Sustainable coastal subdivision in Gisborne DC: Discriminating faecal source contamination of freshwater of coastal communities

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Executive Summary

Most local and regional councils in New Zealand that have habitable coastal areas are experiencing significant pressure to permit coastal residential sections to be sub-divided and allow land use changes that facilitate farm conversions for new coastal residential development. While there are many positives associated with these land use changes and the corresponding increase in residential population, there are also a number of potential negative consequences including: compromised quality of surface and ground-waters, an increase in residents naïve in effective management of non-reticulated water and wastewater, and the exposure of a larger human population to rural hazards.

Water quality is a technical term that describes water characteristics in relation to standards and guidelines. The principal rural hazards for Regional Councils and Health Protection Officers associated with coastal residential developments are that more people are more frequently exposed to potentially pathogenic microorganisms of either human or animal origin due to failure of on-site wastewater treatments (septic systems), microorganism of animal origin capable of causing human disease (termed zoonotic microorganisms), access to drinking water that of an acceptable quality, and more frequent exposure to environmental waters that do not met acceptable recreational quality criteria.

The Gisborne District Council (GDC) faces exactly these problems in coastal communities experiencing coastal development. Like most coastal communities around New Zealand, Wainui-Okitu-Makorori Beach communities collect rain water in tanks for potable supply, and manage wastewater using individual on-site systems (i.e. septic systems), while many access groundwater for domestic irrigation, with occasion reports of groundwater subsidising potable supplies. The sustainability of these systems depends on the ability of coastal soils to mitigate septic seepage, especially during periods of high rainfall, and on user maintenance and behaviour of their septic system and their water use.

A request from GDC and aim of this project was to demonstrate the use faecal source tracking (FST) tools to determine whether the potential sources of presumptive faecal contamination in the Hamanatua Stream lagoon (Okitu) and groundwater from sampling bores (Wainui, Okitu and Makorori) could be discriminated in these coastal residential areas managed by GDC. These sites have an ongoing problem of elevated microbial counts, suggesting faecal contamination of

the water. Historical data supports the on-going contamination problems, with probable sources of contamination suggested to include seepage from septic tanks and/or livestock faecal matter entering surface and ground water systems.

This report presents data for a small preliminary study carried out to determine the microbial quality of one recreational water site and three groundwaters sites along the mid-eastern coast of GDC: the Hamanatua Stream lagoon (Okitu), which is used for recreational contact, and groundwater from bores in Wainui, Okitu and Makorori.

The FST tools used were: (1) fluorescent whitening agents (FWA), (2) faecal sterols and (3) molecular markers specific to faecal-associated bacteria, which can be further discriminated to indicate non-human faecal sources.

These semi-urban coastal environments in this area of Gisborne are complex with multiple potential faecal inputs, including humans, farmed and wild animals, and ducks. The Hamanatua Stream (contact recreation) was sampled at 11 sites along its length behind the residential area. FWA levels were below the detection limit, including the lagoon, suggesting that the contamination source(s) did not contain appreciable levels of FWAs, which may indicate the low use of materials containing FWAs or low human-associated inputs. Faecal sterol analysis showed low levels of sterols, consistent with either a low faecal input or faecal matter that had been significantly degraded. The sterol-ratio analysis suggested the primary source of the faecal contamination was non-human. PCR-marker analysis also suggested primarily non-human faecal source, with a probable herbivore signature dominating. Analysis of the groundwater bore data showed that FWA, faecal sterols and PCR-markers were below the detection limit for all samples analysed, suggesting little recent human contamination at the time of sampling. The dynamic nature of bore water and the dilution effect associated with the likely distance contaminants required to move to the sampling site may dilute contaminants below detection. This was an extremely small-scale study with limited replication and limited environmental coverage. Hence, the current analysis has not resolved the issue of the source of the faecal contamination. However, with a strong suggestion that herbivore faecal matter is entering the stream, it is suggested that restricting stock access to the Hamanatua Stream and increasing riparian planting may reduce farm-associated faecal matter entering the stream. Managing stock faecal inputs may also aid in protecting the shallow groundwater and will help in identification of additional sources of contamination. More intensive and on-going monitoring of additional sites using a suite of detection methods that include advanced FST tools is likely to significantly contribute to determining the degree and timing of human contamination and thus permit environmental and health management of the source of human contamination. The final part of the report (page 34) presents a preliminary decision tree for coastal development.

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Project background

Gisborne District Council (GDC) set up a Special Steering Group to look at future growth options for Wainui/Okitu, Tatapouri, Makorori, and Sponge Bay, and specifically to generate a report to help GDC develop future water and wastewater services for these areas (O'Leary et al., 2006). An on-going problem exists of elevated faecal coliform levels in several waters that are regularly monitored around Gisborne. The source of bacterial contamination of the freshwater lagoon of Hamanatua Stream and several groundwater bores is unclear, thus making it difficult to implement effective management plans to target the issue.

The environmental quality of surface fresh water can be described as water that meets a community or society's aesthetic, recreational and health quality requirements and these are formally detailed in guidelines and standards such as the "Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas", the "Drinking-Water Standards for New Zealand 2005", and the "The Guidelines for Drinking-Water Quality Management for New Zealand" (Ministry for the Environment, 2002; Ministry of Health, 2005a, b). The Ministry for the Environment defines recreational water quality "by the number of samples taken over a bathing season that comply with guidelines for acceptable public health risk. The higher the number of samples that comply with guidelines, the better the water quality". Therefore, from an environmental perspective, fresh water quality is partially classified by the risk posed to human health.

There is an increasing awareness that water contaminated by faecal matter can compromise the environmental quality of fresh water, both surface- and ground-waters. From environmental and health perspectives, it is important to discriminate the source of faecal contamination because the management options may differ. While human-source faecal contamination represents the highest direct risk of disease to people, some animal-borne organisms cause also cause human diseases, and these microorganisms and diseases are termed zoonotic or zoonoses. Therefore, besides decreasing the aesthetic quality, water contaminated with faeces, poses a health risk to humans contacting water, whether the faeces are of human, animal or bird origin.

Heightened awareness is resulting in increased water quality monitoring for the traditional microbial indicators, faecal coliforms, *Escherichia coli* and enterococci (Ministry for the Environment, 2002; Ministry of Health, 2005a, b). There is also an expectation that when these indicators are detected, corrective action will be taken to eliminate these faecal indicators – and by inference the faecal pollution – from the water. While these traditional indicators are usually a good indication of microbial quality and the risk posed, they provide little guidance as to the source of the faecal pollution. Faecal coliforms and other traditional indicators are present in the faeces of humans, cows, sheep, dogs, ducks, seagulls and a wide range of other animals. Identifying the source of faecal pollution can be crucial for effective water management, particularly when, for example, a single seagull can excrete as many as 3×10^8 faecal coliforms and 3×10^9 enterococci per day (Wood and Trust, 1972).

The aim of this small project was to use advanced faecal source tracking (FST) tools to determine the source and quantification of bacterial contamination of Hamanatua Stream lagoon and three bores with variable faecal coliform/*E. coli* presence. The key question addressed was *"Are the faecal source tools able to implicate or exonerate a human source of faecal contamination at this site?"* The intention was to contribute to a more accurate assessment of the environmental quality of these bacterially-contaminated waters.

The report begins with the site description, mainly illustrated by photos highlighting features pertinent to sustainable coastal development and a brief summary of the Hamanatua Stream and groundwater sites with historical data for these sites. The methods section is next and provides perspective for the tools used in FST and the underlying principles of these methods. Next the results from the sampling for October 2007 and January 2008 are presented, followed by a conclusion with a suggested management option based on data interpretation. Finally, there are several appendices, with the first Appendix gives graphical depiction and a balanced ANOVA model analysis of the historical microbiological data to estimate whether causal relationships can be established for the microbial contamination of the sites (page 23). The other Appendices, in order, are the Hamanatua Stream sampling plan (page 36), the GDC and ESR laboratory sample identifications (page 37), and GDC website information showing the area proposed for reticulation of wastewater (page 38)[1].

[1] NOTE IN PRESS (July 2008): The community has decided against the reticulation of wastewater to these areas.

Site Description

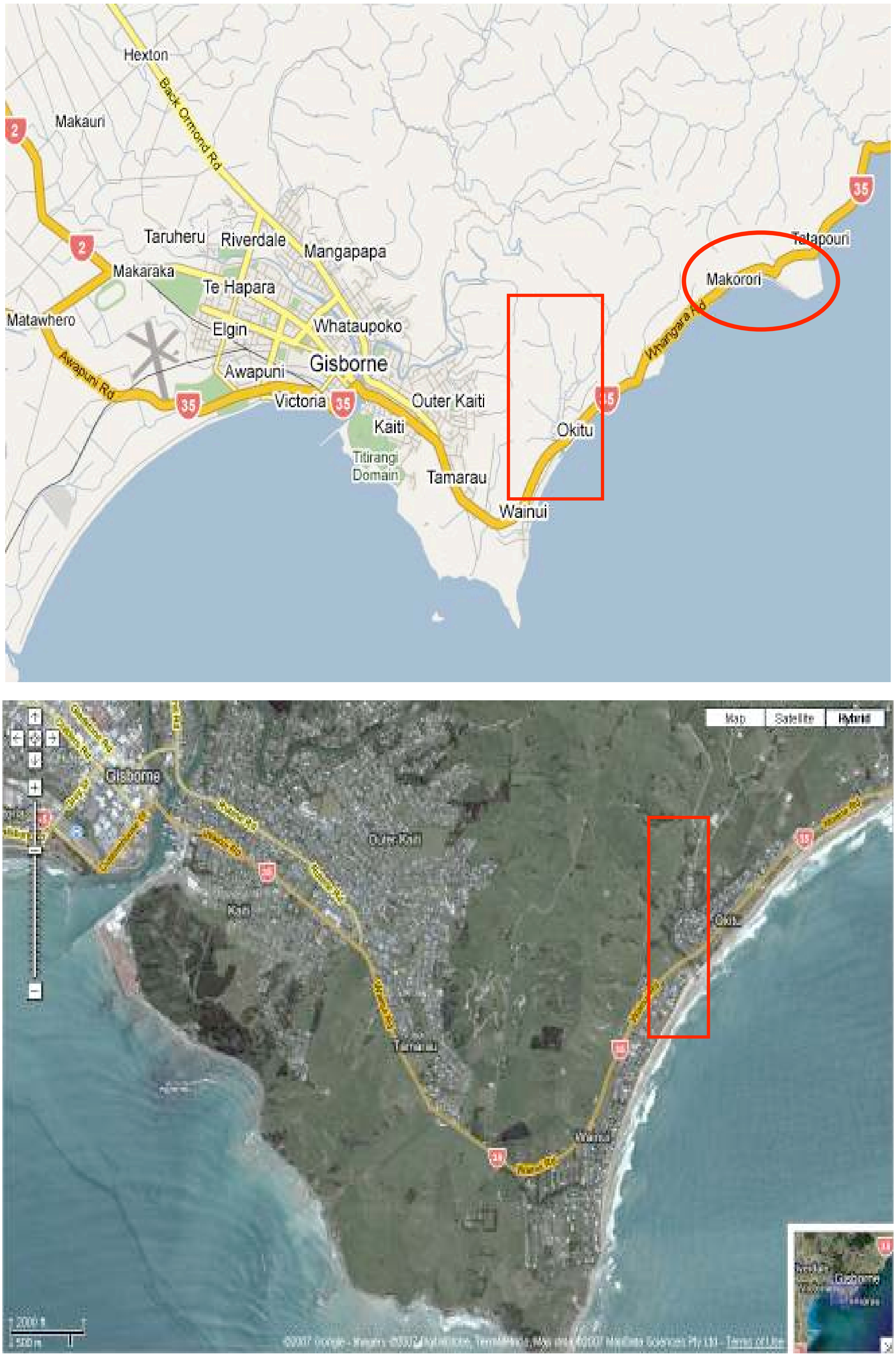

Figure 2 Map showing the location of Wainui and Okitu Beaches. The location of the Hamanatua Stream entrance to the beach is indicated by the red rectangle, relative to Gisborne City. Makorori is indicated by red circle.

