Quantitative Microbial Risk Assessment for Nelson North wastewater treatment plant

Phase 2

Prepared for Nelson City Council

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Climate, Freshwater & Ocean Science

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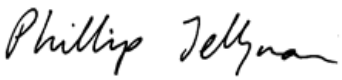
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Executive summary

Nelson City Council (NCC) is responsible for the collection and reticulation of municipal wastewater (domestic sewage and industrial wastewater) arising from Nelson. Most of the wastewater generated within the Nelson City boundary is directed to the Nelson Wastewater Treatment Plant (WWTP), located approximately nine kilometres to the north of the city, between State Highway 6 and Tasman Bay.

NCC wish to renew the consent for the discharge of treated wastewater from the Nelson WWTP. One of the requirements for an assessment of effects is determining the likely health risks that will be associated with the discharge of treated wastewater to Tasman Bay.

NIWA was commissioned by NCC to assess the potential health risks following exposure to treated diluted wastewater in association with primary contact recreation (e.g., swimming), secondary contact with water (e.g., boating, surfing), and consumption of raw harvested shellfish. A Quantitative Microbial Risk Assessment (QMRA) was used to assess health risks arising from viral enteric infection and illness as well as respiratory risks associated with the inhalation of spray droplets following recreation in waters where treated, diluted wastewater would occur. These estimated health risks will be used by others as input to a full assessment of environmental effects.

Output from a hydrodynamic model developed and calibrated by MetOcean Solutions Limited was used as a key input to QMRA modelling, allowing estimates of Individual Illness Risks (IIR) to be calculated for individuals engaged in recreational activities at, or who consumes of raw shellfish gathered at15 sites in Tasman Bay.

The hydrodynamic modelling (from which estimates of contaminant concentrations were derived) indicated that risks were likely to be greatest near the Outfall and extend along a northeast-southwest axis, driven primarily by tidal currents. The impact of climate conditions (e.g., El Niño and La Niña Southern Oscillation events) on hydrodynamic processes was modest, and future increases in wastewater discharge volumes and rates were predicted not to change mixing and dilution characteristics significantly (less than a 10 fold change).

Human health risk assessment at each of the 15 sites considered:

- three model pathogens (norovirus, enterovirus and adenovirus),
- six levels of wastewater treatment (1 to 6 $\log_{10}$ reductions in virus concentrations),
- two discharge scenarios (current and 2059 projected),
- two climate conditions (El Niño and La Niña),
- three routes whereby human receptors are likely to be exposed to pathogens (swimming, secondary contact and shellfish consumption), and
- two health endpoints (infection or illness).

The QMRA modelling generated 3600 health risk estimates. These risk estimates are expressed as the Individual Infection Risk (IInfR) or Individual Illness Risk (IIR) which relate to the average risk of viral infection or illness to an individual following exposure on any random day. Health risk estimates for each site were stratified for the range of $\log_{10}$ removal for wastewater treatment to inform decisions about the treatment level required to manage risks.

Health risks arising from exposure to viral pathogens were related to the exposure site, exposure route and the level of wastewater treatment assumed in the modelling. Other factors (future changes to the volume of wastewater discharge and climate conditions) were not as influential.

- Health risks for all exposure routes were greatest near the Outfall and decreased with distance from the Outfall.
- For each exposure event, the risks at a particular location were highest for individuals who consume raw or lightly cooked shellfish and lowest for those who engage in secondary contact recreational activities, with swimming (primary recreation) between the two.
- Higher levels of wastewater treatment result in lower health risk estimates (for both IIR and IInfR) than lower levels of treatment, assuming all other things remain the same.

QMRAs can help to inform decisions about what level of wastewater treatment may be required by placing the health risk results in the context of the "Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas" (published by the Ministry of Health and Ministry for the Environment). The guidelines provide a reference framework to inform decisions about swimming-related public health risks.

Table H1 of the guidelines provide four illness risk thresholds that are used routinely to grade coastal recreational water quality based on microbiological assessment categories (MAC) for enterococci concentrations. These tables provide context for the estimated risks:

- Waters graded "A" are considered to have a very high recreational water quality, likely to cause fewer than 1 case of gastrointestinal illness or acute febrile illness per 100 individuals (i.e., <1% and <0.3% illness, respectively).
- Waters graded "B" are considered to have high recreational water quality, likely to cause up to 5 cases of gastrointestinal illness and less than 1.9 cases of acute febrile illness per 100 individuals (≤5% and <1.9% illness risk, respectively).
- Waters graded "C" represent a risk of up to 10% for gastrointestinal illness, and up to 3.9% for acute febrile illness.
- Waters graded "D" represent a risk of more than 10% for gastrointestinal illness, and greater than 3.9% for acute febrile illness.

QMRA modelling of viral illness risks indicated that under future flow projections, three $\log_{10}$ orders of pathogen removal by wastewater treatment are likely to be required to reduce the average IIR for consumers of shellfish gathered from all of the exposure sites to less than 1%, except for the Outfall, where four $\log_{10}$ orders of pathogen removal are required under future discharge scenarios. At four $\log_{10}$ levels of treatment, lower risks would prevail for other water uses, such as swimming or secondary contact recreation. However, under current discharge conditions, three $\log_{10}$ orders of pathogen removal would be sufficient to keep the average IIR below 1% at all sites, including the Outfall site.

1 Introduction

Nelson City Council (NCC) is responsible for the collection and reticulation of municipal wastewater (domestic sewage and industrial wastewater) arising from Nelson. Wastewater from the Stoke and Tahunanui areas is directed to the Bell Island wastewater treatment plant (WWTP), operated by the Nelson Regional Sewerage Business Unit (NRSBU). Most of the wastewater however arising from within the Nelson City boundary is directed to the Nelson WWTP. This WWTP is located approximately nine kilometres to the north of the city, between State Highway 6 and Tasman Bay.

The Nelson wastewater treatment system comprises coarse screening, sludge removal via clarifiers, followed by several biological treatment units – biotrickling filters, and treatment ponds. The treated wastewater is discharged to the Tasman Bay via a 400 m long outfall pipe and diffuser system.

Although the treatment system achieves a high standard of treatment (in terms of solids, organic waste strength, and nitrogen and phosphorus removal), reducing the concentrations of potentially harmful microbial contaminants relies principally on inactivation by solar UV radiation during retention of secondary treated wastewater in the treatment ponds. Inactivation may be influenced by several factors, notably the clarity of the treated wastewater and retention time within the pond treatment system.

NCC wish to renew the consent for the discharge of treated wastewater. One of the requirements for an assessment of environmental effects will be determining the human health risk arising from the discharge of treated wastewater to the Tasman Bay.

1.1 Health risk assessment

Previously, health risk assessment studies have relied on “faecal indicators” (faecal indicator bacteria, FIB) to estimate human health risks. In New Zealand freshwaters, the preferred faecal indicator bacteria is *Escherichia coli (E. coli),* whereas the enterococci bacterium is preferred in coastal waters. At best, the faecal indicator approach indicates the *overall pathogenicity* of the water. However, the association between indicators and pathogens tends to break down as higher degrees of wastewater treatment are implemented. One of several factors which may contribute to this is generally greater removal efficacies for bacteria than those achieved for viruses. In these circumstances, complying with FIB numerical limits does not guarantee safety.

As a consequence, the “Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas” (MfE/MoH 2003) are quite clear that FIB should not be used for human health risk assessment under several circumstances, or for specific purposes:

1. *“to directly determine water quality criteria for wastewater discharges because there is the potential for the relationship between indicators and pathogens to be altered by the treatment process. The relationship between indicator bacteria and disease-causing bacteria, viruses and protozoa in the discharge needs to be established”* (p 3),
2. *“to assess the microbiological quality of water that is impacted by a nearby point source discharge of treated effluent without first confirming that they are appropriate …… when planning the location and degree of treatment for wastewater treatment plants to recognise that the guideline values are not necessarily a guarantee of safety”* (p 3), and

3. during periods of "*exceptional circumstances"*, such as when there is a major outbreak of a potentially waterborne disease in the community, and where that community's sewage contributes microbiological contaminants to receiving waters (p D9).

To overcome the limitations imposed by inadequate relationships between indicator organisms and pathogens, risk assessments must consider the actual or likely content of pathogens discharged in the treated wastewater effluent, and the subsequent health risk to individuals exposed to residual pathogens. Quantitative Microbial Risk Assessment (QMRA) is increasingly used to quantify the human health risks associated with wastewater treatment and disposal schemes. This procedure uses dose-response data for representative and specific pathogens – rather than for one or more indicator – alongside water users' exposure to potentially contaminated water. The procedure may be easily extended to include health risks arising from consumption of harvested food (including mahinga kai such as shellfish) that may be exposed to treated, diluted wastewater. These data are used in a set of calculations to estimate an individual's infection or illness risk. NIWA has developed a standardised QMRA methodology that may be customised and applied to most circumstances involving the discharge of treated wastewater to waters (e.g., McBride 2016b; McBride 2017).

1.2 Scope of the project

This QMRA was undertaken using information regarding the wastewater treatment process provided by NCC and STANTEC , dilution data provided by MetOcean Solutions Limited, and information regarding the infectivity of viruses (e.g., dose-response) derived from the literature. No fieldwork or data collection was performed by NIWA for this QMRA report. The QMRA modelling was based on previous models of a similar nature (e.g., McBride 2017), but the selection of key parameters was determined after considering more recent information derived from the international scientific literature.

Fifteen sites were identified by NCC at which human health risks arising from exposure to diluted, treated sewage during primary and secondary contact recreation and consumption of shellfish exposed to diluted, treated sewage were required. These health risks were estimated assuming six levels of wastewater treatment, ranging from one $\log_{10}$ to six $\log_{10}$ (reflecting 10-fold to 1,000,000-fold reduction of virus concentrations from raw sewage at the WWTP inlet to treated sewage discharged from the plant). These risks were estimated using current-day wastewater discharge rates, as well as those likely in the future (represented as values 1.3 times larger than current discharge rates; the method is described in MetOcean Solutions (2021)).

This assessment supersedes a previous QMRA by Hudson and Wood (2023) which originally assessed 13 sites. The second assessment was undertaken to address additional requirements:

1. A requirement to include additional sites, notably the Outfall, a site expected to have the highest public health risks, and a second site of interest (Tasman Bay 2) selected to represent the recovering shellfishery in southern Tasman Bay.

2. Concerns that sites close to the Outfall had similar but lower risks than sites such as Magazine Point, which were further away; this raised a query about whether this was due to assumptions regarding interpolation of the dilution data or some other factor.

3. A numerical error in the initial QMRA model had led to an overestimation of shellfish risks, which needed to be corrected, after which health risk estimates could be re-quantified.

This assessment addressed those requirements, and the updated results are presented in this report.

1.3 Quantitative Microbial Risk Assessment

To assist NCC and the local community to better understand the health risks arising from the discharge of treated wastewater to south Tasman Bay from the Nelson WWTP, NIWA was commissioned to undertake a QMRA for the discharge. This assessment relates to the *incremental* risks associated with the wastewater discharge, i.e., it does not consider background risks or account for risks associated with other potential sources of microbial contaminants, such as stormwater.

In the circumstances under which treated wastewater is discharged to south Tasman Bay, the primary modes of exposure of human targets to pathogenic microorganisms will be via contact recreation (following ingestion or inhalation of organisms after swallowing highly diluted treated wastewater or following inhalation of spray droplets (aerosols) derived from treated wastewater), or consumption of raw or undercooked shellfish that may be exposed to the plume of highly diluted, treated wastewater.

The health risk assessment process comprises multiple steps (described graphically in Figure 1-1), including:

- identifying candidate pathogens (i.e., pathogenic organisms likely to be present in the diluted wastewater),
- identifying routes whereby the community may be exposed to these organisms,
- identifying modes of exposure and estimating the volumes of water likely to be ingested, or meal sizes if the route of exposure is uncooked shellfish,
- defining concentration ranges for the model pathogens, and
- selecting appropriate dose response curves for these model pathogens.

Health risks are usually presented primarily as estimates of Individual Infection Risks (IInfR) or Individual Illness Risks (IIR) determined by the level of treatment proposed for the wastewater. Risks can be estimated for adult and child receptors, and for ingestion and inhalation exposure routes.

Figure 1-1 identifies near- and far-field mixing, dilution and inactivation. These processes are represented using calibrated mixing- and hydrodynamic models which provide essential data that underpin the QMRA process. These models are used to ultimately predict the fate of treated wastewater after it is discharged from the WWTP, as well as potential concentrations of pathogenic organisms anywhere within the model domain. These concentration values are fundamental to predicting exposure doses that may lead to infection or illness as the human health risk outcome.

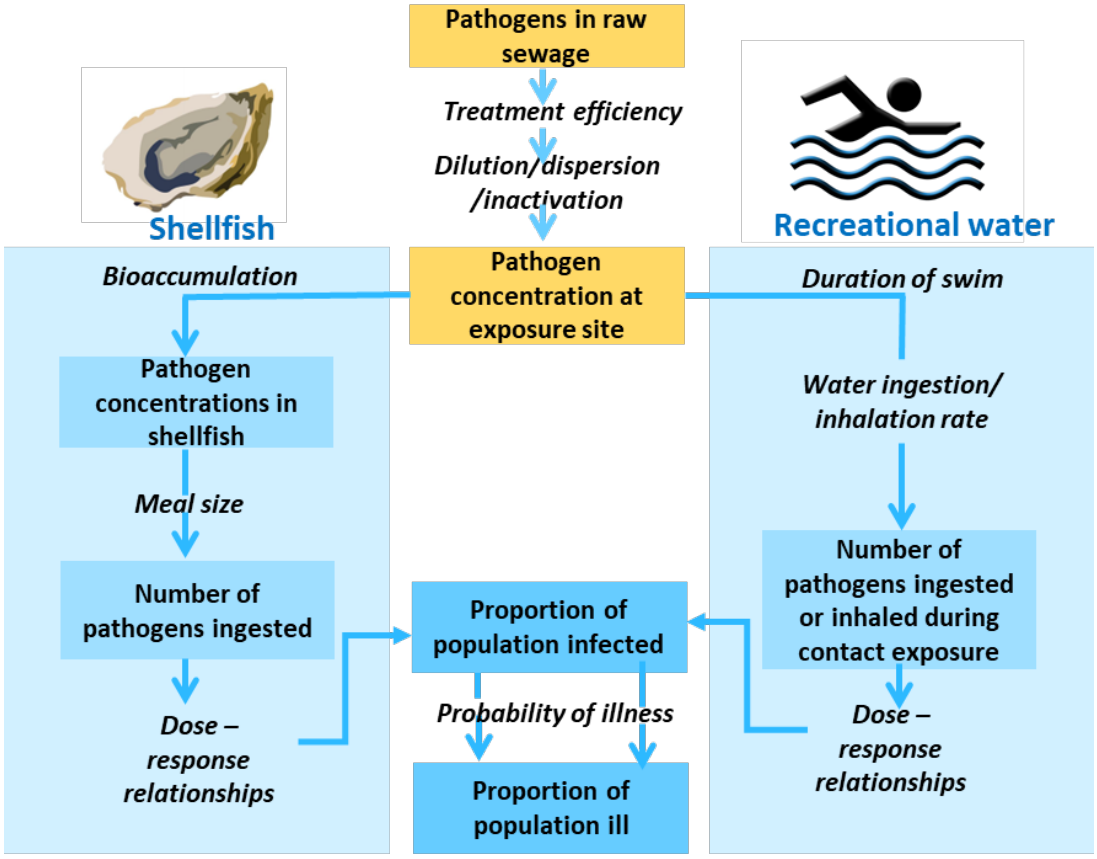


Figure 1-1: Schematic describing the QMRA process.

2 Methods

Quantitative Microbial Risk Assessment (QMRA) integrates the following sequential components.

1. Select the hazard(s), i.e., the pathogen(s) of concern—exposure to which can give rise to illness.
2. Assess exposures to the pathogens at key sites.
3. Characterise the pathogens' dose-response.
4. Calculate and communicate the health risks.

The "Quantitative" aspect of QMRA relates particularly to item 4—calculating risks—in which the Monte Carlo method is used. This calls for repetitive sampling from distributions and ranges of key variables, rather than just using single average values (such as median or 95th percentile values)[1]. This approach is particularly important given that the majority of the risk is caused by combinations of inputs toward the extremes of their ranges, the combined effects of which may not be detected when using averages or other single values.

2.1 Selecting the pathogens of concern

In addressing this issue, extensive use has been made of international literature and previous New Zealand studies.

2.1.1 Pathogens of concern and associated potential illnesses

Pathogens present in sewage that can cause illness are many and varied. Many of the illnesses that may be contracted from exposure to waters contaminated by human-derived treated wastewater are not "notifiable". Reporting for some that are[2] may not necessarily capture or represent much of the disease burden.[3] So, when considering such matters, microbiological water quality guidelines developed both in New Zealand (MfE/MoH 2003) and internationally (WHO 2003) are based on a range of investigations that have led to the understanding that risks associated with wastewater contaminated water comprise two types of infection and illness:

1. Gastrointestinal disease, via
   - 1.1 ingestion during recreational water contact, and
   - 1.2 consumption of raw shellfish flesh.
2. Respiratory ailments, via inhalation of aerosols formed when water-skiing, windsurfing, kiteboarding or kayaking.

Ear, nose, throat and skin infections have generally not been included in QMRA studies to date - while there is evidence of associations between these ailments and microbial water quality

[1] Using a simple-averages approach can substantially underestimate human health risk.

[2] See the list at http://www.health.govt.nz/our-work/diseases-and-conditions/notifiable-diseases

[3] For example, "acute gastroenteritis" is notifiable but is subject to the requirement that "not every case of acute gastroenteritis is necessarily notifiable, only those where there is a suspected common source or from a person in a high risk category (a food handler or an early childhood service worker) or single cases of chemical, bacterial, or toxic food poisoning such as botulism, toxic shellfish poisoning (any type) and disease caused by verotoxin or Shiga toxin-producing *Escherichia coli*.

(Charoenca and Fujioka 1994), dose-response models (especially for ear, nose, and throat infections) have not been developed ((WHO 2003), p. 55).

Appendix A lists potential waterborne diseases and their aetiological agents (i.e., pathogens), derived from the ANZECC guidelines (ANZECC/ARMCANZ 2000). It also indicates whether risk assessment for a pathogen should be based on contact recreation or shellfish consumption exposure routes, and gives a brief rationale for this assessment.

A notable feature of Appendix A is the selection of human viral pathogens. In general terms, for sites impacted by WWTPs discharging well-treated human-derived wastewater, there is widespread agreement that human viruses are the principal aetiological agent causing gastrointestinal disease among water users and consumers of raw shellfish (e.g., Lodder and de Roda Husman 2005; Sinclair et al. 2009).[4] Accordingly, bacteria and protozoa have been excluded from consideration in this QMRA on the expectation that the WWTP wastewater treatment plant effectively removes these microbes— Nelson City (via the Nelson Regional Sewerage Business Unit, NRSBU) is committed to providing a high level of wastewater treatment. However, viruses are more difficult to remove through wastewater treatment processes and are, therefore, the focus of this QMRA.

2.1.2 Selected viruses

The relative merits of the candidate viruses (for which some form of identified dose-response curve is available) are addressed in Table 2-1.

Gastrointestinal illness

Enteroviruses (coxsackie virus and echovirus) and norovirus are the pathogens-of-choice. Enteroviruses are included for three reasons:

1. Enumeration of enteroviruses can be done by culture-based methods, whereas to date noroviruses have had to be analysed by qPCR methods,[5] and the ratio of infectious/total virus numbers can be expected to vary through the wastewater treatment process.
2. Enteroviruses can cause longer-term illnesses.
3. Clinical trial data and associated infection dose-response relationships based on culture methods are available.

Note that the enumeration of noroviruses poses difficulties in terms of assessing WWTP removal efficacy and subsequent infectivity (da Silva et al. 2007; Hewitt et al. 2011; Sima et al. 2011; Flannery et al. 2012; Doré et al. 2013; McBride 2014). QMRAs based on noroviruses as a representative pathogen for human risk assessment have been conducted elsewhere in New Zealand, e.g., Napier and New Plymouth (McBride. 2011; McBride. 2012).[6] We assume that the removal of noroviruses through the WWTP will be at least as effective as that inferred for enteroviruses.

[4] This is not necessarily true for agricultural wastes in rural settings, where bacteria and protozoa predominate—with few exceptions (hepatitis E, some rotaviruses), animal viruses are not pathogenic to humans.

[5] "qPCR" refers to quantitative Polymerase Chain Reaction, a molecular laboratory test that essentially counts the number of virions in a sample, whether infectious or inactivated.

[6] "Norovirus" subsumes the term "Norwalk virus". The clinical trial reported and analysed by Teunis et al. (2008) was for the original Norwalk virus (genotype group GI.1)—it had been stored in a laboratory for some years. Since the time of the first identified norovirus outbreak (in Norwalk, Ohio, 1968) a number of similar caliciviruses have been identified, in genogroups I–V. Current practice is to regard the infectivity of GI.1 norovirus as equivalent to all noroviruses that affect humans (particularly GI and GII).

Norovirus may exist in two forms (clumped/aggregated or discrete/disaggregated), but information regarding which form the virus may take in the marine environment is not available. However, a relationship between dose-response and the form of the virus has been demonstrated, and different dose response models have been proposed for the different forms (Messner et al. 2014, McBride 2014).

Previous research into QMRA modelling e.g., McBride (2014) indicated that disaggregated norovirus creates a consistently greater illness risk than the aggregated form. In response, we have limited our consideration and discussion to illness risks arising from the disaggregated form (i.e., we have taken the more conservative approach) – this is consistent with previous QMRA practice (e.g., McBride 2016b).

Respiratory illness

To assess the risks of respiratory illness, adenovirus was selected as the candidate pathogen because adenovirus strains (e.g., type 4) can cause respiratory illness via inhalation of aerosols from contaminated water during recreational activities (D'Angelo et al. 1979). Its merits and drawbacks are listed in Table 2-1.

Table 2-1: Features of several candidate viruses for which dose-response information is available. GI = gastrointestinal infection, RI = respiratory infection.

Virus	Advantages	Disadvantages
GI - Enteroviruses	Can induce more serious long-term effects compared to other viruses ((Haas, C.N. et al. 1999), (DRG 2002), (Simpson et al. 2003)). Its inclusion is warranted given that it can cause more serious longer-term illnesses.[7]	Restricted to echovirus 12, the only enterovirus for which an infection dose-response relationship is available. Nevertheless, enterovirus by culture captures more than just echovirus, so, for example, would also capture coxsackie virus. Meaning of "dose" not clear, giving rise to two quite different infection ID_{50} values (54 and 1052).[8] See Appendix C.
GI - Norovirus	Reported to be the most common aetiological agent in receiving waters (e.g., (Sinclair et al. 2009)). Infection ID_{50} is in the order of 20 virions (among susceptible people), but the dose-response curve rises steeply from the origin, such that ~20% of people may become infected after ingestion of just one virion— see Figure B-1(b), emphasising that a precautionary approach should be taken when modelling this virus.	Efficacy of wastewater treatment in removing infectious noroviruses is difficult to establish. Restricted to Norwalk virus—norovirus genotype I.1. But note that an outbreak study (Thebault et al. 2013)identified other genotypes to be, if anything, at least as virulent. In the absence of results to the contrary, and taking an appropriate precautionary approach, noroviruses in treated wastewater are assumed to be not aggregated - were they to be aggregated, health risks would be lessened. May require a conversion from the PCR method used in the clinical trial (Lindesmith et al. 2003; Teunis et al. 2008), as described in McBride et al. (McBride 2013a).
GI - Rotavirus	Particularly affects children. The most infective virus for which published dose-response data is available. Has been used as a "model virus" in earlier QMRAs, for Army Bay (Palliser 2011), Snell's (Palliser and Pritchard 2012).	Not as prevalent in treated wastewater as noroviruses. Doses in the one available clinical trial (Ward et al. 1986) were measured in terms of "Focus Forming Units" (FFU), with the lowest "dose" set at 0.009 FFU. So FFU numbers need to be multiplied by an unknown factor to index doses of discrete virions (see the approach taken in a USA-wide study, (McBride et al. 2013a)). See section 2.1.3 for details.
GI - Hepatitis A	A serious illness. Dose-response function indicates virulence (infection ID_{50} = <2).	Present in very low numbers in treated wastewater relative to noroviruses.
GI - Coxsackie (an enterovirus)	May particularly affect children (Suptel 1963).	Studied by (Couch et al. 1965) for coxsackie A21 so restricted to respiratory illness response. Present in low numbers in treated wastewater. Dose-response function (Haas et al. 1999) indicates moderate virulence (infection ID_{50} = 48).
RI - Adenovirus	Found routinely in treated wastewater (DRG 2002, Simpson et al. 2003, Thompson et al. 2003, Hewitt et al. 2011). Very resistant to disinfection (is double stranded DNA). A common cause of gastrointestinal illness (especially the 40/41 complex). Can be applied to respiratory infections, and therefore be relevant for surfers and/or water-skiers.	Dose-response only for adenovirus 4, a respiratory aetiological agent. Haas et al. (1999) report fitting a single parameter exponential model to data reported by (Couch et al. 1966a) giving rise to an infection ID_{50} less than 2 virions. However, most adenoviruses are not respiratory agents. Applying the adenovirus 4 dose-response model to all adenoviruses for gastrointestinal illness appears to over-estimate the dose-response for that form of illness (we can expect more substantial response of the human body's defences to gastrointestinal infection compared to respiratory infection). Applying the model to only the respiratory portion of total adenoviruses requires assumptions about their proportional presence in treated wastewater ((Kundu et al. 2013). The latter authors also considered other studies by (Couch et al. 1966b; Couch et al. 1969).

