Regional information for setting draft targets for swimmable lakes and rivers

A report on work underway to improve water quality in terms of effects on human health

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Background

The driver for this report is the national targets relating to swimming for New Zealand's rivers and lakes that have been added to the National Policy Statement for Freshwater Management 2014, updated August 2017 (NPS-FM).

The targets relating to swimmable lakes and rivers are that:

- 90 per cent of rivers and lakes are suitable for primary contact (i.e. in the blue, green or yellow categories) by 2040 with 80 per cent swimmable by 2030
- Water quality is improved across all categories.

These targets only apply to rivers above Strahler Order 4, and to lakes with a perimeter greater than 1,500 meters. (Strahler Order is determined by the tributaries of the river – a first order stream has no tributaries, a second order stream has only first order tributaries, a third order stream has at least one second order tributary and so on.)

To fulfil these targets, regional councils and unitary authorities (collectively called regional councils) were asked to report to the former government on a proposed regional target by October 2017. On 28 February 2017 the then Minister for the Environment requested information on the:

- rivers and lakes where interventions are planned or in place that will improve water quality so that it is swimmable
- rivers and lakes where additional interventions will improve water quality so that they are swimmable more often, the level of improvement those interventions would achieve, and the timeframes to achieve them
- likely costs of the interventions described above, and the parties on whom those costs would fall.

Since the request, the NPS-FM has been amended. Policy A6 requires that regional councils make draft regional targets available to the public by 31 March 2018, and final targets available to the public by December 2018.

To respond to the previous government's request, regional councils, the Ministry for the Environment, and the Ministry for Primary Industries created a governance group and taskforce to manage and oversee the response. This report contains information on the planned interventions, and the indicative costs of that work. Work on what further interventions may be required is currently on hold pending advice from the current Minister for the Environment, Hon David Parker.

What is a swimmable lake or river?

In the NPS-FM, the approach for measuring water quality for swimming is determined by *E. coli* concentrations in rivers and toxic algae biovolume in lakes. *E. coli* is used as an indicator of the risk to human health presented when swimming in that river. *E. coli* represents the presence of likely faecal contamination, although under some environmental conditions *E. coli* can self-replicate in water ways and this is more common in the north of New Zealand.

E. coli has been adopted in Appendix 2 of the NPS-FM as an attribute for the compulsory value - human health for recreation. The *E. coli* attribute table has five attribute states (i.e. A, B, C, D and E or excellent, good, fair, intermittent and poor respectively). Each attribute state has four criteria, or 'statistical tests', that need to be satisfied for water quality to be in that attribute state. All four criteria are necessary to establish an attribute state. If one or more criteria can't be satisfied, a lower attribute state must apply.

For example, for a river to be in the A state, the water quality of that river must:

- not exceed 540 *E. coli*/100ml more than 5% of the time; and
- not exceed 260 *E. coli*/100ml more than 20% of the time; and
- have a median of ≤130 *E. coli*/100ml; and
- have a 95th percentile of ≤540 *E. coli*/100ml.

If any of those criteria are not satisfied, water quality is in a lower state (e.g. B, or lower, as long as all criteria can be satisfied).

The New Zealand public were the driving force behind establishing national targets for swimming. While *E. coli* is only one measure of water quality, it is an important one with respect to human health. However, it is important to acknowledge that regional councils around the country will be responding to the specific pressures in their region, and may have programmes in place to address other concerns that their communities want to prioritise, such as weeds, access, sediment, clarity nitrogen, or phosphorus.

There is also work happening around the country relating to swimming that could not be modelled in this report. For example, Fonterra has announced its intention to improve water quality for swimming in 50 priority catchments, and successful applicants for the Freshwater Improvement Fund have received provisional funding for *E. coli*-related clean-up projects (including infrastructure projects).

Overview of the approach

The taskforce managing delivery of this work agreed on the approach and deliverable in response to the specific request contained in the background. More specific detail on the approach, limitations and assumptions taken to the water quality for swimming modelling are included in Appendix A and Appendix E. More specific detail on the approach, limitations and assumptions underpinning the economics analysis are included in Appendix B.

The purpose of this report is to identify the work committed to in each region (planning, policy or infrastructure improvements), and provide an indication of the expected improvement in water quality for swimming and the associated cost. This improvement, and the cost, has been calculated both regionally and nationally.

Approach to scientific modelling

The approach taken to produce this report is broadly outlined below:

- the taskforce used the Ministry for the Environment's water quality for swimming map as the baseline for this work. Information was requested from regional councils on whether the maps had any discrepancies (based on local knowledge) and the swimming map was adjusted accordingly. The adjusted swimming map was then taken as the baseline (i.e. national river swimmability as of 2017). This map is attached as Appendix C.

- the taskforce requested and received information from councils that described commitments to water quality mitigation work in each region (the 'committed work'). It was assumed the committed works included stock exclusion proposals associated with the Clean Water Proposals at that time (just after consultation on the Clean Water Package). The committed works also included regional initiatives. Councils were also asked to provide information describing the expected impact of that work based on research that had been completed or commissioned, and cost data (where it was available).
- NIWA was commissioned to model improvements in water quality associated with the committed work and assess how much this would improve water quality for swimming. To do this, NIWA used a national version of the Catchment Land Use for Environmental Sustainability (CLUES, Elliott et al, 2016) water quality model[1] to estimate changes to water quality due to the interventions. More specific information on the water quality modelling is in Appendix A.
- regional councils provided information on planned point source upgrades, and NIWA used this information to model the impact of the upgrades on water quality. A table of the point source upgrades that were modelled, with their current and revised concentrations is included in the report attached as Appendix E.
- the information on non-point source committed work was provided to a mitigation expert panel. The mitigation expert panel worked with NIWA to determine the effectiveness of these mitigations. The rural mitigations around the country fell into three broad categories:
    - Excluding stock from waterways;
    - Riparian planting; and
    - Management of Farm Dairy effluent.
- The model was used to predict how the current baseline water quality represented by the swimming map would change in response to the committed work. It is important to note that the modelling only relates to *E. coli*, and therefore only shows the projected improvement in rivers. These predictions for rivers were combined with information describing the current state of lakes to provide projections of swimmability by region and nationally.

While there are areas where the science can be improved, for example, the ability to model all four criteria for *E. coli* results in rivers, it is unlikely these matters will be resolved over the next six months. The Taskforce felt that these uncertainties should not prevent councils making the best estimations possible with the tools and knowledge available to meet the deadline set in the NPS-FM.

Reliability of modelling potential water quality improvements

In parallel to this work, the Ministry for the Environment and Horizons Regional Council completed a project to better understand improvements in water quality in the Manawatu-Whanganui region (focused on pathogens and sediment). The region has seen a regional improvement in water quality in the past 7 - 10 years. This includes improvements in suspended sediment, water clarity, turbidity

[1] Elliott, A.H., Semadeni-Davies, A.F., Shankar, U., Zeldis, J.R., Wheeler, D.M., Plew, D.R., Rys, G.J. and Harris, S.R. (2016) A national-scale GIS-based system for modelling impacts of land use on water quality. *Environmental Modelling & Software*, 86: 131-144.

and *E. coli*. The study found a 5 - 8% improvement in the swimmability of rivers in the decade ending 2016. Horizons' report was published in February 2018.[2]

The key findings provide evidence that a coordinated approach can have improvements in water quality, and show an association between water quality improvements and the proportion of farms in each catchment where interventions have occurred to reduce hill country erosion. It also demonstrates improvements related to the upgrade of 17 point source discharges.

The key difference between the scientific approach taken to the case-study, and the approach to scientific modelling described above is that the case-study looks back at actual data on water quality improvements which have been measured over time. The scientific approach for the creation of this report takes planned interventions and projects an improvement based on modelling. Read together, the Horizons case-study and this report support the hypothesis that the right interventions can have positive impacts on water quality.