Figure 3 Pressure on local coastal environments from increasing coastal development along the Wainui and Okitu Beaches east of Gisborne (see next figures for examples).

Figure 4 Aerial views of coastal development pressures on local coastal environments from increasing coastal development along the Wainui and Okitu Beaches east of Gisborne (see next figures for examples).


Figure 5 Primary coastal residential development with large sections, which permitted sufficient land for on-site wastewater drainage fields (left). An example of more recent house and section development, where much of the land area has been paved, which limits infiltration of surface water (right).


Figure 6 Subdivision of large sections along the access road to the beach is potentially increasing the number of permanent residents, and hence the pressure on the soils to treat larger volumes of wastewater before it drains through the sandy soils.

Figure 7 New housing developments inland directly off the main beach-access road. Each house has an on-site water capture and storage, with drinking water storage of new houses usually located under the house. Each property has an individual on-site wastewater treatment system. Septic tank systems are often in front yards (top right red circle, and Figure 7), which leaves little room for the system's drainage field. Thus, new coastal developments will increase effluent drainage down the natural gradient to towards the increased population density along the beachfront housing.

Figure 8 Two examples of the placement of on-site wastewater treatment systems in new developments (circled in red) and their location close to property boundaries, and with drainage field close to public footpaths and roads.

Hamanatua Stream

Hamanatua Stream drains an area of mainly beef and sheep farmland ~7 km from east of Gisborne CBD. Stock have almost continuous access to the waterway. The lower reaches of the Hamanatua Stream have low-density residential dwellings along its eastern side. The stream flows onto the Okitu and Wainui Beaches before entering the South Pacific Ocean (Figure 2).

The lagoon at the mouth of the Hamanatua Stream and local groundwater bores are regularly monitored (Table 1 and Table 2). Table 1 shows that the lagoon usually exceeded recommended bacterial indicator guidelines for safe recreational use (150 faecal coliform organisms/100 mL water or four out of five samples containing less than 600 organisms/100 mL), hence a permanent warning sign is in place (Figure 9).

Figure 9 Hamanatua Stream lagoon (left) with the permanent signage indicating the potential of microbial contamination (right).

Sampling has been undertaken at a range of sites (Figure 10). The possible sources of faecal contamination at the Hamanatua Stream lagoon are humans wastes from septic systems, animals accessing the stream, ducks (particularly mallards), and possibly poorly performing septic tanks. Feral animals may also contribute to faecal contamination.

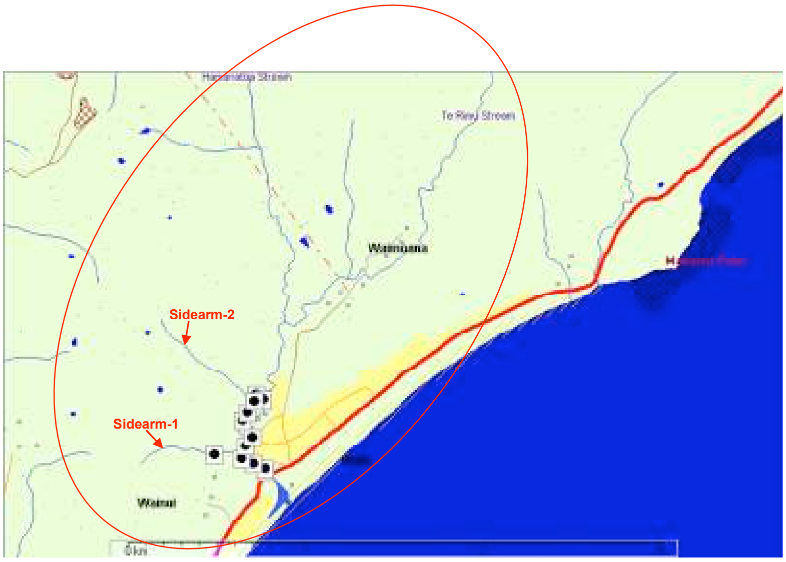

Figure 10 The Hamanatua Stream catchment, showing the two side-arms that feed into the lower reaches of the stream and the 11 sampling sites that span from beyond the last residential property (pale yellow on the map) on the eastern bank to the lagoon at the mouth of the stream.

Groundwater Bores

Three bores were selected for sampling, one north at Makorori (Figure 2) next to the beach on Makorori Beach Road (Figure 11). The Makorori bore has a history of elevated *E. coli* counts (Table 1). The other two were adjacent to Wainui Beach and one on Williamson St above the Hamanatua Stream (Figure 12).

The Makorori Beach Road bore (GPA264, site code 4, located opposite 40 Makorori Beach Rd) was drilled in May 2001 to a depth of 1.905 m through a soil profile of: 0–70 cm top soil/sand mix, 70 cm–1.15 m mainly sand with some soil, and 1.15–1.40 m wet clay to water level at ~1.40 m, followed by sand to well depth at 1.9 m. The bore at this site has consistently tested positive for faecal coliforms or *E. coli* (Table 2), and a septic system at an adjacent property has failed several times; whether other septic system drainage fields in the area function properly is uncertain.

The Wainui Beach groundwater bore (bore #91, GPA142, site code 10, located at 63 Wairere Rd) was drilled in May 1995 to a depth of 2.65 m through a soil profile 0–1.35 m sand/sandstone rocks, 1.35–1.70 m sand/shells/shingle and sandstone mixture, 1.70–1.86 m sand/mustard clay mix, 1.86–2.44 m wet sand/mustard coloured clay mix, and 2.44–2.65 m grey/blue clay. This bore is adjacent to a beach access walkway and has frequently shown positive results for faecal coliforms or *E. coli* (Table 2).

The Williamson St groundwater bore (bore GPA162, located at 11 Williamson St) is 5.0 m deep through a soil profile of 0–0.4 m topsoil, 0.4–1.2 m light brown sandy soil, 1.2–1.25 m coarse sand, 1.25–1.205 m pumice, 1.205–3.25 m light brown clayey sand, 3.25–3.45 m grey-fawn clay, 3.45–4.7 m grey clay, and 4.70–5.20 m water. *E. coli* results from this well are usually negative (Table 2).

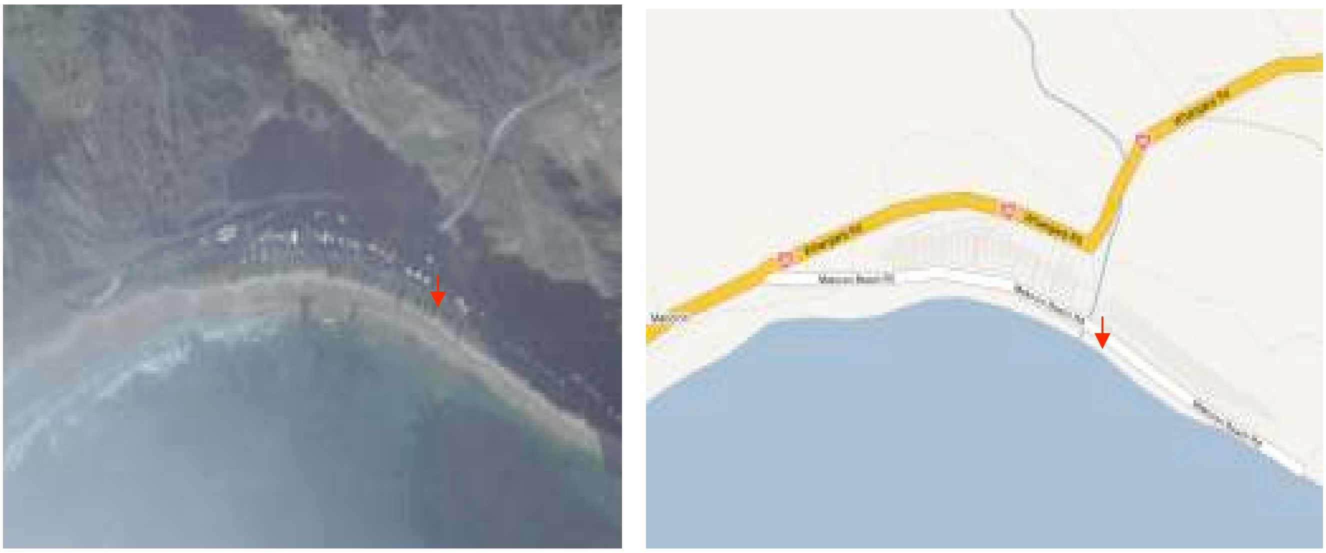

Figure 11 Location of the groundwater bores (red arrow) sampled opposite Makorori Beach Road, Makorori.


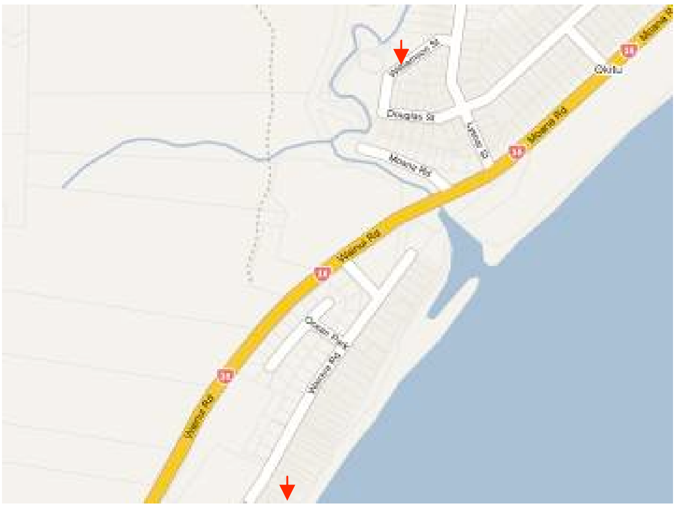

Figure 12 Location of the groundwater bores (red arrows) sampled near Hamanatua Stream (63 Wairere Road, Wainui Beach and Williamson Street, Wainui Beach).

Table 1 Water quality results for Hamanatua Stream lagoon, average annual data.

			Average Annual result	
	Date	Nitrate-N g/m3	Total Coliforms CFU/100ml	Faecal Coliforms CFU/100ml
Hamanatua Stream	1980	0.274	793	67
Hamanatua Stream	1981	0.057	143	186
Hamanatua Stream	1982	0.048	1643	1348
Hamanatua Stream	1983	0.259	204	306
Hamanatua Stream	1984	345.455	909	936
Hamanatua Stream	1985	0.209	388	238
Hamanatua Stream	1987	Not Analysed	2853	2131
Hamanatua Stream	1988	0.090	4851	3800
Hamanatua Stream	1989	0.182	4100	1950
Hamanatua Stream	1990	0.152	4555	3445
Hamanatua Stream	1992	Not Analysed	933	920
Hamanatua Stream	1993	Not Analysed	739	497
Hamanatua Stream	1994	Not Analysed	1845	1231
Hamanatua Stream	1995	Not Analysed	1411	841
Hamanatua Stream	1996	0.251	2438	717
Hamanatua Stream	1997	Not Analysed	1718	812
Hamanatua Stream	1998	Not Analysed	1167	641
Hamanatua Stream	1999	Not Analysed	1159	452
Hamanatua Stream	2000	Not Analysed	3014	1862
Hamanatua Stream	2001	Not Analysed	4193	3121
Hamanatua Stream	2002	Not Analysed	3193	2639
Hamanatua Stream	2003	Not Analysed	2333	1370

Table 2 Water quality results for groundwater bores.

