outfalls, and the Christchurch City Wastewater Treatment Plant as a member of the expert team that reviewed the potential health impacts of the outfall.

1.8 I have been involved in several hearings before Local Authorities and the Environment Court in relation to developments that involve the use of wastewater.

1.9 I have the following qualifications:

- B.Sc. (Hons) from the University of Tasmania (conferred 1980).
- M.Sc. from the University of Tasmania (conferred 1992).
- Dip. Public Health (Dist) from the University of Otago (conferred 1999).
- I am a member of the New Zealand Microbiology Society, the International Water Association and the Public Health Association of New Zealand.

1.10 In this matter, I have been engaged by Masterton District Council to assess:

(a) The implications of the proposed changes to the Masterton Wastewater Treatment Plant (WWTP) on the quality of the receiving water; and

(b) The likely health effects resulting from contaminants from the WWTP entering the receiving water.

1.11 I have been involved with the project since 2005.

1.12 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 by 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.

1.13 My evidence is structured as follows:

(a) scope of evidence;
(b) executive summary;
(c) the proposal;
(d) health risks associated with the discharge;
(e) reduction in pathogen levels as a result of the discharge;
(f) health risk guidelines;

(g) the quantitative health risk assessment;

(h) reduction in pathogen levels as a result of the upgrade;

(i) summary;

(j) submitters' concerns; and

(k) conclusion.

2. SCOPE OF EVIDENCE

2.1 My evidence will address the key aspects of the proposal as they relate to heath risks. This will include the health risks associated with the existing discharge, and the key improvements in terms of pathogen levels and health risks as a result of the proposed upgrade.

2.2 I will discuss the methodology and main findings from the Health Impact Assessment (Ball, 2007), and comment on the Ministry for the Environment / Ministry of Health guidelines (including the degree of compliance with these guidelines). I will also briefly address public health issues that have been raised by submitters.

3. EXECUTIVE SUMMARY

3.1 This risk assessment has examined the pre- and post-upgrade microbial and chemical health risks associated with the discharge of effluent from the Masterton WWTP. Effluent currently enters the Ruamahanga River via a continuous discharge to the Makoura Stream. After the upgrade, effluent will only be discharged to the river when river flows exceed median (in the summer) or half median (in the winter). Effluent will also enter the Ruamahanga River indirectly via recharge following land application of effluent adjacent to the river or oxidation pond leakage.

3.2 Risk requires both the presence of hazard (pathogenic micro-organisms or harmful substances) and exposure to the hazard. The two exposures that have the potential to impact on public health are ingestion of waterborne pathogens during aquatic recreational activity in the river and consumption of mahinga kai (fish) in which certain chemicals present in low levels in the river may concentrate.

3.3 It is not possible to conduct a robust risk assessment regarding bioaccumulated chemicals in fish without sufficient data on the chemical constitution of the wastewater and/or fish. However, examination of the types of discharge that enter the Masterton WWTP and the low concentrations of chemicals present in the small number of wastewater samples tested suggests that this is unlikely to constitute a measurable health risk.

3.4 The highest risk posed by the Masterton WWTP is of infectious disease to recreational users of the river and estimation of this risk is the main focus of this evidence.

3.5 The microbiological water quality of the Ruamahanga River deteriorates during freshes and is sufficiently poor upstream and immediately downstream of Masterton that swimming in it should be discouraged whenever the river is above median flow. During the summer, the contribution of the WWTP effluent to the microbial load in the river will greatly diminish at below-median flows because following the upgrade direct discharge will not occur below this threshold. This is when most of the recreational activity occurs, therefore the estimated risk to swimmers emanating from pathogens in the WWTP effluent will reduce significantly.

3.6 At present, the best estimate of adenovirus infection for swimmers at times when most aquatic recreation occurs in the Ruamahanga River is 7.3 per 1,000. This is estimated to fall to 0.3 per 1,000 after the upgrade, largely due to the practice of discharging to land instead of directly to the river at below-median river flows. This is well below the acceptable limit of 10 per 1,000.

4. HEALTH RISKS ASSOCIATED WITH THE CURRENT DISCHARGE

4.1 Although the current discharge does not cause contact recreation guidelines to be breached, it increases the levels of pathogens downstream and contributes to an increased health risk, particularly at times of low flow when the river is used for primary contact recreation and when the upstream concentrations of pathogens are generally at their lowest.