Approach to economic modelling

To model the cost of the committed work, the following methodology was used. For further information, see Appendix B.

The economic assessment of stream fencing loosely follows the work conducted by the Ministry of Primary Industries (MPI) for the stock-exclusion study. The total cost of committed work is represented as the difference between the current state and that associated with committed work. It is customary to assess only the cost of marginal changes in the national stock of stream fencing. However, the costing of both existing and new fences is estimated here. This approach was taken because many stream fences exist currently, but will require replacing over time given that they vary in age and condition.

New fencing involves the exclusion of stock from both sides of the waterway and is assumed to consist of 2-wire electric fences, constructed to exclude cattle only.

To provide the cost data, all capital costs are converted into an annual cost using a discount rate of 6% and a 25-year payback period. Included in the calculation of costs is:

- The cost of establishing fences, which varies by region as set out by Agribusiness Group (2016, p. 18). Material costs for fencing are presented by Agribusiness Group (2016, p. 18).
- Maintenance costs for fencing (1% of total material costs in flat and rolling land, and 2% in steep land).
- A riparian buffer of three metres width on each side of the waterway is assumed, where riparian buffers are part of committed work. This riparian buffer is assumed to consist of pasture and one row of native plants (flax or sedges) with 1.5 metre spacing.
- The opportunity cost of land within each buffer is considered, based on average national levels of Earnings before Interest, Tax, Depreciation, and Amortisation (EBITDA) computed for each land use (see Appendix B). No opportunity cost of lost land is represented for lifestyle blocks, given their diversity and the central importance of off-farm income to most of these units (Andrew and Dymond, 2012).

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[2] Snelder, Ton (2018). Assessment of recent reductions in *E. coli* and sediment in rivers of the Manawatū-Whanganui Region.

- The cost of additional water reticulation is considered for all land uses, except dairy farms for which troughs are typically already well distributed. The method used to include water-reticulation costs follows that of Grinter and White (2016); these include annual maintenance costs of 5% of total capital costs.
- In the hydrological modelling of committed work, the remediation of wastewater systems is represented in the Auckland region only. Limited information is available with respect to the cost of such activity. Therefore, replacement cost is used to determine the expense incurred with preventing overflows and fixing leaks. Overall, this can be expected to provide a conservative estimate of the cost of wastewater-system remediation. Costs are based on data presented in Watercare (2016) (see Appendix B). The total annual cost of this remediation is computed as $82.15 m.[3]

Key assumptions informing the results of scientific and economic modelling

Specific assumptions relating to the scientific and economic modelling are set out in Appendix A and B, and in the report attached in Appendix E. However, key things to note about the approach to doing this work are:

- It was based on the stock exclusion proposals in the Clean Water Package launched in February 2017. These have not been finalised.
- The model used to undertake the work (CLUES) only considers rivers, and therefore only improvement to rivers has been modelled.
- The modelling assumes current stocking and land use stay static; that is, it does not factor in any changes in land use.
- When modelling stock exclusion on beef and sheep land, only cows are excluded (in line with the policy). Our economics assessment has therefore been based on two-wire fencing (to exclude cows but not sheep).
- The baseline information includes the criteria relating to the 95th percentile where adequate monitoring data is available as directed by Appendix 6 of the NPS-FM. The modelled information does not include the 95th percentile unless there is sufficient monitoring data.
- It does not take into account climate change impacts.
- Due to the way swimmability is measured, improvements in rural communities will have more of an impact on the overall number. This is because there are more kilometres of rivers running through rural areas.

[3] The Department of Internal Affairs is working on some more detailed costing of infrastructure upgrades as part the review into how to improve the management of drinking water, storm water and waste water (three waters) to better support New Zealand's prosperity, health, safety and environment.

Summary of results

The baseline level of swimming, as published on the Ministry for the Environment's website, shows that 71.2 per cent of our rivers and lakes combined are currently swimmable (C, B or A categories). For rivers only, this is slightly lower at 68.6 per cent of rivers being currently swimmable.

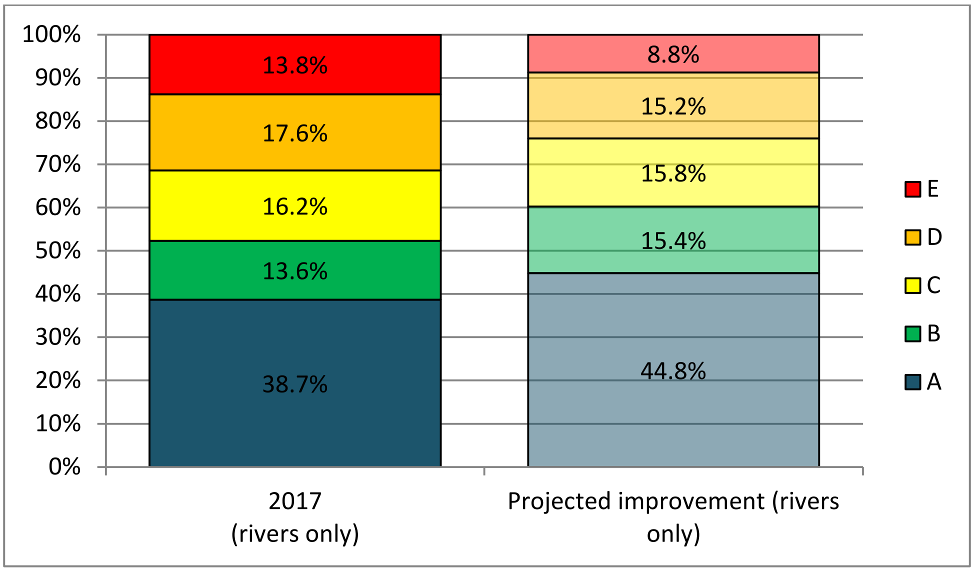

Figure 1: Projected improvement in water quality for swimming

	Health risk from *E. coli* in lakes or rivers	Health risk from cyanobacteria in lakes
E	For more than 30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >7%*	High health risks (eg, respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with fresh water).
D	20-30% of the time the estimated risk is ≥50 in 1000 (>5% risk) The predicted average infection risk is >3%*	High health risks (eg, respiratory, irritation and allergy symptoms) exist from exposure to cyanobacteria (from any contact with fresh water).
C	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 3%*	Moderate risk of health effects from exposure to cyanobacteria (from any contact with fresh water).
B	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 2%*	Low risk of health effects from exposure to cyanobacteria (from any contact with fresh water).
A	For at least half the time, the estimated risk is <1 in 1000 (0.1% risk) The predicted average infection risk is 1%*	Risk exposure from cyanobacteria is no different to that in natural conditions (from any contact with fresh water).

Figure 2: Key for categories used to describe state of a river or lake

Note: The predicted average infection risk indicated by *E. coli* is the overall average infection to swimmers based on a random exposure on a random day, ignoring any possibility of not swimming during high flows or when a surveillance advisory is in place (assuming that the *E. coli* concentration follows a lognormal distribution). Actual risk will generally be lower if a person does not swim during high flows.

The modelling can only project the improvement in rivers, as it models *E. coli*. Swimmability in rivers will improve 7.4 per cent overall, as shown in Figure 1. This raises the swimmability of rivers to 76.0%. The analysis of how far committed work (including proposals for stock exclusion) will improve water quality for swimming shows an **overall improvement to swimmability of 6.9 per cent.** This is the improvement in rivers and lakes combined. This brings overall swimmability to 78.1%.

Our economics assessment indicates that this improvement from committed work will come at **a cost of $217.23 million per annum.** $135.08 million will be borne by the rural sector (based on two-wire fencing), and $82.15 million to the urban sector.

This cost represents the difference between the current state and the committed work. Figures 3 and 4 provide more information on how it will be distributed between regions, and between land uses.