[7] For example, coxsackie virus type B (an enterovirus) is now recognised as the most common viral aetiological agent associated with heart disease (Haas et al. 1999).

[8] Infection ID_{50} is a quantity derived from clinical trials of pathogen infectivity. It is the pathogen dose that would result in 50% of an exposed population becoming infected.

2.2 Assessing exposure

2.2.1 Predicting concentrations in the water

Fifteen sites (shown in Figure 2-1) were identified where risk assessment was required. All sites were used to assess risks associated with primary recreational water contact (swimming), secondary recreational water contact (boating and sailboarding etc.), and for shellfish collection.



Figure 2-1: Map indicating location of 15 sites used for exposure risk, as well as location of the wastewater discharge point. Table 2-2

Table 2-2: Site names and location details for 15 risk assessment sites (including the wastewater discharge). Site locations are shown in Figure 2-1.

Site Name	Longitude	Latitude
Outfall	173.3203	-41.2002
Cable Bay	173.4121	-41.1545
Glenduan	173.3625	-41.183
Snapper Point	173.3285	-41.198
900m SW Outfall	173.3152	-41.2074
Outside Boulder Bank	173.296	-41.2273
Tasman Bay	173.242	-41.2389
Akersten Street	173.2852	-41.2538
The Cut	173.2574	-41.262
Seafarers Memorial	173.2669	-41.265
Magazine Point	173.2577	-41.2737
Tahunanui Beach	173.249	-41.2758
Tasman Bay 2	173.3585	-41.1696
SW edge of mixing zone	173.3183	-41.2018
NE edge of mixing zone	173.3224	-41.1986

A hydrodynamic model was used to predict nominal virus concentration dilutions at each site for treated wastewater discharged from the existing diffuser offshore from the Nelson North wastewater treatment plant (WWTP). The discharge regime was described by MetOcean Solutions (2021). These simulations cover two years, taking account of El Niño and La Niña climate conditions, i.e., April 2010-May 2011, and April 2015-May 2016, respectively. Two wastewater discharge scenarios were modelled – current discharge rates, and a future discharge rate. The latter was 30% larger than the current day discharge rate, and was generated by multiplying current day daily discharge rates by 1.3.

The dilution estimates include the effect of mixing with receiving waters and loss either due to virus particles leaving the modelling domain or reaching an age of 40 days (MetOcean Solution 2021). They do not account for other forms of virus inactivation (such as via sunlight). This precautionary approach was taken to protect public health.

As noted earlier, six levels of treatment "log-removals" have been used (ranging from 1 – 6 $\log_{10}$), describing progressive reductions in virus concentration between the WWTP's influent and effluent, and which reflect the treatment performance range for the removal of adenovirus, enterovirus and norovirus for WWTP in New Zealand (Hewitt et al. 2011). Reductions are driven mainly by secondary treatment plant processes and during tertiary treatment by disinfection facilities (such as UV irradiation or advanced membrane filtration)

Data in Table 2-3 were derived from a large wastewater treatment plant. Information collated by Hewitt et al. (2011) demonstrates that considerable variability exists between small, medium and large WWTPs, and at a given WWTP over time.

Table 2-3: Summary of results of Mangere WWTP enterovirus and adenovirus monitoring. August 2002 to April 2016 for influent flows and for effluent from the BNR (prior to the UV dosing). Units are numbers of viruses per litre. From (Simpson et al. 2003).

Virus	Minimum	Median	95%ile	Maximum	Number of data
Influent: enterovirus	52	2 300	9 610	59 000	520
BNR effluent: enterovirus	0.02	0.5	6.5	39	214
Influent: adenovirus	16	1 020	3 670	7 200	241
BNR effluent: adenovirus	0.04	0.6	6.9	21	132

During the microbiological investigations undertaken in 1999-2000 for the upgrades proposed for the Mangere Wastewater Treatment Plant, substantially greater influent adenovirus and enterovirus concentrations were detected for some weeks. In particular, the Scoping Study component of that investigation (May and June 1999) revealed concentrations for both viruses in the period May-June 1999 that were up to 1,000 times larger than in the other component (the Surrogate Study, conducted from October 1999 to March 2000). The Scoping Study authors (Simpson et al. 2003) stated:

> *…anecdotal evidence of increased levels of viral infection in the community over the period of the Scoping Study. In the absence of appreciable infection in the community raw sewage virus concentrations are present at much lower concentrations.*

The data for the Scoping and Surrogate Studies are listed in Table A-1, and are summarised in Table 2-4.

Table 2-4: Summary statistics for the Mangere Scoping and Surrogate Studies. $TCID_{50}$ Median Tissue Culture Infectious Dose: A laboratory culture technique measuring the amount of virus that produces a cytopathic effect in 50% of cell.

Virus	Study	Virus concentration statistics ($TCID_{50}$/L)			
		Minimum	Median	95th percentile	Maximum
Adenoviruses	Scoping Study	18 200	1 072 000	28 275 000	31 200 000
	Surrogate Study	1 900	3 975	8 501	9 840
	Both Studies combined	1 900	1 072 000	28 275 000	31 200 000
Enteroviruses	Scoping Study	13 100	30 350	16 050 000	50 400 000
	Surrogate Study	400	2 565	5 238	8 220
	Both Studies combined	400	30 350	16 050 000	50 400 000

Because the Resource Management Act defines an “effect” to include a case of “of low probability which has a high potential impact” [RMA, section 3(e)], rare-but-substantial “outbreak” concentrations of enteric and respiratory viruses observed during the Mangere Scoping Study have been included in the QMRA analysis. This has been implemented by fitting a “hockey stick” distribution (McBride 2005a) to these data following appropriate parameterisation, as detailed in Table 2-5 (swimming and secondary contact models) and Table 2-6 (shellfish consumption model).

An important parameter of the hockey stick distribution is the breakpoint percentile (X_p). Typically, New Zealand QMRAs have set the hockey stick hinge at X_p=0.95 as an appropriate value given the usual lognormal distribution of microorganisms. However, after reanalysis of a larger virus dataset now available (including both the scoping and surrogate Mangere WWTP study concentration values), the hinge was set at X_p=0.99 for enteroviruses and adenoviruses to reflect the rarity of the observed extreme events of the Mangere Scoping study (Simpson et al. 2003) which have not been seen again.

This suggests a lower likelihood of these extreme events than in previous QMRAs. As norovirus was not part of the Mangere Scoping and Surrogate studies, this reanalysis had no impact on norovirus risk estimates (Stott and Wood 2022). Consequently the hinge value of X_p=0.95 was retained for norovirus.

2.2.2 Should secondary water uses consider risk from ingestion?

The exposure pathway for kiteboarders/windsurfers and kayakers in this QMRA includes only inhalation, not ingestion. Yet, these water activities can involve some regular immersion, i.e., primary contact. So, it may be thought that health effects on secondary water users should include gastrointestinal illness (as for primary contact) not just respiratory effects. However, overseas studies have shown that the ingestion rate for such secondary exposure is substantially lower than for swimming (e.g., the Chicago waterways secondary exposure study, Rijal et al. (2011)). In addition, although the duration of exposure was based on primary contact activities, those exposure times are considered representative of exposure times for all activities likely to lead to water contact. Therefore, this QMRA does not include gastrointestinal illness risk for secondary water contact.

2.2.2 Predicting doses

The pathogen dose that an individual is exposed to either via ingestion, inhalation or consumption of shellfish is an important part of the QMRA model, specifically for the pathogen dose-response models that are used to determine the probability of infection or illness.

To turn diluted wastewater virus concentrations into doses, the following information is required (see Figure 1-1):

1. influent virus concentrations,
2. wastewater treatment efficacy,
3. effluent dilution in the receiving environment,
4. volume water ingestion or inhalation by water users (including for child or adult receptors),
5. bioaccumulation factors (for shellfish), and
6. meal size (for shellfish consumption).

Details on the selection of the relevant factors and parameters, and how they have been modelled and enumerated are summarised in Table 2-5 and Table 2-6. As far as possible, the values used in this study take into account current knowledge. Therefore some input parameters may differ for that used in the earlier Bell Island QMRA (McBride 2017). For example the norovirus influent data was updated and brought into line with the work of Stott and Wood (2022).

The QMRA procedure can provide estimates of infection and illness risk for both adult and child receptors. For this QMRA, we have elected to base input distributions for exposure on child-related information, where known. Children behave differently from adults around water. For example, they swim more often, stay in the water longer, submerge their heads more often, and swallow more water than adults (Schets et al. 2011; Dufour et al. 2017). The choice of children as the receptor is a precautionary approach.

Estimates of water ingestion rates by swimmers—a key component of dose-calculation—were derived from a clinical trial conducted by (Dufour et al. 2006). Inhalation rates have been derived from Dorevitch et. al (2011), described previously by McBride, G. (2017).

To assess the risks due to consumption of raw harvested shellfish, a modelling approach was followed that related the concentration of viruses in seawater to the pathogen dose an individual would receive if they ate raw shellfish (McBride, 2017b). Estimates from the 1997 National Nutrition Survey (Russell et al. 1999; Parnell et al. 2001) were used to generate daily intake distributions of shellfish meal size. The pathogen dose ingested through the consumption of a shellfish meal that included bivalve molluscs was estimated by multiplying the meal size by a bioaccumulation factor (BAF) (Burkhardt and Calci 2000). This factor accounts for viruses accumulating in shellfish flesh, effectively concentrating the viruses from a plume of well-diluted treated wastewater into the shellfish flesh. It also assumes that pathogen concentrations in the water have persisted long enough for that degree of accumulation to occur. BAF data for eastern oysters in seawater were used for the QMRA model as described by Burkhardt and Calci (2000). These bioaccumulation factors varied by season – we used the maximum values derived from the study in this QMRA in accordance with the precautionary approach, consistent with the approach of McBride (2016).

Table 2-5: Distributions and inputs for the QMRA – swimming and secondary contact models.

Component	Statistic/parameter		Distributions/comments
Influent virus concentration			Bounded "hockey stick" distribution (McBride 2005a), strongly right-skewed.
Influent enterovirus concentration, per litre	Minimum	$2x10^1$	Typical values reported for wastewater in New Zealand. High values found for Mangere influent in a "scoping study" May-Jul 1999 (DRG, 2002, Table B1).
	Median	$2x10^3$	
	Maximum	$1x10^7$	
Hockey stick, Enterovirus, Xp, unitless		0.99	See section 2.2.1
Influent adenovirus concentration, infectious units per litre	Minimum	$2x10^1$	Rationale as above.
	Median	$1x10^3$	
	Maximum	$1x10^7$	
Hockey stick, Adenovirus, Xp unitless		0.99	See section 2.2.1
Proportion of Adenovirus causing respiratory effects, unitless		0.1	10% of adenovirus concentration assumed infectious for respiratory illness effects (Fong et al. 2010).
Influent norovirus concentration, genome copies per litre	Minimum	$1x10^3$	Typical range found for New Zealand cities (e.g., Napier, New Plymouth—(McBride, G.B. 2011; McBride, G.B. 2012; McBride, G. 2016a).
	Median	$1x10^5$	
	Maximum	$1x10^7$	
Hockey stick, Norovirus, Xp unitless		0.95	See section 2.2.1
Method harmonisation factor for Norovirus, Unitless		18.5	Dose response method and current monitoring methods use RT-qPCR methodology but on different genetic target sequences with differences in critical threshold standard curves (McBride, et al. 2013a). Virions more effectively detected by current PCR methods so clinical trial data divided by harmonisation factor
Wastewater treatment efficacy, Log_{10} virus reduction	Unitless	1 - 6	Six log orders

Component	Statistic/parameter		Distributions/comments
Exposure parameters and inputs			
Duration of swim (hours)	Minimum	0.2	Child
	Mode	1	
	Maximum	4	
Swimmers water ingestion rate, mL per hour	Minimum	5	Truncated lognormal distribution (ESR 2016), (Table 19); (Dufour et al. 2017) for children (<16 yr). The minimum value was set at 5 mL/h, an ingestion rate equivalent to one tablespoon of seawater per hour. This estimation of the minimum value took into account information from ESR (2021), which evaluated the raw data from Dufour et al (2017) and the observation that ingestion rates appear to be greater than inhalation rate, so the minimum value was set to be greater than the minimum inhalation rate of Dorevitch et al. (2011)..
	Mean	53	
	Std	75	
	Maximum	250	
Swimmers water inhalation rate, mL per hour	Minimum	4	PERT distribution. (Dorevitch et al. 2011), Table 6); incidental "ingestion" during secondary contact and walking. Assume child rates twice that of adult.
	Median	10	
	Maximum	40	
Dose-response			
Probability infection Adenovirus per exposure event	rAdV	0.4142	Simple binomial (for individual doses, i). The dose response model for pulmonary infection caused by Adenovirus 4, (Haas,. et al. 1999) (Table 9-15). ID_{50} infection ~ 2
Probability infection Echovirus 12- per exposure event	αEnv	1.3	Beta-binomial (for individual doses, i). (Haas 1983)[9] ID_{50} infection =53
	βEnv	75	
Probability infection Norovirus G^{I}[10] per exposure event (disaggregated)	αNoV	0.04	Beta-binomial (for individual doses, i). (Teuniset al. 2008), Table III, 8fII1+8fIIb, no aggregation. ID_{50} infection =26
	βNoV	0.055	
Probability infection Norovirus GI per exposure event (aggregated)		1 106	Fractional Poisson (Messner et al. 2014), Table IV),
Mean NoV aggregate size (μm)			

[9] Although single parameter exponential models are available (Haas et al. 1999), the varying virulence by enterovirus species and observation that enterovirus illness can give rise to more serious consequences (i.e., sequelae) influenced the selection of the double parameter Beta-Poisson to allow for greater uncertainty in estimated probabilities of infection than would using a constant r value for the exponential formula. Parameter values used (α = 1.3 and β = 75, with infection ID_{50} = 53 virions, Haas 1983) conflicts with the values approach suggested by the CAMRA website (α = 1.06 and β = 171.3; infection ID_{50} = 922). However, comparison of dose-response functions for other members of the enterovirus group (e.g., poliovirus, hepatitis A, coxsackie) indicate that an ID_{50} of around 50 is more reasonable than around 1000.

[10] The dose response for norovirus often used in QMRAs is for NoV GI. Both genotypes NoV GI and NoV GII are found in wastewater and a model has recently been proposed for NoV GII by Teunis el a. (2020) but the application of this dose-response model is less certain. This study also compared NoV genotype challenge studies and outbreaks reporting that the infectivity of NoV GI is higher than NoV GII. We have considered that all noroviruses have similar infectivity as NoV GI as a conservative assumption.

Component	Statistic/parameter		Distributions/comments
Fraction of secretor-positive individuals (susceptible to NoV infection), unitless		0.72	Teunis, P.F.M. et al. (2008)
Conditional probability of illness given infection (Adenovirus), unitless		0.5	Pr(ill|Inf) AdV.: (Soller et al. 2010)
Conditional probability of illness given infection (Enterovirus), unitless		0.5	Pr(ill|Inf) Ent: assumed for ingestion (Rose and Sobsey, 1993; McBride, Graham B. et al. 2013b)
Conditional probability of illness given infection (Norovirus)[11], unitless		0.6	Pr (ill|Inf) NoV: (Soller et al. 2010), Table 1.

Table 2-6: Distributions and inputs for the QMRA – Shellfish ingestion models.

Component	Statistic/parameter		Distributions/comments
Shellfish meal size, g	α	2.2046	Using a log logistic distribution, truncated below at 5 g and above at 800 g, from bivalve mollusc consumption data from (Parnell et al. 2001), (McBride, G 2005)).
	β	75.072	
	γ	–0.903	
Bioaccumulation factor, ratio	Mean	49.9	Using normal distributions, truncated at 1 and 100. The pathogen dose ingested on eating 100 grams of shellfish is BAF x the number of pathogens in the equivalent volume of water (Burkhardt and Calci 2000). The chosen factors are for F^+ coliphage in winter. The use of a normal distribution for BAFs allows half of these factors to be below 50 yet retain a precautionary approach.
	Std. dev.	20.93	

[a] Those high values, persisting for over a month, have not been seen in subsequent Mangere influent virus assays. Yet were they to recur during an undetected outbreak in the contributing community, one could expect elevated illness risk.

[11] Teunis et al. 2008 predict substantial illness probabilities (among the infected) only at very high doses. As a precautionary measure, this QMRA assumes that the conditional probability of illness given infection is independent of dose, and constant at 0.6 and that the pathogenicity for NoV GI and NoV GII is approximately equal at a given dose (Teunis et al. 2020).

2.3 Characterising dose-response

These relationships are mostly inferred from data reported by clinical trials.. Occasionally data from viral illness outbreaks have been available from which dose-response information can be inferred (Thebault et al 2013). McBride (2017) describes how these relationships are derived in detail, providing a discussion of the special case of enteroviruses (via a clinical trial on echovirus). In some cases, comparability is required between the definition of "dose" used in the clinical trial or outbreak study and the methods used in assessing virus concentrations in treated wastewater such as for norovirus. . This was accounted for in the dose-response model used in the QMRA as explained in Table 2-5.

2.4 Risk characterisation

To adequately reflect limits to knowledge on key features of the risk assessment, Monte Carlo statistical modelling is used (Haas et al. 1999, McBride 2005a). In simpler models, key inputs are described by a single number (e.g., WWTP influent pathogen concentration). However, such inputs are known to be variable, and some are uncertain. This variability and uncertainty has been addressed as shown in Table 2-5 and Table 2-6. The proprietary Excel plug-in product "@RISK" has been used to perform the calculations, incorporating factors that reflect these distributions and inputs (Palisade Corp 2013).[12]

The results are reported in terms of illness, and this aligns with the New Zealand Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MfE/MoH 2003), where the guideline's values are based on illness for marine recreational waters. However, freshwater recreation values are based on infection. For completeness, infection risk estimates are provided in Appendix C, Appendix D and Appendix E.

The dose-response models used in this QMRA estimate infection as the health outcome. However, not all infected individuals become ill. A conditional probability factor is used to determine the likelihood an individual will become ill if they are infected. These factors are presented in Table 2-5 for Norovirus, Adenovirus and enterovirus.

Finally, note that the results obtained are for attributable risk, i.e., the increment in risk associated with the discharge from the Nelson North WWTP only. It does not encompass risks associated with stormwater runoff or overflows as other potential sources of faecal pathogens.

A summary of the QMRA scenarios and conditions modelled for the assessment of potential health risks from the discharge of treated wastewater from Nelson WWTP is shown in Table 2-7.

[12] The @RISK models use named cells as much as possible, to facilitate checking and readability.

Table 2-7: Summary of scenario, pathogen and wastewater treatment and discharge conditions.

Variable	Number	Details
Number of exposure sites	15	See table 2-2
Number of pathogen ingestion scenarios	5	Three for swimming (ingestion- norovirus aggregated/disaggregated and enterovirus) one for shellfish (ingestion-norovirus disaggregated) and one for secondary contact (inhalation – adenovirus)
Number of model pathogens	3	Norovirus (ingestion during swimming (in aggregated and disaggregated form), and shellfish consumption(disaggregated only)), enterovirus (ingestion during swimming), and adenovirus (inhalation during secondary contact with water, e.g., during boating, surfing)
Number of discharge conditions	2	Current day discharge, future discharge conditions (represented as 1.3 times current day discharge rates). Details provided in the hydrodynamic modelling report (MetOcean Solutions 2021)
Number of climate-forcing conditions	2	El Niño and La Niña conditions
Levels of wastewater treatment	6	Six orders of $\log_{10}$ reductions in pathogen concentrations
Health risk outcomes	2	Infection and illness

3 Results

Regardless of discharge, climate conditions or level of wastewater treatment, the risk of swimming and shellfish contamination at any site was found to be highest for norovirus in its disaggregated form and lowest for norovirus in its aggregated form. Enterovirus risks were neither as high as disaggregated norovirus nor as low as aggregated norovirus risk estimates. Risk estimates for norovirus (disaggregated and aggregated forms) and enterovirus are shown for the swimming exposure route. To reduce the volume of data and the number of tables, shellfish risks are shown only for norovirus in its disaggregated form. This also reflects norovirus as a pathogen of primary concern based on NZ BMS (Bivalve Molluscan Shellfish) monitoring studies that have identified the presence of the virus in recreationally harvested shellfish (Hewitt et al. 2019).

3.1 Assessment of dilution data

MetOcean Solutions provided wastewater dilution data. The hydrodynamic model setup and outputs were described in MetOcean Solutions (2021, 2022). MetOcean provided timeseries of predicted concentrations and dilutions of treated wastewater at hourly timesteps for key sites in the receiving environment (Table 2-2 and Figure 2-1). Dilution data were calculated from relative concentration data as the reciprocal of concentration. This provides dilution as a unitless ratio. The dilution data were investigated prior to the QMRA modelling, as described below.

Dilution data for surface and near seabed waters were provided for each site. Each site has a range of estimated dilution values, as illustrated in Figure 3-2 for two of the 15 sites; the dilution values were similar but differed between surface and near-seabed values).

At the Outfall, the dilution values ranged from 68 to 1.9 x 10^{10} and at Akersten Street dilution values ranged from 1910 to 8.9 x 10^{22}. The median dilution values at the surface under future discharge and La Niña conditions were 976 and 157,000 at the Outfall and Akersten Street sites, respectively.

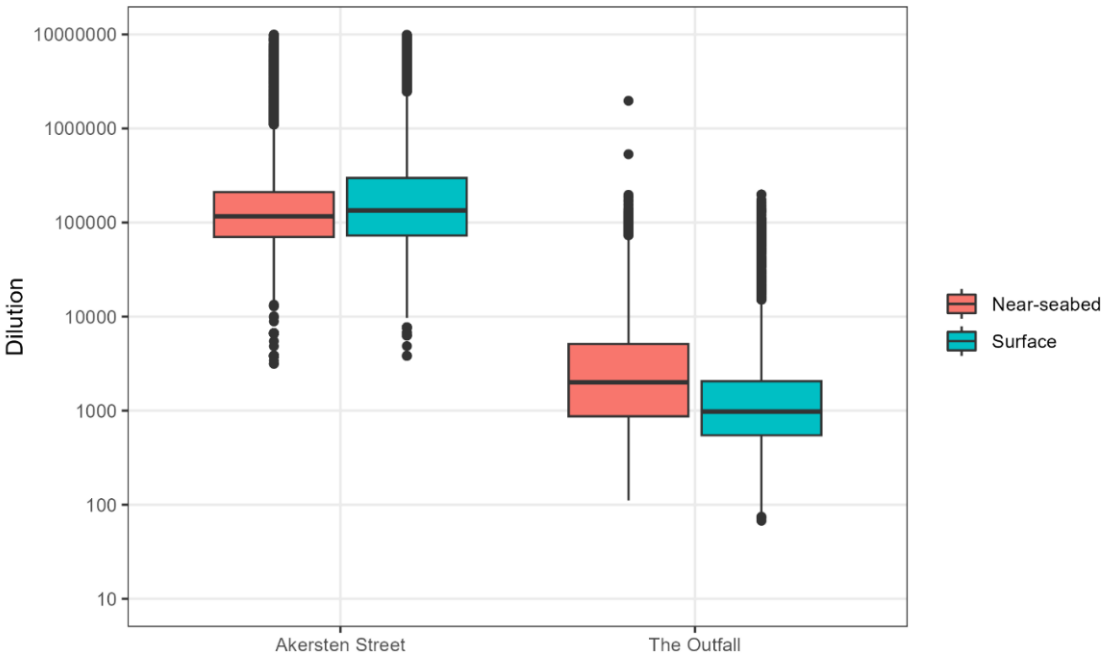


Figure 3-1: Box plot of the dilutions at two sites Akersten Street and the Outfall for near-seabed and the surface. Note the distribution has been truncated at 10,000,000.