4.2 In terms of known or potential public recreation sites, this increase in health risk is highest at Wardell's bridge where the existing discharge is not fully mixed but decreases downstream. At the Cliffs, the nearest commonly used public swimming location, the effects of the existing discharge are minor.

4.3 Although the adverse effects of the current discharge are minor, there are health risks which can be addressed and which this upgrade is directed at.

4.4 In this section I will briefly discuss the health of the community in terms of potential water borne diseases. More detailed information is available in the Health Impact Assessment prepared in relation to the proposed upgrade (Ball, 2007).

4.5 The average number of notified cases of diseases that are potentially waterborne are given in Table 1 below.[1] The data reveals that only salmonellosis has a higher annual incidence rate in the Wairarapa than the national average. Of note, is that only 9/100 salmonellosis cases investigated by the DHB included recreational water as a possible risk factor and the Ruamahanga River was not implicated in any of these cases.

Table 1 (Table 17 in the AEE) Notified Potentially Waterborne Diseases Cases (1997-2004)

	Wairarapa		New Zealand	
Notifiable diseases	**Notified cases**	**Av. annual cases/100,000**	**Notified cases**	**Av. annual cases/100,000**
Campylobacteriosis	657	214.7	86,719	292.3
Cryptosporidiosis	72	23.5	6,587	22.2
Gastroenteritis	59	19.3	6,544	22.0
Giardiasis	69	22.5	14,025	47.4
Hepatitis A	3	1.0	1,004	3.4
Leptospirosis	7	2.3	741	2.5
Salmonellosis	221	72.2	13,895	46.8
Shigellosis	8	2.6	997	3.4
VTEC/STEC disease	1	0.3	534	1.8
Yersiniosis	22	7.2	3,697	12.5

4.6 For most notified diseases, the trend in annual incidence rates for the Wairarapa cases generally follows that of the nationally reported cases (see Ball, 2007 for further detail). It is not possible to determine whether any of the notified cases were linked to contact with the Ruamahanga River, or whether they were from other exposures.

4.7 While these pathogens may be transmitted to people via water, they can also be transmitted via contaminated food, by person-to-person contact and, with the exception of Hepatitis A and *Shigella* (which are human pathogens), contact with infected animals/faeces. Of these exposure routes, it is generally accepted that contaminated food and animal contact are the two most common vehicles of infection for most of these pathogens.

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[1] Information is available through the EpiSurv notifiable diseases database.

4.8 The microbiological quality of water in the Ruamahanga River may potentially impact on human health in three ways:

(a) It may cause additional risk of waterborne disease through recreational contact in the river;

(b) It may cause additional risk of waterborne disease through contaminated drinking-water within the Ruamahanga catchment; or

(c) It may lead to additional risk of disease through consumption of mahinga kai collected from the river.

Risk to recreational users

4.9 In practice, Wardells Bridge is not heavily used for primary contact recreation and accordingly the actual risk of someone contracting disease as a result of even the existing discharge is quite low. The risk of disease also reduces considerably as one moves downstream out of the mixing zone. The risk will be considerably lower as a result of dilution and die-off, by the time the much more popular recreation site at the Cliffs is reached.

4.10 There is minimal recreational use at Wardells Bridge at the present time, partly due to the presence of signs warning of the proximity of the effluent discharge. These warning signs actively discourage recreational use of the river at Wardells Bridge for swimming and food gathering. Access to the site is across private property, and although it is publicised as an access point for fishing, there is no formed public access to the site.

4.11 The health risks to recreational users of the river are discussed in further detail in section 6 of my evidence.

Risks as a source of drinking-water

4.12 The Ruamahanga River is not listed in the Wellington Regional Freshwater Plan (WRFP) as a water body in which water quality needs to be managed for drinking-water supply purposes. There are no registered community drinking-water supplies that are sourced directly from the Ruamahanga River, and no groundwater bores (that use groundwater as a drinking-water source) close enough to the WWTP effluent discharge to be a concern. Hence, the risk of illness arising from using the Ruamahanga River as a drinking water source is considered to be negligible.

Risks as a source of mahinga kai

4.13 Section 4.2 of the WRFP includes a policy to manage sites of special value to the tangata whenua, which includes mahinga kai (aquatic food) sites.

