THE WEST COAST
REGIONAL COUNCIL

Final Report

Impact Investigation into Faecal Contamination of the Arahura Mussel Beds

A Surface Water Quality Investigation of Waterways from the Arahura to Hokitika Rivers

May 2002

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State of the Environment Technical Report # 02004

Impact Investigation into Faecal Contamination of the Arahura Mussel Beds - A Surface Water Quality Investigation of Waterways from the Arahura to Hokitika Rivers.

A technical report presenting results of an investigation conducted during 2001-02 into the likely effects of farm effluent discharges on faecal contamination of the Arahura mussel beds. The report provides information on the relative contaminant loading from a range of potential sources of faecal bacteria.

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Cover photos: Clockwise from top left: Arahura River looking upstream to SH6, Paddy's Creek N branch at One Mile Line Road looking upstream, Unnamed Creek at Arahura Valley Road looking upstream, coastline adjacent to the Arahura Mussel beds to the south of the Arahura River mouth, Stagnant Lagoon.

May 2002
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Executive Summary

This investigation aimed to determine the relative importance of the likely sources of faecal contamination of the Arahura Mussel Beds after Crown Public Health determined in June 2001 that the flesh of the mussels were contaminated with faecal bacteria at levels rendering them unsuitable for consumption. Several complaints and enquiries were fielded by West Coast Regional Council concerning this contamination and the safety of consuming the shellfish. This report provides information about the effects of dairy farm effluent discharges that will be useful for resource management purposes.

These mussels (kutai) are a valued source of kai moana for Maori at Arahura Pa and Te Runaka o Kati Wae Wae and recent illness within the local mussel-eating community prompted further investigation. The Arahura Mussel Beds are located approximately 6 kilometres to the north of Hokitika and extend south from the Arahura River mouth for over a kilometre.

Feacal coliform and *E.coli* samples were taken on five events at 10 locations from Arahura to Hokitika Rivers. Total faecal contaminant loading was estimated from flow estimations.

The results of this investigation suggest the most important source of contaminants is from the Hokitika River over a range of different flow conditions. As the dominant sea current direction is from south to north, the Hokitika River is considered the single biggest contributor to contamination of the mussel beds. Samples comparing faecal bacteria from the north and south ends of the mussel beds also confirm the major source is from the south.

Short-term moderate levels of contamination were discharged to the Arahura River from Paddy's Creek upstream of the confluence of Arahura River Mouth after high rainfall events. The high level of contamination in Paddy's Creek is not significantly mitigated by dilution from Arahura River or the sea at the northern end of the mussel beds. Northerly near-shore surface sea currents were confirmed during times when creeks were in high flow. This current is likely to deposit faecal contaminants from Paddy's Creek over the Arahura mussel beds. The discharges from two dairy farms in the area appear to be the main cause of poor water quality of Paddy's Creek north branch and the Unnamed Creek and Arahura Valley Road. There were also high concentrations of the faecal bacteria in "Mair Creek". It is unknown whether the source of this faecal contamination is of animal or human origin (from the deer abattoir or sewage/septic tanks).

Introduction

The main aim of this investigation was to determine the relative importance of the likely sources of faecal contamination of the Arahura Mussel Beds. The investigation was prompted by several complaints and enquiries to West Coast Regional Council about this contamination and the safety of consuming the shellfish. This report provides information about the effects of dairy farm effluent discharges to land and water that will be useful for resource management purposes.

These mussels (kutai) are a valued source of kai moana for Maori at Arahura Pa and Te Runaka o Kati Wae Wae and recent illness within the local mussel-eating community prompted further investigation. The Arahura Mussel Beds are located approximately 6 kilometres to the north of Hokitika and extend south from the Arahura River mouth for over a kilometre. The mussels are only accessible at low tide in the surf zone.

In June 2001, Crown Public Health determined that the flesh of the mussels were contaminated with faecal bacteria at levels rendering them unsuitable for consumption (Bergin, C., June 2001). Analysis of the mussels failed to detect any enteroviruses. This is strong evidence to suggest that the contamination is from animal origin rather than human origin and therefore unlikely to be caused by the Hokitika sewage oxidation ponds. *The Guidelines for the Management of Recreational and Marine Shellfish-Gathering Waters* (43 most probable number (MPN)/100ml) was exceeded on one occasion (79 MPN/100ml) out of five samples collected in March-April 2001 (Bergin, C., 2001). The average (median) value (11 MPN/100ml) was within the guideline value of 14 MPN per 100ml.

Sampling of the seawater to the north and south of the mussel beds was undertaken from 1976-79. Results showed moderately high faecal contamination in these waters (Westland Catchment Board meeting papers). A full report on this investigation could not be located. The major source of faecal contamination affecting the mussel beds at that time would have most likely to have been the raw sewage discharge from Hokitika (the sewage oxidation ponds for Hokitika were constructed in the early 1980's).