Figure 3 shows the distribution of the total costs of committed work across New Zealand. The top three regions are Auckland (40% of total cost), Canterbury (15% of total cost), and Waikato (9% of total cost). Auckland's costs represent the large proportion of New Zealand's population that live there, and their significant commitment to improve wastewater infrastructure. For Canterbury and Waikato, the scale and intensity of agriculture leads to their significant contribution to total cost. Both of these regions also possess substantial areas of land allocated to lifestyle farming.

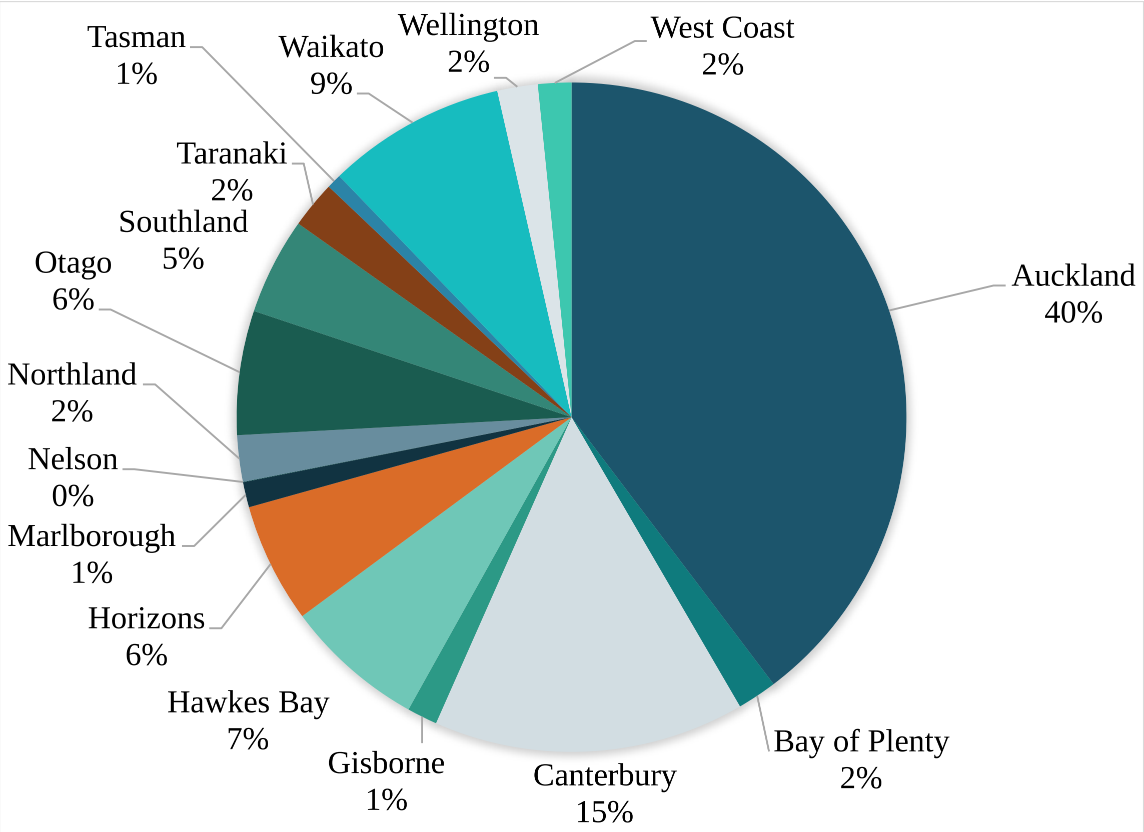

Figure 3: The distribution of the total cost of committed work across the different regions of New Zealand

Figure 4 (below) shows the distribution of the *rural costs* in each region. The rural mitigation costs associated with committed work in the Canterbury and Waikato regions is significant. The allocation of cost across the different sectors at the national scale is dairy (16%), dairy grazing (3%), sheep and beef (59%), deer (3%), and lifestyle farms (19%). The cost for sheep and beef farming is driven by the low level of stream fencing currently on this land, the expense of stream fencing on steep land where much of this land use is located, the need to invest in water reticulation following stream fencing to provide livestock access to water, and the large area used for sheep and beef farming in New Zealand. This cost does not include additional measures to exclude sheep from streams as well. If this became the proposal, there would be significant additional cost. Sheep and beef fencing is the dominant cost in all regions, except in the Waikato where, overall, there is a larger proportion of land used for dairy farming.

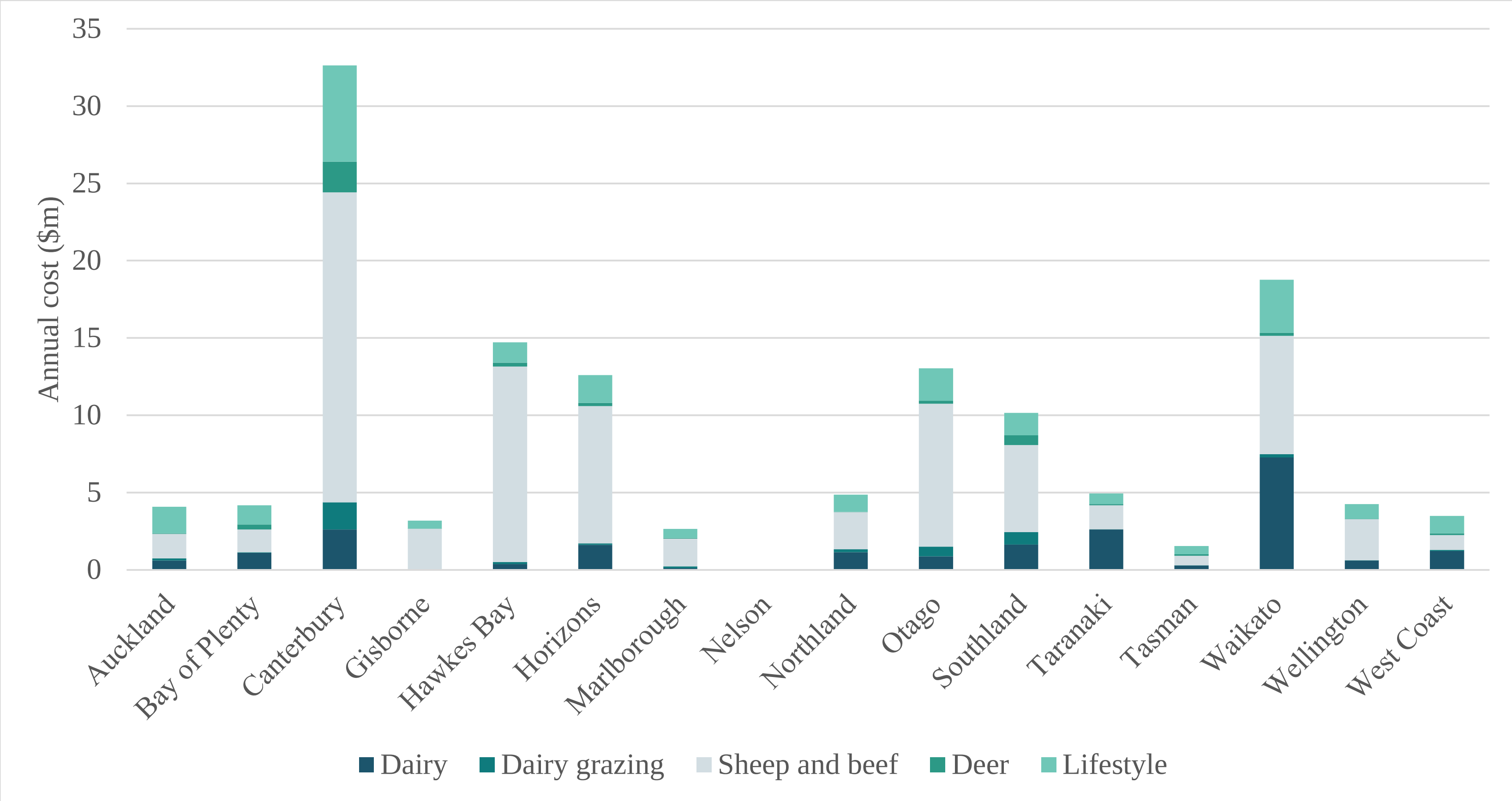

Figure 4: The total annual cost of rural mitigation in each region, shown by land use category

Information gaps

Information we believe would better inform this type of work in the future includes greater understanding of:

- the links between *E. coli*, phosphorus and sediment mitigation
- other contributors to *E. coli* mitigation (for example, sheep)
- the efficacy of certain mitigations
- baseline data on the extent of current fencing across the country.