4.14 With wastewater discharges to water bodies, there is a risk that chemical contaminants and waterborne pathogens may adversely affect human health via consumption of mahinga kai collected from the affected part of the river. Accordingly, the mahinga kai for Ruamahanga River has been assessed, and is reported in more detail in the Health Impact Assessment (ref Ball, 2007).

4.15 Based on the limited chemical monitoring data to date, there would appear to be little health risk via consumption of contaminated mahinga kai, as all of the chemicals tested were below the limit of detection.

5. THE PROPOSAL

5.1 I have assessed the health risk from the proposed upgrade. So far as my evidence is concerned, the key upgrades are:

(a) No direct discharge to the river at times when primary contact recreation is most likely and when upstream microbiological quality is at its highest.

(b) At times when discharge does occur, the effluent will have an improved microbiological quality and be better mixed. At these times upstream water quality is poorer and little contact recreation occurs.

(c) The construction of two new oxidation ponds, resulting in better treatment and less than one third of the current leakage from the existing ponds.

6. HEALTH RISK GUIDELINES

6.1 The effluent contains a variety of pathogens, including bacteria and viruses. Land application of effluent has the potential to increase the risk of groundwater contamination by these pathogenic micro-organisms, which can cause disease in humans and livestock.

6.2 The NZ Drinking Water Standard for *E. coli* is currently set at <1 cfu/100 mL. Groundwater concentrations that exceed this guideline value are indicative that faecal matter and possibly other disease-causing organisms may be present.

6.3 The Microbiological water quality guidelines for marine and recreational areas (Mfe/MoH, 2003) contain the current national guidelines for recreational fresh waters. The suitability for recreation grade (SfRG) is based on a sanitary assessment of the catchment and the microbiological assessment category (MAC), which is assigned on the basis of regular water quality monitoring in the bathing season.

Suitability for Recreation Grade

Susceptibility to faecal influence		**Microbiological Assessment Category (MAC)**			
		A	**B**	**C**	**D**
		≤ 130 *	131 – 260 *	261 – 550 *	> 550 *
Sanitary **I**nspection **C**ategory (**SIC**)	Very low	Very good	Very good	Follow up	Follow up
	Low	Very good	Good	Fair	Follow up
	Moderate	Follow up	Good	Fair	Poor
	High	Follow up	Follow up	Poor	Very poor

* 95th percentile *E. coli* / 100mL

6.4 Explanation of the suitability for recreation grades and recommendations on swimming in water of the various grades is given in Note H(ix) of the 2003 Guidelines. The recommendations are shown in the following table.

SfRG	**Recommendation**
Very good	Considered satisfactory for swimming at all times, and therefore may not require monitoring on a regular basis.
Good	Satisfactory for swimming most of the time. Exceptions may include following rainfall. Such beaches are monitored regularly throughout the summer season and warning signs will be erected if water quality deteriorates.
Fair	Generally satisfactory for swimming, though there are many potential sources of faecal material. Caution should be taken during periods of high rainfall, and swimming avoided if water is discoloured. Sites are monitored weekly and warning signs erected if water quality deteriorates.
Poor	Generally not okay for swimming, as indicated by historical results. Swimming should be avoided, particularly by the very young, the very old and those with compromised immunity. Permanent warning signs may be erected at these sites, although councils may monitor these sites weekly and post temporary warnings.
Very poor	Avoid swimming, as there are direct discharges of faecal material. Permanent signage will be erected at the beach stating that swimming is not recommended.

6.5 Monitoring and public notification is outlined in Note H(x) of the 2003 guidelines. The following recommendations are made in the 2003 Guidelines for recreational waters that have a good, fair or poor SfRG:

> "*Weekly [water quality] monitoring be carried out during the bathing season. The public will be informed when swimming is not recommended (when a sample taken from the beach exceeds the action-level single-sample criteria of the Microbiological Water Quality Guidelines).*"

6.6 The MfE guidelines note the following caveats to their use in waters impacted by wastewater discharges:

> "*These guidelines cannot be directly used to determine water quality criteria for wastewater discharges because there is the potential for the relationship between indicators and pathogens to be altered during the treatment process.*"

> "*These guidelines should not be directly applied to assess the microbiological water quality of water that is impacted by a nearby point source discharge of treated effluent without first confirming that they are appropriate. This is particularly important for … waste stabilisation pond effluent.*"

6.7 The consequence of this is that a health risk assessment based on waterborne pathogens emanating from the WWTP effluent is required. This assessment is reported in the next section of my evidence.