Near-seabed dilution values were used to estimate risk arising from shellfish consumption, whilst surface values were used to assess recreational risks arising from primary contact (swimming) and secondary contact (inhalation). When comparing dilution values at the same time and climate and discharge conditions, the surface and near-seabed dilution values were of the same magnitude but differing by factors of up to three (when we consider dilutions of 1,000,000 or less). Close to the Outfall, dilutions near-seabed were, on average, twice that of the surface (more dilute). In contrast, at other sites as Glenduan, Magazine Point, and Tasman Bay, surface dilutions were up to three times greater than near-seabed values.

Future discharge conditions are predicted to lead to lower dilutions than the current discharge conditions. In addition, the climate was predicted to have an impact on dilution. However, neither climate nor discharge conditions were predicted to fundamentally change the underlying dilution distributions, or cause changes to current dilution estimates likely to alter predicted health risks substantially, as illustrated later in the report (see Figure 4-1).

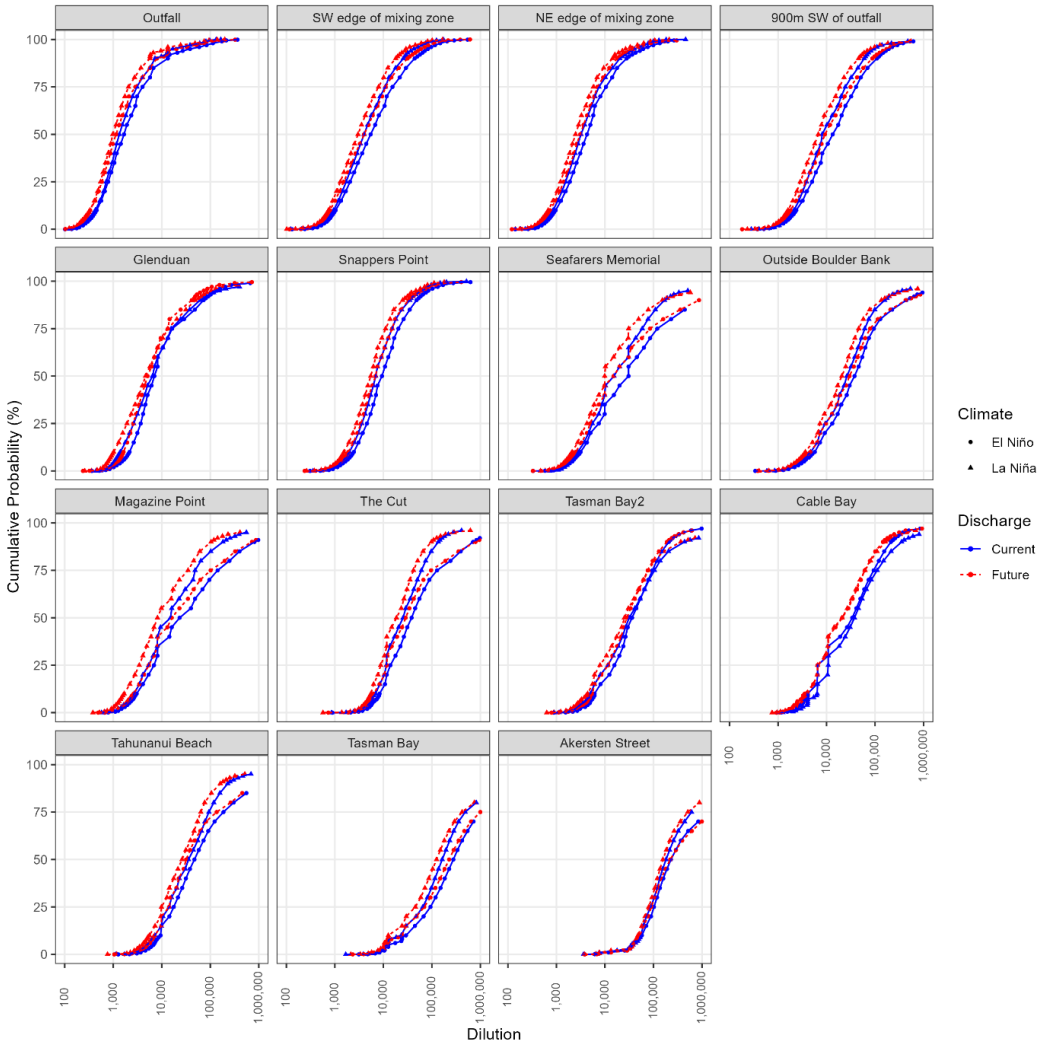


Figure 3-2: Empirical cumulative density distributions of dilution estimates of treated wastewater at the surface for 15 sites. Dilution estimates come from two climate conditions and two discharge conditions (current and future).

A different approach to estimating dilution distributions was used in the report of Hudson and Wood (2023) and the differences are discussed in Appendix B.

3.2 Estimated risks

The modelling generated many results due to the number of exposure sites, ingestion routes, model pathogens, discharge and climatic conditions defined in Table 2-7. In total, 3600 discrete risk estimates were generated from this combination of permutations. Selected, detailed results are given in Appendix C (Primary contact recreation), Appendix D (Secondary contact recreation) and Appendix E (Shellfish consumption) for infection and illness risk estimates.

Viral gastrointestinal (via ingestion) and respiratory (via inhalation) Individual Illness risk (IIR) estimates are presented graphically for:

- primary contact: Gastrointestinal illness (GI) risk in Figure 3-3, Figure 3-4, Figure 3-5 and Figure 3-6,
- secondary contact: Respiratory illness (AFRI) risk in Figure 3-7, and
- shellfish consumption: Gastrointestinal illness risk in Figure 3-8.

Examples of these data are presented in Figure 3-9, Figure 3-10 and Figure 3-11 to illustrate the distribution of risk spatially. The Log Reduction Value (LRV) is measure of the reduction of viruses between the influent and effluent in log base 10 and is an estimate of treatment efficiacy.

In Figure 3-3 through Figure 3-8,the predicted risks are presented as average Individual Illness Risk (IIR) expressed as a percentage. Also shown for comparison are illness risk thresholds for saline waters defined in the "Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas" (MfE/MoH 2003). The NZ risk thresholds differentiate between risks due to gastrointestinal illness (GI) or acute febrile respiratory illness (AFRI).

For GI illness resulting from the ingestion of contaminated water or shellfish harvested from impacted sites, risk thresholds apply for <1% ("no observable adverse effects level" NOAEL), 1-5% (low illness risk), 5-10% (moderate illness risk) or >10% (high illness risk). In the absence of risk thresholds for the consumption of raw shellfish, the same GI risk thresholds have been applied as for primary contact.

For respiratory illness due to inhalation of aerosolised pathogens from contaminated water at impacted sites, risk thresholds are comparatively lower and relate to <0.3% (NOAEL), 0-3-1.9% (low illness risk), 1.9-3.9% (moderate illness risk), and >3.9% (high illness risk).

Note that the terms "low", "moderate" and high" illness risk are used exclusively in a relative manner to allow comparison. They do not imply "acceptability" of a health risk or "tolerable health risk".

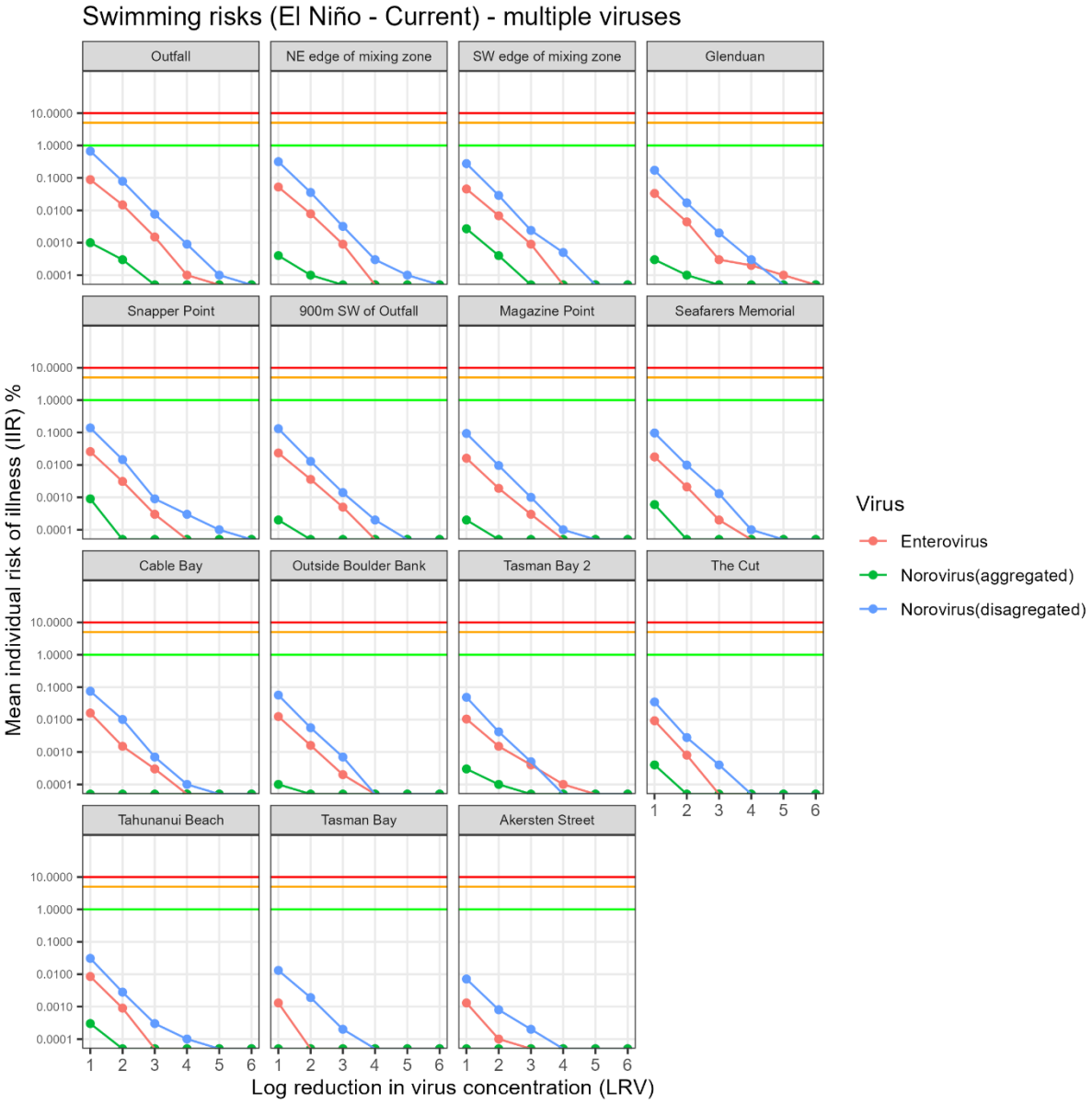


Figure 3-3: Summary of average illness risk estimates for swimmers, El Niño and existing discharge conditions, given six levels of wastewater treatment. Full scenario description: Average Individual illness risk (IIR%) , swimming exposure, norovirus (aggregated and disaggregated forms), enterovirus, El Niño and existing discharge conditions. Note *y*-axis has $\log_{10}$ scale. The red, orange and green horizontal lines represent GI illness risk thresholds in the "Microbiological Water Quality Guidelines" (MfE/MoH 2003) summarised in Table 4-1.

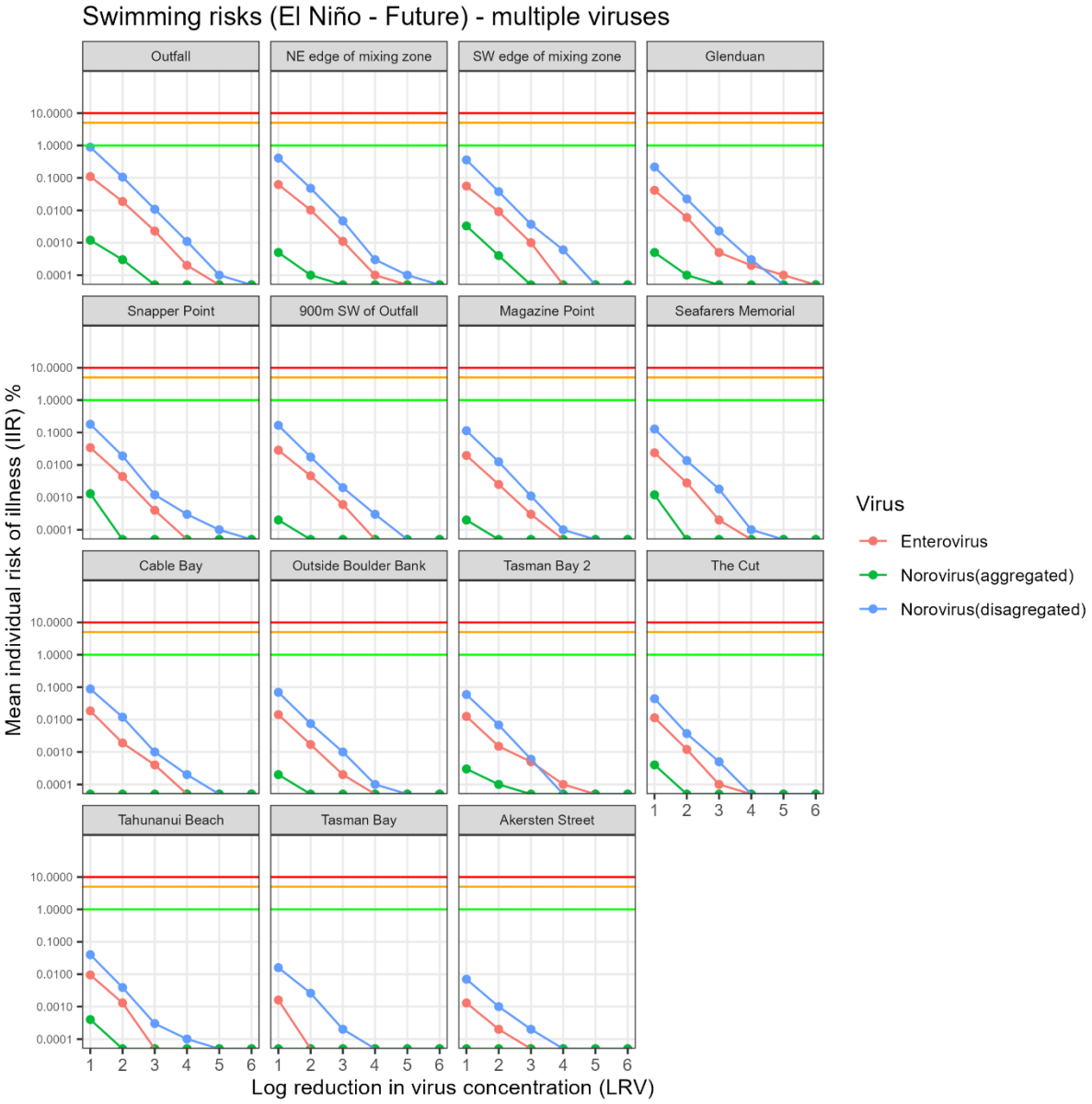


Figure 3-4: Summary of average illness risk estimates for swimmers, El Niño and future discharge conditions, given six levels of wastewater treatment. Full scenario description: Average illness risk, swimming exposure, norovirus (aggregated and disaggregated forms), enterovirus, El Niño and future discharge conditions. Note *y*-axis has $\log_{10}$ scale. The red, orange and green horizontal lines represent GI illness risk thresholds in the "Microbiological Water Quality Guidelines" (MfE/MoH 2003) summarised in Table 4-1.

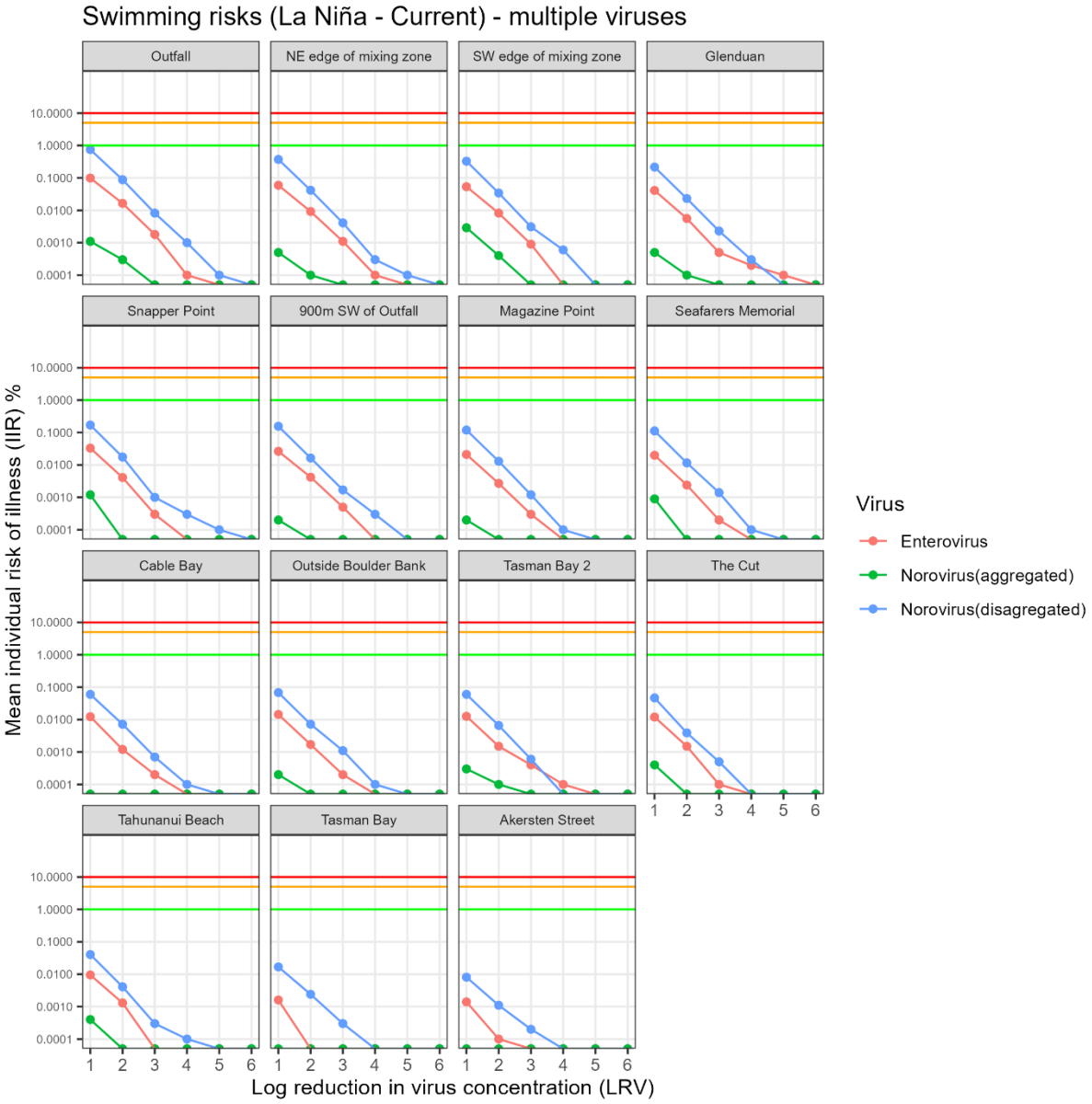


Figure 3-5: Summary of average illness risk estimates for swimmers, La Niña and existing discharge conditions, given six levels of wastewater treatment. Full scenario description: Average illness risk, swimming exposure, norovirus (aggregated and disaggregated forms), enterovirus, La Niña and future discharge conditions. Note *y*-axis has $\log_{10}$ scale. The red, orange and green horizontal lines represent GI illness risk thresholds in the "Microbiological Water Quality Guidelines" (MfE/MoH 2003) summarised in Table 4-1.

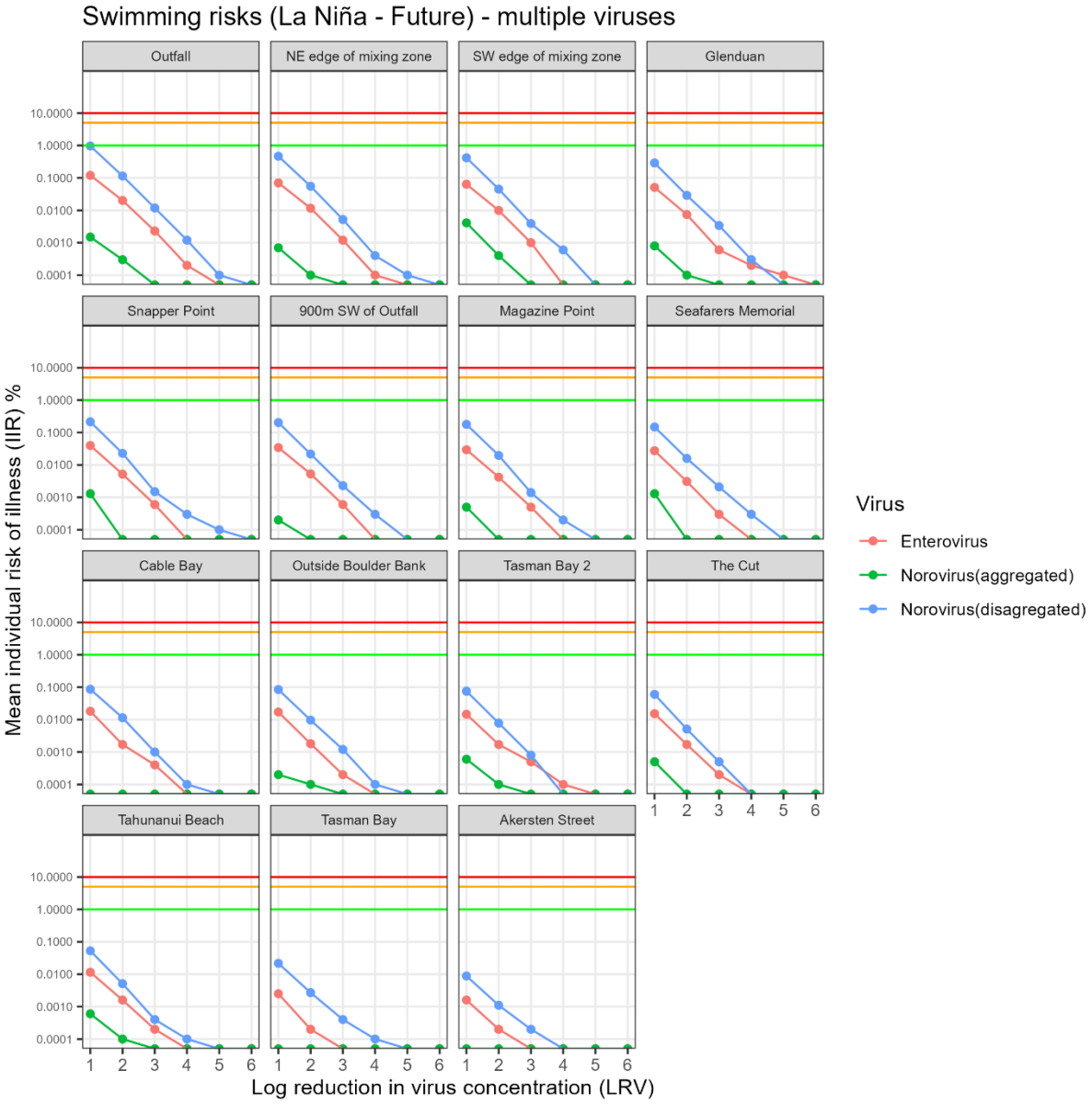


Figure 3-6: Summary of average illness risk estimates for swimmers, La Niña and future discharge conditions, given six levels of wastewater treatment. Full scenario description: Average illness risk, swimming exposure, norovirus (aggregated and disaggregated forms), enterovirus, La Niña and future discharge conditions. Note *y*-axis has $\log_{10}$ scale. The red, orange and green horizontal lines represent GI illness risk thresholds in the "Microbiological Water Quality Guidelines" (MfE/MoH 2003) summarised in Table 4-1.