There is no regional summary for the Chatham Islands because there is currently insufficient water quality information.

Regional summaries

Northland

Overview of swimmability now

Main activities

The Northland region covers nearly 13,300 square kilometres of mostly rolling hill country, narrow river valleys, and long stretches of coast. About 46 per cent of the land is covered by pasture, 32 per cent is native forest, and 14 per cent is exotic forestry, with the remainder divided among horticulture, urban areas and other uses.[4]

The region is characterised by hundreds of short, slow-flowing rivers that drain relatively small catchment areas. A notable exception is the northern Wairoa River, which drains nearly 30 per cent of the region. Northland also contains hundreds of lakes, including more than 280 dune lakes with high ecological importance and complex dynamic hydrology. Most of these are found in clusters on the Aupōuri, Karikari and Poutō peninsulas, and in the Dargaville area.[5]

For rivers, *E. coli* and sediment are typically higher priorities than nitrogen and phosphorus. *E. coli* levels in many Northland rivers periodically exceed safe levels for swimming and other primary contact recreation, particularly after rainfall. All but two of the freshwater sites monitored for recreation exceeded guideline *E. coli* levels for safe swimming at least once during the 2015/16 summer season.[6] This is an issue even in some catchments of unmodified native bush, indicating that natural processes are a contributing factor. According to the Council, many Northland water bodies are unlikely to meet the standards for primary contact, even with optimal mitigation practices.[7]

Lakes Waiparera, Parawanui, Mokeno, Karaka, Kanono, Rotootuauru and Omapere have all experienced potentially toxic algae blooms. In Lakes Rotootaurau and Omapere algae blooms were frequent after the release of grass carp to control hortwort.[8]

In 2016, there were approximately 965 dairy farms in Northland. Of these, 255 discharge farm dairy effluent only to land (two-pond system); 285 discharge only to water; and 425 have resource consents that authorise discharges to water when land application is not possible.[9]

There are two main types of point-source discharges – treated municipal wastewater from wastewater treatment plants, and treated trade wastewater from an Affco NZ Ltd processing

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4 Northland Regional Council. 2012. *State of the Environment Report 2012*. Whangārei: Northland Regional Council.

5 Land Air Water Aotearoa. www.lawa.org.nz/explore-data/northland-region

6 Northland Regional Council. 2016. *Recreational Swimming Water Quality in Northland*. Whangārei: Northland Regional Council.

7 Ministry for the Environment, NPS-FM. Implementation Review Northland chapter

8 Survey response

9 Implementation Review

plant. The trade wastewater contains a potentially large *E. coli* load, although its consent stipulates that the discharge must not significantly change the *E. coli* concentrations.[10]

Main sources of *E. coli*

The main sources of *E. coli* in the region are (in order of dominance):

- ruminants
- wildfowl
- people
- plants.

Research also suggests that some types of *E. coli* may be the result of naturalised *E. coli*, which refers to *E. coli* that (with or without faecal inputs) may be capable of persisting in the environment.[11]

Planned work

Four wastewater treatment plants have recently undergone upgrades. One is currently non-compliant but no upgrade is planned due to affordability issues. There is an ongoing process to determine what, if any, upgrades are needed for another treatment plant. There are no upgrades for *E. coli* removal planned for the remaining five treatment plants.[12]

While the length of rivers that have been fenced in Northland has increased over the last 10 years and there have been major improvements in the management of farm dairy effluent, *E. coli* concentrations have not changed at 33 of the 36 river water quality monitoring network sites.[13]

The draft regional plan for Northland (notification planned for late 2017) contains rules for the access of livestock (dairy cattle, dairy support, beef, deer, and pigs) to freshwater bodies. In summary, they require that:

- dairy cattle and pigs are excluded from all permanently flowing rivers and drains, lakes and natural wetlands
- dairy support, beef cattle and deer must be excluded from permanently flowing rivers and drains in lowland areas (<15 degrees), and all natural wetlands and lakes by certain dates (up to 10 years from operative date of plan or circa. 15 years).[14]

Northland Regional Council expects these rules to result in a 60 per cent reduction in *E. coli* load. The council has assumed that dairy farmers have completed the fencing requirements as per the Sustainable Dairying Water Accord, which is very similar to the Council's proposed

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[10] Information provided by Northland Regional Council in response to swimming survey

[11] Northland Regional Council response to swimming survey

[12] Response to survey

[13] Response to survey

[14] Response to survey

rules. They assume that 20–30 per cent of permanently flowing streams in lowland areas used for drystock farming are fenced.[15]

These are default region-wide rules. Individual catchments may have different rules in catchment-specific chapters of the regional plan. Catchment-specific rules have been developed for several priority catchments:[16]

- Doubtless Bay – defaults to proposed regional plan stock exclusion rules
- Mangere – the draft catchment plan rules vary from the default regional requirements by extending stock exclusion rules to include beef cattle, dairy support cattle and deer in hill country rivers (not only in lowland rivers as per the draft regional plan)
- Waitangi – defaults to stock exclusion rules
- Whangārei Harbour – the catchment plan varies from the default regional requirements by:
  - setting an objective for primary contact recreation during the summer swimming season in regionally significant swimming sites within 10 years
  - requiring that all dairy cows, pigs, beef cattle, dairy support cattle and deer be excluded from all waterways upstream of swimming sites mapped in the plan within two years from the date the regional plan becomes operative.

Because of the relatively low productivity of Northland farms, the costs of stock exclusion and other measures are relatively more burdensome on land owners than in other regions. Northland Regional Council has attempted to address land-owner capacity by offering farm environment plans free of charge, and providing subsidies for fencing and riparian planting for those farms with completed plans.

State of swimming in Northland

Overall swimmability for Northland is 24 per cent of rivers and 67 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Northland is represented below.

[15] Response to survey

[16] Implementation Review

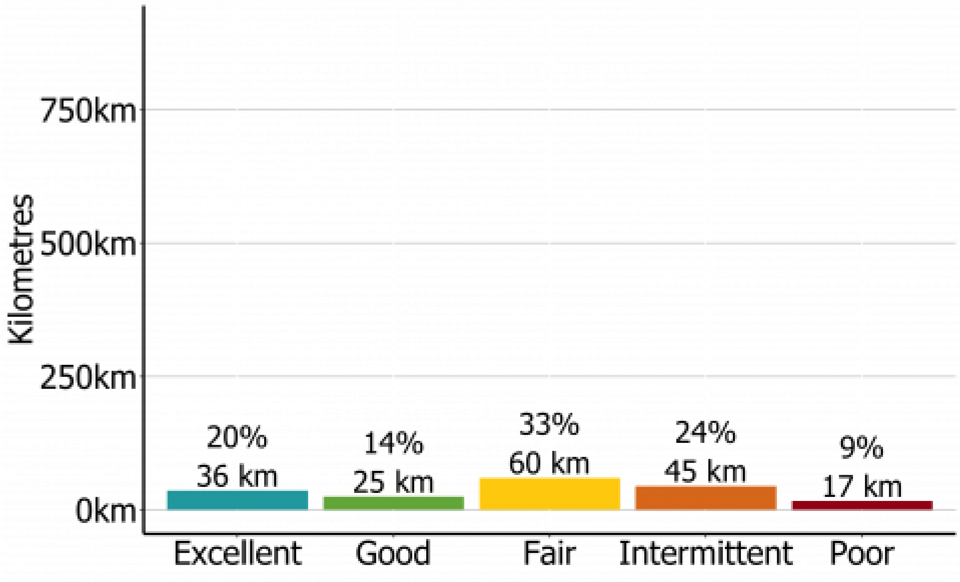

Figure 5: **Percentage of Northland lakes currently in each swimming category**

Rivers

The modelling indicates that there will be improvement in the overall swimmability of rivers of 2 per cent, to 25.6 per cent of rivers being swimmable.