7. THE QUANTITATIVE HEALTH RISK ASSESSMENT

7.1 This section describes the derivation and outcome of a quantitative health risk assessment (QHRA) of the potential health effects resulting from recreational exposure to micro-organisms discharged from the WWTP.

7.2 Risk is the product of hazard and exposure. The greater the hazard and/or exposure, the greater the risk. In this scenario, the hazards are pathogens (micro-organisms that can cause infection) present in wastewater. The exposure is the amount of water ingested and/or inhaled during contact recreation.

7.3 The risk estimating procedure involves ascribing numerical values to hazard, exposure and infectious doses. In its simplest form, one could get a crude risk estimate to recreational water users by multiplying "average" values of pathogen concentration in the effluent by the river water dilution factor, further multiplication by the "average" volume of water ingested/inhaled during recreational pursuits to give the "average" number of pathogens consumed. This can then be entered into the infectious dose equation for that pathogen to give an "average" risk of infection. However, this completely ignores the fact that the risk itself has a distribution of values. For example, some days the receiving environment may be quite uncontaminated and so risk will be low, possibly even zero, but on another day there may be appreciable contamination and so the risk higher. These probability distributions are used to derive the mean or most likely risk, which is reported hereafter.

7.4 The accuracy of a risk assessment is dependent upon the assumptions used in the risk model. For this reason, the assumptions used are stated below.

Impact site

7.5 Wardells Bridge was used in the risk model because, while this is not a designated recreational site, it is the closest one below the discharge point for which flow and monitoring data were available. This is a conservative assumption because the risk at Wardells Bridge will exceed that at the Cliffs, the first designated recreational site downstream of the WWTP. That site could not be readily modelled due to lack of flow and monitoring data.

Microbial hazards

7.6 The micro-organisms of potential public health significance that can be associated with sewage effluent were derived from the ANZECC & ARMCANZ Guidelines (2000). Those are not relevant to these particular circumstances, and the reasons for their exclusion, are given in Table 14 of Ball (2007). The pathogens assessed in the QHRA were: human adenoviruses and enteroviruses, *Campylobacter jejuni*, *Salmonella* sp., *Giardia* sp. and *Cryptosporidium* sp.

Microbial quality of the effluent

7.7 The effluent pathogen concentrations were derived from the Christchurch wastewater treatment plant at Bromley, which is the only pertinent survey of pathogen concentrations from New Zealand wastewater treatment plants that incorporate oxidation ponds. (The summary statistics of pathogen concentrations at Bromley are given in Table 16 of Ball (2007).) The sewage treatment process at Bromley differs from that at Masterton in that the effluent passes through trickling filtration and activated sludge before entering the oxidation pond. These steps are estimated to reduce the microbial load by about one order of magnitude, so the pathogen concentrations for the QHRA were derived from ten-fold multiplication of the Bromley pathogen concentrations. This approach was validated by a small survey of the Masterton WWTP effluent and by assessment of effluent *E. coli* data from both Masterton and Bromley. The resultant concentration estimates were used to best-fit frequency distribution models for each pathogen using the @Risk software, the parameters for which are shown in Table 17 of Ball (2007). Use of the Bromley pathogen data may result in an overestimation of the risk (although probably not by much), this follows the precautionary approach. In particular it should be noted that the new upgraded ponds proposed at Masterton will result in better disinfection than at present.

Survival of micro-organisms in the environment

7.8 There is no need to factor in survival because the travel time in the river between the point of entry of the treated effluent into the Ruamahanga River and the closest designated recreational site downstream (The Cliffs) is a few hours (4.5 hours at median flow). The amount of die-off over such a short period would be small (1-2% for adenoviruses) and has been ignored. This also follows the precautionary approach.

Dilution / dispersion

7.9 Following the WWTP upgrade, treated wastewater will be discharged via three routes: direct discharge into the Ruamahanga River, leakage from the oxidation ponds and land discharge by means of border dyke irrigation. As the three disposal routes are completely different they are addressed separately below.

Direct discharge to the Ruamahanga River

7.10 It is proposed that direct discharge into the Ruamahanga River will be governed by the following discharge rules:

- Summer (November – April) – no direct discharge below median flows in the Ruamahanga River.
- Winter (May – October) - no direct discharge below half-median flows in the Ruamahanga River.