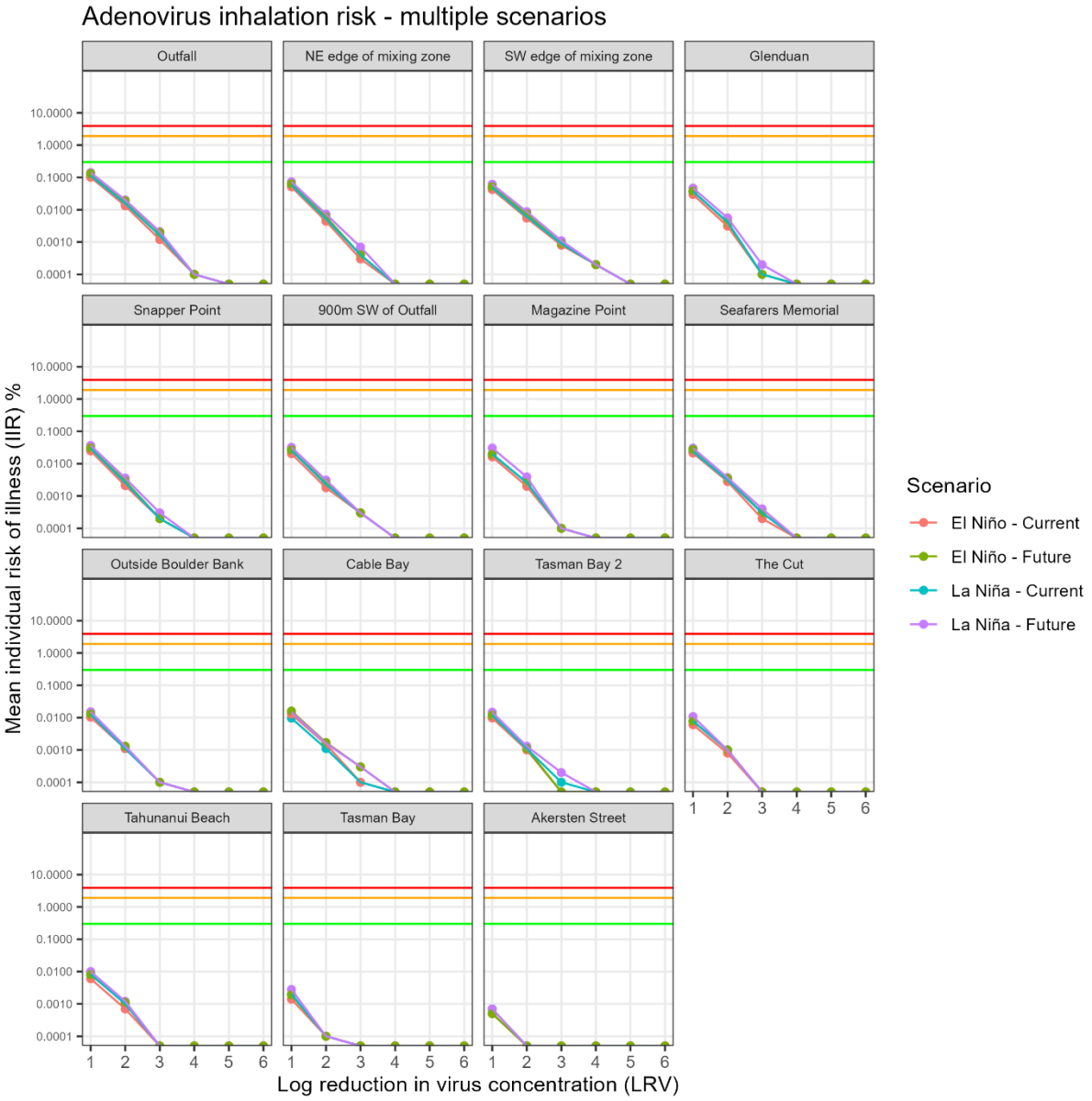


Figure 3-7: Summary of average illness risk estimates for secondary recreation, inhalation exposure given six levels of wastewater treatment. Full scenario description: Average illness risk, inhalation exposure during secondary recreation, adenovirus, El Niño , La Niña and existing and future discharge conditions. Note *y*-axis has $\log_{10}$ scale. The red, orange and green horizontal lines represent AFRI illness risk thresholds in the "Microbiological Water Quality Guidelines" (MfE/MoH 2003) summarised in Table 4-1. Estimates of IIR less than 0.0001 cannot be calculated by the model.

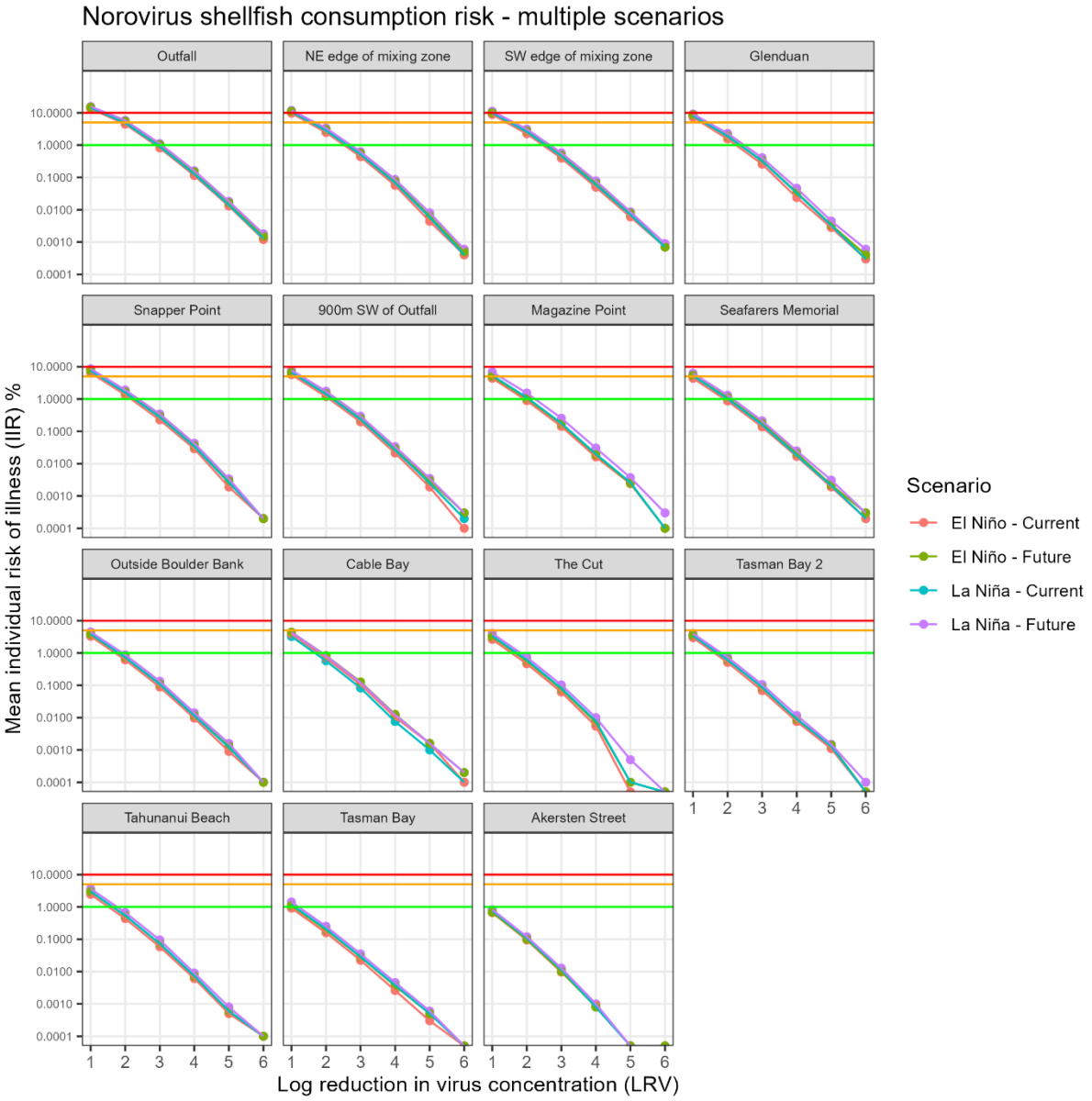
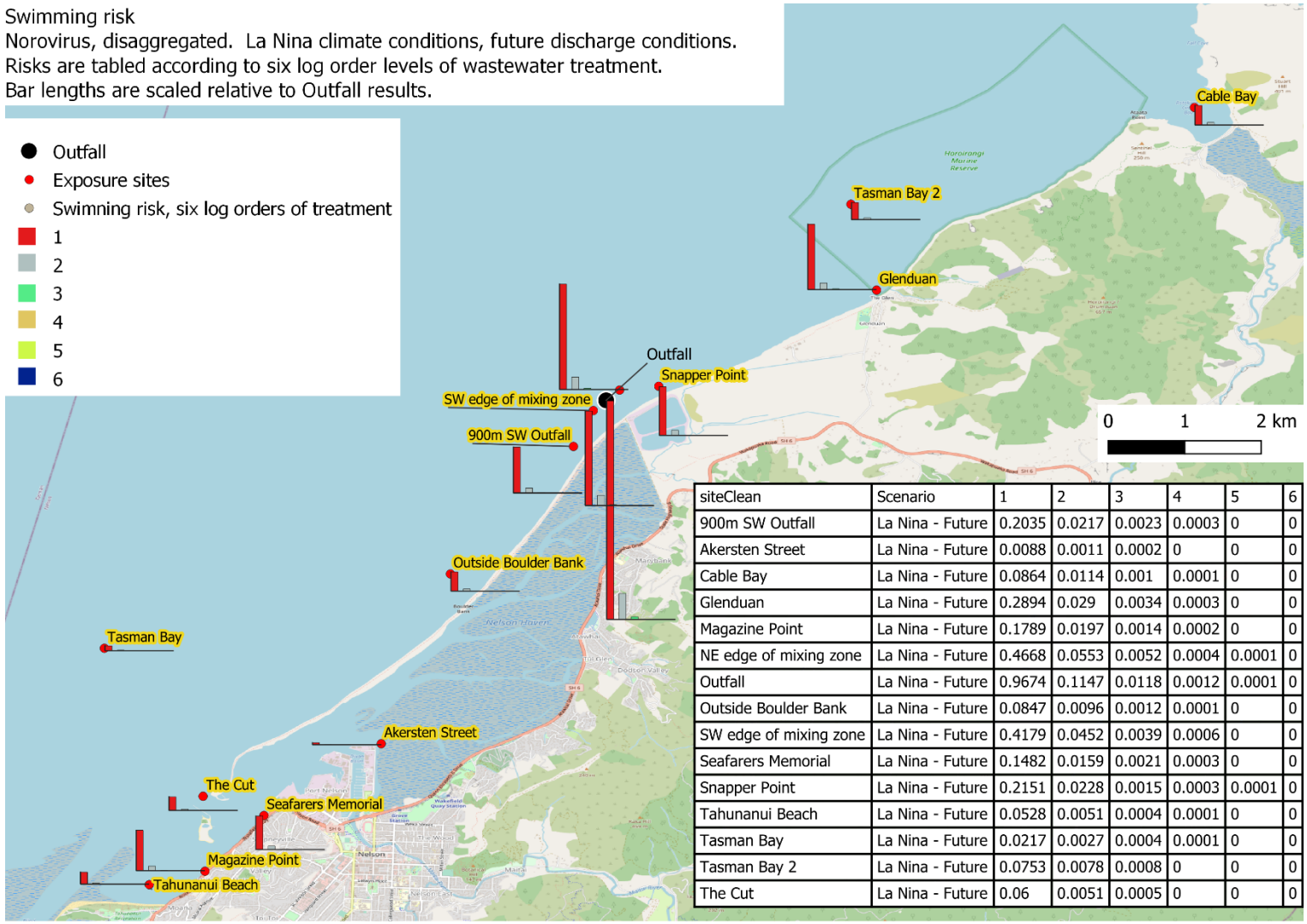
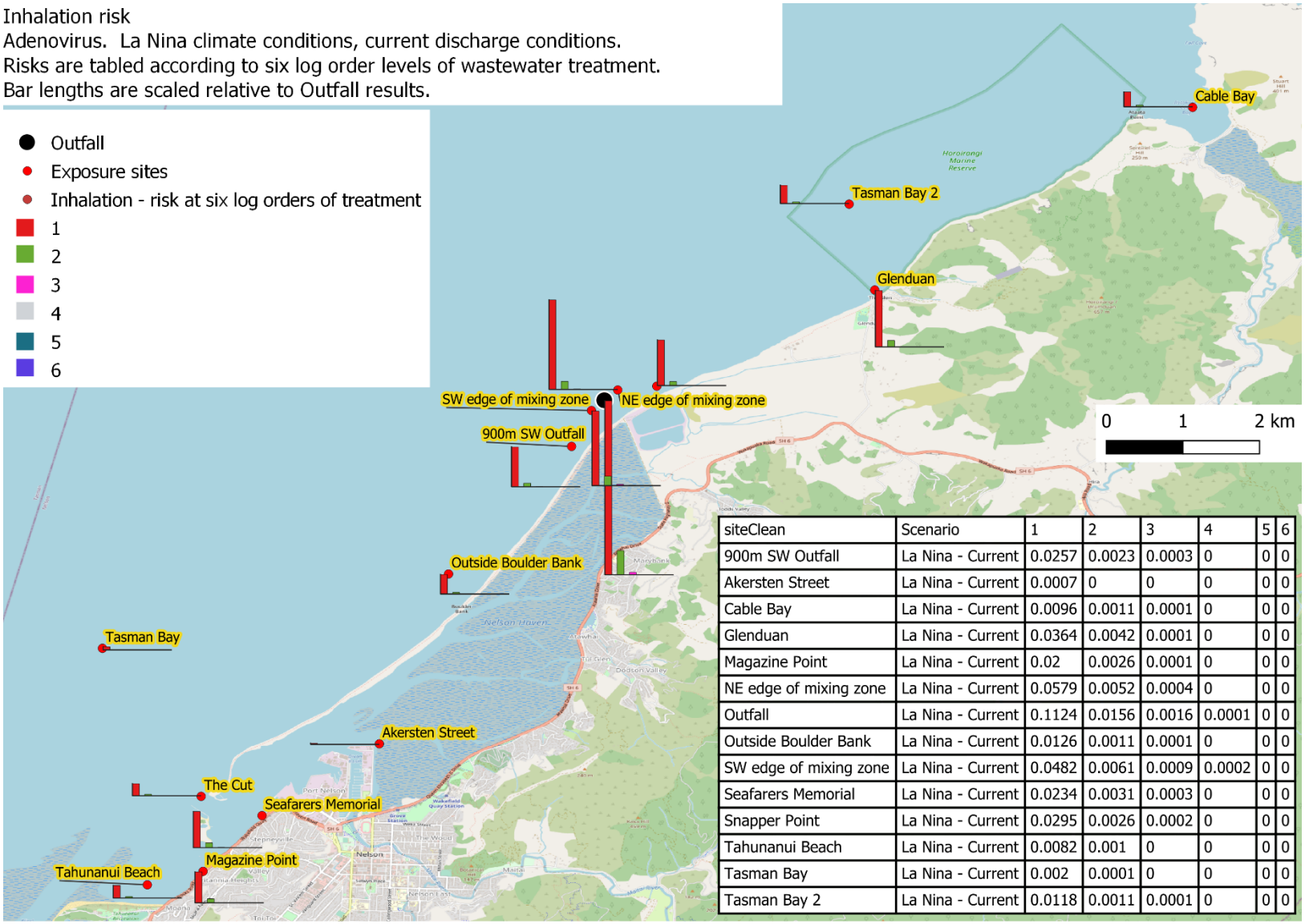


Figure 3-8: Summary of average illness risk estimates for consumers of shellfish gathered in waters exposed to treated wastewater, given six levels of wastewater treatment. Full scenario description: Average illness risk, shellfish consumption exposure norovirus, El Niño , La Niña and existing and future discharge conditions. Note *y*-axis has $\log_{10}$ scale. The red, orange and green horizontal lines represent GI illness risk thresholds in the "Microbiological Water Quality Guidelines" (MfE/MoH 2003), summarised in Table 4-1, and are indicative.



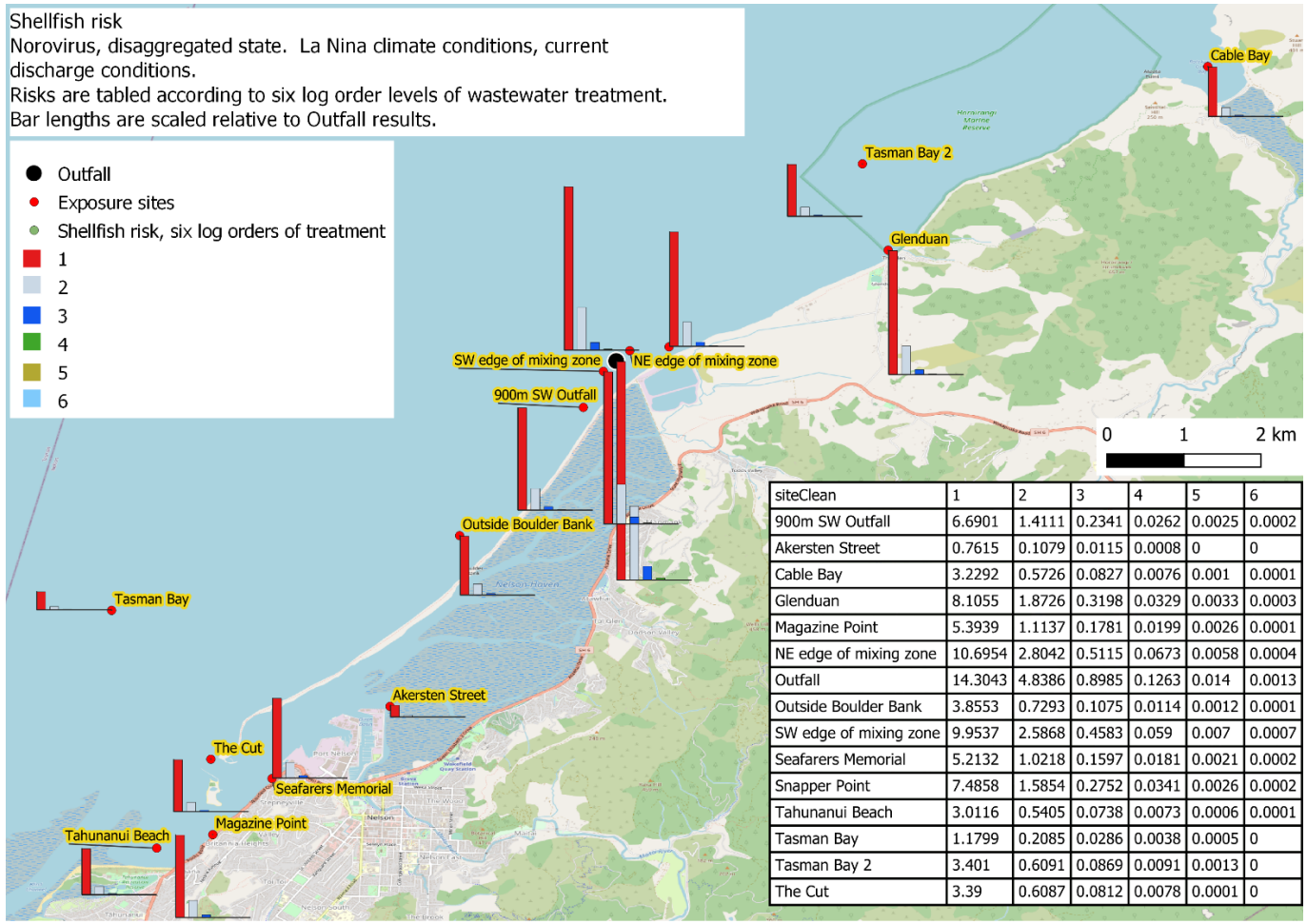
siteClean	Scenario	1	2	3	4	5	6
900m SW Outfall	La Nina - Future	0.2035	0.0217	0.0023	0.0003	0	0
Akersten Street	La Nina - Future	0.0088	0.0011	0.0002	0	0	0
Cable Bay	La Nina - Future	0.0864	0.0114	0.001	0.0001	0	0
Glenduan	La Nina - Future	0.2894	0.029	0.0034	0.0003	0	0
Magazine Point	La Nina - Future	0.1789	0.0197	0.0014	0.0002	0	0
NE edge of mixing zone	La Nina - Future	0.4668	0.0553	0.0052	0.0004	0.0001	0
Outfall	La Nina - Future	0.9674	0.1147	0.0118	0.0012	0.0001	0
Outside Boulder Bank	La Nina - Future	0.0847	0.0096	0.0012	0.0001	0	0
SW edge of mixing zone	La Nina - Future	0.4179	0.0452	0.0039	0.0006	0	0
Seafarers Memorial	La Nina - Future	0.1482	0.0159	0.0021	0.0003	0	0
Snapper Point	La Nina - Future	0.2151	0.0228	0.0015	0.0003	0.0001	0
Tahunanui Beach	La Nina - Future	0.0528	0.0051	0.0004	0.0001	0	0
Tasman Bay	La Nina - Future	0.0217	0.0027	0.0004	0.0001	0	0
Tasman Bay 2	La Nina - Future	0.0753	0.0078	0.0008	0	0	0
The Cut	La Nina - Future	0.06	0.0051	0.0005	0	0	0

Figure 3-9: Spatial display of average GI illness risk estimates for swimmers in waters exposed to diluted treated wastewater, given six levels of wastewater treatment. Full scenario description: Average Individual illness risk (IIR%), swimming exposure, norovirus (disaggregated state), La Niña and future discharge conditions. Note scaling of bar as indicated in text box above.



siteClean	Scenario	1	2	3	4	5	6
900m SW Outfall	La Nina - Current	0.0257	0.0023	0.0003	0	0	0
Akersten Street	La Nina - Current	0.0007	0	0	0	0	0
Cable Bay	La Nina - Current	0.0096	0.0011	0.0001	0	0	0
Glenduan	La Nina - Current	0.0364	0.0042	0.0001	0	0	0
Magazine Point	La Nina - Current	0.02	0.0026	0.0001	0	0	0
NE edge of mixing zone	La Nina - Current	0.0579	0.0052	0.0004	0	0	0
Outfall	La Nina - Current	0.1124	0.0156	0.0016	0.0001	0	0
Outside Boulder Bank	La Nina - Current	0.0126	0.0011	0.0001	0	0	0
SW edge of mixing zone	La Nina - Current	0.0482	0.0061	0.0009	0.0002	0	0
Seafarers Memorial	La Nina - Current	0.0234	0.0031	0.0003	0	0	0
Snapper Point	La Nina - Current	0.0295	0.0026	0.0002	0	0	0
Tahunanui Beach	La Nina - Current	0.0082	0.001	0	0	0	0
Tasman Bay	La Nina - Current	0.002	0.0001	0	0	0	0
Tasman Bay 2	La Nina - Current	0.0118	0.0011	0.0001	0	0	0

Figure 3-10: Spatial display of average respiratory illness risk estimates for individuals engaged in secondary recreation in waters exposed to treated wastewater, given six levels of wastewater treatment. Full scenario description: Average Individual illness risk (IIR%), secondary exposure, adenovirus, La Niña and existing discharge conditions. Note scaling of bar as indicated in text box above.



siteClean	1	2	3	4	5	6
900m SW Outfall	6.6901	1.4111	0.2341	0.0262	0.0025	0.0002
Akersten Street	0.7615	0.1079	0.0115	0.0008	0	0
Cable Bay	3.2292	0.5726	0.0827	0.0076	0.001	0.0001
Glenduan	8.1055	1.8726	0.3198	0.0329	0.0033	0.0003
Magazine Point	5.3939	1.1137	0.1781	0.0199	0.0026	0.0001
NE edge of mixing zone	10.6954	2.8042	0.5115	0.0673	0.0058	0.0004
Outfall	14.3043	4.8386	0.8985	0.1263	0.014	0.0013
Outside Boulder Bank	3.8553	0.7293	0.1075	0.0114	0.0012	0.0001
SW edge of mixing zone	9.9537	2.5868	0.4583	0.059	0.007	0.0007
Seafarers Memorial	5.2132	1.0218	0.1597	0.0181	0.0021	0.0002
Snapper Point	7.4858	1.5854	0.2752	0.0341	0.0026	0.0002
Tahunanui Beach	3.0116	0.5405	0.0738	0.0073	0.0006	0.0001
Tasman Bay	1.1799	0.2085	0.0286	0.0038	0.0005	0
Tasman Bay 2	3.401	0.6091	0.0869	0.0091	0.0013	0
The Cut	3.39	0.6087	0.0812	0.0078	0.0001	0

Figure 3-11: Spatial display of average gastrointestinal illness risk estimates for individuals consuming shellfish from waters exposed to treated wastewater, given six levels of wastewater treatment. Full scenario description: Average individual illness risk (IIR%) , shellfish consumption, Norovirus, La Niña and existing discharge conditions. Note scaling of bar as indicated in text box above.