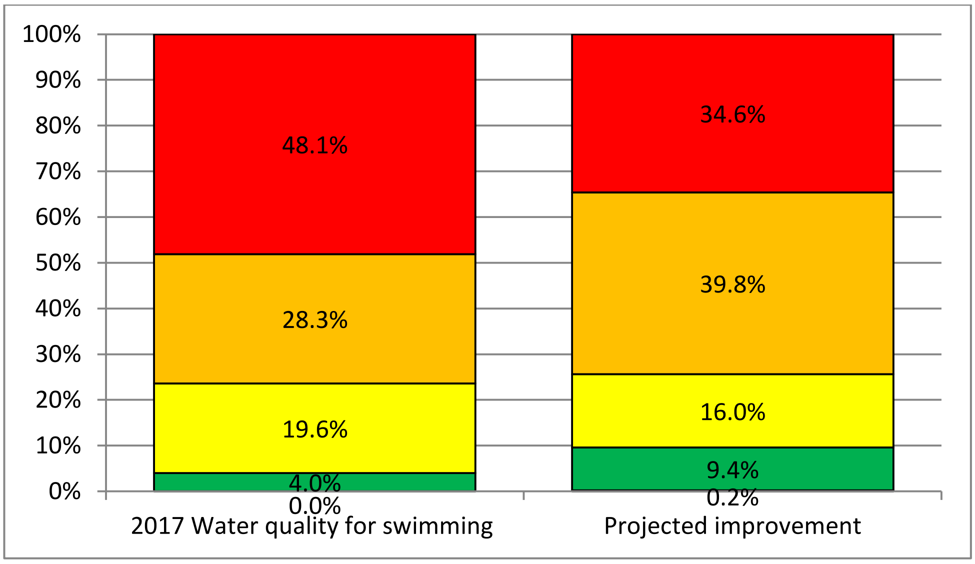

Figure 6: **Projected improvement in water quality for swimming of Northland's rivers**

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Northland region is $4.86 m. The rural costs of committed work are spread across the dairy (24%), dairy grazing (4%), sheep and beef (50%), and lifestyle (22%) sectors.

Region-specific modelling considerations

Northland's planning provisions largely reflect the Sustainable Dairy Accord, and the proposed Stock Exclusion Regulations. We have not modelled this because the proposed Stock Exclusion Regulations are already modelled and this would therefore result in double counting the reduction.

Northland Regional Council Reservations about the modelled results in this report

Northland Regional Council disagrees with the modelled costs of implementing stock exclusion in their region. The council estimates that implementing the proposed stock exclusion regulations in Northland would cost approximately $10 million per year for 25 years. This could be because Northland Regional Council estimates the current level of stock exclusion on beef and sheep farms is 20-30 percent, whereas this report estimated this at 60%. The economic model for costs may be re-run prior to councils setting their final regional targets later in 2018.

Auckland

Overview of swimmability now

Main activities

Although Auckland is most known for its urban centre, this only represents about 11 per cent of the region's land area.[17] Nearly half the region is farmland, and the rich soils around Pukekohe and Franklin are among the nation's most productive for agriculture. Another quarter of Auckland is covered by native vegetation, with the remainder being exotic forests and other uses.[18]

Catchments are generally small, with short first- or second-order rivers, and intermittent streams. Fewer than 10 per cent of these drain urban areas. Most come from rural farmland, native bush or exotic forests.[19]

Despite covering less than 2 per cent of New Zealand's total land area, the Auckland region contains over a third of the population and is growing at a very high rate. This population growth is driving significant land use change in Auckland's rural areas with productive rural land uses such as dairying, pastoral and horticulture declining in favour of suburban development and lifestyle blocks.[20] The resulting housing and infrastructure development, increasing vehicle numbers and delivery of wastewater services places severe pressures on freshwater quality, particularly with regard to sediment, metals and other contaminants associated with urban areas.[21]

E. coli levels do not meet guidelines for swimming or other primary contact recreation in many Auckland rivers. Health risks are evident at popular beaches, to varying degrees, where the majority of swimming takes place. In urban areas, this is typically the result of wastewater overflows and contaminated stormwater during rainstorms. Rural streams generally have better water quality, although they also face problems with elevated levels of nutrients, sediment and *E. coli* in some areas of more intensive agriculture and towns with aging or improperly maintained septic systems.

Groundwater quality varies considerably according to land use, age, and degree of confinement. Some aquifers, particularly in the central and southern volcanic zones, have levels of nitrates, *E. coli*, metals or other contaminants above guideline standards for drinking water.[22]

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17 Ministry for the Environment. n.d. *Environmental Reporting: Area of land cover 1996–2012*. Retrieved from https://data.mfe.govt.nz/table/2478-land-cover-area-of-land-cover-1996-2001-2008-and-2012/data/ (10 July 2017).

18 Land Air Water Aotearoa www.lawa.org.nz/explore-data/auckland-region/

19 LAWA

20 Core Logic (2017)

21 Implementation Review, Auckland Chapter

22 Implementation Review

The two main point sources of *E. coli* in fresh water are the Wellsford and Warkworth wastewater treatment plants.[23] However, there are also various non-point source discharges of *E. coli* into fresh water bodies within many catchments.

Auckland has complex sources of pathogen contamination. Auckland Council is developing a contaminant load model, due to be delivered in September 2018. The model will enable Auckland Council to better calculate the pathogen inputs to Auckland's rivers and develop effective solutions.

Main sources of *E. coli*

Auckland Council is carrying out work to identify and mitigate sources of faecal pollution for swimming in several coastal locations. The same principles and lessons are now to be applied for freshwater reaches. Sources of contamination in these coastal locations include human, dog, and avian, with some ruminant in the Te Henga catchment.[24]

Planned work

Point sources

Upgrades are planned for both major point sources. The Warkworth wastewater treatment plant will stop discharging treated wastewater to the receiving water body (the Mahurangi River). Instead, wastewater will be transferred to an upgraded treatment plant at Snells Beach and discharged into coastal waters adjacent to Martins Bay. This upgrade was successfully consented in late 2017.[25] The Wellsford wastewater treatment plant will be upgraded to an advanced wetland treatment process.[26]

Urban

In developing greenfield sites, the Council has made a philosophical change from big pipe infrastructure to water-sensitive design, which aims at preserving and enhancing freshwater systems and mitigating effects at source, if possible, which leads to a more decentralised management approach. Mitigation measures include a range of devices, including rain gardens, rainwater tanks and controls on maximum impervious areas allowed in some zones. The goal is to provide for growth in a way that will not only prevent further degradation but improve conditions.[27]

Brownfield development has historically proven more challenging for the Council, in particular in areas with combined wastewater and stormwater networks. In these areas, the Council says it has placed emphasis on the use of enlarged interceptor systems to manage wastewater

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23 Survey response

24 Survey response

25 www.watercare.co.nz/about-watercare/Projects%20around%20Auckland/Warkworth_Snells_Algies/Pages/Warkworth-Snells-Algies-wastewater-services.aspx

26 www.aucklandcouncil.govt.nz/EN/ratesbuildingproperty/consents/getinvolved/Documents/Wellsford4.pdf

27 Implementation Review

overflows, combined with localised sewer separation as part of long-term infrastructure upgrades. The Council expects these required infrastructure interventions to cost upwards of $2 billion.[28]

Auckland Council and Watercare are investing significantly to improve water quality throughout the region. This is a public health risk based approach, focussing on the locations where people have contact with water. In Auckland region this is predominantly at coastal beaches.