	Date	Nitrate-N ($g\ m^{-3}$)	*E. coli* MPN Per 100 mL	Total coliforms Per 100 mL	Faecal coliforms Per 100 mL	Static water level (m)
Makorori	10-5-01	Not Analysed	Not Analysed	Not Analysed	Not Analysed	1.40
Makorori	31-5-01	Not Analysed	Not Analysed	Not Analysed	660	1.07
Makorori	18-7-02	Not Analysed	Not Analysed	Not Analysed	6	Not Recorded
Makorori	10-6-04	Not Analysed	660	Not Analysed	Not Analysed	1.07
Makorori	14-6-04	3.21	1	6	Not Analysed	1.19
Makorori	21-6-04	Not Analysed	14	1,100	Not Analysed	0.94
Makorori	12-7-04	5.59	2	110	Not Analysed	0.82
Makorori	6-4-05	2.60	4	4,000	Not Analysed	1.62
Makorori	12-5-05	4.58	73	1,400	Not Analysed	1.27
Makorori	25-5-06	4.59	77	24,000	Not Analysed	Not Recorded
Makorori	26-10-06	1.61	23	Not Analysed	Not Analysed	1.34
Makorori	30-4-07	0.31	>2,400	Not Analysed	Not Analysed	1.73
Wairere Rd	17-5-95	Not Analysed	Not Analysed	200	7	Not Recorded
Wairere Rd	14-6-95	Not Analysed	Not Analysed	57	1	1.575
Wairere Rd	24-7-95	Not Analysed	Not Analysed	3	1	1.558
Wairere Rd	2-11-95	Not Analysed	Not Analysed	2	2	1.740
Wairere Rd	22-4-96	0.49	Not Analysed	7,500	1900	1.408
Wairere Rd	6-4-05	7.22	8	120	Not Analysed	1.665
Wairere Rd	12-5-05	3.49	650	4,800	Not Analysed	1.455
Wairere Rd	26-10-06	0.04	6	Not Analysed	Not Analysed	1.080
Wairere Rd	11-1-07	0.54	1	Not Analysed	Not Analysed	1.380
Wairere Rd	30-4-07	4.21	20	Not Analysed	Not Analysed	1.580
Williamson St	22-4-96	0.002	Not Analysed	200	8	2.990
Williamson St	6-4-05	0.003	2	500	Not Analysed	3.190
Williamson St	12-5-05	0.002	2	2	Not Analysed	3.315

Methods

In addition to normal sampling and analysis for *E. coli*, an additional 500 mL sample was collected from 11 sites along the Hamanatua Stream (see Appendix 1), and from three groundwater bores (Makarori Rd, Wairere Rd and Williamson St) on 31 October 2007. Based on preliminary results, additional samples were taken from Hamanatua Stream sites #1, #2, #9 and from Makarori St and Williamson St groundwater bores on 24th January 2008, with an additional 2 L sample for sterol analysis. Water samples were sent on ice to ESR for analysis using PCR markers, FWAs, and, where appropriate, sterol analysis.

Molecular Indicators

There are microorganisms other than faecal coliforms, *E. coli* and enterococci present in the faeces that are specific to particular animal hosts. Difficulties in culturing and identifying these organisms have limited their useful application to faecal source identification. An alternative approach is to extract total DNA from a water sample and examine the sample using the polymerase chain reaction (PCR) for DNA from source-specific organisms. Three assays that are currently under development were applied to the samples in this study. The first targets *Bacteroidetes* bacteria which are indicative of faecal pollution. The second targets human-specific *Bacteroidetes* DNA, and the third herbivore-specific *Bacteroidetes* DNA.

The **general faecal PCR marker** indicates total faecal pollution. Human and herbivore markers target a subset of the *Bacteroidetes* specific for human and herbivore sources.

Fluorescent Whitening Agents (FWAs)

FWAs are common constituents of washing powders that adsorb to fabric and brighten clothing. There is a range of FWAs, but only one (4,4'-bis[(4-anilino-6-morpholino-1,3,5-triazin-2-yl)-amino]stilbene-2,2'-disulfonate) is used in New Zealand. Most household plumbing mixes effluent from toilets with "grey water" from washing machines. Consequently, FWAs are usually associated with human faecal contamination in both septic tanks and community wastewater systems. Therefore, the presence of FWAs indicates human effluent.

Fluorescent compounds absorb light at a lower wavelength (higher energy) and re-emit light at a higher wavelength (lower energy). Each fluorescent compound has a signature fluorescent spectrum, which depends on its excitation and emission wavelengths. FWAs absorb light at 350 nm (the excitation wavelength) and re-emit the light as fluorescence at a higher wavelength (emission wavelength) in the range 430 nm (Poiger et al., 1993).

Synchronous scanning spectrofluorophotometer

A synchronous scanning spectrofluorophotometer (SSS) scans through a defined wavelength range for both the excitation and emission wavelengths of a fluorescent compound. This analysis produces a plot of fluorescence intensity versus emission wavelength and is very useful for identifying a mixture of fluorescent molecules in an unknown sample. Fluorescence sensitivity is up to 1000-times better than absorbance methods and allows analysis to nanogram and picogram levels. SSS is rapid and inexpensive, and provides preliminary and discriminatory information on the types of contaminants present in a sample, e.g. the presence of FWAs, fuels, polyaromatic hydrocarbons and pesticides in an aquatic environment.

Samples positive for FWAs by SSS are further analysed by the quantitative method of High Pressure Liquid Chromatography (HPLC). FWAs are extracted from 50 mL samples and analysed by HPLC as previously described (Gregor et al., 2002). Results are expressed in parts per billion (ppb) equivalent to µg/litre.

Faecal Sterols

Faecal sterols are a group of C27-, C28- and C29- cholestane-based sterols found mainly in animal faeces. The sterol profile of faeces depends on the interaction of three factors. Firstly, the animal's diet determines the relative quantities of sterol precursors (cholesterol, 24-ethylcholesterol, 24-methylcholesterol and/or stigmasterol) entering the digestive system. Secondly, animals differ in their endogenous biosynthesis of sterols (for example, human beings on a low cholesterol diet synthesise cholesterol). Thirdly, and perhaps most importantly, is that the anaerobic bacteria in the animal gut biohydrogenate sterols to stanols of various isomeric configurations.

The sterol, cholesterol, can be hydrogenated to one or more of four possible stanols. In human beings, cholesterol is preferentially reduced to coprostanol, whereas in the environment cholesterol is predominately reduced to cholestanol. Similarly, plant-derived 24-ethylcholesterol is reduced to 24-ethylcoprostanol and 24-ethylepicoprostanol in the gut of herbivores, whereas in the environment it is primarily reduced to 24-ethylcholestanol. As a consequence, analysis of the sterol composition of animal faeces can generate a sterol fingerprint, which can be quite distinctive from one species to another.

Faecal sterols analysis was performed by filtering 2–4 L of river water onto glass fibre filters. Filters were stored frozen until they were analysed using the extraction procedure described by Gregor et al. (2002). Each sterol and stanol result is expressed as parts per trillion (ppt). The key sterol values reported were the level of coprostanol, and two key ratios.

Coprostanol is the principal human biomarker. High relative amounts indicate fresh human faecal material. Coprostanol constitutes 60% of the total sterols found in human faeces, while dogs and birds have either no coprostanol or only trace amounts, in their faeces.

Coprostanol:24-ethylcoprostanol: These stanols are present in both human and herbivore faeces, but in significantly different amounts. Therefore, the relative contributions of each stanol can be determined by examining the ratio of one stanol to the other. Human faecal pollution typically has a ratio greater than one.

Coprostanol:cholestanol: The ratio of coprostanol:cholestanol can indicate whether the coprostanol present is of faecal origin. A ratio greater than 0.5, suggests faecal contamination (preferential reduction from sterol by gut microbiota), whereas a ratio less than 0.3 may suggest environmental reduction by, for example, anaerobic bacteria in sediments.

Results and Discussion

Results from the October 2007 sampling are presented in Table 3 and Table 4. Results from the January 2008 sampling are in Table 5, Table 6 and Table 7.

October 2007 Sampling

Fluorescent whitening agent analysis by synchronous scanning spectrofluorophotometer (SSS) was performed on the October 2007 set of samples for each of the 11 Hamanatua Stream sites and the three bores (Makorori Rd, Wairere Rd and Williamson St). The SSS-FWA results indicated that four of the sites had low levels of FWA; Site #9 of the stream and each of the bores (Table 3). These sites warranted a more detailed FWA analysis using FWA-HPLC methodology (see FWA, page 16). The levels of FWA at these four sites were below the limit of quantification by HPLC (Table 3). Hence, the conclusion using FWA analysis for the October 2007 sampling, which was just after heavy rainfall, was that there was no detectable presence of FWAs in the waters sampled.

Table 3 October 2007 FST analysis using FWA analysis for the Hamanatua Stream and groundwater bore water samples.

			FWA-SSS-Method			**FWA-HPLC-Method**
Site	**Sample Details**	**Date sampled**	**D120m**	**D190m**	**D120h**	
Hamanatua Stream #1	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	- [1]
Hamanatua Stream #2	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Hamanatua Stream #3	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Hamanatua Stream #4	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Hamanatua Stream #5	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Hamanatua Stream #6	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Hamanatua Stream #7	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Hamanatua Stream #8	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Hamanatua Stream #9	Stream water	31-10-07	Not Detected	Not Detected	**Present**	Not Detected
Hamanatua Stream #10	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Hamanatua Stream #11	Stream water	31-10-07	Not Detected	Not Detected	Not Detected	-
Makarori Rd	Bore water	31-10-07	Not Detected	Not Detected	**Possible**	Not Detected
63 Wairere Rd	Bore water	31-10-07	Not Detected	Not Detected	**Possible**	-
Williamson St	Bore water	31-10-07	Not Detected	Not Detected	**Present**	Not Detected

[1] " – " not analysed

The elevated level of *E. coli* in the Hamanatua Stream during October 2007 was consistent with the ongoing evidence of faecal contamination (Table 4). These results indicate that for the length of the stream behind the residential development, the water exceeded the limit of 150 CFU/100 mL of the Recreational Guidelines for Contact Recreation (Ministry for the Environment, 2002), and the general trend of increasing faecal contamination is consistent with non-point sources for contamination. A number of PCR-markers were present in water samples collected from the Hamanatua Stream in October 2007, with all the stream samples positive for markers that were more consistent with herbivore faecal contamination, i.e. consistent with non-human markers; (Table 4). The Hamanatua lagoon was very weakly positive for a human-specific PCR-marker however, low confidence was placed in this result because only one of the two replicates returned a positive result.

None of the groundwater samples were positive for human or non-human PCR markers. Hence, the conclusion is that there was no detectable presence of human-specific faecal contamination in the waters sampled when the FST tool of PCR-markers for the October 2007 sampling was used. However, significant presence of non-human faecal contamination, possibly from herbivores, in the Hamanatua Stream waters is of concern for the environmental and public health quality of the water.

Table 4 October 2007 FST analysis using the PCR-marker tool for Hamanatua Stream and groundwater bore water samples.