A meeting was convened in October 2001 at Arahura Pa by the Customary Fisheries Officer, Tamai Sinclair, to discuss the results of Crown Public Health's report, further sampling programme and Regional Council response. It is claimed by members of Arahura Pa that it is relatively common to get diarrhoea after eating raw mussels (the preferred way to eat the shellfish). However, there have been no official reports of illnesses (ie reports from medical professionals) attributed to eating the mussels despite the warning signs being in place since July 2001. According to Crown Public Health it is common for illnesses caused by eating contaminated mussels or swimming in contaminated water to go unreported. According to members of the Arahura Pa, it is unlikely that many of the Maori community would consult medical practitioners about such illnesses and, even if they did, they may not admit to eating mussels because of potential embarrassment.

Potential Sources of Animal Faecal Contamination

The first step in managing adverse effects from resource use activities is to conduct an impact investigation to determine the cause or source of the contamination. Suspected animal faecal contamination sources include: farm effluent from the Hokitika River catchment, Arahura River catchment, or Paddy's Creek North or South Branch catchments and other creeks in the near vicinity such as Houhou Creek and a small creek south of the Hokitika oxidation ponds ("Mair Creek"). Guano from seagulls and other birds that congregate near the mouth could contribute to faecal bacteria loading.

There are two dairy farms and nine small farmlets in the Kaihinu area. Of the two dairy farms in the Kaihinu area both now discharge to land with one milking approximately 100 cows and the other 240 cows. Stormwater run-off from the 100-cow farm is likely to discharge into Unnamed Creek at Arahura Valley Rd and to Paddy's Creek North Branch with stormwater from the 240 cow farm most likely to discharge into Paddy's Creek North Branch. Effluent discharge to water from the 100 cow farm ceased between 1-5 October, 2001 after which time the effluent was discharged to land (Farmer, *pers.comm*.). Both farmers now apply effluent to pasture in such a manor as to avoid areas near drains or creeks in the area. The slope of the land in the area discharged is flat (<5 degrees average). The dominant soils in the area include a mix of Karangarua gley soils that are classified as "poorly drained", Harihari "imperfectly-drained" gleyed soils, and Hokitika sand and silts that are well-drained derived of young alluvium (Mew, G, 1980). The Hokitika soils tend to be closer to the Arahura River. Due to the greater surface runoff velocities over poorly drained soils contaminant discharge to streams is more likely than for well-drained soils. There is also one small pig farm in the area, the effluent from which is discharged to this creek.

Septic tanks from residential dwellings in the Kaihinu area are a potential source of faecal loading to Paddy's Creek but due to the low population number in the area it is unlikely to be a significant source. There are approximately 6 dwellings in the Paddy's Creek North Branch and approximately 20 dwellings in the South Branch catchment. "Mair Creek" could be affected by discharges from Seaview Hospital, an 8-unit motel, approximately 7 dwellings and/or Mair Venison. This creek has been identified from compliance monitoring by Westland District Council as a potential source for high enterococci concentrations at the monitoring site in the sea 200m south of the discharge point from the Hokitika Oxidation Ponds.

Dairy farms in the Hokitika catchment number 66 with an estimated total of 16,500 cows in the catchment (based on an average herd size of 250). This equates to a human population equivalent of 165,000 people. Most of these farms discharge to water with many not having adequate treatment systems in order to meet stock drinking water guidelines in the receiving water. Faecal coliform results from State of the Environment monitoring show that major tributary creeks in the Kokatahi-Kowhitirangi area continue to exceed stock drinking water standards during the dairy farming season. Using mean faecal contaminant loading from three creeks draining dairy farmland in the Kokatahi-Kowhitirangi area (Murray Creek, Harris Creek and Duck Creek) is estimated to account for 6% of the total loading to the Hokitika River (see Appendix 2). These creeks make up approximately 42% of farms in the catchment.

At least 15 farms (approximately 23%) in the catchment are now discharging dairy farm effluent to land in the Kokatahi-Kowhitirangi area (based on those farms that have been visited). The dominant soils in this area are Rotokohu organic soils that are classified as "poorly to very poorly drained". The soils are complexed in some parts with Harihari and Maimai soils which are "poorly drained gley" soils.

Regulation of Farm Effluent to Date

The Resource Management Act 1991 in Section 107 states that after reasonable mixing, a consent authority cannot grant a discharge (to water) permit that will render natural waterways unsuitable for the purpose of stock drinking. Ministry of Health and Ministry for the Environment water quality guidelines set a threshold for stock drinking at 1000 faecal coliform colony-forming units (cfu) per 100ml. Under the Regional Plan for Discharges to Land, the discharge of dairy farm effluent is a permitted activity provided that there are no discharges of contaminants to water from runoff (amongst other provisions).

Regulation of farm effluent discharges to water under the Resource Management Act 1991 has been achieved by on-farm visits by a consents officer to initiate a resource consent application. This process started in mid 1999. Regulatory visits for farm effluent discharges have been undertaken for exactly half of all farms in the Hokitika catchment. All high priority farms (those that had direct discharge of raw effluent to water) have been visited with 8 medium priority farms still to visit. Regulatory visits to both the dairy farms in the Kaihinu area were conducted by West Coast Regional Council on 26 September, 2001 and followed up by subsequent visits. As these farms were either already discharging to land, or about to convert to discharge to land, no follow-up was undertaken. The pig farm effluent discharge to water at Kaihinu has not been visited in regard to regulation.