- Whenever there is a direct discharge the effluent : river ratio will be 1:30 until the maximum effluent discharge rate of 1,200 L/sec is reached.

7.11 The effluent dilution distributions derived from PDP modelling for the different discharge regimes are shown in the appendix.

Pond leakage

7.12 The volume of pond leakage was estimated to be between 1,200 – 1,700 m^3/day (PDP, 2007). No estimate has been made of the microbiological quality of the leakage material. It is likely that passage of pond effluent through the sediment layer on the bottom of the ponds will filter out many of the microorganisms in the wastewater, particularly those associated with particulate material. However, in the absence of a reliable estimate, the precautionary approach has been followed. The risk assessment is made on the assumption that all of the pond leakage material enters the Ruamahanga River and that the effect is equivalent to an additional 1,200 – 1,700 m^3/day of pond effluent being piped into the river. The revised plan to build lined oxidation ponds further away from the river will significantly reduce both the volume of leakage and the microbial load of the leaked effluent that enters the river (approximately 1/3 of present volumes).

Land discharge

7.13 When the treated wastewater is discharged onto land, micro-organisms are also removed by filtration through the soil and during transport through the aquifer. The dilution and filtration through soil and the aquifer are best dealt with independently. Given the short travel times to the river for the effluent discharged to land the losses due to die-off have been ignored.

7.14 Losses through the soil were modelled by (PDP, 2006) using a static *E. coli* concentration of 1,000/100 mL and 10 adenoviruses/L. The output of this model was used as the input for the groundwater modelling carried out by PDP (PDP, 2008).

7.15 At times when direct discharge to the river is not occurring, the risk assessment is based on land discharge and pond leakage only. In these circumstances the risk assessment is made with the following inputs and assumptions:

- Pathogen distributions as described in Section 6.3 (from Table 17 of Ball, 2007) are used in place of the fixed values of 1,000 *E. coli*/100 mL and 10 adenoviruses/L.
- Applying log reductions (derived above for adenovirus and *E. coli*) of 1.4 for viruses and 2.8 for the bacterial and protozoal pathogens.

Exposure assessment

7.16 The following exposures were used in the risk model:

- duration of swimming as a rectangular distribution with minimum and maximum durations ¼ and 2 hours.
- volume ingested/inhaled per hour as a triangular distribution with minimum and maximum volumes = 10.5 and 100.5 mL, with mode = 50.5 mL.

Infectious dose

7.17 The infectious dose equations used in the risk model are shown in Table 21 of Ball (2007).

QHRA

7.18 The QHRA was carried out using the aforementioned parameters and assumptions in the risk model as described pictorially in Figure 7 of Ball (2007). Where available, accepted values from the published literature (e.g. infectious dose) or able to be derived reliably form the available data (e.g. effluent dilution from flow data) were used. Otherwise, the precautionary approach was adopted. This means that the outputs of the risk assessment are conservative (i.e. will not overstate the risk). The aspects of the model that are precautionary and therefore will over-estimate the risk are:

- Use of the Bromley effluent pathogen concentrations, which are likely to be higher than at Masterton;
- Assuming no pathogen die-off in the river;

- Modelling at Wardells bridge instead of at the Cliffs where pathogen loads will be lower;
- Ignoring any filtration effect (i.e. no reduction of pathogens) during pond leakage; and
- Assuming all exposures to be via primary contact.

7.19 The risk to recreational users has been estimated for various flow conditions and associated discharge scenarios. The risks associated with each of the modelled pathogens for each scenario are shown in Table 24 of Ball (2007). However, for the sake of clarity, the risk of adenovirus infection is used hereafter to compare the risks for the different scenarios as adenovirus infection resulted in the greatest risk under all scenarios.