Site	Sample Type	Date Sampled	*E.coli* MPN per 100 mL	Human *Bacteroidetes* SybrGreen	Human *B. adolescentis*	Ruminant - Animal
Hamanatua Stream #1	Stream water	31-10-07	>2,400 [a]	Not Detected	**Possible** [c]	**Positive**
Hamanatua Stream #2	Stream water	31-10-07	>2,400	Not Detected	Not Detected	**Positive**
Hamanatua Stream #3	Stream water	31-10-07	1,200	Not Detected	Not Detected	**Positive**
Hamanatua Stream #4	Stream water	31-10-07	1,700	Not Detected	Not Detected	**Positive**
Hamanatua Stream #5	Stream water	31-10-07	1,100	Not Detected	Not Detected	**Positive**
Hamanatua Stream #6	Stream water	31-10-07	870	Not Detected	Not Detected	**Positive**
Hamanatua Stream #7	Stream water	31-10-07	980	Not Detected	Not Detected	**Positive**
Hamanatua Stream #8	Stream water	31-10-07	920	Not Detected	Not Detected	**Positive**
Hamanatua Stream #9	Stream water	31-10-07	820	Not Detected	Not Detected	**Positive**
Hamanatua Stream #10	Stream water	31-10-07	460	Not Detected	Not Detected	**Positive**
Hamanatua Stream #11	Stream water	31-10-07	340	Not Detected	Not Detected	**Positive**
Makarori Rd Site #4	Bore water	31-10-07	24 [b]	Not Detected	Not Detected	Not Detected
63 Wairere Rd	Bore water	31-10-07	1,400	Not Detected	Not Detected	Not Detected
Williamson St	Bore water	31-10-07	1	Not Detected	Not Detected	Not Detected

[a] Limit of *E. coli* for contact recreation is <150 faecal coliforms per 100 mL
[b] Limit of *E. coli* for drinking water is <1 faecal coliforms per 100 mL
[c] Possible = The human ***B. adolescentis*** present very low and found only in one of the two replicates, so presence is unclear.

January 2008 Sampling

Additional sampling was undertaken on 24 January 2008, during the height of the summer season when most of the residential properties were occupied. There had been no rainfall in the days preceding the January sampling to facilitate direct transfer of human-based contamination to the waters. Like the previous sampling, no FWAs were detected in these waters.

Additional follow-up of the suspect sites could be carried out if unacceptable levels of apparent faecal contamination continue. Possible human sources in the area could be tested directly for FWA content, and if they do contain FWAs, it would suggest these direct components are not a source of the on-going faecal contamination. However, if they do not contain FWAs, then it simply means the FWA test is not helpful in source discrimination in this area.

In addition, the January 2008 samples were analysed for faecal sterols (see page 17). The samples contained low levels of the primary sterols (coprostanol, 24-ethylcoprostanol), and the ratios of the different sterols were not consistent with a human faecal source, nor were they consistent with profiles typical of ruminant animal sources either (Table 6). The low levels of sterols present in the water samples are likely to make any ratio analysis unreliable. One way to address this may be to take a larger volume of water, but 2 L of water had been used for this analysis, which is significantly more than usually used for human-contaminated water.

For comparison, a control sample (50 mL) comprising 5% primary human effluent in river water is included with the sterol results. Even when low sterol signatures are returned from this control human sample, the ratio calculation clearly shows a profile consistent with human faecal contamination (Table 6).

Table 5 January 2008 FWA-SSS and FWA-HPLC results from Hamanatua Stream and groundwater bores.

Site	Date sampled	FWA-SSS-Method			FWA-HPLC-Method
		D120m	D190m	D120h	
Hamanatua Stream #1	24-01-08	Not Detected	Not Detected	Not Detected	Not Detected
Hamanatua Stream #2	24-01-08	Not Detected	Not Detected	Not Detected	Not Detected
Hamanatua Stream #9	24-01-08	Not Detected	Not Detected	Not Detected	Not Detected
Makarori Rd	24-01-08	Not Detected	Not Detected	Not Detected	Not Detected
Williamson St	24-01-08	Not Detected	Not Detected	Not Detected	Not Detected

Table 6 January 2008 sterol results from Hamanatua Stream and groundwater bore.

Sterol (Results in PPT)	**HS-1**	**HS-2**	**HS-9**	**Makorori Site**	**Williamson St**	**Control**	**Reliable limit of detection**
Coprostanol	*8* [a]	*19*	*12*	*5*	*10*	97	30
24-ethylcoprostanol	14	58	41	*4*	15	47	7
Epicoprostanol	*5*	*7*	*5*	*0*	*16*	*16*	31
Cholesterol	310	465	558	1002	1341	434	34
Cholestanol	45	107	45	113	81	*28*	33
24-methylcholesterol	95	127	69	234	211	*38*	41
24-ethylepicoprostanol	*13*	*30*	*21*	*1*	*6*	*4*	49
Stigmasterol	365	482	128	555	4176	285	36
24-ethylcholesterol	542	1006	454	987	1365	348	31
24-ethylcholestanol	*24*	64	42	54	111	*10*	41
Total Sterols	**1422**	**2366**	**1376**	**2955**	**7331**	**1306**	
Ratios							
Coprostanol-to-cholestanol [1]	0.18	0.17	0.26	0.04	0.12	**3.45**	
24-ethylcoprostanol-to-24-ethylcholestanol [2]	**0.59** [b]	**0.90**	**0.98**	0.07	0.13	**4.84**	
%Coprostanol-to-total sterols [3]	0.6%	0.8%	0.9%	- [7]	-	**7.4%**	
5β-to-(5β+5α stanols) [4]	0.16	0.15	0.20	-	-	**0.78**	
Coprostanol-to-24-ethylcoprostanol [5]	0.60	0.32	0.28	-	-	**2.05**	
Coprostanol-to-epicoprostanol [6]	**-**	**-**	**-**	**-**	**-**	**6.12**	
Estimate of percentage of sterols from human source	**-**	**-**	**-**	**-**	**-**	**84%**	

[1] Coprostanol-to-cholestanol Interpretation: ratio >0.5 indicates human or animal faecal contamination.
[2] 24-ethylcoprostanol-to-24-ethylcholestanol Interpretation: ratio >0.5 indicates human or animal faecal contamination.
[3] %Coprostanol-to-total sterols Interpretation: > 5.6% suggests human faecal contamination.
[4] 5β-to-(5β+5α stanols) Interpretation: ratio > 0.7 suggests human faecal contamination.
[5] Coprostanol-to-24-ethylcoprostanol Interpretation: ratio > 1.0 suggests human faecal contamination.
[6] Coprostanol-to-epicoprostanol interpretation: ratio > 2.0 suggests fresh/untreated sewage.
[7] " – " represents no further analysis based on previous results not indicating human faecal contamination.
[a] Numbers highlighted in grey are below reliable limit of detection.
[b] Numbers highlighted in green indicate samples that suggest a human component and thus warrant further data analysis.

Table 7 January 2008 results for PCR-markers from Hamanatua Stream and groundwater bores.

Site	Date Sampled	*E.coli* MPN per 100 mL	Human Bacteroidetes SybrGreen	Human *B. adolescentis*	Ruminant - Animal	Wildfowl	Dog
Hamanatua Stream #1	24-01-08	Not determined [a]	**Positive**	Not Detected	Not Detected	Not Detected	Not Detected
Hamanatua Stream #2	24-01-08	Not determined	Not Detected	Not Detected	Not Detected	**Positive**	Not Detected
Hamanatua Stream #9	24-01-08	Not determined	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
Makarori Rd	24-01-08	Not determined	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
Williamson St	24-01-08	Not determined	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected

[a] Not Determined because the sampled failed to arrive at the laboratory within 24 hours of sampling.

Even though the Hamanatua Stream does not appear to be contaminated by human faecal sources, the presence of significant faecal contamination, presumably contributed to by livestock, is a cause for concern due to the increased risk of zoonotic diseases (Cotruvo et al., 2004). Zoonotic diseases are caused by microorganisms of animal origin that also infect humans. Water is one of the primary transmission routes and greatly facilitates the dissemination of zoonotic microorganisms through the environment. The decreased environmental quality and the increased risk to human health due to water contaminated with animal faecal material is important as it may be that up to 75% of emerging human pathogens are zoonoses, with organisms like *E. coli* O157:H7, *Campylobacter*, and *Cryptosporidium* being zoonotic (Cotruvo et al., 2004). This risk exists whether that water is used for recreation or drinking, and the need to protect the health of people and the environment needs to include consideration of water contaminated by faeces, independent of the source of the faeces (Till and McBride, 2004).

Management of surface- and ground-waters from surface run-off of animal faeces, effluent and urban storm water can be facilitated by reducing stock access to surface waters and increasing riparian planting to intercept excess nutrients and microorganisms entering the water. For example, The Taranaki Regional Council is working with farmers and Fonterra to fence and plant the 17,500 km of stream boundaries to protect the waterways from the impacts of animals. The planting is being done with minimal financial burden on the landowners. There was considerable evidence along the banks of the Hamanatua Stream that stock were entering the water (

Figure 13). Thus, simple steps to provide alternative water sources for these animals and prevent them from entering the Hamanatua Stream, as well as increasing the vegetation along the stream banks are likely to contribute to the improvement in quality of the stream water.

Figure 13 Evidence of stock and storm water entering the Hamanatua Stream. Top (site #2): small beach where stock tracks on beach (left) and the slide marks from hooves (right) indicate easy access to water. Middle (sidearm-2 near site #9): one of the sidearm streams that run across the paddock and enter the Hamanatua Stream (left) showing the animal tracks in the mud (right). Bottom: combination of easy stock access to water and urban storm water drainage (site #9) to the stream (left), and slide marks of animals eroding stream bank while accessing water (right near site #10). For site locations see Appendix 1 (page 36).

Analysis of Historical Data (Supplied by GDC)

The aim of the following section of the report was to use the historical data to determine whether a reason for the high bacterial loadings of the Hamanatua Stream could be explained. The analysis is based on GDC data, however the data have been manipulated to attempt to make inferences possible when discontinuities in the data set exist. Balanced data sets that met the assumption of statistical normality allow parametric statically analysis and therefore mean that no subjective assumptions are required for analysis. A critical level for comparison of significant means was when $P<0.05$.

Data manipulation: Balanced data sets (four seasons each with 3 reps), where only the years that met these characteristics were used to test the trend of faecal coliform changes with time. Seasons were defined as: Summer = December, January, February; Autumn = March, April, May; Winter = June, July, August; Spring = September, October, November. Where a balanced data set was not quite possible (missing a datum at the boundary of seasonal change), then if the month before/after had a datum within seven days of the seasonal change, then that datum was assigned to the next/previous season, as appropriate. If a month had more than one datum, then the data for that month were averaged and the average for the month was used, unless there were insufficient data for the season, then all the data for that season were used. For example, if December data were missing, but Nov 28th had a datum, then the November datum was assigned as "Dec" and classified as "Summer". If January had three data, then the average of these was assigned to "Jan", assuming February or December were also present.

Information Box – From *Recreational Water Quality Guidelines* (NZ Ministry for the Environment 1999); **Table 5.2.2** Summary of water quality guidelines for recreational waters (Primary contact = swimming).

Parameter Guideline
Microbiological
Primary contact The median bacterial content in **fresh** and marine waters taken over the **bathing season** should not exceed **150 faecal coliform organisms/100 mL** or 35 enterococci organisms/100 mL.

5.2.3.1 Microbiological characteristics
Primary contact
The median bacterial content in samples of fresh or marine waters taken over the bathing season should not exceed:
150 faecal coliform organisms/100 mL (minimum of five samples taken at regular intervals not exceeding one month, with **four out of five samples containing less than 600 organisms/100 mL)**;

Figure 14 and the Information Box show that several events, particularly five during the normal bathing period 2000–2002, consistently exceeded the Recreational Water Quality Guidelines (NZ Ministry for the Environment 1999). However, the questions that need to be asked are:

- Whether overall the water quality is decreasing in the Hamanatua Stream lagoon?
- Is there a seasonal tendency to water quality status?