Dispersal and Dilution

Faecal bacteria are well-known to adsorb to sediment particles in waterways and settle to the bed of slow-moving parts of a stream and that the survival of such bacteria are much greater in stream sediments than in the water column. Such slow-moving pools or backwaters of waterway can then act as reservoirs of faecal contaminants during low flows. Then, during higher flow periods when water velocity and turbulence are greater, this sediment can get resuspended and transported downstream (eg Nagels, J, 2000). The die-off of such bacteria when attached to sediment occurs at a lesser rate as they are protected from the ultraviolet rays from the sun.

Sea current direction monitoring by NIWA in the mid 1990's revealed variability of near-shore surface current direction was related to wind direction (Basil Stanton, *pers.comm*.). This variability is due to two mechanisms: 1. Direct wind forcing of currents (occurring on the time scale of hours to several days) and 2. Changing wind patterns resulting from alternating high and low pressure weather systems generate long ocean waves ("coastal trapped waves"). These waves only propagate southwards as a result of the earth's rotation. The majority of the time the near-shore surface current is from south to north. Unfortunately NIWA ceased this monitoring in the late 1990's. This relationship of sea currents and wind direction is also found from

observations recorded as part of resource consent monitoring for the Hokitika oxidation ponds.

It is hypothesised that after northerly winds contamination from creeks such as Paddy's Creek in the Kaihinu area could flow out the mouth of the Arahura River and track south (without the benefit of full dilution and dispersal) along the coast over the mussel beds. During south or south-west winds the sea current would transport faecal contaminants from the Hokitika catchment north over the Arahura mussel beds.

In an electric fishing event in October 2001, the north and south branches of Paddy's Creek were found to support few sensitive native fish. However, one fish survey at these sites is not sufficient to assess fish populations due to possible temporal variations. Whitebait and eels have been observed to penetrate up the north branch of Paddy's Creek and the Unnamed Creek at Arahura Valley Road (G.Bill, *pers com*.).This was correlated with to poor stream habitat such as riparian vegetation and trampling by cattle in the bed of the creeks (James, TI et al, 2002).

Methods

Water samples were collected from 11 sites from the Arahura River to the Hokitika River mouth (see Table 1). Many of the sites represent cumulative effects of a large number of farms.

Table 1: Description of Sample Sites: (See Figure 1 for exact location and Appendix 1 for grid references).

SITE NAME	SITE NO.	REASON FOR CHOSING SITE
PADDYS CK S BRANCH @ SH6	1	Determine the effect of two dwellings and small-scale farming activities upstream
PADDYS CK N BRANCH @ ONE MILE LINE RD	2	Determine the effect of dairy farm effluent spray irrigation unit in catchment upstream
PADDY'S CK N BRANCH @ SH6	3	Determine the attenuation of contaminants from site 2 through grazed pasture
UNNAMED CK @ ARAHURA VALLEY RD	4	Determine the effect of pig farm effluent discharge to creek and dairy effluent sprayed to land. During high flow this creek discharges into the Stagnant Lagoon and out through the mouth of Paddy's Creek.
UNNAMED CK @ FORD E SH6	5	Determine the attenuation of contaminants from site 4 thr\ough grazed pasture
UNNAMED CK @ STAGNANT LAGOON	6	Determine the attenuation of contaminants from site 5 through ungrazed pasture
PADDY'S CK @ MOUTH	7	Determine the total combined loadings from north and south branches of Paddy's Creeks and suspected main source of contamination of the mussel beds
ARAHURA RV @ SH6 (approx 2 metres out from the true left bank)	8	Reference site
ARAHURA RV @ MOUTH (approx 2 metres out from the true left bank)	9	Determine dilution afforded by lateral mixing of Paddy's Creek with Arahura River
"MAIR" CK @ SH6	10	Determine the potential effect of dwellings (at least 7), motels (8 units), Seaview Hospital and a deer abattoir in catchment upstream
HOKITIKA RV @ MOUTH TRB	11	Determine the potential impact of a large volume river draining significant area of dairy farmland (Kokatahi-Kowhitirangi) where significant volumes of faecal contamination originate. Town stormwater overflows may also influence this site.

Water samples were collected using standard grab techniques and sent chilled to Cawthron Institute for analysis for faecal coliforms and *E.coli* (by membrane filtration) and, in some cases, ammoniacal nitrogen. Eight sites were used on the first round to screen potential sources of contamination with eleven sites being used in the final analysis. A WTW multimeter was used on several occasions (depending on its availability) to measure conductivity, pH, and temperature. One seawater sample was taken on 12/12/2001 for enterococci, faecal coliforms and *E.coli*.