Scenario	**Adenovirus infections Mean (best estimate)**
(a) Present situation for below median flows	7.3 / 1,000
(b) Present situation for above median flows	2.5 / 1,000
(c) Post-upgrade – summer below median flows	1.0 / 1,000
(d) Post-upgrade – summer above median flows	4.2 / 1,000
(e) Post-upgrade – winter below half-median flows	1.1 / 1,000
(f) Post-upgrade – winter above half-median flows	3.5 / 1,000

7.20 However, the revised plan is to build lined oxidation ponds further away from the river. It is estimated that the new lined ponds will result in less than one third of the worst case rate of leakage for the existing ponds, which will reduce the risk for the no-discharge summer scenario when the river flow is less than median. This change is expected to reduce pond leakage by two-thirds and reduce the microbial load of the leaked effluent that enters the river and thus will further reduce the risk to swimmers. The most significant impact will be in summer at below-median flows when pond leakage constitutes the predominant transmission route. Under this scenario the estimated risk falls from 1.0 to ca. 0.3 cases per thousand swimmers at Wardells Bridge. For less than half median flow in winter the risk falls to 1.1 per thousand.

7.21 For comparison purposes, the acceptable risk was defined as being 8/1,000 in the previous freshwater guidelines (MfE, 1999). The present recreational guidelines (MfE/MoH, 2003) do not state an acceptable limit. However, it can be inferred as being

1% (10/1,000) from the risk of *Campylobacter* infection equivalent to the upper 95th percentile *E. coli* concentration of 260/100 mL (Table H2 of MfE/MoH, 2003), above which the water is graded as poor (Table E2 of MfE/MoH, 2003). Recommendations regarding swimming in water of various grades is given in Note H(ix) of the 2003 Guidelines. The recommendation pertaining to a Suitability for Recreation Grade of "poor" is: *"Generally not okay for swimming, as indicated by historical results. Swimming should be avoided, particularly by the very young, the very old and those with compromised immunity. Permanent warning signs may be erected at these sites, although councils may monitor these sites weekly and post temporary warnings."*

7.22 In summary, the best estimate of adenovirus infection for swimmers at times when most aquatic recreation occurs in the Ruamahanga River is 7.3 per 1,000 at present, which is below but close to the acceptable limit. This risk will fall to 0.3 per 1,000 after the upgrade, largely due to the practice of discharging to land instead of directly to the river at below-median river flows, when most recreational activity occurs. This is well below the acceptable limit of 10 per 1,000.

7.23 The pre upgrade figure of 7.3 per 1,000 at Wardells Bridge (below median flow) assumes full mixing, which is not the case at present because the effluent plume discharged to the river via the Makoura Stream hugs the right bank downstream of the confluence. The actual risk is likely to be lower than 7.3 per 1,000 towards the left bank, and higher towards the right bank. It should be noted that these risk figures are based on 1,000 people engaging in primary contact recreation at Wardells Bridge.

7.24 To provide perspective for the 7.3 figure, the HIA (Ball, 2007) reports that the MfE/MoH guidelines measure health risk from recreational exposure to freshwater in terms of *E. coli* concentrations with the equivalent risk of *Campylobacter* infection, with the alert mode being triggered at an infection rate of 1% (*i.e.* 10/1,000).

7.25 The current risk for adenovirus/*Gastroenteritis* at median flow for recreational users (7.3 per 1,000) reduces due to the effect of die-off (sunlight and time) and dilution (Waingawa confluence) as the river continues to the Cliffs. Accordingly, taking into account the relatively low exposure rates (low primary recreational usage) the current risk of infection as a result of swimming in the Ruamahanga River at the Cliffs from the existing (continuous) effluent discharge is acceptable according to the MfE/MoH 2003 Guidelines.

8. REDUCTION IN PATHOGEN LEVELS AS A RESULT OF THE UPGRADE

8.1 Removal of direct discharge from the river at times of lower flow and high contact recreation use will result in the following improvements:

(a) There will be no direct discharge of pathogens at times when most primary contact recreation occurs and when upstream microbiological quality is very good.

(b) The indirect discharge from irrigation is well treated/filtered in terms of pathogens (a conservative estimate is that the risk of illness at Wardell's Bridge will be reduced from 7.3 per 1,000 swimmers to 0.3 per 1,000 at times when there is no direct discharge).

8.2 When there is a direct discharge to the river, there will be a significant reduction in health risk (already relatively low risk) and residual risks will be minimal because:

(a) In summer there will be no direct discharge when the river flow is less than median. At such times, monitoring records show that the upstream water quality is generally very good.

(b) When discharge does occur (at flows greater than median in summer, and half median in winter) the microbiological quality of the discharge will be better than at present because of the new maturation cells.

(c) The new discharge point and diffuser will result in greater mixing and dilution of the effluent plume by the time it reaches Wardell's bridge.