Table 8 Historical data for Hamanatua Lagoon used for further analysis. Data manipulation as in text above.

Yr_Summer	Yr_yr	Yr_Rep	Season	Sea_Rep	Month	Faec_Coli	Month
1	1981_82	1	Summer	1	Dec	0	Dec
1	1981_82	2	Summer	2	Jan	0	Jan
1	1981_82	3	Summer	3	Feb	1067	Feb
1	1981_82	4	Autumn	1	Mar	100	Mar
1	1981_82	5	Autumn	2	Apr	0	Apr
1	1981_82	6	Autumn	3	May	400	May
1	1981_82	7	Winter	1	Jun	450	Jun
1	1981_82	8	Winter	2	Jul	50	Jul
1	1981_82	9	Winter	3	Aug	150	Aug
1	1981_82	10	Spring	1	Sep	1500	Sep
1	1981_82	11	Spring	2	Oct	7100	Oct
1	1981_82	12	Spring	3	Nov	0	Nov
2	1982_83	1	Summer	1	Dec	0	Dec
2	1982_83	2	Summer	2	Jan	100	Jan
2	1982_83	3	Summer	3	Feb	33	Feb
2	1982_83	4	Autumn	1	Mar	0	Mar
2	1982_83	5	Autumn	2	Apr	0	Apr
2	1982_83	6	Autumn	3	May	0	May
2	1982_83	7	Winter	1	Jun	2700	Jun
2	1982_83	8	Winter	2	Jul	200	Jul
2	1982_83	9	Winter	3	Aug	120	Aug
2	1982_83	10	Spring	1	Sep	0	Sep
2	1982_83	11	Spring	2	Oct	1130	Oct
2	1982_83	12	Spring	3	Nov	140	Nov
3	1994_95	1	Summer	1	Dec	1020	Dec
3	1994_95	2	Summer	2	Jan	30	Jan
3	1994_95	3	Summer	3	Feb	500	Feb
3	1994_95	4	Autumn	1	Mar	1100	Mar
3	1994_95	5	Autumn	2	Apr	900	Apr
3	1994_95	6	Autumn	3	May	3400	May
3	1994_95	7	Winter	1	Jun	430	Jun

Table 8 cont'd

Yr_Summer	Yr_yr	Yr_Rep	Season	Sea_Rep	Month	Faec_Coli	Month
3	1994_95	8	Winter	2	Jul	460	Jul
3	1994_95	9	Winter	3	Aug	160	Aug
3	1994_95	10	Spring	1	Sep	400	Sep
3	1994_95	11	Spring	2	Oct	130	Oct
3	1994_95	12	Spring	3	Nov	435	Nov
4	1995_96	1	Summer	1	Dec	1700	Dec
4	1995_96	2	Summer	2	Jan	290	Jan
4	1995_96	3	Summer	3	Feb	890	Feb
4	1995_96	4	Autumn	1	Mar	660	Mar
4	1995_96	5	Autumn	2	Apr	960	Apr
4	1995_96	6	Autumn	3	May	1800	May
4	1995_96	7	Winter	1	Jun	1020	Jun
4	1995_96	8	Winter	2	Jul	420	Jul
4	1995_96	9	Winter	3	Aug	80	Aug
4	1995_96	10	Spring	1	Sep	110	Sep
4	1995_96	11	Spring	2	Oct	620	Oct
4	1995_96	12	Spring	3	Nov	20	Nov
5	1997_98	1	Summer	1	Dec	30	Dec
5	1997_98	2	Summer	2	Jan	500	Jan
5	1997_98	3	Summer	3	Feb	3200	Feb
5	1997_98	4	Autumn	1	Mar	270	Mar
5	1997_98	5	Autumn	2	Apr	140	Apr
5	1997_98	6	Autumn	3	May	1300	May
5	1997_98	7	Winter	1	Jun	170	Jun
5	1997_98	8	Winter	2	Jul	800	Jul
5	1997_98	9	Winter	3	Aug	110	Aug
5	1997_98	10	Spring	1	Sep	180	Sep
5	1997_98	11	Spring	2	Oct	500	Oct
5	1997_98	12	Spring	3	Nov	220	Nov
6	1999_00	1	Summer	1	Dec	700	Dec
6	1999_00	2	Summer	2	Jan	1967	Jan
6	1999_00	3	Summer	3	Feb	900	Feb
6	1999_00	4	Autumn	1	Mar	1300	Mar
6	1999_00	5	Autumn	2	Apr	1700	Apr
6	1999_00	6	Autumn	3	May	80	May
6	1999_00	7	Winter	1	Jun	900	Jun
6	1999_00	8	Winter	2	Jul	500	Jul
6	1999_00	9	Winter	3	Aug	80	Aug
6	1999_00	10	Spring	1	Sep	14000	Sep
6	1999_00	11	Spring	2	Oct	70	Oct
6	1999_00	12	Spring	3	Nov	500	Nov

Table 8 cont'd

Yr_Summer	Yr_yr	Yr_Rep	Season	Sea_Rep	Month	Faec_Coli	Month
7	2000_01	1	Summer	1	Dec	1100	Dec
7	2000_01	2	Summer	2	Jan	80	Jan
7	2000_01	3	Summer	3	Feb	800	Feb
7	2000_01	4	Autumn	1	Mar	800	Mar
7	2000_01	5	Autumn	2	Apr	80	Apr
7	2000_01	6	Autumn	3	May	1600	May
7	2000_01	7	Winter	1	Jun	1300	Jun
7	2000_01	8	Winter	2	Jul	500	Jul
7	2000_01	9	Winter	3	Aug	1600	Aug
7	2000_01	10	Spring	1	Sep	130	Sep
7	2000_01	11	Spring	2	Oct	16000	Oct
7	2000_01	12	Spring	3	Nov	1600	Nov
8	2001_02	1	Summer	1	Dec	16000	Dec
8	2001_02	2	Summer	2	Jan	1700	Jan
8	2001_02	3	Summer	3	Feb	11850	Feb
8	2001_02	4	Autumn	1	Mar	5700	Mar
8	2001_02	5	Autumn	2	Apr	90	Apr
8	2001_02	6	Autumn	3	May	240	May
8	2001_02	7	Winter	1	Jun	800	Jun
8	2001_02	8	Winter	2	Jul	1100	Jul
8	2001_02	9	Winter	3	Aug	500	Aug
8	2001_02	10	Spring	1	Sep	210	Sep
8	2001_02	11	Spring	2	Oct	500	Oct
8	2001_02	12	Spring	3	Nov	1450	Nov

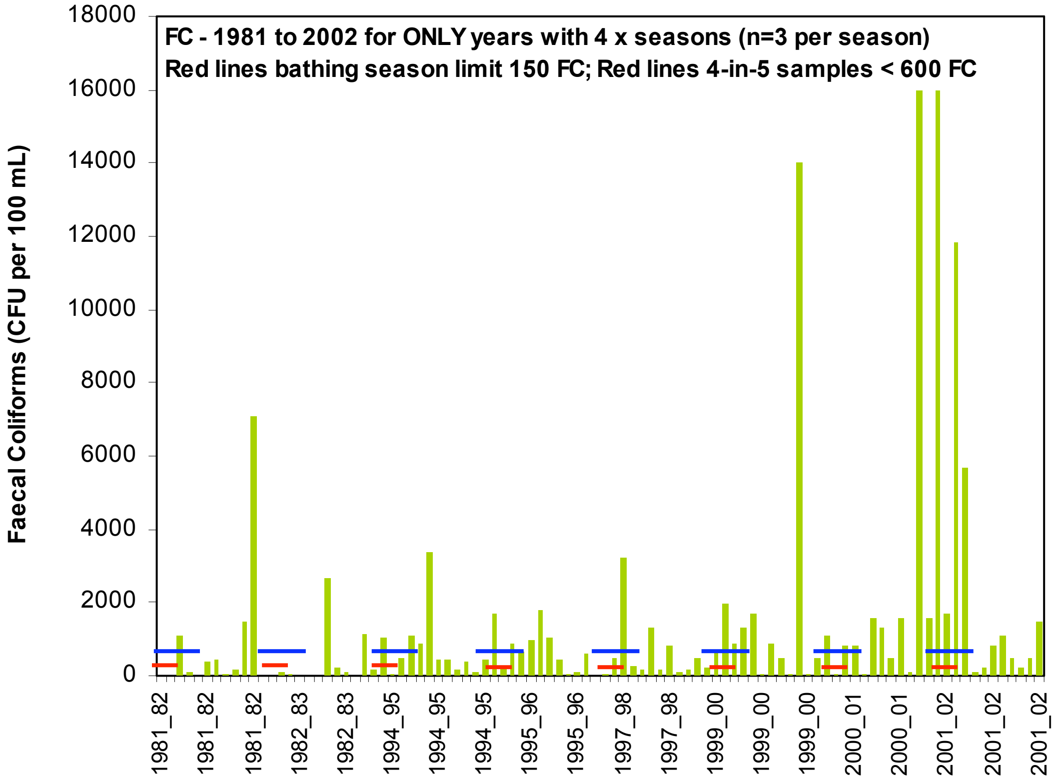

Figure 14 Shows the faecal coliform levels over yearly time-spans in the Hamanatua Stream lagoon from 1981–1982 summer to 2001–2002 summer-spring year. Only years for which there are no missing values were used, and all years had three replicates for each season. Thus, "zero" points are really zero faecal coliforms found in the water samples (not missing data). The limits indicated in RED indicate 150 faecal coliform per 100 mL, and the limits indicated in BLUE indicate 600 faecal coliforms per 100 mL, according to the *Recreational Water Quality Guidelines* (NZ Ministry for the Environment 1999); see Information Box (page 23) with the bathing season extended either side of Summer. Data for ANOVA n = 8 for year, n = 32 for seasons, n = 96 for months.

Table 9 Rainfall data for Gisborne for the period August 2001–December 2002, which corresponds to a period of elevated faecal coliform levels shown in Figure 14.