Observations recorded at the time of sampling include: Sea current direction, odour, colour, presence of scums/foams, turbidity, and bank stability as well as any land use activities that may effect the water quality. Approximate flow rate in the Unnamed

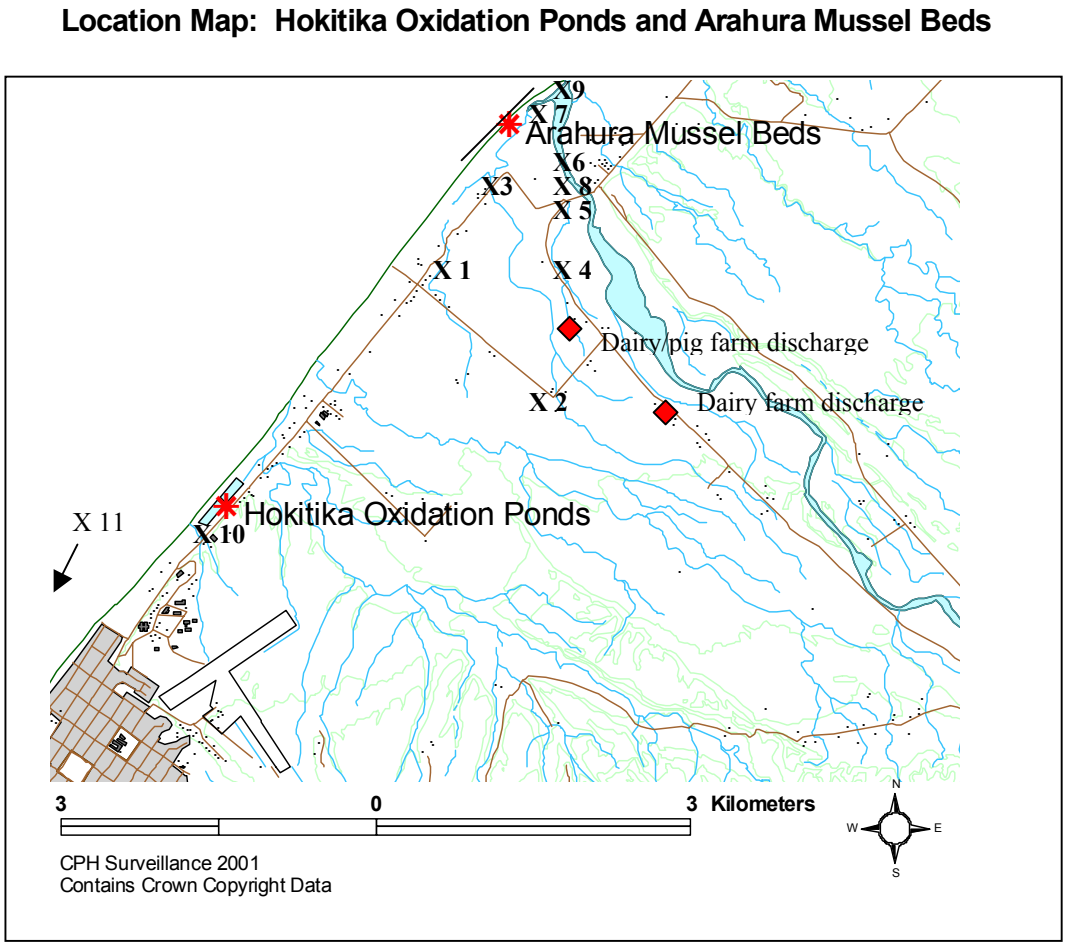
Creek flowing through the culvert under Arahura Valley Road was measured using a 10 litre bucket and timer (+/- approximately 10%). Flow rates in the Hokitika River at the mouth were estimated from comparing data from the telemetric gauge at "Hokitika River at Gorge" to that of the same day/time as one gauging carried out on the Hokitika River at Kaniere Bridge (accounts for over 99% of the flow at the mouth) and expolating from data for Hokitika River at Gorge on the day sampled for faecal bacteria. (The flow at Hokitika River at Gorge accounted for almost 92% of the flow on 11/02/1999). Given that only one gauging is available for the Kaniere Bridge site (and this was at relatively low flows) the accuracy of the estimated flow at the Hokitika River mouth is limited (perhaps +50% and -10%). Gaugings of this river were not taken due to the cost involved. However, this flow at the mouth is considered conservative given that at higher flows a greater proportion of flow is expected from the rivers entering the Hokitika downstream of the Hokitika River at Gorge site (Styx, Kokatahi and Toaroha Rivers). Flow rates in other creeks were estimated from cross-sectional area and surface velocity (accuracy of approximately +/- 50%).

It was intended to use freshwater mussels collected from Lake Ianthe and deployed in Paddy's Creek and the Stagnant lagoon but floods in November and December resulted in their disappearance. Mussels used in this manner are very useful because they accumulate contaminants such as faecal bacteria. Due to high analytical costs for differentiating between animal or human origin of faecal bacteria, such analysis was not undertaken.

Additional samples of Greenshell mussels (unshucked) were taken on 26/11/01 and flesh analysed at ESR in Christchurch for total and faecal coliforms.

Dilution of contaminants from Paddy's Creek by the Arahura River was calculated by first substracting the background concentration of faecal coliforms from that of the Arahura River Mouth on any one sampling occasion. For each sampling occasion the concentration of faecal coliforms in Paddy's Creek at the Mouth was divided by that of the Arahura River at the Mouth.