In addition, several specific projects are planned or under way for Henderson Creek:[29]

- Project Twin Streams, involving the planting of 750,000 riparian trees
- restoration of Epping wetland
- ongoing work by Auckland Council to ensure the integrity of the stormwater network and therefore reduce wastewater spills
- ongoing work by Watercare to ensure the integrity of the wastewater network and reduce spills from the wastewater network, and cross-transfer of wastewater into the stormwater network.

Rural

The Council reports that almost all dairy land in the Auckland region is fenced from stock. Farmers in the region face peer pressure to achieve environmental standards.[30]

There are a number of projects planned or under way to work with communities to fence and plant riparian areas throughout Auckland:[31]

- Funding is provided to rural land managers through Auckland Council's Waterway Protection Fund for fencing and planting to prevent livestock having free access to waterways. This funding will match up to 50 per cent of the project costs. Funding will be given to projects with the greatest positive environmental impact in the Hoteo, Henderson, Wairoa, Papakura, and Kaipara catchments.
- Funding for stock exclusion through fencing and planting will also be available through Rodney Local Board's Healthy Harbours and Waterways Fund. This scheme will provide $230,000 to match fund 46,000 new plants and 322 km of new fencing aimed at increasing swimmability in Auckland's at-risk catchments (Mahurangi, Makarau and Upper Kaipara River).
- The Lower Kaipara River Land Owner Collective Project aims to start the process of rehabilitating the Kaipara River. The project supports land owners to implement strategies such as planting and fencing so that the river banks can be managed in the long term. Stock exclusion and planting may occur at all or some of the reaches throughout the

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[28] Implementation Review

[29] Survey response

[30] Implementation Review

[31] Survey response

catchment. The project has already led to 2 kilometres of fencing and 500 metres of planting.[32]

- Development of a community catchment management plan (Wairoa River Catchment management strategy). This will utilise the Wairoa landcare community group to work with land owners to implement improvements to the river catchment including through planting and fencing to exclude stock.
- The Forest Bridge Trust is working with land owners to increase planting and fencing in Kaipara and Hoteo catchments.
- The Mahurangi Action Plan includes actions around planting trees and riparian retirement.[33]
- The Auckland Unitary Plan requires stock exclusion from water sources on intensively grazed farm land (where a stocking rate is equal or more than 18 stock units throughout the region) five years after the stock exclusion provisions become operative (i.e. five years after 2016); from intermittent streams 10 years after the stock exclusion provisions become operative. The Auckland Unitary Plan also introduces new rules for farm effluent storage and disposal. The measures and behaviours required by the plan should reduce levels of *E. coli* being discharged from farms.
- A proactive compliance and monitoring programme for on-site wastewater systems has been proposed as part of the Water Quality Targeted Rate in the 2018 Long Term Plan. This programme seeks to improve water quality at high risk rural swimming locations by ensuring on-site wastewater systems are maintained and upgraded as required by the Unitary Plan.

State of swimming in Auckland

Overall swimmability for Auckland is 23 per cent of rivers (by length) and 97 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Auckland is represented below.

32 http://infocouncil.aucklandcouncil.govt.nz/Open/2017/05/RD_20170518_AGN_7140_AT_files/RD_20170518_AGN_7140_AT_Attachment_53186_2.PDF

33 www.mahurangi.org.nz/Action-Plan/PDF/Mahurangi-Action-Plan.pdf

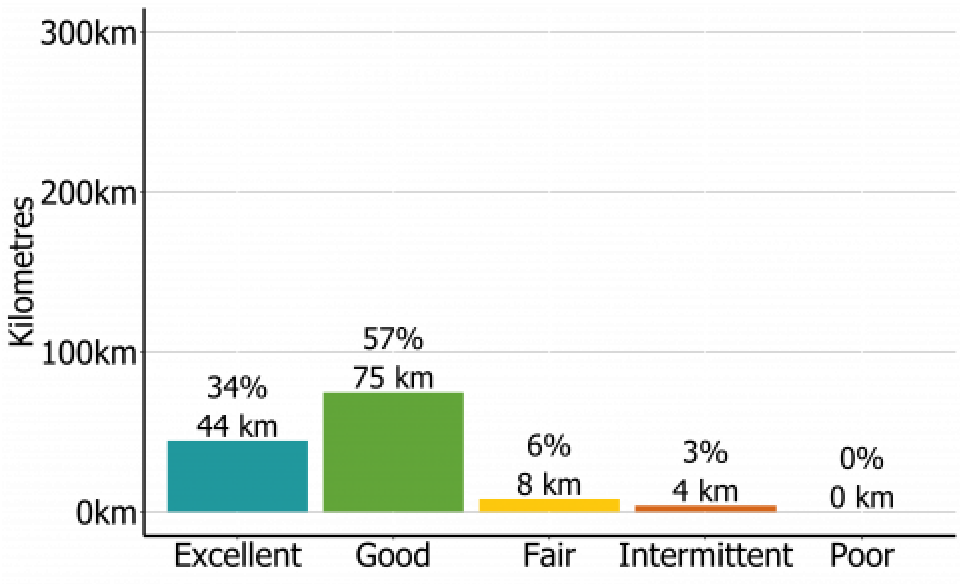

Figure 7: Percentage of Auckland lakes currently in each swimming category

Rivers

The modelling indicates that there will be improvement of 7.4 per cent, to 30.5 per cent of rivers being swimmable.

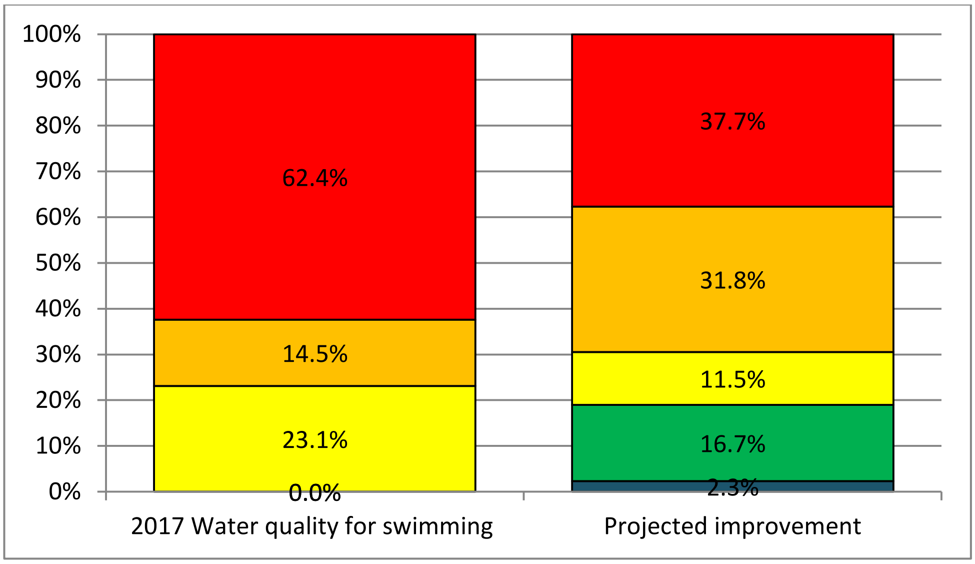

Figure 8: Projected improvement in water quality for swimming for Auckland's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the Auckland region is $86.22 m. Only $4.07 m of this occurs on rural land, with the majority ($82.15 m) associated with the improvement of urban wastewater infrastructure. The rural costs of committed work are spread across the dairy (15%), dairy grazing (3%), sheep and beef (39%), deer (1%), and lifestyle (42%) sectors.