	Rainfall (mm)		
	Average	Max	Total
Aug-01	2.3	26.7	72.7
Sep-01	3.1	34.2	93.5
Oct-01	5.1	70.1	158.9
Nov-01	2.0	11.3	61.6
Dec-01	Missing	Missing	Missing
Jan-02	3.8	50.8	112.9
Feb-02	3.0	47.7	85.2
Mar-02	0.4	5.8	13.6
Apr-02	2.3	17.0	68.0
May-02	1.2	10.5	38.3
Jun-02	3.9	61.8	118.0
Jul-02	5.3	25.0	163.2
Aug-02	4.2	58.8	130.0
Sep-02	1.5	13.8	45.6
Oct-02	2.5	13.4	77.2
Nov-02	2.0	16.7	59.7
Dec-02	2.1	24.3	65.7

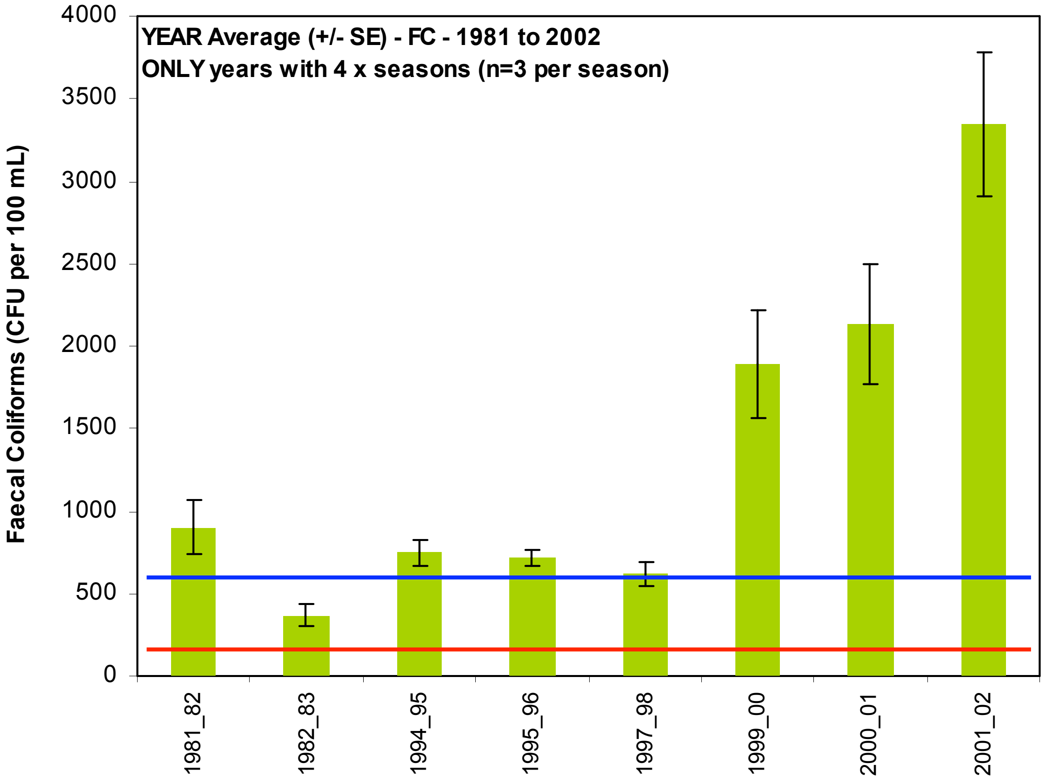

Figure 15 Average annual faecal coliform levels in the Hamanatua Stream lagoon for the years with complete data from 1981–1982 summer to 2001–2002 summer-spring year. The limits indicated in RED indicate 150 faecal coliform per 100 mL, and the limits indicated in BLUE indicate 600 faecal coliforms per 100 mL, according to the *Recreational Water Quality Guidelines* (NZ Ministry for the Environment 1999); see Information Box (page 23).

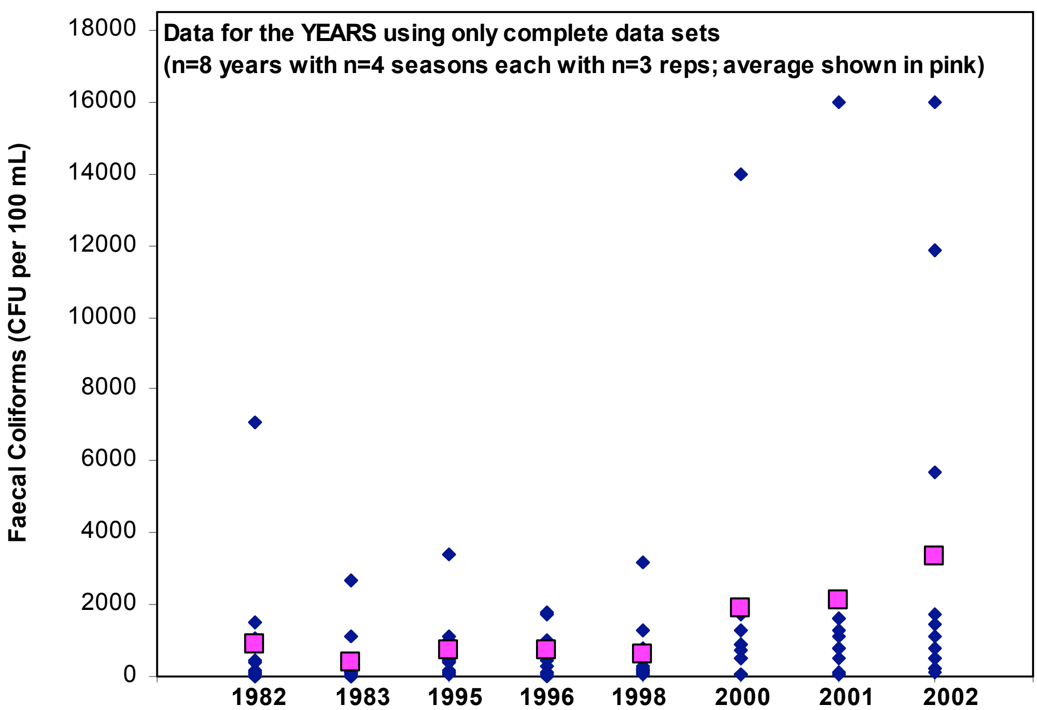

Figure 16 Individual points that underlie the annual average faecal coliform levels in the Hamanatua Stream lagoon for the complete summer-years (summer-autumn-winter-spring) from 1981–1982 summer to 2001–2002 summer-spring year.

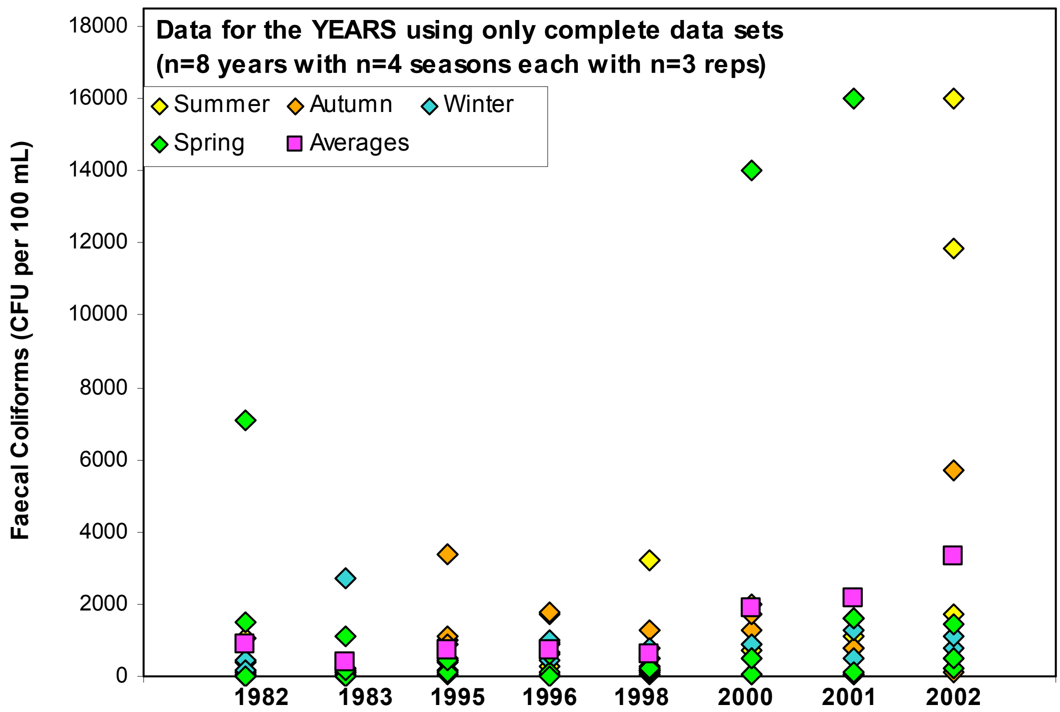

Figure 17 Individual points, coloured to distinguish seasonal variation that underlie the annual average faecal coliform levels in the Hamanatua Stream lagoon for the complete summer-years (summer-autumn-winter-spring) from 1981–1982 summer to 2001–2002 summer-spring year.

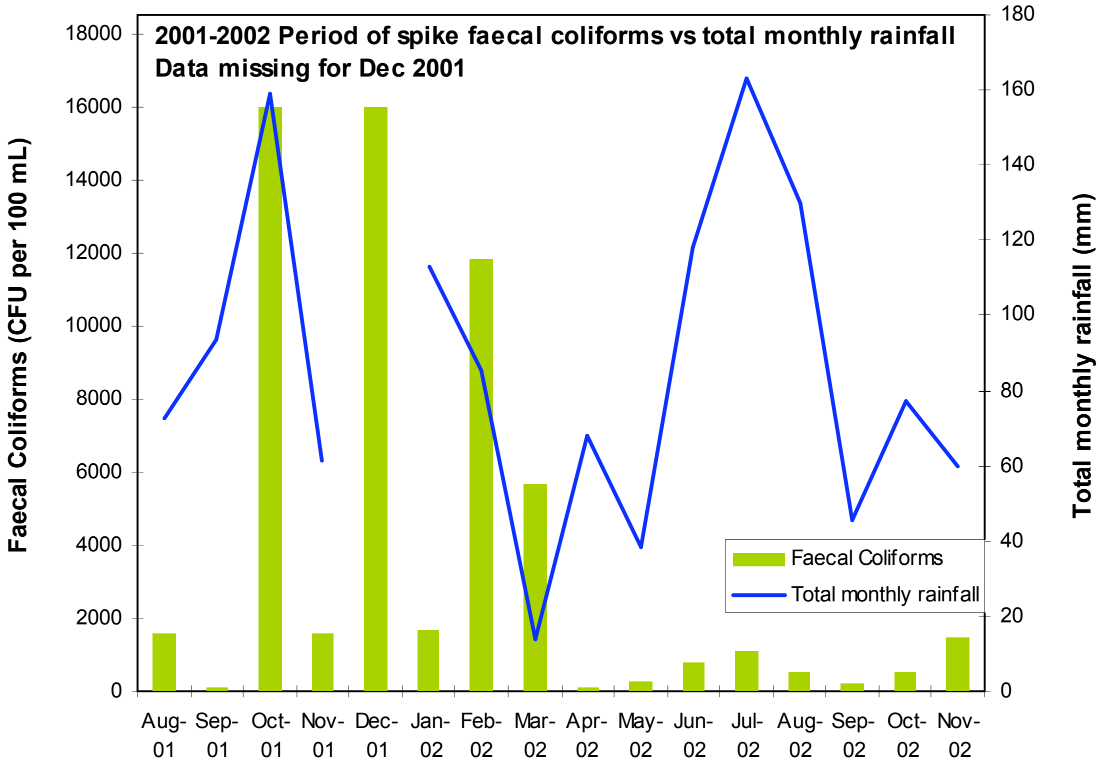

Figure 18 The faecal coliform spikes in the Hamanatua Stream water of October 2001 through to March 2002 with the total monthly rainfall. Initially, the peak faecal coliform levels appeared to coincide with a heavy rain event. However, rain events of a similar magnitude occurred in June and August of 2002 that were not matched by spikes in faecal coliform levels. Rainfall data for Ohui, Gisborne (station #2910) from NIWA Climate Information (http://cliflo.niwa.co.nz/pls/niwp/wgenf.genform1).

Figure 15 suggests a trend of decreasing water quality over recent years, however Figure 16 and Figure 17 indicate that the dramatic annual increases in faecal coliform levels in 2000, 2001 and 2002 are being driven primarily by a few extreme events of elevated faecal coliform levels. These spikes in the average annual levels of faecal coliforms are not necessarily consistent seasonally, occurring in spring for 2000 and 2001, but in summer for 2002.