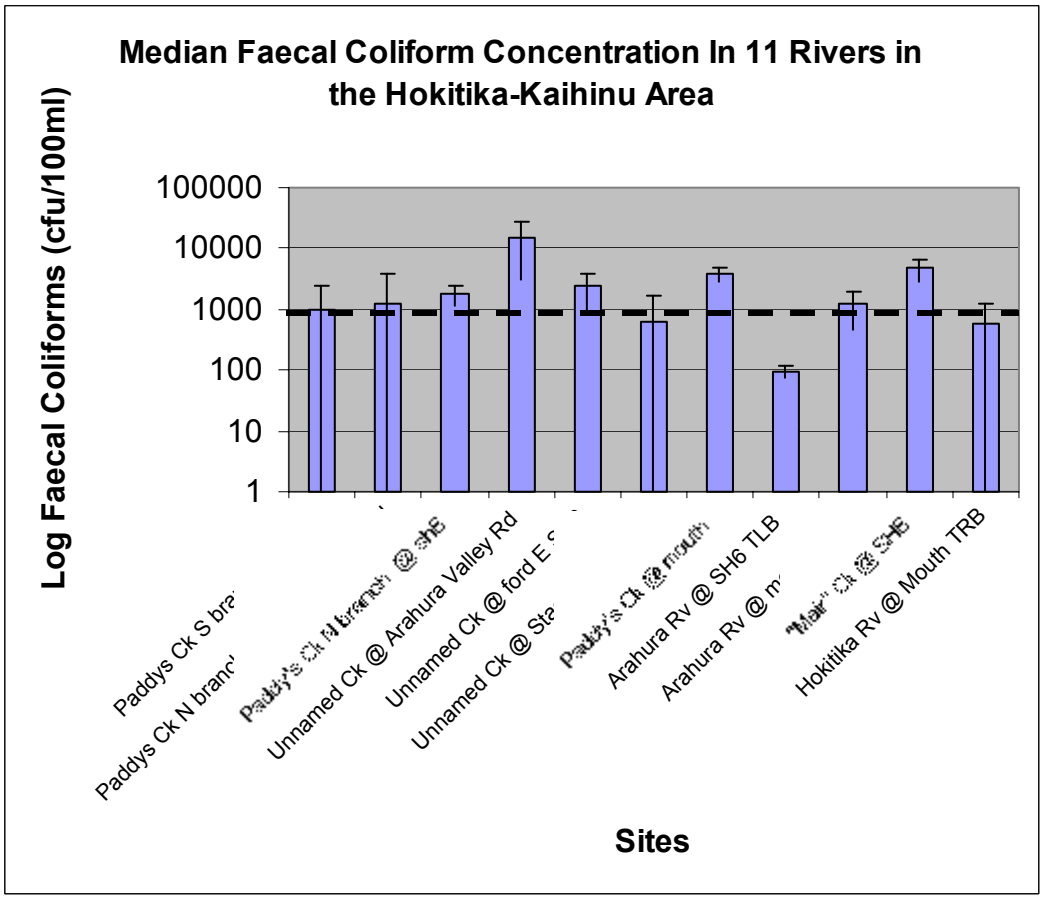
Figure 1: Map of the Kaihinu-North Hokitika Area



Results and Discussion

Water Quality.
Faecal coliform concentrations in many tributary creeks of the Arahura River and "Mair Creek" exceeded national guidelines for stock drinking water (1000 cfu/100ml) (see Figure 2). While this is useful information for managing the creeks for the purpose of stock drinking water use, it is not useful for defining the relative importance of each site to contamination of the mussel beds. The latter can only be done by taking flow measurements and calculating total contaminant loading.

Figure 2:



The water of the Unnamed creek @ Arahura Valley Rd was foamy, highly turbid, green-brown and had a strong odour of dairy farm effluent on most of the sampling events. The flow in this creek/drain at the Arahura Valley Rd culvert during low flows ranged from nil on 29/01/02 to 0.7 l/sec (14/9/2001) and during high flows 6 l/sec (12/12/2001). From the results it appears that higher flow in the creek resulted in lower concentrations of contaminants, although the total contaminant load during high flow was higher. During low flow periods this creek dried up. On several sampling occasions during high flow, this Unnamed Creek flowed into the Arahura River flood channel under the road-rail bridge near the southern end of the bridge.
Conductivity regularly exceeded 100µS/cm at the Arahura Valley Road site.
Consistent attenuation of faecal bacteria was found from the Arahura Valley Road site (upstream) and the ford upstream of SH6 (downstream) with an average reduction of 10% between the two sites. There was no clear pattern of attenuation or increase

between the site at the ford and the stagnant lagoon or the two sites on the north branch of Paddy's Creek.

Faecal coliform concentrations in Paddy's Creek South branch were moderately high during higher flows indicating that that dry-stock farming can contribute contamination, probably due to non-point sources. However, average concentrations were lower than for farms where intensive dairy farming takes place.