4 Discussion

The results presented in the tables in Appendix C, D and E contain several statistics that create a "health risk" index. These include:

- The IIR% – the average Individual's Illness Risk, expressed as a percentage.
  - The IIR(%) is the typical risk faced by any person exposed to waters potentially containing diluted, treated wastewater or consuming shellfish gathered in these waters, on any random day, with no prior knowledge of microbial conditions in the water.
- The 95% illness risk.
  - The 95%ile, together with the IIR, indicates the spread in risks. Estimated risks will be higher on some days than others. Without prior knowledge of microbial conditions in the water, it is impossible to precisely estimate an individual's actual risk on a given day. Ninety-five percent of the time, we expect the risk to be equal or lower than the 95%ile, and over the longer term, the average risk an individual will face per exposure is given by the IIR.

The risk thresholds in Table H1 of the "Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas"(MfE/MoH 2003) assist in understanding and interpreting reported risk estimates and to determine what an "acceptable risk" might be.

These risk thresholds relate measured faecal indicator organism concentrations (enterococci in the case of marine waters) to illness risk thresholds for gastrointestinal illness or acute febrile respiratory illness arising based on epidemiological studies[13] for exposure to contaminated marine waters.

The marine microbiological guideline values and associated risk thresholds from Table H1 are shown in Table 4-1. The same risk thresholds can be used to identify the level of wastewater treatment (in terms of $\log_{10}$ reduction) required to reduce risk estimates below risk thresholds.

[13] The work that preceded publication of the guidelines suggested that the robust relationships between faecal streptococci ("enterococci") concentrations and gastroenteritis was possibly due to the presence of "Norwalk-like virus", i.e., a pathogen (Kay et al. 1994).

Table 4-1: Risks associated with 95th percentile enterococci concentration. From MfE/MoH (2003) guidelines, Table H1, and associated text. "GI" is a gastrointestinal illness, and "AFRI" is Acute Febrile Respiratory Illness.

Category	Threshold value (95th percentile value of enterococci/100 mL)	Estimated risk (%)		Commentary
		GI	AFRI	
A	≤ 40	<1	<0.3	Less than No Observable Adverse Effects Level (NOAEL) <1 case of gastroenteritis/100 exposures
B	41 - 200	1 - 5	0.3 – 1.9	1 case of gastroenteritis/20 exposures 1 case of AFRI/50 exposures
C	201 – 500	5 – 10	1.9 – 3.9	1-2 cases of gastroenteritis/10 exposures 1-2 cases of AFRI/50 exposures
D	>500	>10	>3.9	1 case of gastroenteritis/10 exposures 1 case of AFRI/25 exposures

4.1 Individual Illness Risks – swimming

Mean estimates of individual illness risks (IIR%) are summarised in Appendix C for all sites and scenarios defined in terms of health outcome (infection or illness) following exposure to pathogens climate conditions, discharge volumes, model pathogens and level of wastewater treatment during contact recreation.

The key outcome from the modelling with regard to swimming risk is demonstrated as graphical summaries provided in Figure 3-3 through Figure 3-6, and a spatial display of risks is provided in Figure 3-9 for norovirus (disaggregated) only. Key features are discussed below.

4.1.1 Individual illness risk (IIR)

Mean IIR for gastrointestinal illness is less than 1% for all sites under all climate and discharge conditions in terms of exposure to norovirus and enterovirus (Figure 3-3 through Figure 3-6). The highest estimated risk was 0.97% at the Outfall for disaggregated norovirus under future discharge and La Niña conditions The greatest risk for any combination of site, discharge and climate was associated with norovirus in its disaggregated form and the lowest risks from aggregated norovirus. Risks associated with enterovirus were less than those for disaggregated norovirus but greater than for aggregated norovirus. The precautionary approach is to assume norovirus is disaggregated as it is not known what form norovirus will take in the marine receiving environment.

Respiratory illness risk is discussed in Section 4.2 for secondary contact recreation.

4.1.2 Spatial distribution of individual illness risk

Hydrodynamic modelling demonstrates a pronounced, general northeast – southwest movement of water under tidal influence, which was also evident in the earlier Bell Island QMRA (McBride 2017). MetOcean Solutions describe dispersion of the wastewater discharge as "clearly elongated in a southwest-northeast axis which is driven by the local hydrodynamics (see Figure 3.3, Figure 3.4)" (MetOcean Solutions 2021). Dispersal patterns are similar for La Niña and El Niño conditions, with the plume slightly more pronounced to the northeast and southwest under the La Niña hydrodynamic regime.

Dilution contours (Figures 3.5 through Figure 3.8 of MetOcean Solutions (2021)) show that the plume of wastewater tends to hug the coastline, extending along the coast to the northeast and southwest, rather than dispersing out into Tasman Bay. Over the extent of plumes selected to demonstrate dispersion under climate conditions and discharge scenarios, shoreline dilutions are likely to be consistently greater than 5000 times, relative to the wastewater discharge. Modelling of the particle cloud used to represent any conservative contaminant discharged at the Outfall indicated that there was potential for contaminants to enter the estuary but transport of contaminants over the whole estuary was unlikely (Figure 2.12 of MetOcean Solutions (2021)).

A spatial display of estimated risks is provided in Figure 3-9. These results should be considered in conjunction with the results for hydrodynamic modelling (MetOcean Solutions 2021).

Gastrointestinal and respiratory illness risks are predicted to be greatest at the Outfall and in its immediate vicinity, such as the SW and NW edge of the mixing zone sites, followed by Glenduan to the northeast and Magazine Point to the southwest. The lowest risks were at the Tasman Bay site about 8 km southwest of the discharge and approximately 4 km offshore.

4.1.3 Impact of climate and discharge conditions on risk of illness

Risk of infection are always greater than risk of illness because individuals must be infected to become ill, whereas not all individuals who are infected actually become ill. This trend holds for all scenarios. A four-scenario example is shown in Figure 4-1, using norovirus as model pathogen at three representative sites: Glenduan, Outfall and Magazine Point . This figure demonstrates:

- illness risks are likely to be slightly greater under La Niña conditions than El Niño conditions (for both existing and future discharge conditions), and
- future discharge conditions (greater volume and discharge rate of treated wastewater) increase illness risk, relative to existing conditions.
- Risk estimates are below 1% for all treatment levels but 2 $\log_{10}$ reduction markedly reduces estimated risks for all scenarios of climate and discharge.

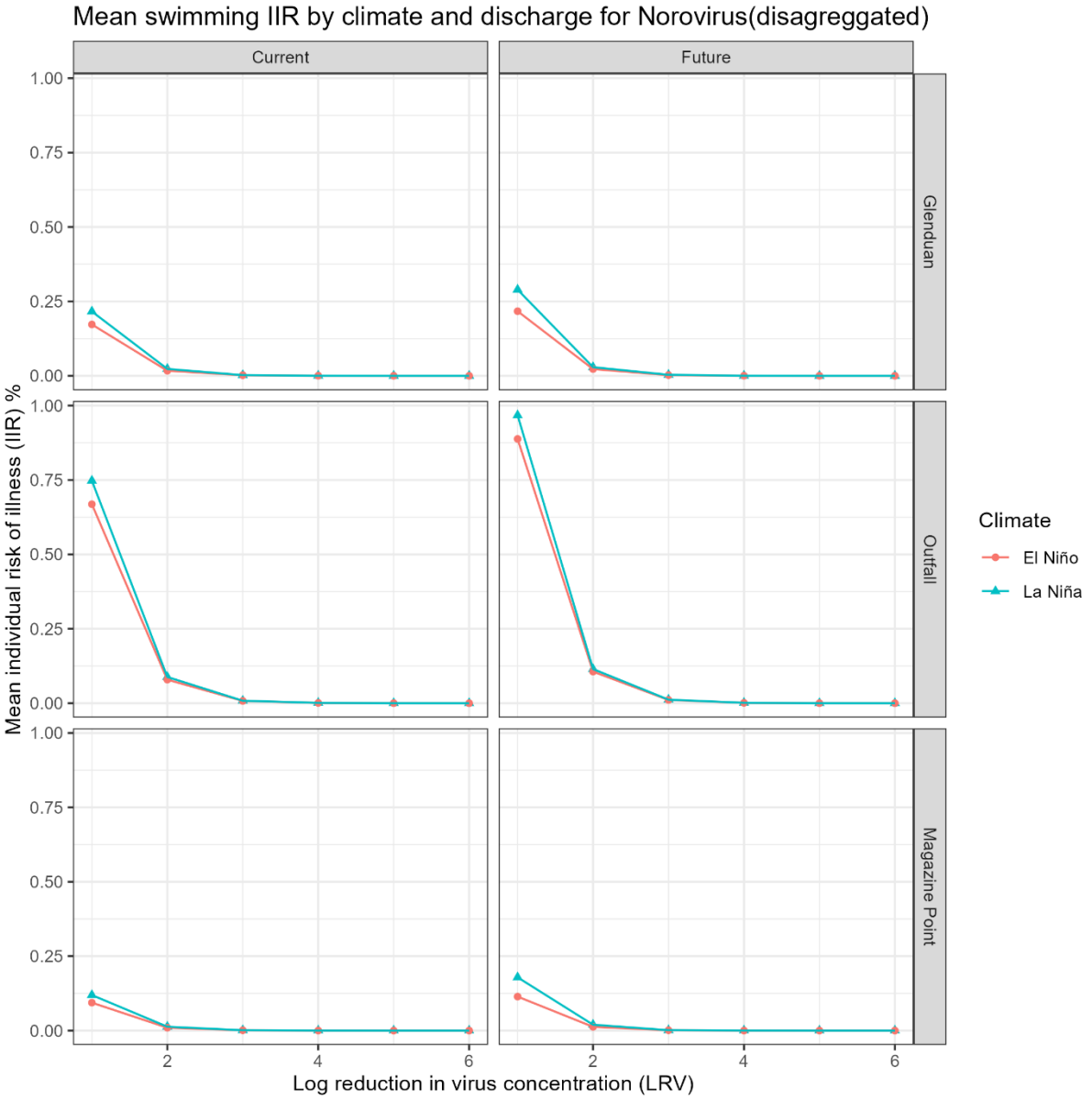


Figure 4-1: Relationship between mean risk of infection and illness versus level of treatment at three sites under two climate and discharge conditions. Full scenario description: Model pathogen = Norovirus(disaggregated), climate conditions = La Niña, El Niño , existing and future discharge conditions. The dots and triangles represent the estimated values the line are interpolations.

4.2 Individual Illness Risks – Secondary contact recreation

Using adenovirus as a model pathogen, average respiratory illness risks to water users engaged in secondary contact recreation were predicted to be lower than the risks faced by swimmers, under all conditions (Figure 3-7). Mean average risks were below 0.2% for all scenarios and levels of wastewater treatment and exposure sites, and hence below the 0.3% risk threshold for respiratory illness for marine recreational activities. The highest mean IIR was 0.14% at the Outfall under future discharge scenario, La Niña climatic conditions and LRV = 1.

The spatial pattern of IIR for secondary contact water users (Figure 3-10) was similar to that seen for swimmers – greatest in the vicinity of the Outfall, decreasing at sites to the immediate northeast and southwest of the discharge.

4.3 Individual Illness Risks – shellfish consumption

The consumption of shellfish gathered from waters likely to be impacted by treated wastewater will pose the highest risk to humans, as shown in Figure 3-8.

Health risks exceed the 1% IIR for gastrointestinal illness at half the sites (8 out of 15) until three log orders of wastewater treatment are applied. Under future discharge scenarios, the Outfall requires four log orders of wastewater treatment to reduce the risk below 1%IIR. The tendency for shellfish to accumulate pathogens will most likely determine the level of wastewater treatment required.

Without adequate wastewater treatment, there is potential for considerable risk to exist. Selected data from Table E-1 and Table E-2 are summarised graphically in Figure 4-2 – the mean IIR, and Figure 4-3 - the 95th percentile IIR.

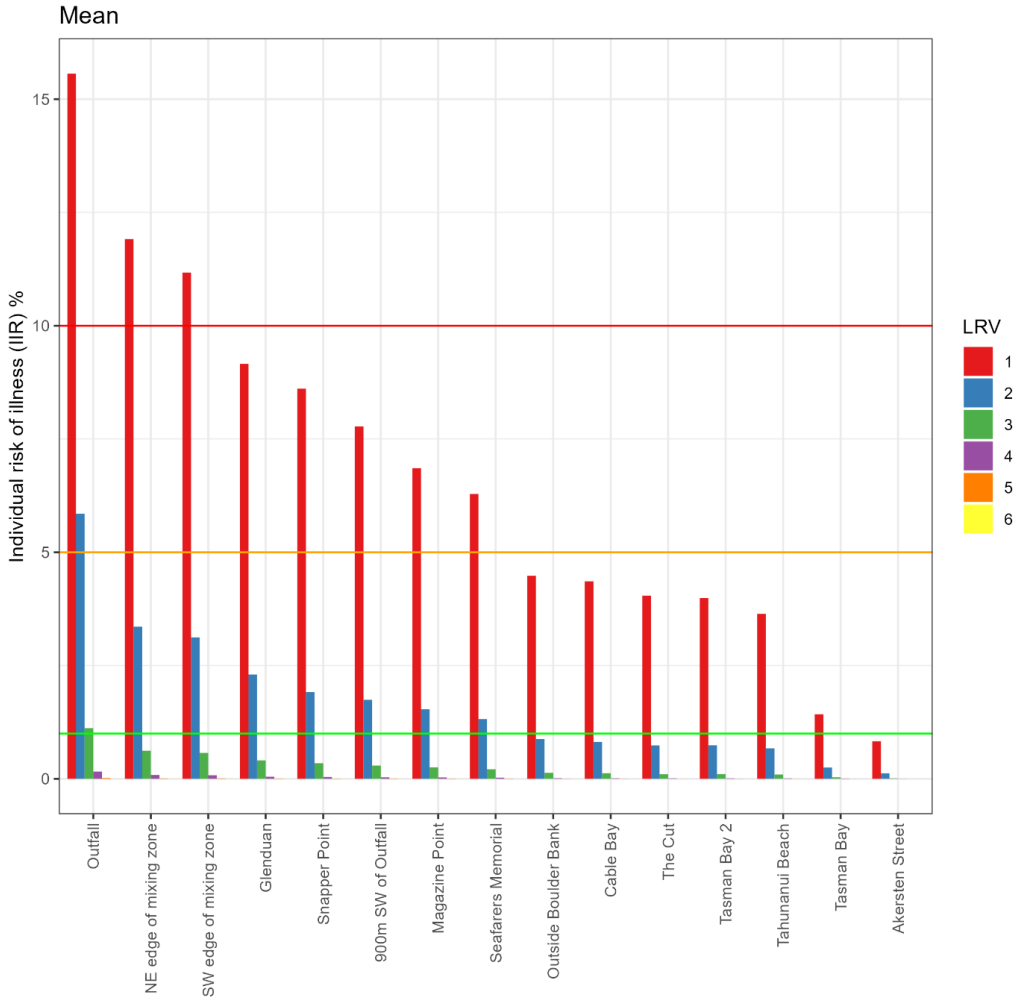


Figure 4-2: Relationship between mean risk of GI illness following consumption of shellfish gathered at 15 exposure sites and level of wastewater treatment. Full description: Model pathogen norovirus disaggregated, climate conditions = La Niña, future discharge conditions. LRV=6, not shown as the risk were too small to be plotted.

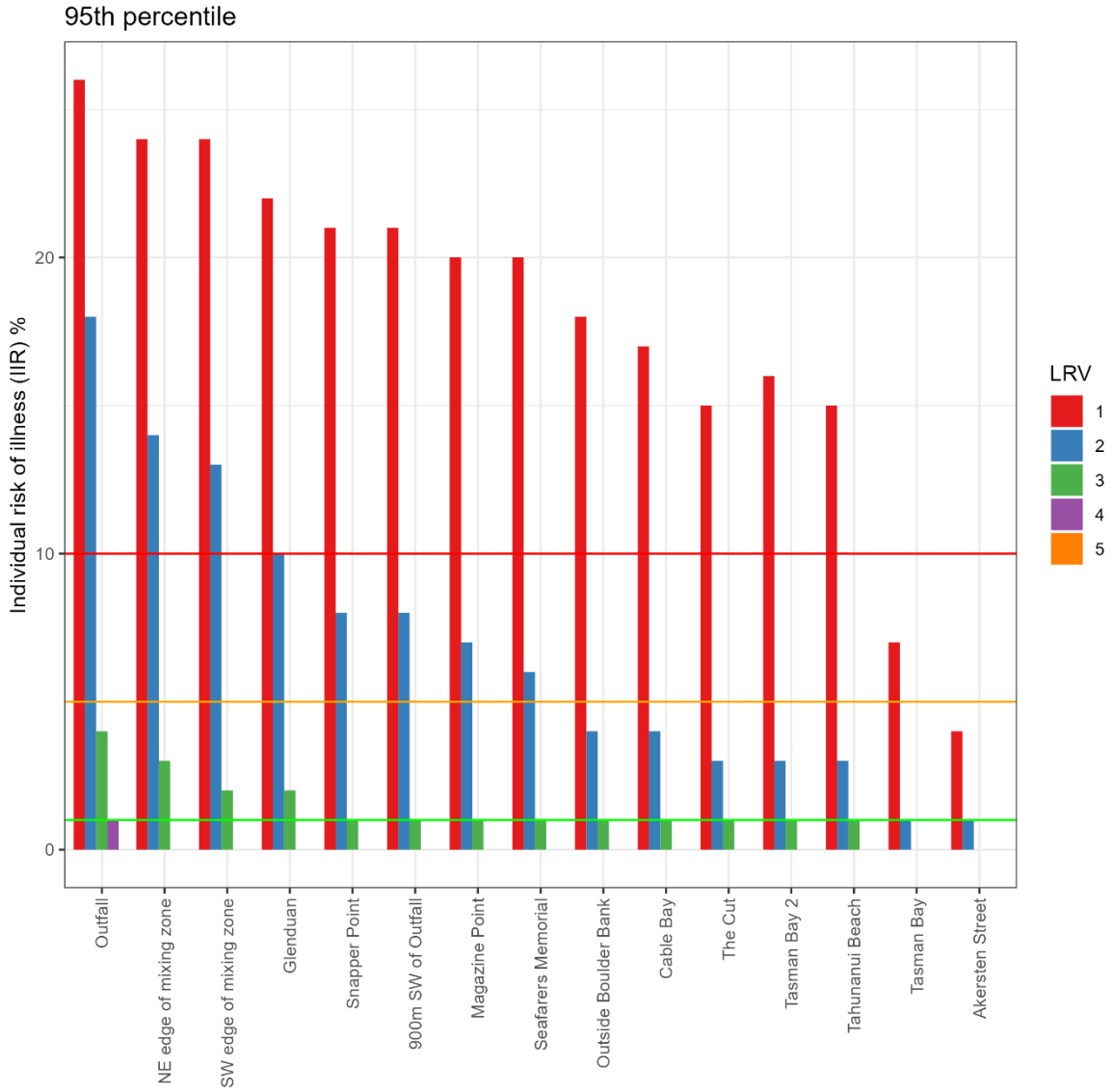


Figure 4-3: Relationship between 95%ile risk of GI illness following consumption of shellfish gathered at 15 exposure sites and level of wastewater treatment. Full description: Model pathogen norovirus disaggregated, climate conditions = La Niña, future discharge conditions. LRV=6, not shown as the risk were too small to be plotted.

5 Summary

Quantitative Microbial Risk Assessment modelling has estimated the potential risks for gastrointestinal- and respiratory illness related to viral pathogens. This includes risks to individuals engaged in activities such as swimming, secondary contact recreation (e.g., boating), and following consumption of uncooked shellfish gathered in waters likely to contain diluted treated wastewater.

Hydrodynamic modelling (and associated estimates of contaminant concentrations) indicated that risks are likely to be greatest in the vicinity of the Outfall, and extend along a northeast-southwest axis, driven primarily by tidal currents. The impact of climate conditions on hydrodynamics is modest, and future increases in wastewater discharge volumes and rates are predicted not to affect mixing and dilution characteristics significantly.

Human health risk assessment considered numerous permutations associated with scenario conditions. These included three reference pathogens (enterovirus, norovirus, adenovirus), the level of wastewater treatment (six log orders of contaminant reduction), two discharge conditions (existing, future), two climate conditions (El Niño or La Niña), three routes whereby human receptors are likely to be exposed to pathogens (ingestion, inhalation, shellfish consumption), and two health endpoints (illness or infection). In total, approximately 3,600 health risk estimates were generated.

Risks for all pathogens were driven primarily in terms of pathogen type and exposure route in relation to the level of wastewater treatment. Other factors (future wastewater discharge and climate) were not as influential.

In summary, QMRA modelling found that;

- Gastrointestinal illness risks were greatest for individuals who consumed raw shellfish collected from waters exposed to diluted treated wastewater.
- Gastrointestinal recreational risks were greater for swimmers than respiratory secondary recreation water users.
- For all exposure routes, GI and RI health risks were greatest near the outfall.
- In the southwest, there was some evidence that the plume of treated wastewater impacted the estuary. The risks were variable but lower than locations closer to the outfall.

Information from the QMRA can help the community, health professionals, the Council and wastewater treatment specialists decide what level of wastewater treatment will be required to achieve an acceptable level of risk. QMRA modelling indicates that risks to the community are greatest for consumers of raw shellfish. This information (and the health risks estimated for other water users) suggests that if sufficient wastewater treatment is achieved to reduce risk to consumers of uncooked shellfish, risks to other water users are likely to be reduced to acceptable levels.

Consideration of the “Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas” (MfE/MoH 2003) provides a reference framework to assist in determining what a tolerable health risk might be for a community. Table H1 of the guidelines provide four illness risk thresholds that are used to routinely grade marine recreational water quality:

- Waters graded “A” are considered to have a very high recreational water quality, likely to cause fewer than 1 case of gastrointestinal illness or acute febrile illness per 100 individuals.
- Waters graded “B” are considered to have high recreational water quality, likely to cause up to 5 cases of gastrointestinal illness and less than 2 cases of acute febrile illness per 100 individuals (≤5% and <2% illness risk, respectively).
- Waters graded “C” represent a risk of up to 10% for gastrointestinal illness, and up to 4% for acute febrile illness.
- Waters graded “D” represent a risk of more than 10% for gastrointestinal illness, and greater than 3.9% for acute febrile illness

QMRA modelling indicated that three $\log_{10}$ orders of wastewater treatment pathogen removal are likely to reduce the average IIR for consumers of shellfish gathered at most of the exposure sites to less than 1%. The exception is at the Outfall under future discharge conditions, where four $\log_{10}$ orders of wastewater treatment pathogen removal would be required. At the latter level of treatment, much lower risks would prevail for other water uses, such as swimming or secondary contact recreation.

6 Acknowledgements

We appreciate the constructive discussions with MetOcean modelling specialists (Mariana Cussiola, Simon Weppe and Alexis Berthot), assistance with coordinating data provision (Kathryn Halder, STANTEC), and management of the project by Nelson City Council and STANTEC, and particularly the constructive feedback we have received from Dr Rob Lieffering (SLR Consulting).

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Appendix A Candidate pathogens of concern

Class	Pathogen	Incl?	Principal disease	Rationale
Bacteria	*Campylobacter spp*.	No	Gastroenteritis	Poor survival in seawater.
	Pathogenic *E. coli*	No	Gastroenteritis	Low concentration expected in treated wastewater.
	Legionella pneumophila	No	Legionnaires' disease	No evidence of environmental infection route.
	Leptospira sp.	No	Leptospirosis	Low concentration expected in treated wastewater.
	Salmonella sp.	No	Gastroenteritis	Low concentration expected in treated wastewater.
	Salmonella typhi	No	Typhoid fever	Rare in New Zealand.
	Shigella sp.	No	Dysentery	Low concentration expected in treated wastewater.
	Vibrio cholerae	No	Cholera	Rare in New Zealand.
	Yersinia enterolitica	No	Gastroenteritis	Low concentration expected in treated wastewater.
Helminths	*Ascaris lumbricoides*	No	Roundworm	Rare in New Zealand.
	Enterobius vernicularis	No	Pinworm	Low concentration expected in treated wastewater.
	Fasciola hepatica	No	Liver fluke	Rare in New Zealand.
	Hymnolepis nana	No	Dwarf tapeworm	Rare in New Zealand.
	Taenia sp.	No	Tapeworm	Rare in New Zealand.
	Trichuris trichiura	No	Whipworm	Rare in New Zealand.
Protozoa	*Balantidium coli*	No	Dysentery	Low concentration expected in treated wastewater.
	Cryptosporidium oocysts	No	Gastroenteritis	Will be removed by proposed wastewater treatment processes.
	Entamoeba histolytica	No	Amoebic dysentery	Rare in New Zealand.
	Giardia cysts	No	Gastroenteritis	Moderate survival in seawater but will be removed by proposed wastewater treatment processes.
Viruses	Adenoviruses	Yes (SW only)[14]	Respiratory disease[15]	Very infective. Significant concentrations may be present in wastewater.
	Enteroviruses	Yes (SW,SF)	Gastroenteritis	Less infective, but health consequences can be more severe than for exposure to adenovirus.
	Hepatitis A virus	No	Infectious hepatitis	Minimal concentration in treated wastewater; very infective. Can affect recreational water users in contaminated waters.
	Noroviruses	Yes, (SW, SF)	Gastroenteritis	Increasing evidence of its prevalence in treated wastewater. Clinical trials and dose-response now available. However, it hasn't been possible to culture in the laboratory until now.[16] This makes assessment of treatment efficacy problematic.
	Rotavirus[17]	No	Gastroenteritis	Limited evidence of waterborne infection in NZ; infection in children would be of concern.[18] Difficult to translate units used in clinical trial (FFU, (Ward et al. 1986)) to those used in culture methods. See section 2.1.3 for detailed justification for its omission.