(d) Little, if any, primary contact recreation is likely at times/flows when direct discharge will occur and at such times the risk to recreational users from the WWTP effluent is minimal by Wardell's bridge and further reduced by the time it reaches the Cliffs.

8.3 Recreational health risk will be mitigated by eliminating the discharge of treated effluent to the river during low flow periods. At these times the river is often clear and warm, attracting peak numbers of swimmers. In the future, treated effluent will only be discharged to the river during the summer when freshes occur and the flow exceeds the median value of 12.3 m^3/s.

8.4 During freshes, water quality deteriorates (colour, turbidity and microbiological), the water temperature drops and the current becomes swifter. These factors all discourage swimming, which markedly reduces numbers of swimmers and consequent exposure to health risk.[2] In addition, the water quality upstream of the WWTP deteriorates to such an extent that the addition of treated effluent has a negligible negative effect on health risk.[3] The threshold flow range where the river is most sensitive to the discharge (just above median flow) only occurs for a short duration.

8.5 The potential risks resulting from any chemical and microbial hazards emanating from the upgraded WWTP were investigated for the three potential exposure routes identified previously: accidental ingestion/inhalation during aquatic recreational activities, consumption of drinking-water, and mahinga kai harvested from the Ruamahanga River (Ball, 2007).

9. SUMMARY

9.1 The removal of effluent from the river during low river flow in summer will benefit both the SIC (no direct discharge of treated effluent close to a swimming location) and MAC (the 95%ile upstream *E. coli* concentration at < median flow is < 130 per 100ml). With reference to Table E2 of the Guidelines, the Suitability for Recreation Grade for the Wardells Bridge and Cliffs sites at less than median flow will be "Very Good".

9.2 When freshes occur, discharge with a 30:1 minimum dilution will commence at median flow. The health risk attributed to the effluent for river flows > median have been assessed as 4.2 per 1,000 swimmers at Wardells Bridge (Ball, 2007), which is below the acceptable limit of 10 per 1,000 referred to above. It should also be noted that during freshes upstream water quality deteriorates as flow increases (turbidity and microbiological), the water temperature drops and the current becomes swifter.

9.3 These factors all discourage swimming, which markedly reduces numbers of swimmers and consequent exposure to health risk. As discussed in the evidence of Chris Hickey, the water quality upstream of the WWTP deteriorates to such an extent that the addition of treated effluent has only a marginal negative effect on health risk.

[2] See section 8.2.6 AEE.
[3] See tables 35 and 36 of the AEE.

Furthermore, the threshold flow range between discharge occurring and when the river becomes more polluted upstream only occurs for a very short duration.

9.4 Based on the limited chemical monitoring data to date, there would appear to be little health risk via consumption of contaminated mahinga kai, as all of the chemicals tested were below the limit of detection in the samples of pond effluent tested. The investigation of the existing state of mahinga kai found no significant effects from 35 years of the existing discharge,[4] and the upgraded plant, with its more limited discharge into the river taking place at higher flows, together with higher standards of treatment, would, if there were any effect, improve the quality of the aquatic environment.

9.5 In terms of the guidelines and the risk of infectious disease to recreational users of the river downstream of the ponds, the estimated degree of this improvement at below-median flows in summer (no direct discharge) is a reduction in risk from 7.3 cases per thousand at present to 0.3 case per thousand contacts at Wardells Bridge after the upgrade (the actual reduction is likely to be higher given the conservative assumptions involved). This risk is well within the acceptable limit of 8 per thousand stated in the previous Recreational Water Guidelines (MfE, 1999), and the 10 per thousand limit inferred from the current *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas* (MfE/MoH, 2003).

9.6 The period during which discharge will occur and flows will be unsuitable for recreation is of very short duration (see the evidence of Jim Cooke).

9.7 In summary, the effects on health risk will primarily be mitigated by eliminating the direct discharge of effluent to the river during low flow periods. At these times the river is often clear and warm, attracting peak numbers of swimmers and upstream microbiological quality is high. At times when there is a direct discharge, effects on health risk will be less than minor for the reasons outlined above. Neither the pond leakage nor the direct discharge will cause contact recreation standards to be breached after reasonable mixing.

[4] See section 5.5.3 of the AEE.

10. SUBMITTERS' CONCERNS

Andrew Stewart – submitter 242620

10.1 Andrew Stewart has suggested that swimming has been observed at flows of 19 m^3/sec and that clarity does not fall to less than MfE guideline levels until the river reaches 20 m^3/sec.