The faecal coliform concentration in a seawater sample taken at the north end of the mussel beds on 12/12/01 was 420 cfu/100ml which is 35% of the concentration of faecal coliforms taken at the Arahura River mouth at a similar time. While the analysis method is not comparable to the water quality guidelines for shellfish-gathering waters (guidelines specify the MPN method of analysis), it indicates likely non-compliance with these guidelines as the two methods are very comparable. The water quality guidelines for shellfish-gathering water is 14 cfu/100ml.

Results of observations of current direction and wind direction confirmed results of earlier studies (NIWA and Westland District Council). There was very high correlation between the wind direction and flow in the creeks with the near-shore sea current direction. This study found that in low flows the sea current tracked from south to north and in high flows the sea current tracked to the south.

The concentrations of total ammoniacal nitrogen in the Unnamed Creek at Arahura Valley Road exceeded national guidelines (1.2 g/m3) and therefore is likely to adversely affect the diversity and abundance of fish in this creek.

Temperature recorded at all the sites was within thresholds to support life for fish and macroinvertebrates. However, cooler water is more prevalent during periods of higher flow.

River Flow and Dilution

Flow in the Hokitika River at the mouth varied from 48 to 430 cubic metres per second. The dilution of the Hokitika River with the sea is uncertain and would have to be calculated using dye testing. From a very low velocity discharge at Karoro, Greymouth dilution in the surf zone was estimated at 1:200 (Sorrell and Norton, 2001). However, the level of dilution 8km north of the Hokitika River at the mussel beds is likely to be more than 10 times this level given greater mixing, dispersion and diffusion forces over this greater distance. Enterococci concentrations upcurrent and downcurrent of the Hokitika oxidation pond discharge suggest greater variability of faecal bacteria loading than that found in the Hokitika River (West Coast Regional Council, RC82/009). This may be because of incomplete mixing of the Hokitika River and the Tasman Sea at this location or some other source of contamination such as "Mair Creek".

Water flow in the north and south branches of Paddy's Creek continued through the drier periods but flows from the mouth ceased approximately 2 weeks after a heavy rainfall event. The degree of mixing of Paddy's Creek with the Arahura River at the mouth was variable but generally limited. Evidence of lack of mixing was visually obvious, particularly at high flow, from the colour difference between the two rivers, the Arahura River being a very turbid grey colour and Paddy's Creek being brown-

green. The proportion of faecal coliforms in the Arahura River upstream of Paddy's Creek compared to that at the mouth ranged from 2.7% to 71% with the proportion of faecal coliforms in Paddy's Creek compared to that at the mouth of Arahura River on any one sampling occasion ranged from 5% to 34%. A median dilution of faecal contamination from Paddy's Creek by Arahura River was 4.26 times. This is very low considering the volume of the Arahura River. The uniformity of the channel morphology near the mouth and lack of mixing features (ie a smooth sandy bed) is considered the reason for this limited dilution. There are good mixing features on this river upstream of SH6 so any dilution should be fully effective at the sampling site downstream of SH6.

Faecal Contaminant Loadings

The range in faecal contaminant loading from the Hokitika River at the mouth was relatively small: between 0.5 – 2.7 billion colony forming units per cubic meter per second (see Table 2). This consistency was across a wide range of flow conditions. Given that the predominant near-shore current flow direction is from south to north, this loading could have significant impact on the Arahura mussel beds.

Table 2: The estimated flow and contaminant loading in the Hokitika River at mouth

DATE	ESTIMATED FLOW (l/sec)	FAECAL COLIFORMS (CFU/L)	ESTIMATED TOTAL CONTAMINANT LOADING (CFU/L/SEC)
19/09/01	48,000	39,000	1,872,000,000
1/11/01	196,000	14,000	2,744,000,000
2/11/01	107,000	4,800	513,000,000
22/11/01	318,000	4,600	1,462,800,000
12/12/01	430,000	5,800	2,494,000,000
Mean			1,514,300,000

The faecal bacteria loading from the Hokitika River on 12/12/01 (at medium-high flow) was estimated to be over 97% of the other major sources investigated (see Table 3). It is unknown at this stage as to what proportion of faecal bacteria in these waterways is from animal origin compared to human origin but it is suggested that the major contribution of faecal bacteria at the sites listed in Table 3 is from animal sources given low human population densities compared to stock densities and comprehensive sewage reticulation in Hokitika township.

Table 3: Estimated Total Contaminant loading during a high flow event (12/12/01).

Site	Estimated Volume (l/sec)	Faecal Coliform concentration (cfu/l)	Estimated Total Contaminant Loading (cfu/l/sec)
Unnamed Ck @ Arahura Vly Rd	6	57,000	342
Paddy's Ck N Branch @ One Mile Line Rd	50	16,000	800
Paddy's Ck S Branch @ SH6	50	9,800	490
Paddy's Ck @ Mouth	500	61,000	30,500
Hokitika Rv @ Mouth	430,000	5,800 (this was also the mean concentration)	1,247,000 (assuming dilution of 1:2000 from the Tasman Sea)

The reason for the high loading at the mouth of Paddy's Creek compared to the upstream sites may be due to the physical resuspension of faecal-contaminated sediment in the often-stagnant waters near the mouth of the south and north branches of Paddy's Creek. Another reason could be contaminated groundwater percolating to the surface at a point downstream of SH6. The flow rate of groundwater, and consequently contaminant transport, in the recent alluvial gravels that underlay the gley soils would be expected to be high. The discharge of campervan effluent beside the highway in this area is considered unlikely as it is a relatively busy public place where cars don't tend to stop unless waiting for traffic on the bridge. No other sources of contamination other than non-point farm run-off were found in the vicinity between SH6 and Paddy's Creek mouth.