Auckland Council has proposed a Water Quality targeted rate in the long term plan for 2018-2028. This would generate $400 million towards funding a Water Quality Improvements Programme. Projects included in this programme include targeting contaminant concentrations in stormwater and proactive monitoring of discharges from on-site wastewater treatment systems.

Region-specific modelling considerations

When modelling the impact of Auckland's committed work, assumptions about the level of implementation of planning rules were made. Specifically:

- where there was a focus on co-funding for fencing and planting, the modelling has assumed 50 per cent of streams with order 3 or more will be planted (Hoteo, Henderson Creek, Wairoa and Kaipara)
- the Mahurangi Action Plan also assumes 50 per cent of streams with order 3 or more are planted
- where community catchment management is planned, the modelling approach taken to stock exclusion has been extended to all streams in that catchment (Wairoa, Kaipara and Hoteo)
- where there is a focus on stock exclusion or an extension to the Sustainable Dairy Accord, the modelling approach taken is to extend the stock exclusion provisions to all streams in that catchment (Mahurangi, Hoteo, Rangitopuni, Kaukapakapa, Wairoa, Makarau, Kaipara, Henderson Creek).

The modelling has excluded double counting where applicable.

All initiatives involving riparian planting in Auckland assume a minimum width of 3 metres.

Waikato

Overview of swimmability now

Main activities

The Waikato has three major river systems, the Waikato (including the Waipa sub-catchment), the Waihou, and the Piako/Waitoa; and in the southwest of the region, bordering the Taranaki region, the Mokau River. In the Waikato, groundwater makes up approximately two-thirds of the total freshwater resource. The groundwater resource is strongly connected to the surface water resource.

The Waikato River is the longest river in New Zealand. Its catchment covers 14,260 square kilometres, or 12 per cent of the area of the North Island. The river starts its journey to the sea from high in the central North Island volcanic zone, 2797 metres above sea level. Leaving Lake Taupo, the river cuts through the volcanic plateau flowing north, passing through eight hydro-electric dams, and onto the lowlands from Cambridge to Mercer. The river finally flows into the Tasman Sea at Port Waikato, after a journey of 425 kilometres from Lake Taupo. Significant amounts of fresh water leave the Waikato in the north, providing water for the Auckland region municipal water supply. *Te Ture Whaimana O Te Awa O Waikato: the Vision and Strategy for the Waikato River*, is the primary direction-setting document for the Waikato and Waipa Rivers and their catchments. Where there is inconsistency between a national policy statement and the vision and strategy, the vision and strategy prevails.

The region has more than 100 lakes, including New Zealand's largest Lake Taupo. Twenty per cent of the water entering Lake Taupo at Tokaanu comes via the Tongariro Power Development. The other lakes can be grouped in the following manner:

- Taupo Volcanic Zone lakes
- Waikato River Hydro lakes
- peat lakes
- riverine lakes
- west coast sand dune lakes.

Demand for farmland means that Waikato lakes are now smaller and shallower, with some completely drained. More than 95 per cent of Waikato wetlands have been converted to pasture.

The Waikato region covers 25,000km^2 of land; just over half of the region's land area is used for pastoral farming; over a quarter is native forest and vegetation, particularly in the Coromandel, with plantation forestry accounting for around 15 per cent of land areas. The remaining land area is used for horticulture, predominantly in the fertile Northern Waikato area, and also supports a large of urban communities including the regional centre of Hamilton.[34]

[34] LAWA www.lawa.org.nz/explore-data/waikato-region/

In regard to *E. coli* in the Waikato River hydro lakes, routine monitoring has continued in conjunction with several other agencies since late 2003.

In regard to other Waikato lakes, routine monitoring of levels of blue-green algae in several of the smaller lakes continues. Hamilton City Council provides the results for Lake Rotoroa (Hamilton Lake) and Lake Rotokeao.

Main sources of *E. coli*

Human sources from sewage are a minor portion of the total impact on the rivers. In the Waipa River the influence of farm animals is the likely dominant source. *E. coli* levels are very low in the upper Waikato because bacteria die off in the hydro lakes. Downstream of Karapiro, and once the undammed Waipa River joins the Waikato, the levels in the river rise.

Levels of *E. coli* exceed Australian and New Zealand guidelines for fresh and marine water quality in most water bodies.[35] Lakes Hakanoa, Ngaroto, Waahi, Waikare and Whangape all have histories of toxic algae blooms.[36]

There are a variety of point-source discharges in the Waikato including wastewater treatment plants (25), stormwater discharge (1), meatworks (6) and dairy factories (8), power station cooling water (1), a pulp and paper mill and a gold mine.[37]

In a study of water quality in five Waikato streams, ruminant and wildfowl pollution was detected in almost all samples. No human pollution was detected at any of the sites.

Table 1: Sources of faecal contamination in Waikato rivers[38]

Water body	Sources of *E. coli*	Contribution to total *E. coli* load
Karapiro Stream	Ruminant, both cow and sheep	Ruminant generally 50–100%
Komakorau Stream	Ruminant, some wildfowl	Ruminant up to 50% (but could be minor)
Mangaone Stream	Wildfowl (all flows), ruminant (high flows)	Varied over time
Mangaonua Stream	Ruminant, wildfowl	Ruminant often up to 100%
Mangawhero Stream	Wildfowl (low flows), ruminant (some high flows)	Varied over time

35 *E. coli, nitrogen, phosphorus and sediment in the Waikato and Waipa Rivers* www.waikatoregion.govt.nz/assets/PageFiles/28959/1/15%20-%202728663.pdf

36 Survey response

37 Waikato survey response

38 Sources of Faecal pollution in selected Waikato Rivers – July 2015 www.waikatoregion.govt.nz/assets/PageFiles/40444/3469090.pdf

Planned work

Point sources

The majority of wastewater treatment plants either have planned upgrades, options for upgrades, or have recently undergone upgrades.[39]

Wastewater treatment plant upgrades are planned for Pukete, Tuakau/Pukekohe, Te Awamutu, Cambridge, Te Kauwhata, Waihi and Turua.

Options are being considered for upgrading several other wastewater treatment plants (Tokoroa, Putaruru, Tirau, Huntly) or piping wastewater to another plant (Te Kauwhata, Meremere). Consent renewals for the Raglan wastewater treatment plan are in the formative stages. A number of other treatment plants have recently undergone significant upgrades (Te Kuiti, Benneydale, Thames, Morrinsville, Te Aroha, Matamata, Waihou, Tahuna).

Should a government decision be made to proceed with the Waikeria Corrections Facility then both the existing Waikeria and Tokanui plants will become redundant and the reticulation will need to be connected to the Te Awamutu wastewater treatment plant. In the Waitomo district a new treatment plant is to be constructed and commissioned for Piopio

Upgrades are also planned for dairy factories and meatworks. The Te Rapa and Te Awamutu dairy factories are proposing to upgrade to tertiary treatment within six years, as part of current consent applications. There are also plans to upgrade the current wastewater treatment plant for Waitomo Village, cater for 600,000 annually.

From 1 April 2021, the *E. coli* concentration in the wastewater discharge from Waitoa meatworks shall not exceed the following (estimated from all test results over the winter period): a median of 300 cfu/100ml, and a 95th percentile of 5,000 cfu/100ml. The type of upgrade that will achieve this is not yet specified.