An attempt to determine whether these spikes in average annual faecal coliforms were associated with months of high cumulative rainfall was inconclusive (Figure 18). There were two primary reasons for this. Firstly, the data for December 2001 were not in the NIWA database, and secondly, the high rainfall during June to August 2002 was of a similar magnitude to that of October 2001, but did not have an associated spike in faecal coliforms for those months.

To test these interpretations from the graphical display, statistical analysis using ANOVA showed no significant difference across the whole data set for year or for season (see below for output from the ANOVA model). Therefore, the data were tested to determine whether there was a statistical difference between seasons (Figure 19). The data in (Table 11) indicate that there was no significant difference due to season even though there is a strong trend of spring and summer having greater average faecal coliform levels. The reason for the non-significance can be seen in Figure 20 where the individual points for each season show that most of the points for spring and summer are similar to those of autumn and winter, but a few extremely elevated points for spring and summer pull the averages up.

Table 10 ANOVA output from *Statistix 8.0* for faecal coliforms in Hamanatua Stream Lagoon testing for the difference between years.

Analysis of Variance Table for FAEC_COLI

Source	DF	SS	MS	F	P	
Year	7	8.823E+07	1.260E+07	1.45	**0.1965**	**Not significant**
YR_REP	11	8.529E+07	7753985	0.89	0.5496	
Error	77	6.675E+08	8668939			
Total	95	8.410E+08				

Grand Mean 1339.8 CV 219.76

LSD All-Pairwise Comparisons Test of FAEC_COLI for YR_YR

Year	Mean	Homogeneous Groups
2001	3345.0	A
2000	2132.5	AB
1999	1891.4	AB
1981	901.4	B
1994	747.1	B
1995	714.2	B
1997	618.3	B
1982	368.6	B

```
Alpha              0.05     Standard Error for Comparison  1202.0
Critical T Value  1.991     Critical Value for Comparison  2393.5
Error term used: YR_YR*YR_REP, 77 DF
There are 2 groups (A and B) in which the means
are not significantly different from one another.
```

Conclusion: Due to the wide variation in the data over a year (see Figure 16), there is no significant difference between years when all seasons are taken together (n = 3 for season; n = 8 for years). However, there is a strong trend from 1999 onwards that faecal coliform levels in the Hamanatua Stream lagoon increased, thus decreasing the quality of the water for recreational uses.

Table 11 ANOVA output from *Statistix 8.0* for faecal coliforms in Hamanatua Stream Lagoon testing for the difference between seasons

Analysis of Variance Table for FAEC_COLI

Source	DF	SS	MS	F	P
SEASON	3	3.205E+07	1.068E+07	1.20	0.3149 Not significant
SEA_REP	2	6824440	3412220	0.38	0.6830
Error	90	8.022E+08	8912829		
Total	95	8.410E+08			

Grand Mean 1339.8 CV 222.82

LSD All-Pairwise Comparisons Test of FAEC_COLI for SEASON

SEASON	Mean	Homogeneous Groups
Spring	1956.0	A
Summer	1852.4	A
Autumn	942.5	A
Winter	608.3	A

Alpha 0.05 Standard Error for Comparison 861.82
Critical T Value 1.987 Critical Value for Comparison 1712.2
Error term used: Error, 90 DF
There are no significant pairwise differences among the means.

Conclusion: No significant difference is seen between the seasons, however there is a strong trend of higher faecal coliform counts in the spring and summer than those in autumn and winter.

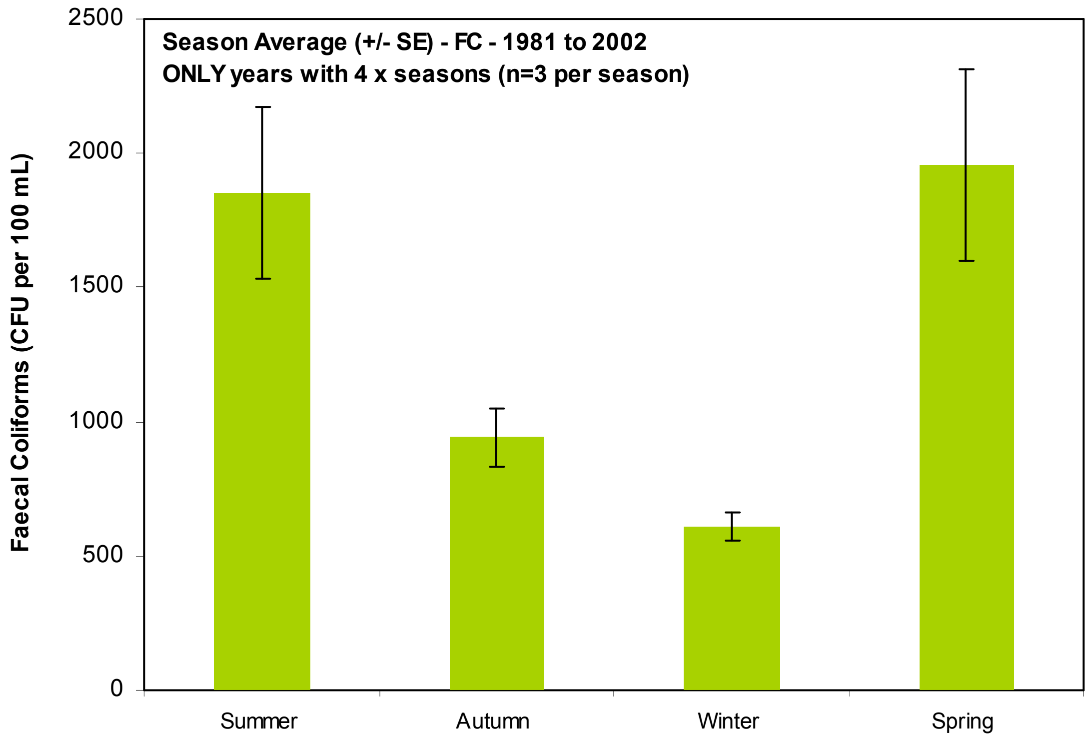

Figure 19 Average faecal coliform levels in the Hamanatua Stream water across the seasons (data pooled for 1981 to 2002. Although the standard error values suggest a difference, the ANOVA test found no seasonal influence due to the high degree of scatter in the data.

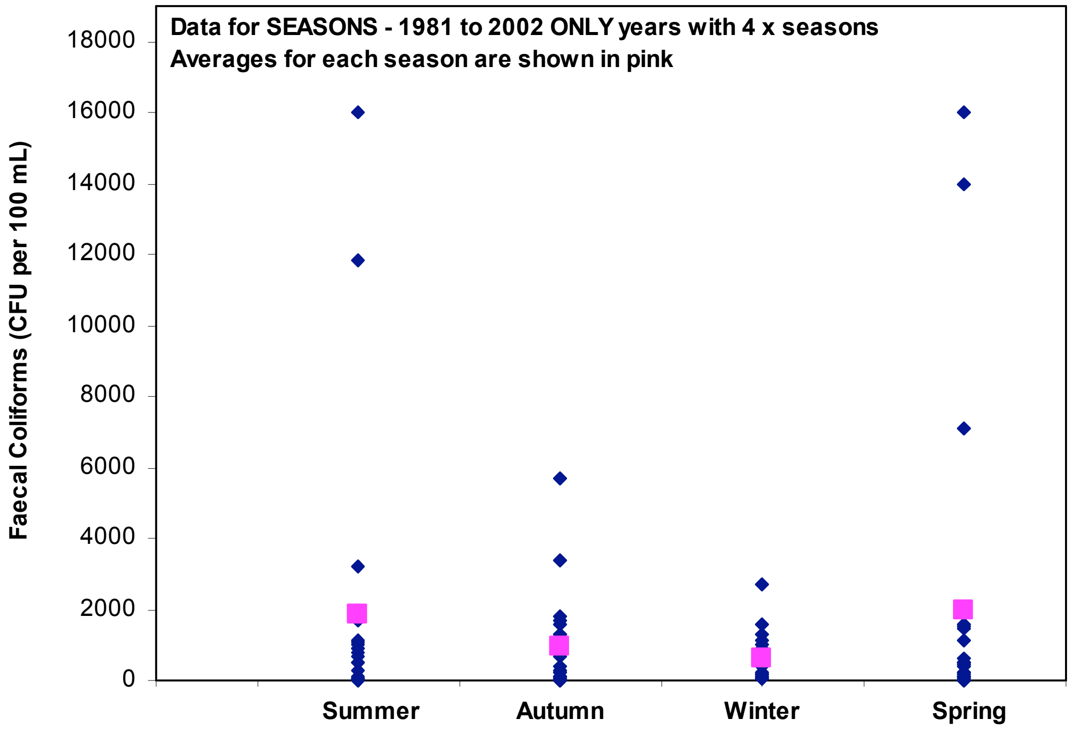

Figure 20 Individual data points of faecal coliform levels in the Hamanatua Stream water across the seasons, with the averages shown in pink. Again the higher average faecal coliforms seem to be driven mainly by the few extreme events rather than a seasonal effect directly.

The conclusion from this analysis of some of the historical data for Hamanatua Stream is that the elevation of the average faecal coliform/*E. coli* contamination is been driven by quite discrete events. Therefore, establishing the relationship of the microbial indicator spikes to activities in the catchment preceding the spike is necessary to aid in the management of the water quality.

Conclusions

The results of this small study of the Hamanatua Stream and three bores in the local area, all of which have an extended monitoring history of elevated faecal coliforms consistent with faecal contamination of the water, was inconclusive for the source of the source of the faecal coliforms and whether they were of human origin. However, the data suggested that most probable dominant faecal source was of animal origin. Herbivores are the most likely animal source, based on observations during the sampling, where obvious animal tracks on the stream bank and easy water access were evident. Therefore, two possible strategies to improve the quality of the Hamanatua Stream water quality is to fence the stream to prevent livestock accessing the water, which would also necessitate provision of alternative water sources for stock. In addition, riparian planting the stream would provide an additional barrier to the overland flow of faecal material. These management options are consistent with the current approach by several regional councils, including Taranaki District Council, which in conjunction with Fonterra plan to fence and plant all stream boundaries under their jurisdiction. While the source of the groundwater contamination is not clear, the shallow nature of the groundwater in this area would suggest that measures taken to protect surface water may also benefit the groundwater system.

The main objective of the project was to identify the source of the faecal contamination in the Hamanatua Stream and groundwater monitoring bores. It has not been possible to definitively discriminate the source of the faecal contamination, however the data were sufficiently indicative to suggest a management option. There are several follow-up steps that could be taken to increase the likelihood of identifying the sources of the faecal contamination, and these include carrying out more frequent and additional types of analyses on the regular monitoring samples collected, such as analysis for PCR markers and SSS for FWAs. Further analysis of the wastewater from homes suspected of contributing to the faecal source would aid in determining whether FWAs are a reasonable monitoring option for that wastewater source, as it is possible that these agents are either not used by these households, or that they are degrading before reaching the sampling point. Dye tests to follow the wastewater flow paths could help determine whether FWAs are likely to persist to the monitoring point, which should be a relatively inexpensive tool to establish likely contamination routes. In addition, intensive monitoring of surface and groundwaters in areas during and following septic system failure to determine a reasonable temporal monitoring scale.

This project has shown that it can be difficult to conclusively identify the source of faecal contamination in surface- and ground-waters, however indications of where to look for additional evidence of the source can help towards focusing future investigations. For example in the GDC case study, while the faecal profiles were not strong, they did suggest that animals were a more likely source of the dominant contamination (non-compliance with Recreational Water Quality Guidelines) than humans, and therefore, suggest that management of the stream boundaries is likely to significantly improve the water quality of the Hamanatua Stream. The analysis of a selection of the historical data for the Hamanatua Stream suggest that there may be specific activities in the Hamanatua catchment that significantly contribute to low quality of the water for recreational purposes. The extreme spikes in faecal coliforms was not necessarily explained by rainfall, indicating that further investigation of land use activities is required to understand the source of these spikes. While speculative, the spring spike could be animal associated with calving and lambing, while the summer spike may be associated with increased human activity of the coastal area.