The contribution to faecal contaminant loading by birdlife in the area was considered low. Seagulls (mostly Red-Billed Gulls) and Pied Stilts as well as some other species appeared to congregate in the area around the mouth of Paddy's Creek. The highest numbers of birds observed in the Paddy's Creek Mouth area were estimated to be between 100 - 150 but usually there were less than 80. Small groups (less than 6) ducks were observed in the Paddy's Ck tributaries. The contribution of faecal bacteria from the bird recovery centre on One Mile Line Road is considered relatively minor given that the numbers of birds are generally less than 70. Contribution of faecal contamination from birds is only usually a problem when very large numbers of birds congregate in a small area (ie greater than 500-1000 birds at densities of greater than 1 bird/m^2).

Faecal contamination of Paddy's Creek by septic tank discharges is unlikely to be a major contributing factor given the low human population density and the fact that contaminant loading from one cow is considered to be 10 times that of one human and from one pigs is equivalent to that from 14 humans the risk is considered low.

Bacteriology of Shellfish Flesh

The concentration of indicator disease-causing organisms in shellfish flesh exceed the *Microbiological Reference Criteria for Food* that provide a faecal coliform level of 330 CFU/100g shellfish flesh (see Table 4). While the most recent samples show

compliance with the criteria, the mussels can only be considered safe to eat after at least 3 samples below the criteria. This would require further sampling.

Table 4: Results of bacteriological testing on the mussel flesh (units are in cfu/100g of shellfish flesh):

Sample Date	Location	Presumptive Coliforms	Faecal Coliforms	*E. coli*
8 May 2001	North beds	2800	2800	2800
26 Nov 2001	North beds	170	330	-
29 Jan 2002	South beds	1700	130	-
29 Jan 2002	North beds	790	<18	-

These results only indicate that the mussels are contaminated by faeces from the gut of a warm blooded animal (don't distinquish between animal or human). Additional sampling for enteroviruses would be needed to confirm whether the contamination is of animal origin (as suggested in the Crown Public Health study).

The difference between the samples taken on the South beds compared to the north beds indicate that the primary source of faecal contamination is coming from the south. This is further evidence that the predominant faecal contaminant source is from the south and most likely to be the Hokitika River, given that the contamination of the mussels was found to be largely of animal origin and not human (Bergin, C, 2001).

Conclusions

This investigation aimed to isolate the relative importance of the different potential sources of faecal contamination to the Arahura mussel beds. The results of this investigation suggest the most important source of contaminants is from the Hokitika River. Given that the high faecal contaminant loading from the Hokitika River over the period sampled was relatively consistent over different flow conditions and that the dominant sea current direction is from south to north, the Hokitika River is considered the single biggest contributor to contamination of the mussel beds. Samples comparing faecal bacteria from the north and south ends of the mussel beds also confirm the major source is from the south.

The results of this investigation also confirm short-term moderate contaminant loading of faecal coliforms to the Arahura River from Paddy's Creek upstream of the confluence of Arahura River Mouth after high rainfall events. The high level of contamination in Paddy's Creek is not significantly mitigated by dilution from Arahura River or the sea at the northern end of the mussel beds. Northerly near-shore surface sea currents were confirmed during times when creeks were in high flow. This current is likely to deposit faecal contaminants from Paddy's Creek over the Arahura mussel beds. The discharges from two dairy farms in the area appear to be the main cause of poor water quality of Paddy's Creek north branch and the Unnamed Creek and Arahura Valley Road.This suggests an effect of contaminant discharge to water from dairy farm effluent discharges to land. There were also high concentrations of the faecal bacteria in "Mair Creek". It is unknown whether the source of this faecal contamination is of animal or human origin (from the deer abattoir or sewage/septic tanks).

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West Coast Regional Council RC82009. Resource consent to discharge sewage contaminants to the Tasman Sea from the Hokitika Oxidation Ponds. Consent holder: Westland District Council.