10.2 While no doubt the occasional person will swim in the river during high flow conditions, I would expect this to be an uncommon occurrence. Most people do not swim at elevated flows because of the greater risk of drowning. Furthermore, the elevated turbidity and lower water temperatures that generally occur at higher flows also tend to dissuade most people from swimming. It should be noted that in rivers flowing through pastoral catchments the greatest microbial load (and risk of infection) generally occurs after heavy rain events when the river flow is increased. The increased *E. coli* concentrations at such times are caused by animal faeces being washed into the river and sediment resuspension. It is not good practice to swim at these times when the *E. coli* concentrations are often higher than guideline values and the risk of waterborne infection is elevated.

10.3 Swimming in rivers in general during high flows is associated with increased risk of waterborne infection compared to that during lower flows because of the runoff caused by rain events. The contribution of the effluent discharge to the faecal coliform concentration in the river at such times is minimal (as indicated by Table 11 of Chris Hickey's evidence. The average infection risk at > median flows falls below the threshold risk in the guidelines and in my opinion will not result in an unacceptable risk.

10.4 In conclusion, while the risk of infection increases at higher flows, it will be only marginally higher after the upgrade than it is at present. The risk will still be within acceptable MfE/MoH guideline limits at threshold flows and the greatest risk will only occur when recreational exposures are minimal.

11. CONCLUSION

11.1 The existing discharge of effluent to the river increases the levels of pathogens downstream and thereby contributes, albeit at a minor level, to an increased health risk. This is particularly at times of low flow when the river is used for primary contact recreation and when the upstream concentrations of pathogens are at their lowest.

11.2 The proposed upgrade will ensure that health risks are low at times when the river is most used for contact recreation. Whilst residual risks will still be elevated at other times (particularly at threshold flows just above the trigger flows), these risks are considered to be acceptable (Ball, 2007).

11.3 In summary, the proposed upgrade will ensure that the discharges will have no more than minor adverse effects on the environment and will not compromise public health.

Andrew Ball
Water Microbiology Consultant, ESR
13 February 2009

12. REFERENCES

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13. APPENDIX

Effluent dilution distributions based on PDP Modelling

[Reproduced from Table 1 of the HIA (Ball, 2007)]

River flow regime	Frequency distribution (best-fit effluent : river flow ratio)
Summer - above median flows	Loglogistic (α = 0.00024504; σ = 0.0067052; shift = 1.5963) for viruses Loglogistic (α = 0.00023731; σ = 0.0066128; shift = 1.5753) for bacteria/protozoa
Summer - below median flows	BetaGeneral (min = 1.2081; max = 4.8337; α1 = 0.0011491; α2 = 0.011475) for viruses Exponential (β = 0.0016878; shift = 0.0011323) for bacteria/protozoa
Winter – above half-median flows	BetaGeneral (min = 1.7729; max = 24.945; α1 = 0.00059962; α2 = 0.15634) for viruses BetaGeneral (min = 1.7747; max = 26.354; α1 = 0.00059656; α2 = 0.16369) for bacteria/protozoa
Winter - below half-median flows	InverseGauss (μ = 0.0011953; λ = 0.0021165; shift = 0.0021713) for viruses InverseGauss (μ = 0.0010857; λ = 0.0018093; shift = 0.0020658)) bacteria/protozoa

Effluent flows include direct river discharge, subsurface flows following effluent irrigation to land and 1,200 m^3/day pond leakage.

Pathogen distributions derived from the 10xBromley WWTP data

[Reproduced from Table 17 of the HIA (Ball, 2007)]

Pathogen	Frequency distribution (best-fit pathogen concentration)
Campylobacter jejuni	Inverse Gauss (μ = 75.696; λ = 8.9561; shift = 18.168)
Salmonella sp.	Normal (μ = 50.167; σ = 108.37)
Giardia	Inverse Gauss (μ = 3.6142; λ = 1.5548; shift = -0.18135)
Cryptosporidium	Lognormal (α = 4.4026; σ = 0.656; shift = -0.019681)
Adenoviruses	Inverse Gauss (μ = 17.989; λ = 3.4559; shift = 1.2381)
Enteroviruses	Inverse Gauss (μ = 133.61; λ = 11.86; shift = -2.0244)