[14] "SW" = swimming; "SF" = shellfish.

[15] Adenoviruses can also cause pneumonia, eye infections and gastroenteritis.

[16] A new culture-based method has recently been published—Jones, M.K., Watanabe, M., Zhu, S., Graves, C.L., Keyes, L.R., Grau, K.R., Gonzalez-Hernandez, M.B., Iovine, N.M., Wobus, C.E., Vinje, J., Tibbetts, S.A., Wallet, S.M., Karst, S.M. (2014) Enteric bacteria promote human and mouse norovirus infection of B cells. *Science*, 346(6210): 755-759. DOI: 10.1126/science.1257147.: http://www.ncbi.nlm.nih.gov/pubmed/25378626.

[17] Rose, J.B., Sobsey, M. (1993) Quantitative risk assessment for viral contamination of shellfish and coastal waters. *Journal of Food Protection*, 56(12): 1043–1050. Documented a rationale for concern about potential contamination of shellfish by rotavirus, but risk appears to have been over-estimated [they equated FFU (Focus Forming Units) with actual numbers of virions].

[18] Bell Island Wastewater Treatment Plant

Table A-1: Virus results from the Mangere studies (1999-2000). (a) Scoping study, (b) Surrogate study. For original data see Figure 3.3.5 and Tables B1 and B6 in DRG (2002) and Figure 1 in Simpson et al. (2003). All virus enumerations are in units of $TCID_{50}$ per litre, where $TCID_{50}$ is a laboratory tissue culture technique measuring the amount of virus that produces a cytopathic effect in 50% of the cell cultures inoculated.

Scoping study (DRG 2002))			Surrogate study (DRG 2002)		
Date	Adenovirus	Enterovirus	Date	Adenovirus	Enterovirus
17-May-99	3 680 000	31 800	8-Oct-99	3 420	664
19-May-99	1 960 000	25 000	13-Oct-99	2 530	400
21-May-99	1 800 000	71 100	15-Oct-99	3 470	1 230
24-May-99	27 300 000	4 600 000	22-Oct-99	5 340	400
26-May-99	31 200 000	50 400 000	27-Oct-99	4 200	832
28-May-99	2 570 000	22 600	29-Oct-99	9 840	2 560
31-May-99	1 710 000	182 000	3-Nov-99	4 590	1 730
2-Jun-99	88 200	28 300	10-Nov-99	4 620	2 200
8-Jun-99	66 809	28 300	17-Nov-99	4 660	2 150
10-Jun-99	189 900	37 600	26-Nov-99	3 800	2 920
16-Jun-99	8 820 000	146 000	1-Dec-99	3 420	2 900
17-Jun-99	433 000	18 200	10-Dec-99	4 120	1 890
21-Jun-99	434 000	51 000	15-Dec-99	3 410	1 820
28-Jun-99	211 000	28 700	22-Dec-99	3 100	2 600
30-Jun-99	23 600	28 900	29-Dec-99	3 560	3 220
1-Jul-99	18 200	13 100	5-Jan-00	3 480	2 440
			12-Jan-00	3 880	1 940
			19-Jan-00	3 400	3 750
			26-Jan-00	3 720	2 570
			4-Feb-00	4 700	3 570
			9-Feb-00	3 900	3 800
			17-Feb-00	4 050	3 320
			23-Feb-00	1 900	1 470
			1-Mar-00	5 860	5 500
			10-Mar-00	4 820	4 750
			16-Mar-00	5 080	3 850
			22-Mar-00	8 980	8 220
			30-Mar-00	7 610	3 470

Appendix B Comparisons of previous and current QMRA results

Hudson and Wood (2023) prepared a previous QMRA for the Nelson North wastewater treatment plant. In this section, we explore key differences between the results in this current QMRA and prior reports and explain why the analysis was redone.

There were three reasons why the analysis was repeated.

1. There was a need to include additional sites – the Outfall and Tasman Bay 2 site in the Horoirangi Marine Reserve).
2. Concerns were raised that sites close to the Outfall had similar but lower shellfish risks than sites like Magazine Point, which were further away. The question was "could this have been due to the assumptions about interpolating the dilution data?"
3. A numerical error led to an overestimation of shellfish risks, which needed correcting.

Additional Sites

This report estimated health risks at 15 sites. Eleven sites were the same as those in the previous QMRA report (Hudson and Wood 2023). Two of the sites in the current report are entirely new, the Outfall and Tasman Bay 2 and two of the sites, NE mixing zone and SW mixing zone, were similar to but not the same as the sites 300m NE of Outfall and 300m SW of Outfall in the previous report.

Dilution

The second issue was that some sites further away from the Outfall had similar through slightly higher risks than those close to the Outfall; notably, the risk at Magazine Point was approximately twice that of the site 300m SW of the Outfall. Risks increasing, even by a small amount with distance, was unexpected, and questions were raised about how the dilution data were interpolated.

Hydrodynamic modelling was undertaken by MetOcean Solutions, who provided the dilution data. For sites beyond the mixing zone surrounding the Outfall, effluent dilution at times is reported as infinite. For some sites, such as Akersten Street, infinite dilution was reported most of the time. Though effluent may have been highly diluted, it is improbable that it was infinite dilute. Incorporating infinite values into the QMRA modelling is problematic and if infinite values were used in the QMRA, it could introduce a bias towards underestimating the risk. Instead, infinite values were replaced with the maximum estimated non-infinite dilution value for each site, a precautionary approach that may overestimate risk. In this "histogram" approach, the degree of overestimation was site-specific, influencing any assessment of relative risks between sites. So in some cases sites further away from the outfall had maximum dilutions of the order of 1×10^4, but closer the outfall the values were approximately 1×10^5.

An alternative approach was also proposed called the kernel density estimate (KDE). This KDE approach would overcome the infinite dilution problem by smoothing the dilution estimate. However, doing so would come at the cost of overestimating dilutions when effluent dilution was low and health risk high, so this approach was rejected.

In response to feedback on the original report, further work was carried out to investigate the sensitivity of the results to dilution estimates. MetOcean proposed a hybrid mixed model. The hybrid model is a mixture of the histogram and KDE and retains the low dilutions. The current report used the hybrid mixed model approach. Figure B-1 shows a comparison of risks derived from each of the

three dilution approaches considered. Though the risk is a function of the dilution model, risks are also sensitive to the LRV.

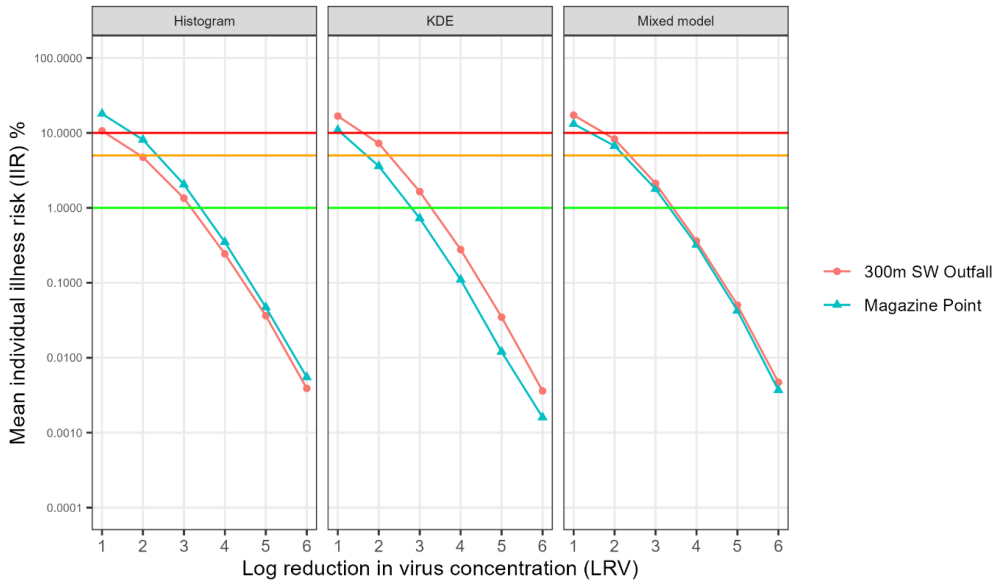


Figure B-1: Comparison of the Mean Individual Illness Risk (shellfish) for each dilution model and two sites.

Numerical error

After the previous report had been completed, it was noted that the Method Harmonisation Factor (MHF) had not been correctly applied to norovirus, particularly for shellfish risks, resulting in overstated shellfish risk. The MHF accounts for differences between the methods used in dose-response studies and the more sensitive molecular methods currently used to estimate norovirus concentration in wastewater. The current analysis corrects this error.

Differences between estimated risk in the current and previous report

There were eleven sites in common between the current and previous reports. A comparison of the mean IIR under future discharge conditions and El Niño scenarios was made for shellfish and inhalation risks.

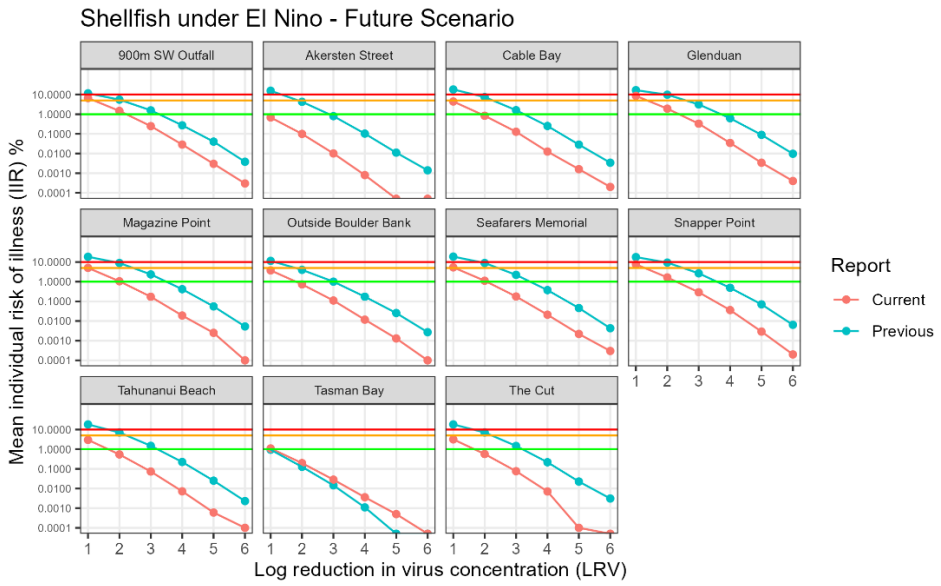


Figure B-2: Comparison of the Shellfish risks between the current and previous reports.

The current risk estimates for shellfish risk were consistently lower than the previous estimate (Figure B-2). An exception is the Tasman Bay sites, where risks increased, though the Tasman Bay site had lower risks than other sites.

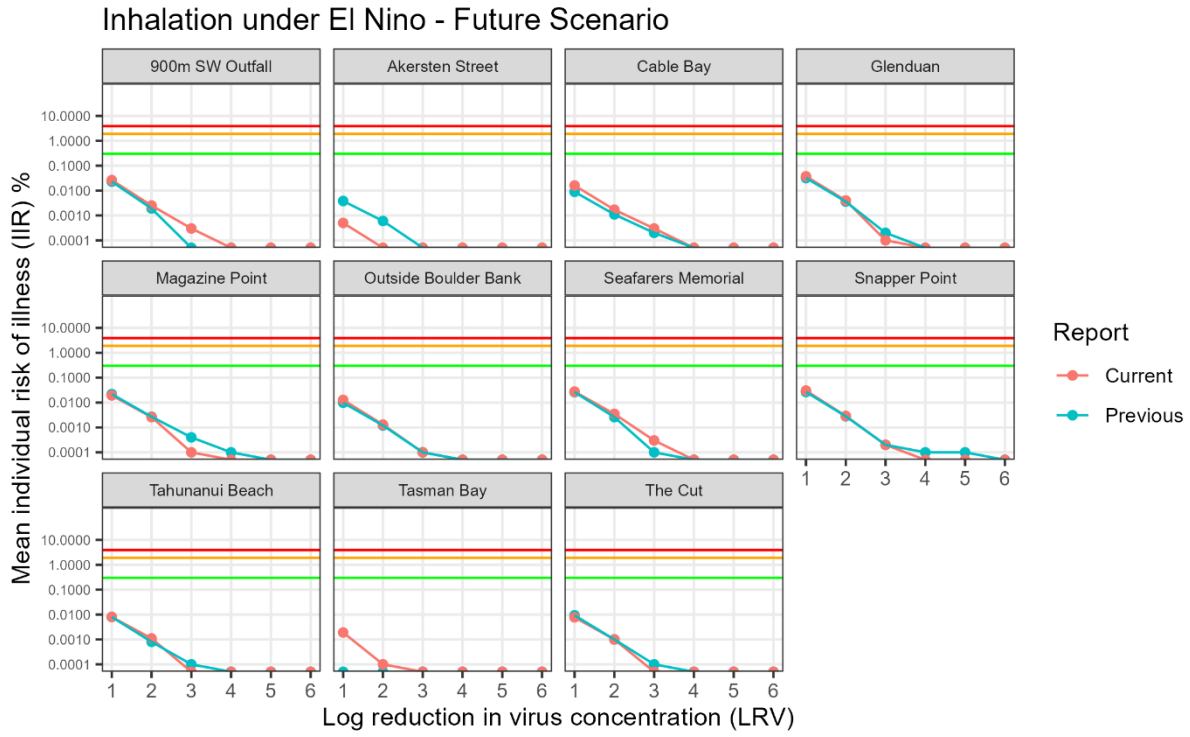


Figure B-3: Comparison of the secondary contact (inhalation) risks for the current and previous report.

The risks of inhalations from secondary contact were similar, except for Akersten Street, where the risks had decreased but were still lower than sites close to the Outfall (Figure B-3).

Overall risks are highest close to the Outfall. There is a tendency for risk to reduce with distance, though it is not a case of all risks reducing with distance. For example, risks at Magazine Point are generally slightly higher (by a factor of two or less) than at The Cut, a site closer to the Outfall. The estimated risk are a function of the estimated dispersion rather than a simple matter of distance.

Generally, the hybrid mixed model approach to estimating dilution did not have a significant impact on risk apart from sites such as Akersten Steet and Tasman Bay which had a high ponderance of infinite dilution values, more than three quarters of values, under the original approach. The inclusion of the MHF reduced shellfish risks.

Appendix C Health risks primary contact recreation

Table C-1: Estimates of Gastrointestinal mean Individual illness risk (IIR) associated with contact recreation at exposure sites at given level of wastewater treatment.
Endpoint indicates illness (Ill) statistics are the mean IIR, Exposure is swimming, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge conditions, Path. = norovirus or enterovirus, State (applies to norovirus only) indicates disaggregated or aggregated forms, Site no. is unique site identifier number, Site name is unique site name, Level of treatment = $\log_{10}$ level of treatment. Colours green, yellow, orange and red refer to category A, B, C and D see Table 4-1

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reductions in virus concentration (LRV)					
					1	2	3	4	5	6
Swim	Enterovirus	La Niña	Current	900m SW Outfall	0.0264	0.0042	0.0005	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	Akersten Street	0.0014	0.0001	0.0000	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	Cable Bay	0.0123	0.0012	0.0002	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	Glenduan	0.0410	0.0056	0.0005	0.0002	0.0001	0
Swim	Enterovirus	La Niña	Current	Magazine Point	0.0211	0.0027	0.0003	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	NE edge of mixing zone	0.0592	0.0092	0.0011	0.0001	0.0000	0
Swim	Enterovirus	La Niña	Current	Outfall	0.0991	0.0164	0.0018	0.0001	0.0000	0
Swim	Enterovirus	La Niña	Current	Outside Boulder Bank	0.0144	0.0017	0.0002	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	SW edge of mixing zone	0.0536	0.0082	0.0009	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	Seafarers Memorial	0.0199	0.0024	0.0002	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	Snapper Point	0.0331	0.0041	0.0003	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	Tahunanui Beach	0.0095	0.0013	0.0000	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	Tasman Bay	0.0016	0.0000	0.0000	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Current	Tasman Bay 2	0.0126	0.0015	0.0004	0.0001	0.0000	0
Swim	Enterovirus	La Niña	Current	The Cut	0.0120	0.0015	0.0001	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	900m SW Outfall	0.1560	0.0164	0.0017	0.0003	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	Akersten Street	0.0081	0.0011	0.0002	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	Cable Bay	0.0600	0.0072	0.0007	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	Glenduan	0.2161	0.0231	0.0023	0.0003	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	Magazine Point	0.1193	0.0130	0.0012	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	NE edge of mixing zone	0.3720	0.0416	0.0041	0.0003	0.0001	0
Swim	Norovirus(disaggregated)	La Niña	Current	Outfall	0.7477	0.0881	0.0082	0.0010	0.0001	0
Swim	Norovirus(disaggregated)	La Niña	Current	Outside Boulder Bank	0.0682	0.0072	0.0011	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	SW edge of mixing zone	0.3278	0.0342	0.0031	0.0006	0.0000	0

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reductions in virus concentration (LRV)					
					1	2	3	4	5	6
Swim	Norovirus(disaggregated)	La Niña	Current	Seafarers Memorial	0.1123	0.0116	0.0014	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	Snapper Point	0.1704	0.0176	0.0010	0.0003	0.0001	0
Swim	Norovirus(disaggregated)	La Niña	Current	Tahunanui Beach	0.0405	0.0041	0.0003	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	Tasman Bay	0.0168	0.0024	0.0003	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	Tasman Bay 2	0.0600	0.0066	0.0006	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Current	The Cut	0.0468	0.0039	0.0005	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	900m SW Outfall	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Akersten Street	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Cable Bay	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Glenduan	0.0005	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Magazine Point	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	NE edge of mixing zone	0.0005	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Outfall	0.0011	0.0003	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Outside Boulder Bank	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	SW edge of mixing zone	0.0029	0.0004	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Seafarers Memorial	0.0009	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Snapper Point	0.0012	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Tahunanui Beach	0.0004	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Tasman Bay	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	Tasman Bay 2	0.0003	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Current	The Cut	0.0004	0.0000	0.0000	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	900m SW Outfall	0.0344	0.0053	0.0006	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	Akersten Street	0.0016	0.0002	0.0000	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	Cable Bay	0.0181	0.0017	0.0004	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	Glenduan	0.0510	0.0074	0.0006	0.0002	0.0001	0
Swim	Enterovirus	La Niña	Future	Magazine Point	0.0295	0.0042	0.0005	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	NE edge of mixing zone	0.0703	0.0116	0.0012	0.0001	0.0000	0
Swim	Enterovirus	La Niña	Future	Outfall	0.1201	0.0202	0.0023	0.0002	0.0000	0
Swim	Enterovirus	La Niña	Future	Outside Boulder Bank	0.0171	0.0018	0.0002	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	SW edge of mixing zone	0.0637	0.0099	0.0010	0.0000	0.0000	0

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reductions in virus concentration (LRV)					
					1	2	3	4	5	6
Swim	Enterovirus	La Niña	Future	Seafarers Memorial	0.0275	0.0031	0.0003	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	Snapper Point	0.0398	0.0052	0.0006	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	Tahunanui Beach	0.0115	0.0016	0.0002	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	Tasman Bay	0.0025	0.0002	0.0000	0.0000	0.0000	0
Swim	Enterovirus	La Niña	Future	Tasman Bay 2	0.0146	0.0017	0.0005	0.0001	0.0000	0
Swim	Enterovirus	La Niña	Future	The Cut	0.0152	0.0017	0.0002	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	900m SW Outfall	0.2035	0.0217	0.0023	0.0003	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	Akersten Street	0.0088	0.0011	0.0002	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	Cable Bay	0.0864	0.0114	0.0010	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	Glenduan	0.2894	0.0290	0.0034	0.0003	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	Magazine Point	0.1789	0.0197	0.0014	0.0002	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	NE edge of mixing zone	0.4668	0.0553	0.0052	0.0004	0.0001	0
Swim	Norovirus(disaggregated)	La Niña	Future	Outfall	0.9674	0.1147	0.0118	0.0012	0.0001	0
Swim	Norovirus(disaggregated)	La Niña	Future	Outside Boulder Bank	0.0847	0.0096	0.0012	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	SW edge of mixing zone	0.4179	0.0452	0.0039	0.0006	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	Seafarers Memorial	0.1482	0.0159	0.0021	0.0003	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	Snapper Point	0.2151	0.0228	0.0015	0.0003	0.0001	0
Swim	Norovirus(disaggregated)	La Niña	Future	Tahunanui Beach	0.0528	0.0051	0.0004	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	Tasman Bay	0.0217	0.0027	0.0004	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	Tasman Bay 2	0.0753	0.0078	0.0008	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	La Niña	Future	The Cut	0.0600	0.0051	0.0005	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	900m SW Outfall	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Akersten Street	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Cable Bay	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Glenduan	0.0008	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Magazine Point	0.0005	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	NE edge of mixing zone	0.0007	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Outfall	0.0015	0.0003	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Outside Boulder Bank	0.0002	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	SW edge of mixing zone	0.0041	0.0004	0.0000	0.0000	0.0000	0

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reductions in virus concentration (LRV)					
					1	2	3	4	5	6
Swim	Norovirus(aggregated)	La Niña	Future	Seafarers Memorial	0.0013	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Snapper Point	0.0013	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Tahunanui Beach	0.0006	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Tasman Bay	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	Tasman Bay 2	0.0006	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	La Niña	Future	The Cut	0.0005	0.0000	0.0000	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	900m SW Outfall	0.0234	0.0036	0.0005	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Akersten Street	0.0013	0.0001	0.0000	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Cable Bay	0.0159	0.0015	0.0003	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Glenduan	0.0332	0.0044	0.0003	0.0002	0.0001	0
Swim	Enterovirus	El Niño	Current	Magazine Point	0.0161	0.0019	0.0003	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	NE edge of mixing zone	0.0523	0.0078	0.0009	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Outfall	0.0885	0.0147	0.0015	0.0001	0.0000	0
Swim	Enterovirus	El Niño	Current	Outside Boulder Bank	0.0124	0.0016	0.0002	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	SW edge of mixing zone	0.0455	0.0068	0.0009	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Seafarers Memorial	0.0177	0.0021	0.0002	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Snapper Point	0.0258	0.0031	0.0003	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Tahunanui Beach	0.0085	0.0009	0.0000	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Tasman Bay	0.0013	0.0000	0.0000	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Current	Tasman Bay 2	0.0104	0.0015	0.0004	0.0001	0.0000	0
Swim	Enterovirus	El Niño	Current	The Cut	0.0092	0.0008	0.0000	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	900m SW Outfall	0.1313	0.0129	0.0014	0.0002	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	Akersten Street	0.0071	0.0008	0.0002	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	Cable Bay	0.0751	0.0101	0.0007	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	Glenduan	0.1725	0.0170	0.0020	0.0003	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	Magazine Point	0.0937	0.0096	0.0010	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	NE edge of mixing zone	0.3168	0.0356	0.0032	0.0003	0.0001	0
Swim	Norovirus(disaggregated)	El Niño	Current	Outfall	0.6687	0.0790	0.0076	0.0009	0.0001	0
Swim	Norovirus(disaggregated)	El Niño	Current	Outside Boulder Bank	0.0569	0.0056	0.0007	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	SW edge of mixing zone	0.2763	0.0288	0.0024	0.0005	0.0000	0