Appendix 1: Results of Water Quality Sampling in the Hokitika – Arahura Area (units for faecal coliforms and E.coli: cfu/100ml)

DATE	FLOW	CURRENT DIRECTION	TEST	PADDYS CK S BRANCH @ SH6 SITE 1	PADDYS CK N BRANCH @ ONE MILE LINE RD SITE 2	PADDY'S CK N BRANCH @ SH6 SITE 3	UNNAMED CK @ ARAHURA VALLEY RD SITE 4	UNNAMED CK @ FORD E SH6 SITE 5	UNNAMED CK @ STAGNANT LAGOON SITE 6	PADDY'S CK @ MOUTH SITE 7	ARAHURA RV @ SH6 TLB SITE 8	ARAHURA RV @ MOUTH TLB SITE 9	"MAIR" CK @ SH6 SITE 10	HOKITIKA RV @ MOUTH TRB SITE 11
			Grid Ref	J32:471-349	J32:481-335	J32:477-351	J32:483-345	J32:482-352	J32: 481-359	J32:480-360	J32:482-353	J32: 483-363	J32: 448-321	J33: 423-299
14/9/01	low	North	Faecal coliforms	36	-	-	**46,000**	-	10	-	-	5	**2,500**	**3900**
			E.coli	36	-	-	**28,000**	-	10	-	-	5	**2,100**	**280**
			Ammonia g/m^3	0.014	-	-	**32**	-	-	-	-	-	**0.088**	0.009
18/1/010	Mod	-	Faecal coliforms	-	-	-	**80,000**	**6400**	**580**	**1300**	-	210	-	-
			E.coli	-	-	-	**69000**	**6400**	**580**	**1300**	-	210	-	-
			Ammonia g/m^3	-	-	-	**5.5**	**2.6**	**0.022**	**0.055**	-	0.013	-	-
1/11/01	High	South	Faecal coliforms	**6800**	-	-	**20,000**	-	**1,600**	-	-	**4700**	**13000**	**1400**
			E.coli	**6800**	-	-	**20,000**	-	**1,200**	-	-	**4700**	**12000**	**1400**
			Ammonia g/m^3	**3.9**	-	-	**1.2**	-	**0.042**	-	-	**0.072**	**0.038**	**0.037**
2/11/01	High	South	Faecal coliforms	-	**900**	**1100**	**7300**	**600**	**5800**	**3800**	35	**1300**	**2900**	**480**
			E.coli	-	**900**	**980**	**7300**	**600**	**5800**	**3800**	35	**1300**	**2900**	**480**
			Ammonia g/m^3	-	-	**0.052**	-	**0.13**	**0.048**	**0.052**	0.01	**0.021**	**0.013**	**0.035**
22/11/01	High	South	Faecal coliforms	**3100**	**9000**	**3300**	**10000**	**4200**	-	**2600**	100	140	**4700**	**460**
			E.coli	**3300**	**9000**	**3300**	**10000**	**4200**	-	**100**	100	110	**4700**	**300**
			Ammonia g/m^3	-	-	-	-	-	-	-	-	-	-	-
12/12/01	Very High	South	Faecal coliforms	**980**	**1600**	**1800**	**5700**	**680**	**640**	**6100**	95	**1200**	**5200**	**580**
			E.coli	**980**	**1600**	**1800**	**5700**	**680**	**640**	**6100**	57	**880**	**5200**	**580**
			Ammonia g/m^3	-	**0.88**	**0.91**	-	-	-	**0.47**	-	-	**0.028**	-
29/01/02	Low	-	Faecal coliforms	**140**	**20**	-	-	-	-	-	<5	**100**	-	-
			E.coli	**140**	**20**	-	-	-	-	-	<5	**100**	-	-
			Ammonia g/m^3	-	-	-	-	-	-	-	-	-	-	-
11/02/02	High	-	Faecal coliforms	-	-	-	-	-	-	**14000**	**1700**	**8200**	-	-
			E.coli	-	-	-	-	-	-	**14000**	**1700**	**8200**	-	-
			Ammonia g/m^3	-	-	-	-	-	-	-			-	-
Median Faecal Coliform concentration				980	1250	1800	15000	2440	640	6100	97.5	1200	4700	580

APPENDIX 2: Faecal coliform loading in important dairy farming catchments in the Hokitika catchment

Faecal Coliform loading at Murray Ck @ Ford Rd S

	Faecal Coliforms cfu/litre	Flow (l/sec)	Faecal Loading cfu/l/sec
13/12/1998 09:00	62000	3082	191084000
20/01/1999 12:10	6600	2756	18189600
28/02/1999 10:30	9000	2764	24876000
12/04/1999 10:15	1300	2695	3503500
Mean			59413275

Faecal Coliform loading at Harris Ck @ Mulvaney Rd

	Faecal coliforms (cfu/litre)	Flow (l/sec)	Faecal Loading
25/03/1998 14:54	2600	1244	3234400
13/12/1998 11:30	200000	705	141000000
20/01/1999 10:50	11000	463	5093000
28/02/1999 11:30	8800	617	5429600
12/04/1999 10:00	3200	556	1779200
12/04/1999 12:30	5800	556	3224800
Mean			26626833.33

Faecal Coliform loading at Duck Ck @ Kokatahi-Kowhitirangi Rd Br

	Faecal Coliforms cfu/litre	Flow (l/sec)	Feacal Loading (cfu/l/sec)
25/03/1998 14:15	1100	1870	2057000
26/03/1998 17:00	5600	660	3696000
13/12/1998 12:01	15000	1800	27000000
20/01/1999 11:15	2200	877	1929400
28/02/1999 12:30	6000	2170	13020000
12/04/1999 13:25	400	949	379600
Mean			8013667