This project has provided direction for a sustainable coastal development decision tree, based on environmental quality criteria (Figure 21). A first step is to identify whether there are non-compliant attributes of the target area that can be managed to prevent or mitigate the source of non-compliance. The reduction/management of the dominant contamination source allows other contamination contributors to be identified. Faecal contamination is an example of a potentially non-compliant activity that may influence whether an area can sustain additional development. Decision trees can help councils plan how to respond to suspected faecal contamination, with a new website to be launched late July 2008 (waterquality.org.nz).

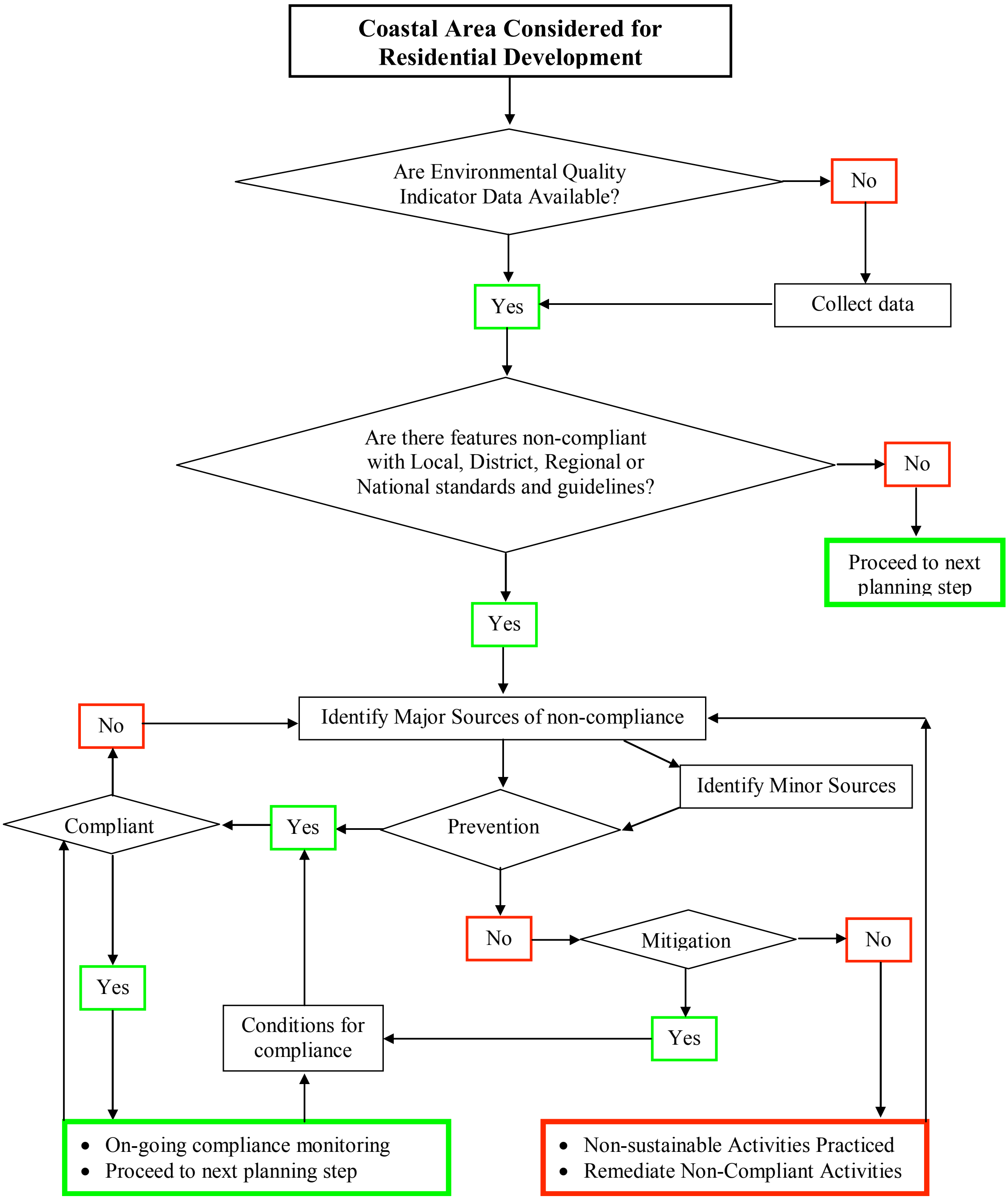

Figure 21 A preliminary decision tree to aid assessment about whether the development of a coastal area is likely to adversely impact on environmental quality, where environmental quality is based on compliance with environmental standards and guideline.

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Appendix 1: Sampling Plan for Hamanatua Stream

Sampling Plan (as provided to GDC)

The samples can be taken from either side, depending on what is easiest, I have referred to sites from the farm side, because that is what I did, but provided the reason for sampling at a site is maintained, then it is not important which side the sample is taken from. Samples are from lagoon moving upstream, and can be taken in either order IF and ONLY IF there is no disturbance of the sediment. I suggest taking the samples in the order given to avoid potential contamination from sediment disturbance. Aseptic sampling methodology needs to be used to isolate the sampler from potential contamination of the sample – ensure that any bugs in the sample are from the environment and not from the person taking of the sample.

Sample 1: At the usual location that the routine sample is taken. **Reason** – normal monitoring site.

Sample-2: Move up stream, beyond the shabby gates to a little beach, which is opposite the large horse paddock behind the houses over the stream. **Reason** – downstream of sidearm-1 and also, Sample-2 is the upstream of the regular so that we get an idea of what is feeding into the normal lagoon site.

This is a place where I am interested, to explain where all the water has come from for the site near the old bridge, as the water at Sample-site-2 looks quite clear and relatively low flow compared to the volume of water downstream. There could be groundwater resurfacing between here and the old bridge site. However, when the actual outflow from the lagoon over the beach is looked at, the flow over the sand at the beach is low, although I suspect most of the stream outflow will be below visual due to flowing through the sand.

If sampling from the farm side, you need to retrace steps now, as it is not possible to easily follow the stream past this point due to the step sides and the unstable banks.

Sample-3: This is probably more easily sampled from residential side unless you have a long grab-sampling pole. There is a fence over the stream with a sort of fence barrier in the stream. **Reason** – upstream of sidearm-1.

Sample-4: Fallen log has partially blocked the stream and made a pond upstream. The pond has a very low flow rate, as most of the water by-passes it and the water looks less clean than the flowing water (could just be because it is deeper). **Reason** - due to the low-flow dynamics of the pond, the pond may act as a reservoir for microbes and periodic flushing during rain events may contribute microbial pollution downstream.

Sample-5: Sidearm-2 actually feeds in to the stream over a reasonable area, rather than a discrete place, so several samples are required to capture this. **Reason** – "downstream" sidearm-2 sample. Slightly upstream of the sampling place is a backyard with a large tree that is fenced off from the rest of the backyard, and this tree is in a significant dip in the ground, so look for a site to collect the sample in the stretch of stream downstream from that particular backyard, but upstream of the little waterfall.

Sample-6: Another pond formed by a fallen tree, and is middle of sidearm-2. **Reason** – middle sidearm-2 and potential source of on-gong microbial contamination if this pond is not flushed out regularly.

Ponds like this may contribute to contamination a few days after rainfall IF the still water is promoting microbial persistence and even replication if the temperature is warm enough – ponds like this are classical features to look at during low flow-warm temperature.

Sample-7 and Sample 8:The black polythene pipe around the tree. **Sample-7** is upstream of black pipe, and is the downstream sample for Sample-9 "the storm water outlet". **Sample-8** is downstream of the pipe in the pond about 10-15 m from tree with pipe wrapped around. It is not clear whether this pipe is just looped around the tree trunk or if it is connected to some outflow from the house; the pond where the pipe appears to finish, is quite discoloured and may represent another source of microbial contamination. **Reason** – IF the pipe is a septic system overflow then this could be a direct contribution of human faecal waste, therefore test this general area.

Sample-9: Upstream sample from the new storm water outlet. A storm water outlet could be a major input to the stream of residential-associated contamination. **Reason** – upstream of potential contamination point.

Sample-10: **Reason** - upstream of sidearm-2 but still with residential influence.

Sample-11: **Reason** – upstream from residential influence.

Appendix 2: Sample Identification Numbers

Client Ref No	ESR Ref No	Sample Description	Date Received
81219	CMB07320	Hamamatua Stream Site1	31-10-07
81220	CMB07321	Hamamatua Stream Site2	31-10-07
81221	CMB07322	Hamamatua Stream Site3	31-10-07
81222	CMB07323	Hamamatua Stream Site4	31-10-07
81223	CMB07324	Hamamatua Stream Site5	31-10-07
81224	CMB07325	Hamamatua Stream Site6	31-10-07
81225	CMB07326	Hamamatua Stream Site7	31-10-07
81226	CMB07327	Hamamatua Stream Site8	31-10-07
81227	CMB07328	Hamamatua Stream Site9	31-10-07
81228	CMB07329	Hamamatua Stream Site10	31-10-07
81229	CMB07330	Hamamatua Stream Site11	31-10-07
81230	CMB07331	Bore Water Makarori Site4	31-10-07
81231	CMB07332	Bore Water 63 Wairere Rd	31-10-07
81232	CMB07333	Bore Water Williamson St	31-10-07

Client Ref No	ESR Ref No	Site Name	Date Received
WW0803	CMB08210	Hamanatua Stream site 1	24-2-08
WW0804	CMB08211	Hamanatua Stream site 2	24-2-08
WW0805	CMB08212	Hamanatua Stream site 9	24-2-08
WW0802	CMB08209	Makarori Rd	24-2-08
WW0801	CMB08208	Williamson St	24-2-08

Appendix 3: Proposed reticulation for Wainui-Okitu-Sponge Bay[2]

Figure 22 Proposed Reticulation areas of Sponge Bay, Wainui/Okitu and Makorori as outlined in them Statement of Proposal for consultation. This is a proposed amendment to the 2006-2016 Community Plan and part of the 2008-2009 Draft Annual Plan process.

[2] NOTE IN PRESS: This reticulation scheme is not proceeding based on community consultation.

“The areas depend primarily on rooftop rainwater collection for drinking water. The standard of primary water supply is regulated only in terms of the requirements of the Building Act for new installations. Individuals are responsible for maintenance and quality monitoring of their collection/distribution and storage systems. Additional water is sourced predominantly from the Gisborne City water supply and transported by private water carriers at the request of residents. Wastewater is currently managed in private on-site systems. Recent requirements for improved wastewater systems have resulted in the installation of a number of improved systems such as dual tank systems, site-specific effluent soakage systems, dose loaded soakage systems and home treatment plants with irrigation of effluent. However the majority of existing systems were installed prior to the implementation of the 2002 GDC Onsite Wastewater Guidelines 2002 and treatment and disposal is mainly via conventional septic tanks and in-ground disposal drains. Gisborne District Council has no septic system design information for about 40% of the properties, which are also likely to contain older systems. Management of on-site wastewater systems is the responsibility of owners/occupiers and Council’s involvement is limited to consideration of building consent and discharge consent applications for new or upgraded systems, answering queries and investigating complaints.” From Report to Council for GDC (29 November 2007) summarising (O'Leary et al., 2006). ***Note: July 2008, this reticulation scheme is NOT proceeding due to community comment.***