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reductions in virus concentration (LRV)					
					1	2	3	4	5	6
Swim	Norovirus(disaggregated)	El Niño	Current	Seafarers Memorial	0.0968	0.0099	0.0013	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	Snapper Point	0.1389	0.0146	0.0009	0.0003	0.0001	0
Swim	Norovirus(disaggregated)	El Niño	Current	Tahunanui Beach	0.0308	0.0028	0.0003	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	Tasman Bay	0.0131	0.0019	0.0002	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	Tasman Bay 2	0.0487	0.0042	0.0005	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Current	The Cut	0.0350	0.0028	0.0004	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	900m SW Outfall	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Akersten Street	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Cable Bay	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Glenduan	0.0003	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Magazine Point	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	NE edge of mixing zone	0.0004	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Outfall	0.0010	0.0003	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Outside Boulder Bank	0.0001	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	SW edge of mixing zone	0.0027	0.0004	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Seafarers Memorial	0.0006	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Snapper Point	0.0009	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Tahunanui Beach	0.0003	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Tasman Bay	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	Tasman Bay 2	0.0003	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Current	The Cut	0.0004	0.0000	0.0000	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	900m SW Outfall	0.0285	0.0046	0.0006	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	Akersten Street	0.0013	0.0002	0.0000	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	Cable Bay	0.0186	0.0019	0.0004	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	Glenduan	0.0413	0.0060	0.0005	0.0002	0.0001	0
Swim	Enterovirus	El Niño	Future	Magazine Point	0.0196	0.0025	0.0003	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	NE edge of mixing zone	0.0622	0.0102	0.0011	0.0001	0.0000	0
Swim	Enterovirus	El Niño	Future	Outfall	0.1101	0.0187	0.0023	0.0002	0.0000	0
Swim	Enterovirus	El Niño	Future	Outside Boulder Bank	0.0142	0.0017	0.0002	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	SW edge of mixing zone	0.0561	0.0091	0.0010	0.0000	0.0000	0

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reductions in virus concentration (LRV)					
					1	2	3	4	5	6
Swim	Enterovirus	El Niño	Future	Seafarers Memorial	0.0237	0.0028	0.0002	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	Snapper Point	0.0343	0.0044	0.0004	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	Tahunanui Beach	0.0095	0.0013	0.0000	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	Tasman Bay	0.0016	0.0000	0.0000	0.0000	0.0000	0
Swim	Enterovirus	El Niño	Future	Tasman Bay 2	0.0125	0.0015	0.0005	0.0001	0.0000	0
Swim	Enterovirus	El Niño	Future	The Cut	0.0114	0.0012	0.0001	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	900m SW Outfall	0.1665	0.0176	0.0020	0.0003	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	Akersten Street	0.0070	0.0010	0.0002	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	Cable Bay	0.0884	0.0119	0.0010	0.0002	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	Glenduan	0.2170	0.0225	0.0023	0.0003	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	Magazine Point	0.1141	0.0125	0.0011	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	NE edge of mixing zone	0.4091	0.0478	0.0047	0.0003	0.0001	0
Swim	Norovirus(disaggregated)	El Niño	Future	Outfall	0.8879	0.1060	0.0108	0.0011	0.0001	0
Swim	Norovirus(disaggregated)	El Niño	Future	Outside Boulder Bank	0.0695	0.0075	0.0010	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	SW edge of mixing zone	0.3589	0.0378	0.0037	0.0006	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	Seafarers Memorial	0.1286	0.0136	0.0018	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	Snapper Point	0.1805	0.0190	0.0012	0.0003	0.0001	0
Swim	Norovirus(disaggregated)	El Niño	Future	Tahunanui Beach	0.0401	0.0039	0.0003	0.0001	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	Tasman Bay	0.0159	0.0026	0.0002	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	Tasman Bay 2	0.0591	0.0068	0.0006	0.0000	0.0000	0
Swim	Norovirus(disaggregated)	El Niño	Future	The Cut	0.0441	0.0037	0.0005	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	900m SW Outfall	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Akersten Street	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Cable Bay	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Glenduan	0.0005	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Magazine Point	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	NE edge of mixing zone	0.0005	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Outfall	0.0012	0.0003	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Outside Boulder Bank	0.0002	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	SW edge of mixing zone	0.0033	0.0004	0.0000	0.0000	0.0000	0

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reductions in virus concentration (LRV)					
					1	2	3	4	5	6
Swim	Norovirus(aggregated)	El Niño	Future	Seafarers Memorial	0.0012	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Snapper Point	0.0013	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Tahunanui Beach	0.0004	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Tasman Bay	0.0000	0.0000	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	Tasman Bay 2	0.0003	0.0001	0.0000	0.0000	0.0000	0
Swim	Norovirus(aggregated)	El Niño	Future	The Cut	0.0004	0.0000	0.0000	0.0000	0.0000	0

Table C-2: Estimates of Gastrointestinal 95%ile Individual illness risk (IIR) associated with primary recreation at exposure sites at given level of wastewater treatment.
Endpoint indicates illness (Ill), statistic is the 95%ile, Exposure is swimming, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge conditions.

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Enterovirus	ill	95%ile	La Niña	Current	900m SW Outfall	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Akersten Street	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Cable Bay	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Glenduan	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Magazine Point	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	NE edge of mixing zone	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Outfall	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Outside Boulder Bank	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	SW edge of mixing zone	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Seafarers Memorial	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Snapper Point	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Tahunanui Beach	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Tasman Bay	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	Tasman Bay 2	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Current	The Cut	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	900m SW Outfall	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Akersten Street	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Cable Bay	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Glenduan	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Magazine Point	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	NE edge of mixing zone	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Outfall	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Outside Boulder Bank	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	SW edge of mixing zone	0	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Enterovirus	ill	95%ile	La Niña	Future	Seafarers Memorial	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Snapper Point	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Tahunanui Beach	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Tasman Bay	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	Tasman Bay 2	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	La Niña	Future	The Cut	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	900m SW Outfall	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Akersten Street	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Cable Bay	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Glenduan	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Magazine Point	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	NE edge of mixing zone	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Outfall	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Outside Boulder Bank	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	SW edge of mixing zone	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Seafarers Memorial	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Snapper Point	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Tahunanui Beach	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Tasman Bay	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	Tasman Bay 2	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Current	The Cut	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	900m SW Outfall	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Akersten Street	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Cable Bay	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Glenduan	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Magazine Point	0	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Enterovirus	ill	95%ile	El Niño	Future	NE edge of mixing zone	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Outfall	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Outside Boulder Bank	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	SW edge of mixing zone	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Seafarers Memorial	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Snapper Point	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Tahunanui Beach	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Tasman Bay	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	Tasman Bay 2	0	0	0	0	0	0
Swim	Enterovirus	ill	95%ile	El Niño	Future	The Cut	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	900m SW Outfall	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Cable Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Glenduan	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Magazine Point	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	NE edge of mixing zone	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Outfall	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Outside Boulder Bank	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	SW edge of mixing zone	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Seafarers Memorial	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Snapper Point	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Tahunanui Beach	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	Tasman Bay 2	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Current	The Cut	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	900m SW Outfall	0	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Cable Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Glenduan	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Magazine Point	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	NE edge of mixing zone	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Outfall	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Outside Boulder Bank	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	SW edge of mixing zone	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Seafarers Memorial	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Snapper Point	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Tahunanui Beach	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	Tasman Bay 2	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	La Niña	Future	The Cut	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	900m SW Outfall	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Cable Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Glenduan	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Magazine Point	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	NE edge of mixing zone	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Outfall	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Outside Boulder Bank	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	SW edge of mixing zone	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Seafarers Memorial	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Snapper Point	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Tahunanui Beach	0	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	Tasman Bay 2	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Current	The Cut	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	900m SW Outfall	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Cable Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Glenduan	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Magazine Point	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	NE edge of mixing zone	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Outfall	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Outside Boulder Bank	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	SW edge of mixing zone	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Seafarers Memorial	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Snapper Point	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Tahunanui Beach	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	Tasman Bay 2	0	0	0	0	0	0
Swim	Norovirus(aggregated)	ill	95%ile	El Niño	Future	The Cut	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	900m SW Outfall	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Cable Bay	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Glenduan	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Magazine Point	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	NE edge of mixing zone	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Outfall	3	1	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Outside Boulder Bank	1	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	SW edge of mixing zone	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Seafarers Memorial	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Snapper Point	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Tahunanui Beach	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	Tasman Bay 2	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Current	The Cut	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	900m SW Outfall	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Cable Bay	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Glenduan	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Magazine Point	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	NE edge of mixing zone	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Outfall	4	1	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Outside Boulder Bank	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	SW edge of mixing zone	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Seafarers Memorial	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Snapper Point	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Tahunanui Beach	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	Tasman Bay 2	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	La Niña	Future	The Cut	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	900m SW Outfall	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Cable Bay	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Glenduan	1	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Magazine Point	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	NE edge of mixing zone	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Outfall	3	1	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Outside Boulder Bank	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	SW edge of mixing zone	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Seafarers Memorial	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Snapper Point	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Tahunanui Beach	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	Tasman Bay 2	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Current	The Cut	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	900m SW Outfall	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Cable Bay	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Glenduan	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Magazine Point	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	NE edge of mixing zone	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Outfall	4	1	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Outside Boulder Bank	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	SW edge of mixing zone	2	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Seafarers Memorial	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Snapper Point	1	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Tahunanui Beach	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	Tasman Bay 2	0	0	0	0	0	0
Swim	Norovirus(disaggregated)	ill	95%ile	El Niño	Future	The Cut	0	0	0	0	0	0

Table C-3: Estimates of Gastrointestinal mean Individual infection risk (IInfR) associated with primary recreation at exposure sites at given level of wastewater treatment. Endpoint indicates infection (Inf), statistic is the mean, Exposure is swimming, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge.

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Enterovirus	inf	Mean	La Niña	Current	900m SW Outfall	0.0548	0.0076	0.001	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Akersten Street	0.0032	4.00E-04	0	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Cable Bay	0.0253	0.0028	3.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Glenduan	0.0826	0.0118	0.0014	2.00E-04	1.00E-04	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Magazine Point	0.0431	0.0051	4.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	NE edge of mixing zone	0.1131	0.0165	0.0021	1.00E-04	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Outfall	0.1925	0.03	0.0035	1.00E-04	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Outside Boulder Bank	0.0265	0.0026	3.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	SW edge of mixing zone	0.1074	0.0143	0.0016	2.00E-04	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Seafarers Memorial	0.0397	0.0049	4.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Snapper Point	0.0621	0.0068	8.00E-04	1.00E-04	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Tahunanui Beach	0.0187	0.0019	0	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Tasman Bay	0.0046	3.00E-04	0	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	Tasman Bay 2	0.0243	0.0022	5.00E-04	2.00E-04	0	0
Swim	Enterovirus	inf	Mean	La Niña	Current	The Cut	0.0251	0.0031	2.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	900m SW Outfall	0.0683	0.0101	0.0011	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Akersten Street	0.0035	5.00E-04	0	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Cable Bay	0.0361	0.004	6.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Glenduan	0.1026	0.0154	0.0016	2.00E-04	1.00E-04	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Magazine Point	0.0607	0.0077	6.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	NE edge of mixing zone	0.1357	0.0214	0.0023	3.00E-04	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Outfall	0.2342	0.0377	0.0044	2.00E-04	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Enterovirus	inf	Mean	La Niña	Future	Outside Boulder Bank	0.0316	0.0036	3.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	SW edge of mixing zone	0.13	0.0191	0.0018	2.00E-04	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Seafarers Memorial	0.0541	0.0062	6.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Snapper Point	0.0761	0.0084	0.0011	1.00E-04	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Tahunanui Beach	0.0234	0.0026	2.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Tasman Bay	0.0059	6.00E-04	1.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	La Niña	Future	Tasman Bay 2	0.0294	0.0027	6.00E-04	2.00E-04	1.00E-04	0
Swim	Enterovirus	inf	Mean	La Niña	Future	The Cut	0.0313	0.0039	3.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	900m SW Outfall	0.0479	0.0068	0.001	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Akersten Street	0.0028	3.00E-04	0	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Cable Bay	0.0317	0.0036	5.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Glenduan	0.0655	0.0089	0.0011	2.00E-04	1.00E-04	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Magazine Point	0.0335	0.004	4.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	NE edge of mixing zone	0.0978	0.0139	0.0016	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Outfall	0.173	0.0267	0.003	1.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Outside Boulder Bank	0.0229	0.0023	3.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	SW edge of mixing zone	0.0923	0.0123	0.0014	2.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Seafarers Memorial	0.0352	0.0042	5.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Snapper Point	0.0504	0.0054	8.00E-04	1.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Tahunanui Beach	0.0148	0.0014	0	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Tasman Bay	0.0039	1.00E-04	0	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	Tasman Bay 2	0.0198	0.0021	5.00E-04	2.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Current	The Cut	0.0194	0.002	1.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	900m SW Outfall	0.0572	0.0087	0.0011	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Enterovirus	inf	Mean	El Niño	Future	Akersten Street	0.0029	4.00E-04	0	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Cable Bay	0.0383	0.0043	7.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Glenduan	0.0843	0.0119	0.0014	2.00E-04	1.00E-04	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Magazine Point	0.0405	0.0048	4.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	NE edge of mixing zone	0.1198	0.0184	0.0022	1.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Outfall	0.2135	0.0349	0.0043	2.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Outside Boulder Bank	0.0264	0.0031	3.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	SW edge of mixing zone	0.1131	0.0164	0.0018	2.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Seafarers Memorial	0.0457	0.0055	5.00E-04	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Snapper Point	0.0643	0.0073	9.00E-04	1.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Tahunanui Beach	0.0188	0.0019	0	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Tasman Bay	0.0046	2.00E-04	0	0	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	Tasman Bay 2	0.0243	0.0022	6.00E-04	2.00E-04	0	0
Swim	Enterovirus	inf	Mean	El Niño	Future	The Cut	0.0243	0.0027	2.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	900m SW Outfall	3.00E-04	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Cable Bay	1.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Glenduan	0.0011	3.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Magazine Point	4.00E-04	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	NE edge of mixing zone	0.0013	2.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Outfall	0.0023	4.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Outside Boulder Bank	3.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	SW edge of mixing zone	0.0048	5.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Seafarers Memorial	0.0021	2.00E-04	1.00E-04	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Snapper Point	0.0025	2.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Tahunanui Beach	0.001	2.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	Tasman Bay 2	5.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Current	The Cut	0.0012	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	900m SW Outfall	3.00E-04	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Cable Bay	3.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Glenduan	0.0014	3.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Magazine Point	8.00E-04	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	NE edge of mixing zone	0.0017	3.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Outfall	0.0034	4.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Outside Boulder Bank	3.00E-04	2.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	SW edge of mixing zone	0.0067	6.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Seafarers Memorial	0.0033	3.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Snapper Point	0.0029	3.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Tahunanui Beach	0.0012	4.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	Tasman Bay 2	8.00E-04	2.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	La Niña	Future	The Cut	0.0014	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	900m SW Outfall	3.00E-04	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Cable Bay	2.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Glenduan	9.00E-04	3.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Magazine Point	3.00E-04	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	NE edge of mixing zone	0.0011	2.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Outfall	0.002	4.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Outside Boulder Bank	2.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	SW edge of mixing zone	0.0045	5.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Seafarers Memorial	0.0017	2.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Snapper Point	0.0018	2.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Tahunanui Beach	8.00E-04	1.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	Tasman Bay 2	5.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Current	The Cut	0.0011	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	900m SW Outfall	3.00E-04	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Akersten Street	0	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Cable Bay	3.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Glenduan	0.0011	3.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Magazine Point	4.00E-04	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	NE edge of mixing zone	0.0015	3.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Outfall	0.0029	4.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Outside Boulder Bank	3.00E-04	1.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	SW edge of mixing zone	0.0053	5.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Seafarers Memorial	0.0028	2.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Snapper Point	0.0026	3.00E-04	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Tahunanui Beach	9.00E-04	1.00E-04	1.00E-04	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Tasman Bay	0	0	0	0	0	0
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	Tasman Bay 2	5.00E-04	1.00E-04	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(aggregated)	inf	Mean	El Niño	Future	The Cut	0.0013	1.00E-04	0	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	900m SW Outfall	0.2594	0.0269	0.0023	4.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Akersten Street	0.0133	0.002	5.00E-04	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Cable Bay	0.094	0.0113	0.0013	2.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Glenduan	0.3577	0.0378	0.0038	3.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Magazine Point	0.1985	0.0208	0.0019	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	NE edge of mixing zone	0.6137	0.0692	0.0073	6.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Outfall	1.2393	0.1394	0.0143	0.0019	3.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Outside Boulder Bank	0.1102	0.0111	0.0013	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	SW edge of mixing zone	0.538	0.0566	0.0061	0.0011	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Seafarers Memorial	0.1816	0.0179	0.0023	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Snapper Point	0.2867	0.0296	0.0022	6.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Tahunanui Beach	0.069	0.0064	5.00E-04	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Tasman Bay	0.0281	0.0031	3.00E-04	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	Tasman Bay 2	0.0991	0.0117	0.001	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Current	The Cut	0.0812	0.0083	6.00E-04	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	900m SW Outfall	0.3385	0.036	0.0035	4.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Akersten Street	0.015	0.002	5.00E-04	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Cable Bay	0.1367	0.0173	0.0018	2.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Glenduan	0.4784	0.0495	0.0053	3.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Magazine Point	0.2906	0.0318	0.0027	2.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	NE edge of mixing zone	0.7709	0.0907	0.0095	7.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Outfall	1.6079	0.1852	0.0191	0.0025	3.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Outside Boulder Bank	0.1421	0.014	0.0014	1.00E-04	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	SW edge of mixing zone	0.6866	0.074	0.0072	0.0012	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Seafarers Memorial	0.2455	0.0257	0.003	3.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Snapper Point	0.361	0.0382	0.0034	7.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Tahunanui Beach	0.0887	0.0084	6.00E-04	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Tasman Bay	0.0356	0.0035	4.00E-04	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	Tasman Bay 2	0.1245	0.0136	0.0014	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	La Niña	Future	The Cut	0.1041	0.0102	7.00E-04	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	900m SW Outfall	0.2178	0.0218	0.0017	3.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Akersten Street	0.0116	0.0017	5.00E-04	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Cable Bay	0.1193	0.0149	0.0015	2.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Glenduan	0.2817	0.0274	0.0031	3.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Magazine Point	0.1568	0.0152	0.0017	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	NE edge of mixing zone	0.5222	0.0595	0.0058	4.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Outfall	1.11	0.1245	0.0135	0.0017	3.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Outside Boulder Bank	0.0906	0.0085	9.00E-04	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	SW edge of mixing zone	0.4513	0.0467	0.0048	8.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Seafarers Memorial	0.1577	0.0155	0.002	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Snapper Point	0.2335	0.0249	0.002	5.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Tahunanui Beach	0.0523	0.0045	5.00E-04	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Tasman Bay	0.0217	0.0025	2.00E-04	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	Tasman Bay 2	0.0795	0.0076	9.00E-04	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Current	The Cut	0.06	0.0061	4.00E-04	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	900m SW Outfall	0.278	0.0287	0.0029	4.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Akersten Street	0.0115	0.0019	5.00E-04	1.00E-04	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Cable Bay	0.1415	0.0186	0.0019	3.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Glenduan	0.359	0.037	0.0037	3.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Magazine Point	0.1905	0.0196	0.0018	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	NE edge of mixing zone	0.6729	0.079	0.008	6.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Outfall	1.4737	0.1701	0.0175	0.0023	3.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Outside Boulder Bank	0.113	0.0113	0.0012	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	SW edge of mixing zone	0.5891	0.0625	0.0068	0.0011	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Seafarers Memorial	0.2091	0.022	0.0027	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Snapper Point	0.3027	0.0318	0.0027	7.00E-04	1.00E-04	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Tahunanui Beach	0.0679	0.006	5.00E-04	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Tasman Bay	0.0268	0.0033	2.00E-04	0	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	Tasman Bay 2	0.098	0.0116	0.001	1.00E-04	0	0
Swim	Norovirus(disaggregated)	inf	Mean	El Niño	Future	The Cut	0.0761	0.008	5.00E-04	0	0	0

Appendix D Health risks secondary contact recreation

Table D-1: Estimates of mean Individual illness risk (IIR) associated with secondary recreation at exposure sites at given level of wastewater treatment. Endpoint indicates illness (Ill), statistics are the mean IIR, Exposure is inhalation, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge conditions, Path. = norovirus or enterovirus, State (applies to norovirus only) indicates disaggregated or aggregated forms, Site no. is unique site identifier number, Site name is unique site name, Level of treatment = $\log_{10}$ level of treatment. Colours green, yellow, orange and red refer to category A, B, C and D see Table 4-1

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reduction in virus concentration (LRV)					
					1	2	3	4	5	6
Inhalation	Adenovirus	La Niña	Current	900m SW Outfall	0.0257	0.0023	0.0003	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Akersten Street	0.0007	0.0000	0.0000	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Cable Bay	0.0096	0.0011	0.0001	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Glenduan	0.0364	0.0042	0.0001	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Magazine Point	0.0200	0.0026	0.0001	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	NE edge of mixing zone	0.0579	0.0052	0.0004	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Outfall	0.1124	0.0156	0.0016	0.0001	0	0
Inhalation	Adenovirus	La Niña	Current	Outside Boulder Bank	0.0126	0.0011	0.0001	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	SW edge of mixing zone	0.0482	0.0061	0.0009	0.0002	0	0
Inhalation	Adenovirus	La Niña	Current	Seafarers Memorial	0.0234	0.0031	0.0003	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Snapper Point	0.0295	0.0026	0.0002	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Tahunanui Beach	0.0082	0.0010	0.0000	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Tasman Bay	0.0020	0.0001	0.0000	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	Tasman Bay 2	0.0118	0.0011	0.0001	0.0000	0	0
Inhalation	Adenovirus	La Niña	Current	The Cut	0.0078	0.0010	0.0000	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	900m SW Outfall	0.0321	0.0031	0.0003	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	Akersten Street	0.0007	0.0000	0.0000	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	Cable Bay	0.0149	0.0016	0.0003	0.0000	0	0

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reduction in virus concentration (LRV)					
					1	2	3	4	5	6
Inhalation	Adenovirus	La Niña	Future	Glenduan	0.0468	0.0056	0.0002	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	Magazine Point	0.0305	0.0039	0.0001	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	NE edge of mixing zone	0.0734	0.0073	0.0007	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	Outfall	0.1413	0.0201	0.0021	0.0001	0	0
Inhalation	Adenovirus	La Niña	Future	Outside Boulder Bank	0.0152	0.0013	0.0001	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	SW edge of mixing zone	0.0615	0.0087	0.0011	0.0002	0	0
Inhalation	Adenovirus	La Niña	Future	Seafarers Memorial	0.0303	0.0037	0.0004	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	Snapper Point	0.0367	0.0036	0.0003	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	Tahunanui Beach	0.0100	0.0012	0.0000	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	Tasman Bay	0.0028	0.0001	0.0000	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	Tasman Bay 2	0.0147	0.0013	0.0002	0.0000	0	0
Inhalation	Adenovirus	La Niña	Future	The Cut	0.0108	0.0010	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	900m SW Outfall	0.0204	0.0018	0.0003	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	Akersten Street	0.0005	0.0000	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	Cable Bay	0.0128	0.0015	0.0001	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	Glenduan	0.0295	0.0031	0.0001	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	Magazine Point	0.0162	0.0020	0.0001	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	NE edge of mixing zone	0.0510	0.0044	0.0003	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	Outfall	0.1009	0.0132	0.0012	0.0001	0	0
Inhalation	Adenovirus	El Niño	Current	Outside Boulder Bank	0.0103	0.0011	0.0001	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	SW edge of mixing zone	0.0422	0.0055	0.0008	0.0002	0	0
Inhalation	Adenovirus	El Niño	Current	Seafarers Memorial	0.0213	0.0028	0.0002	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	Snapper Point	0.0248	0.0021	0.0002	0.0000	0	0

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six log reduction in virus concentration (LRV)					
					1	2	3	4	5	6
Inhalation	Adenovirus	El Niño	Current	Tahunanui Beach	0.0060	0.0007	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	Tasman Bay	0.0014	0.0001	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	Tasman Bay 2	0.0097	0.0010	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Current	The Cut	0.0060	0.0008	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	900m SW Outfall	0.0263	0.0025	0.0003	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Akersten Street	0.0005	0.0000	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Cable Bay	0.0160	0.0017	0.0003	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Glenduan	0.0374	0.0040	0.0001	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Magazine Point	0.0194	0.0026	0.0001	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	NE edge of mixing zone	0.0629	0.0060	0.0004	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Outfall	0.1305	0.0187	0.0020	0.0001	0	0
Inhalation	Adenovirus	El Niño	Future	Outside Boulder Bank	0.0128	0.0013	0.0001	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	SW edge of mixing zone	0.0514	0.0074	0.0009	0.0002	0	0
Inhalation	Adenovirus	El Niño	Future	Seafarers Memorial	0.0275	0.0035	0.0003	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Snapper Point	0.0304	0.0029	0.0002	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Tahunanui Beach	0.0080	0.0011	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Tasman Bay	0.0019	0.0001	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	Tasman Bay 2	0.0117	0.0011	0.0000	0.0000	0	0
Inhalation	Adenovirus	El Niño	Future	The Cut	0.0077	0.0010	0.0000	0.0000	0	0

Table D-2: Estimates of 95%ile Individual illness risk (IIR) associated with secondary contact recreation at exposure sites at given level of wastewater treatment. Endpoint indicates infection (Illness), statistic is the 95%ile, Exposure is inhalation, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge.

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	900m SW Outfall	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Akersten Street	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Cable Bay	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Glenduan	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Magazine Point	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	NE edge of mixing zone	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Outfall	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Outside Boulder Bank	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	SW edge of mixing zone	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Seafarers Memorial	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Snapper Point	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Tahunanui Beach	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Tasman Bay	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	Tasman Bay 2	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Current	The Cut	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	900m SW Outfall	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Akersten Street	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Cable Bay	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Glenduan	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Magazine Point	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	NE edge of mixing zone	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Outfall	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Outside Boulder Bank	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	SW edge of mixing zone	0	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Seafarers Memorial	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Snapper Point	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Tahunanui Beach	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Tasman Bay	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	Tasman Bay 2	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	La Niña	Future	The Cut	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	900m SW Outfall	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Akersten Street	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Cable Bay	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Glenduan	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Magazine Point	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	NE edge of mixing zone	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Outfall	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Outside Boulder Bank	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	SW edge of mixing zone	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Seafarers Memorial	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Snapper Point	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Tahunanui Beach	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Tasman Bay	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	Tasman Bay 2	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Current	The Cut	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	900m SW Outfall	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Akersten Street	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Cable Bay	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Glenduan	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Magazine Point	0	0	0	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	NE edge of mixing zone	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Outfall	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Outside Boulder Bank	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	SW edge of mixing zone	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Seafarers Memorial	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Snapper Point	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Tahunanui Beach	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Tasman Bay	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	Tasman Bay 2	0	0	0	0	0	0
Inhalation	Adenovirus	ill	95%ile	El Niño	Future	The Cut	0	0	0	0	0	0

Table D-3: Estimates of mean Individual infection risk (IInfR) associated with secondary contact recreation at exposure sites at given level of . Endpoint indicates infection (Inf), statistic is the mean, Exposure is inhalation, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge.

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Inhalation	Adenovirus	inf	Mean	La Niña	Current	900m SW Outfall	0.0471	0.0045	7.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Akersten Street	0.0022	5.00E-04	0	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Cable Bay	0.0177	0.0015	1.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Glenduan	0.0699	0.0087	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Magazine Point	0.0393	0.005	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	NE edge of mixing zone	0.1198	0.011	6.00E-04	1.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Outfall	0.2333	0.0308	0.0026	1.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Outside Boulder Bank	0.0258	0.0021	2.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	SW edge of mixing zone	0.0995	0.0104	0.0012	2.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Seafarers Memorial	0.0483	0.0053	4.00E-04	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Snapper Point	0.0575	0.0051	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Tahunanui Beach	0.0168	0.0016	0	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Tasman Bay	0.004	4.00E-04	0	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	Tasman Bay 2	0.0225	0.0019	2.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Current	The Cut	0.0176	0.0015	1.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	900m SW Outfall	0.0604	0.0061	7.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Akersten Street	0.0024	5.00E-04	1.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Cable Bay	0.0285	0.0023	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Glenduan	0.0901	0.0109	5.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Magazine Point	0.0579	0.0074	5.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	NE edge of mixing zone	0.1495	0.0148	9.00E-04	1.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Outfall	0.2865	0.0406	0.0032	1.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Outside Boulder Bank	0.0314	0.0028	2.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	SW edge of mixing zone	0.1274	0.015	0.0018	2.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Seafarers Memorial	0.0629	0.0069	6.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Snapper Point	0.0708	0.0074	5.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Tahunanui Beach	0.0208	0.0021	0	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Tasman Bay	0.0053	4.00E-04	0	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	Tasman Bay 2	0.0278	0.0025	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	La Niña	Future	The Cut	0.0223	0.0018	1.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	900m SW Outfall	0.0373	0.0035	7.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Akersten Street	0.0018	3.00E-04	0	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Cable Bay	0.0235	0.0021	1.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Glenduan	0.0555	0.0062	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Magazine Point	0.0317	0.0039	2.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	NE edge of mixing zone	0.1053	0.0095	5.00E-04	1.00E-04	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Outfall	0.2112	0.0274	0.0021	1.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Outside Boulder Bank	0.0217	0.0019	2.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	SW edge of mixing zone	0.0867	0.0092	0.001	2.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Seafarers Memorial	0.0446	0.0052	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Snapper Point	0.048	0.0044	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Tahunanui Beach	0.0133	0.0011	0	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Tasman Bay	0.0031	2.00E-04	0	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	Tasman Bay 2	0.018	0.0016	1.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Current	The Cut	0.013	0.0011	1.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	900m SW Outfall	0.0496	0.0049	7.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Akersten Street	0.0018	4.00E-04	0	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Cable Bay	0.0297	0.0026	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Glenduan	0.0715	0.0082	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Magazine Point	0.0379	0.005	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	NE edge of mixing zone	0.1289	0.0126	6.00E-04	1.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Outfall	0.2663	0.0377	0.003	1.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Outside Boulder Bank	0.0265	0.0022	2.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	SW edge of mixing zone	0.1076	0.0123	0.0013	2.00E-04	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Seafarers Memorial	0.0568	0.0065	5.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Snapper Point	0.0602	0.0056	3.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Tahunanui Beach	0.0166	0.0017	0	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Tasman Bay	0.0039	4.00E-04	0	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	Tasman Bay 2	0.0221	0.0019	1.00E-04	0	0	0
Inhalation	Adenovirus	inf	Mean	El Niño	Future	The Cut	0.017	0.0015	1.00E-04	0	0	0

Appendix E Health risks shellfish consumption

Table E-1: Estimates of Gastrointestinal mean Individual illness risk (IIR) associated with shellfish consumption at exposure sites at given level of wastewater treatment. Endpoint indicates illness (Ill), statistics are mean IIR, Exposure is shellfish, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge conditions, Path. = norovirus or enterovirus, State (applies to norovirus only) indicates disaggregated or aggregated forms, Site no. is unique site identifier number, Site name is unique site name, Level of treatment = $\log_{10}$ level of treatment. Colours green, yellow, orange and red refer to category A, B, C and D see Table 4-1.

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six Log reduction in virus concentration (LRV)					
					1	2	3	4	5	6
Shellfish	Norovirus(Dis)	La Niña	Current	900m SW Outfall	6.6901	1.4111	0.2341	0.0262	0.0025	0.0002
Shellfish	Norovirus(Dis)	La Niña	Current	Akersten Street	0.7615	0.1079	0.0115	0.0008	0.0000	0.0000
Shellfish	Norovirus(Dis)	La Niña	Current	Cable Bay	3.2292	0.5726	0.0827	0.0076	0.0010	0.0001
Shellfish	Norovirus(Dis)	La Niña	Current	Glenduan	8.1055	1.8726	0.3198	0.0329	0.0033	0.0003
Shellfish	Norovirus(Dis)	La Niña	Current	Magazine Point	5.3939	1.1137	0.1781	0.0199	0.0026	0.0001
Shellfish	Norovirus(Dis)	La Niña	Current	NE edge of mixing zone	10.6954	2.8042	0.5115	0.0673	0.0058	0.0004
Shellfish	Norovirus(Dis)	La Niña	Current	Outfall	14.3043	4.8386	0.8985	0.1263	0.0140	0.0013
Shellfish	Norovirus(Dis)	La Niña	Current	Outside Boulder Bank	3.8553	0.7293	0.1075	0.0114	0.0012	0.0001
Shellfish	Norovirus(Dis)	La Niña	Current	SW edge of mixing zone	9.9537	2.5868	0.4583	0.0590	0.0070	0.0007
Shellfish	Norovirus(Dis)	La Niña	Current	Seafarers Memorial	5.2132	1.0218	0.1597	0.0181	0.0021	0.0002
Shellfish	Norovirus(Dis)	La Niña	Current	Snapper Point	7.4858	1.5854	0.2752	0.0341	0.0026	0.0002
Shellfish	Norovirus(Dis)	La Niña	Current	Tahunanui Beach	3.0116	0.5405	0.0738	0.0073	0.0006	0.0001
Shellfish	Norovirus(Dis)	La Niña	Current	Tasman Bay	1.1799	0.2085	0.0286	0.0038	0.0005	0.0000
Shellfish	Norovirus(Dis)	La Niña	Current	Tasman Bay 2	3.4010	0.6091	0.0869	0.0091	0.0013	0.0000
Shellfish	Norovirus(Dis)	La Niña	Current	The Cut	3.3900	0.6087	0.0812	0.0078	0.0001	0.0000
Shellfish	Norovirus(Dis)	La Niña	Future	900m SW Outfall	7.7796	1.7452	0.2943	0.0337	0.0035	0.0003
Shellfish	Norovirus(Dis)	La Niña	Future	Akersten Street	0.8304	0.1199	0.0128	0.0010	0.0000	0.0000

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six Log reduction in virus concentration (LRV)					
					1	2	3	4	5	6
Shellfish	Norovirus(Dis)	La Niña	Future	Cable Bay	4.3587	0.8155	0.1221	0.0121	0.0016	0.0002
Shellfish	Norovirus(Dis)	La Niña	Future	Glenduan	9.1593	2.3028	0.4069	0.0463	0.0045	0.0006
Shellfish	Norovirus(Dis)	La Niña	Future	Magazine Point	6.8528	1.5375	0.2549	0.0305	0.0037	0.0003
Shellfish	Norovirus(Dis)	La Niña	Future	NE edge of mixing zone	11.9119	3.3589	0.6218	0.0868	0.0081	0.0006
Shellfish	Norovirus(Dis)	La Niña	Future	Outfall	15.5639	5.8483	1.1188	0.1611	0.0182	0.0018
Shellfish	Norovirus(Dis)	La Niña	Future	Outside Boulder Bank	4.4829	0.8816	0.1338	0.0141	0.0016	0.0001
Shellfish	Norovirus(Dis)	La Niña	Future	SW edge of mixing zone	11.1726	3.1231	0.5733	0.0785	0.0086	0.0009
Shellfish	Norovirus(Dis)	La Niña	Future	Seafarers Memorial	6.2867	1.3186	0.2108	0.0250	0.0031	0.0003
Shellfish	Norovirus(Dis)	La Niña	Future	Snapper Point	8.6091	1.9148	0.3455	0.0429	0.0034	0.0002
Shellfish	Norovirus(Dis)	La Niña	Future	Tahunanui Beach	3.6418	0.6734	0.0952	0.0090	0.0008	0.0001
Shellfish	Norovirus(Dis)	La Niña	Future	Tasman Bay	1.4250	0.2514	0.0352	0.0046	0.0006	0.0000
Shellfish	Norovirus(Dis)	La Niña	Future	Tasman Bay 2	3.9918	0.7409	0.1059	0.0117	0.0015	0.0001
Shellfish	Norovirus(Dis)	La Niña	Future	The Cut	4.0429	0.7384	0.1028	0.0100	0.0005	0.0000
Shellfish	Norovirus(Dis)	El Niño	Current	900m SW Outfall	5.6894	1.1925	0.1969	0.0213	0.0019	0.0001
Shellfish	Norovirus(Dis)	El Niño	Current	Akersten Street	0.6651	0.0951	0.0097	0.0009	0.0000	0.0000
Shellfish	Norovirus(Dis)	El Niño	Current	Cable Bay	3.8413	0.6992	0.1065	0.0103	0.0016	0.0001
Shellfish	Norovirus(Dis)	El Niño	Current	Glenduan	7.2807	1.5519	0.2571	0.0239	0.0028	0.0003
Shellfish	Norovirus(Dis)	El Niño	Current	Magazine Point	4.4090	0.8922	0.1426	0.0162	0.0024	0.0001
Shellfish	Norovirus(Dis)	El Niño	Current	NE edge of mixing zone	9.7107	2.4613	0.4397	0.0567	0.0044	0.0004
Shellfish	Norovirus(Dis)	El Niño	Current	Outfall	13.4303	4.4239	0.8164	0.1141	0.0130	0.0012
Shellfish	Norovirus(Dis)	El Niño	Current	Outside Boulder Bank	3.2721	0.6148	0.0885	0.0096	0.0009	0.0001
Shellfish	Norovirus(Dis)	El Niño	Current	SW edge of mixing zone	8.8456	2.2424	0.3940	0.0499	0.0060	0.0007
Shellfish	Norovirus(Dis)	El Niño	Current	Seafarers Memorial	4.3831	0.8717	0.1373	0.0168	0.0019	0.0002

Exposure	Pathogen	Climate	Time	Site name	Mean IIR (%) for six Log reduction in virus concentration (LRV)					
					1	2	3	4	5	6
Shellfish	Norovirus(Dis)	El Niño	Current	Snapper Point	6.4735	1.3509	0.2258	0.0289	0.0019	0.0002
Shellfish	Norovirus(Dis)	El Niño	Current	Tahunanui Beach	2.4462	0.4353	0.0585	0.0061	0.0005	0.0001
Shellfish	Norovirus(Dis)	El Niño	Current	Tasman Bay	0.9159	0.1591	0.0224	0.0026	0.0003	0.0000
Shellfish	Norovirus(Dis)	El Niño	Current	Tasman Bay 2	2.9703	0.5110	0.0688	0.0076	0.0011	0.0000
Shellfish	Norovirus(Dis)	El Niño	Current	The Cut	2.6312	0.4632	0.0619	0.0054	0.0000	0.0000
Shellfish	Norovirus(Dis)	El Niño	Future	900m SW Outfall	6.6152	1.4671	0.2478	0.0286	0.0030	0.0003
Shellfish	Norovirus(Dis)	El Niño	Future	Akersten Street	0.6835	0.0994	0.0101	0.0008	0.0000	0.0000
Shellfish	Norovirus(Dis)	El Niño	Future	Cable Bay	4.4192	0.8341	0.1276	0.0126	0.0016	0.0002
Shellfish	Norovirus(Dis)	El Niño	Future	Glenduan	8.5644	1.9168	0.3297	0.0345	0.0034	0.0004
Shellfish	Norovirus(Dis)	El Niño	Future	Magazine Point	5.0391	1.0518	0.1713	0.0190	0.0025	0.0001
Shellfish	Norovirus(Dis)	El Niño	Future	NE edge of mixing zone	11.0171	3.0032	0.5542	0.0751	0.0064	0.0005
Shellfish	Norovirus(Dis)	El Niño	Future	Outfall	14.7437	5.4281	1.0340	0.1487	0.0163	0.0015
Shellfish	Norovirus(Dis)	El Niño	Future	Outside Boulder Bank	3.7618	0.7305	0.1102	0.0117	0.0013	0.0001
Shellfish	Norovirus(Dis)	El Niño	Future	SW edge of mixing zone	10.0277	2.7386	0.4920	0.0660	0.0078	0.0007
Shellfish	Norovirus(Dis)	El Niño	Future	Seafarers Memorial	5.3673	1.1169	0.1770	0.0209	0.0022	0.0003
Shellfish	Norovirus(Dis)	El Niño	Future	Snapper Point	7.6503	1.6527	0.2900	0.0360	0.0029	0.0002
Shellfish	Norovirus(Dis)	El Niño	Future	Tahunanui Beach	2.9686	0.5411	0.0729	0.0072	0.0006	0.0001
Shellfish	Norovirus(Dis)	El Niño	Future	Tasman Bay	1.0918	0.1960	0.0282	0.0036	0.0005	0.0000
Shellfish	Norovirus(Dis)	El Niño	Future	Tasman Bay 2	3.4978	0.6235	0.0857	0.0090	0.0014	0.0000
Shellfish	Norovirus(Dis)	El Niño	Future	The Cut	3.1608	0.5674	0.0761	0.0071	0.0001	0.0000

Table E-2: Estimates of Gastrointestinal 95%ile Individual illness risk (IIR) associated with shellfish consumption at given level of wastewater treatment. Endpoint indicates illness, statistic is the 95%ile, Exposure is shellfish, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge. (dis) indicates disaggregated state.

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	900m SW Outfall	20	6	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Akersten Street	3	1	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Cable Bay	14	2	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Glenduan	21	8	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Magazine Point	19	5	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	NE edge of mixing zone	23	12	2	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Outfall	25	16	4	1	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Outside Boulder Bank	16	3	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	SW edge of mixing zone	23	11	2	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Seafarers Memorial	18	5	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Snapper Point	20	7	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Tahunanui Beach	13	2	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Tasman Bay	6	1	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	Tasman Bay 2	15	3	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Current	The Cut	13	2	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	900m SW Outfall	21	8	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Akersten Street	4	1	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Cable Bay	17	4	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Glenduan	22	10	2	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Magazine Point	20	7	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	NE edge of mixing zone	24	14	3	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Outfall	26	18	4	1	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Outside Boulder Bank	18	4	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	SW edge of mixing zone	24	13	2	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Seafarers Memorial	20	6	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Snapper Point	21	8	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Tahunanui Beach	15	3	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Tasman Bay	7	1	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	Tasman Bay 2	16	3	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	La Niña	Future	The Cut	15	3	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	900m SW Outfall	19	6	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Akersten Street	3	1	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Cable Bay	16	3	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Glenduan	20	6	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Magazine Point	18	4	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	NE edge of mixing zone	22	11	2	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Outfall	25	16	3	1	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Outside Boulder Bank	15	3	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	SW edge of mixing zone	22	10	2	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Seafarers Memorial	18	4	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Snapper Point	20	6	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Tahunanui Beach	11	2	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Tasman Bay	5	1	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	Tasman Bay 2	13	2	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Current	The Cut	11	2	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	900m SW Outfall	20	7	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Akersten Street	3	1	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Cable Bay	17	4	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Glenduan	21	8	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Magazine Point	19	5	1	0	0	0

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Ninety-fifth percentile IIR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	NE edge of mixing zone	23	13	2	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Outfall	26	18	4	1	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Outside Boulder Bank	16	3	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	SW edge of mixing zone	23	12	2	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Seafarers Memorial	19	5	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Snapper Point	21	7	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Tahunanui Beach	13	2	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Tasman Bay	6	1	0	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	Tasman Bay 2	15	3	1	0	0	0
Shellfish	Norovirus(dis)	ill	95%ile	El Niño	Future	The Cut	13	2	0	0	0	0

Table E-3: Estimates of Gastrointestinal mean Individual infection risk (IInfR) associated with shellfish consumption at given level of wastewater treatment.
Endpoint indicates infection, statistic is the mean, Exposure is shellfish, Climate is for La Niña or El Niño conditions, Time indicates Existing or future discharge.

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	900m SW Outfall	15.0269	3.1813	0.5352	0.0639	0.0065	2.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Akersten Street	1.7178	0.2403	0.0273	0.0026	0	0
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Cable Bay	7.3133	1.2959	0.1892	0.0199	0.0022	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Glenduan	18.1952	4.1782	0.7122	0.0795	0.0081	8.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Magazine Point	12.1474	2.5169	0.4047	0.0463	0.0047	6.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	NE edge of mixing zone	24.1075	6.305	1.1497	0.1571	0.0168	0.0013
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Outfall	32.1973	10.9152	2.0211	0.2836	0.0316	0.0026
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Outside Boulder Bank	8.6113	1.6384	0.241	0.025	0.0027	4.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	SW edge of mixing zone	22.3372	5.7852	1.0363	0.1348	0.014	0.0013
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Seafarers Memorial	11.6512	2.2909	0.3498	0.0403	0.0047	5.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Snapper Point	16.8252	3.5786	0.6036	0.0724	0.0059	5.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Tahunanui Beach	6.7543	1.2059	0.1584	0.0165	0.0015	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Tasman Bay	2.6484	0.458	0.0605	0.0064	7.00E-04	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	Tasman Bay 2	7.6673	1.3833	0.1954	0.0205	0.0029	0
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Current	The Cut	7.6633	1.3608	0.1846	0.018	0.0011	2.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	900m SW Outfall	17.4753	3.9189	0.671	0.083	0.009	6.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Akersten Street	1.868	0.2669	0.0299	0.0029	0	0
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Cable Bay	9.8357	1.8316	0.2785	0.0306	0.0037	3.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Glenduan	20.5461	5.1509	0.9072	0.1095	0.0108	0.0014
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Magazine Point	15.448	3.4589	0.579	0.0702	0.007	9.00E-04

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	NE edge of mixing zone	26.8526	7.5475	1.4033	0.2012	0.0213	0.0018
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Outfall	35.0561	13.198	2.5257	0.3661	0.0421	0.0038
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Outside Boulder Bank	10.0374	1.975	0.2977	0.0309	0.0036	4.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	SW edge of mixing zone	25.071	7.0067	1.282	0.177	0.0172	0.0016
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Seafarers Memorial	14.0922	2.946	0.4625	0.0547	0.0063	6.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Snapper Point	19.3548	4.3133	0.7564	0.0935	0.008	6.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Tahunanui Beach	8.1659	1.4955	0.2089	0.0209	0.0019	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Tasman Bay	3.2038	0.5584	0.0745	0.0086	8.00E-04	2.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	Tasman Bay 2	8.9756	1.6804	0.2399	0.0253	0.0035	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	La Niña	Future	The Cut	9.1231	1.6536	0.2324	0.0233	0.0017	2.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	900m SW Outfall	12.7968	2.6932	0.4523	0.0528	0.0053	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Akersten Street	1.5024	0.2094	0.0226	0.0024	0	0
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Cable Bay	8.6871	1.5745	0.2408	0.0263	0.0033	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Glenduan	16.3425	3.4691	0.5688	0.0584	0.0066	6.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Magazine Point	9.9422	2.0252	0.3264	0.0366	0.004	5.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	NE edge of mixing zone	21.8701	5.5335	0.9946	0.1334	0.0132	0.0011
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Outfall	30.2399	9.968	1.8317	0.2547	0.029	0.0025
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Outside Boulder Bank	7.307	1.3801	0.1977	0.0205	0.0023	4.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	SW edge of mixing zone	19.8391	5.0185	0.8903	0.1144	0.012	0.0013
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Seafarers Memorial	9.8214	1.9504	0.2982	0.0365	0.0042	4.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Snapper Point	14.5543	3.0335	0.5001	0.0619	0.0047	5.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Tahunanui Beach	5.5027	0.974	0.1246	0.0137	0.0011	1.00E-04

Exposure	Pathogen	End Point	Stat	Climate	Time	Site name	Mean IInfR (%) for six Log reduction in virus concentration (LRV)					
							1	2	3	4	5	6
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Tasman Bay	2.0461	0.3442	0.045	0.0046	5.00E-04	0
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	Tasman Bay 2	6.687	1.1556	0.1543	0.0164	0.0021	0
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Current	The Cut	5.9434	1.0343	0.1404	0.0127	7.00E-04	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	900m SW Outfall	14.8636	3.3042	0.5616	0.0699	0.0072	4.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Akersten Street	1.5416	0.2189	0.0238	0.0022	0	0
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Cable Bay	9.9862	1.8743	0.2909	0.0324	0.0038	3.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Glenduan	19.1978	4.287	0.7336	0.0819	0.0085	8.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Magazine Point	11.3578	2.3753	0.3883	0.0443	0.0044	6.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	NE edge of mixing zone	24.8284	6.7503	1.2429	0.175	0.0184	0.0016
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Outfall	33.186	12.2616	2.3203	0.336	0.0388	0.0034
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Outside Boulder Bank	8.3997	1.6373	0.2451	0.0258	0.0028	4.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	SW edge of mixing zone	22.4953	6.1241	1.1084	0.1508	0.0155	0.0014
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Seafarers Memorial	12.0364	2.4965	0.3901	0.0464	0.005	6.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Snapper Point	17.1903	3.7296	0.6365	0.0777	0.0067	5.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Tahunanui Beach	6.6638	1.2012	0.1575	0.0168	0.0013	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Tasman Bay	2.4546	0.4286	0.0582	0.006	7.00E-04	1.00E-04
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	Tasman Bay 2	7.874	1.4102	0.1941	0.02	0.003	0
Shellfish	Norovirus(dis)	inf	Mean	El Niño	Future	The Cut	7.1462	1.2682	0.1756	0.0169	0.001	1.00E-04