Urban

All district councils within the Waikato Region have Comprehensive Stormwater Discharge Consents (CSDCs) that authorise their urban stormwater discharges. All CSDCs have comprehensive conditions of consent that provide direction or compliance requirements to manage specific contaminants within their stormwater discharges. These contaminants include suspended solids, hazardous substances, micro-organisms, etc. All CSDCs must have Stormwater Management Plans that provide direction on how the district councils will manage their urban stormwater systems to mitigate and prevent these contaminants from entering the environment.[40]

Rural

Waikato Regional Council works closely with farmers and land owners to reduce the impact of their activities through ongoing programme or erosion protection, fencing and planning, and lake and wetland protection. Council is implementing the Waipa Catchment Plan to achieve

[39] Survey response

[40] Survey response

20-year aspirational goals, and is the first in an ongoing programme of integrating catchment planning. In 2016/17 the implementation of the Waipā Catchment Plan includes works of approximately $1 million for soil conservation in priority catchments. In addition, there has been continued implementation of the large Waipā Rerenoa and Mangaotama Wetland restoration projects, partly funded by Waikato River Authority, including working with land owners, iwi and the community.

The Whangapoua Harbour and Catchment Plan has been signed off by the Department of Conservation, Thames Coromandel District Council, industry, iwi, land owners, and Council. Council is also partnering with the Waikato River Authority, the administering authority for $220 million Treaty settlement funding for the improvement of the Waikato and Waipa Rivers, and DairyNZ in the development of a Restoration Strategy. The Restoration Strategy takes a strategic catchment approach to prioritising areas of non-regulatory interventions and mitigations.

In 2016/17 Upper Waikato catchment 63 land owner maintenance programmes have been progressed. The new works established 12,593 metres of fencing (including 3500 metres of riparian protection). Across the Waihou/Piako and Lower Waikato zones catchment, new works were completed and included 29,714 metres of fencing and 212,161 plantings. Fifty rural land owners worked with Council to complete environmental protection agreements, and a total of 50.56 hectares of land was retired from pasture.

Lakes

The Waikato Regional Council is currently reviewing its lakes' water quality and toxic cyanobacteria monitoring programme, with the intention of expanding the current monitoring efforts and improving representativeness.[41] *Huntly Domain and Lake Hakanoa Reserve Management Plan* by Waikato District Council (2012) lists and prioritises a range of actions to "progressively improve Lake Hakanoa's water quality". These include actions to reduce nutrient inputs to the lake.[42]

Landcare Trust have developed a community-led Catchment Action Plan (2014) for Lake Ngaroto that resulted in whole-farm management plans developed as part of the process and end of drain treatment systems (that is, silt traps and infiltration wetland) on two inflows. Waipa District Council has diverted a major inflow to the lake, which will reduce nutrients entering the lake. Waipa District Council has consent to construct a drain treatment system that will mitigate nutrients from a 100 hectare sub-catchment.[43]

Waahi Whaanui Trust have undertaken work at Lake Waahi to improve water quality (mostly riparian fencing and planting). Waikato Regional Council have also been involved in fencing and planting the lake margin. The lake is not yet fully fenced.[44]

A catchment management plan is currently being drafted to look at options for improving lake water quality at Lake Waikare. Most of the lake has been fenced; however, not all of the fencing keeps stock out of the lake at high-water levels. The main stem of the largest inflow

41 www.waikatoregion.govt.nz/assets/PageFiles/37521/TR201459.pdf

42 Survey response

43 Survey response

44 Survey response

has mostly been fenced, along with several other tributaries. Fencing and riparian planting has occurred in other contributing catchments. Riparian planting has occurred in some of the fenced areas. A small silt trap/infiltration wetland has been constructed at the southern end of the lake. The two lakes (Ohinewai and Rotokawau) that feed into Lake Waikare are fenced. Considerable riparian planting has occurred around Lake Ohinewai. Lake Rotokawau is surrounded by a large wetland.

Lake Whangape is approximately 50 per cent fenced, but not all fences keep stock out of the lake at high-water levels. Riparian planting has occurred in conjunction with fencing where required. There have been a number of riparian planting and fencing projects in the upper catchment, however these would not total more than 10 per cent of the waterways within the catchment.[45]

Healthy Rivers Wai Ora Waikato and Waipa Plan Change 1

The Waikato community has consistently identified water quality as the top issue for the Waikato region for the past two decades. Healthy Rivers/Wai Ora Proposed Waikato Regional Plan Change 1 is the bold response to addressing the complex problem of water quality facing our Waipa and Waikato Rivers. The proposed plan change gives effect to Government legislation on the management of fresh water (passed in 2014) and *Te Ture Whaimana o Te Awa o Waikato (The Vision and Strategy for the Waikato and Waipa rivers)*, which was adopted by Government as part of Treaty Settlement legislation. The proposed plan has been developed using a collaborative process involving community and sector representation, which has ensured that those who are most affected by the changes have been at the table developing the policy and providing input and feedback from their communities and sectors over a two-and-a-half-year period.

The proposed plan aims to encompass or include all land owners over 2 hectares within the Waikato River and Waipa River catchments. New rules will complement existing rules in the Waikato Regional Plan. Existing rules in the Waikato Regional Plan will continue to apply, for example, farm dairy effluent rules, earthwork rules and point-source discharge rules.

The approach taken to reducing contaminant losses from land use activities requires:

- stock exclusion from water bodies
- registration of all properties over 2 hectares within the catchment
- Farm Environment Plans, including for commercial vegetable growers, that ensure industry-specific good management practices, identify additional mitigation actions to reduce diffuse discharges by specified dates
- a property-scale nitrogen reference point to be established by modelling current nutrient losses from each property, with no property being allowed to exceed its reference point in the future and higher discharges being required to reduce their nutrient losses
- an accreditation system to be set up for people who will assist farmers to prepare their Farm Environment Plan, and to certify agricultural industry schemes

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[45] Survey response

- Waikato Regional Council to development approaches outside the rule framework that allow contaminant loss risk factors to be assessed at a sub-catchment level, and implement mitigations that look beyond individual farm boundaries to identify the most cost-effective solutions.

It will have implications for all rural land owners in the catchments who are on land over 2 hectares. The Proposed Plan is presently progressing through the submissions process.

State of swimming in Waikato

Overall swimmability for Waikato is 37 per cent of rivers and 79 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of *E.coli* for lakes in Waikato is represented below.

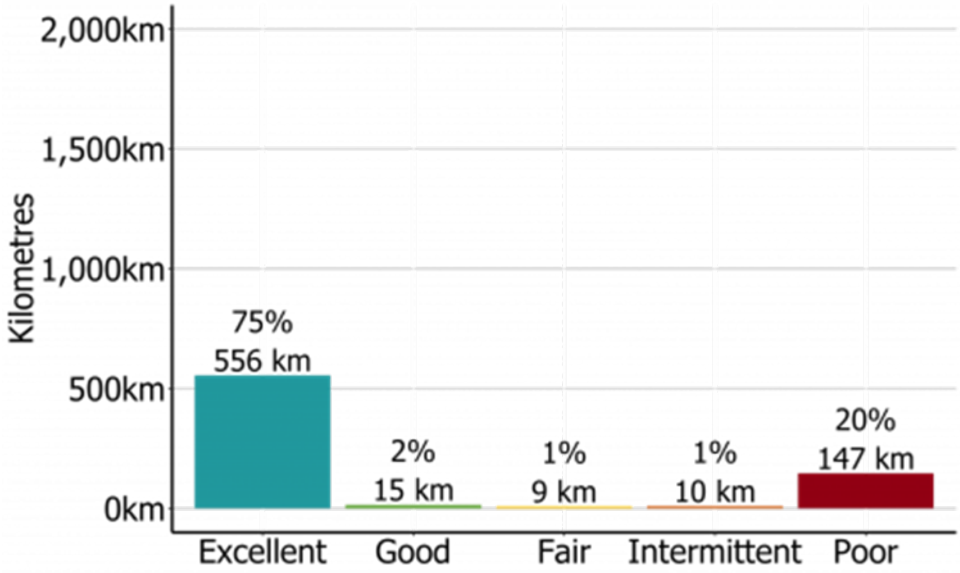

Figure 9: Percentage of Waikato lakes currently in each swimming category

Rivers

Modelling indicates an improvement in swimmability of rivers from 37 per cent to 40.4 per cent.

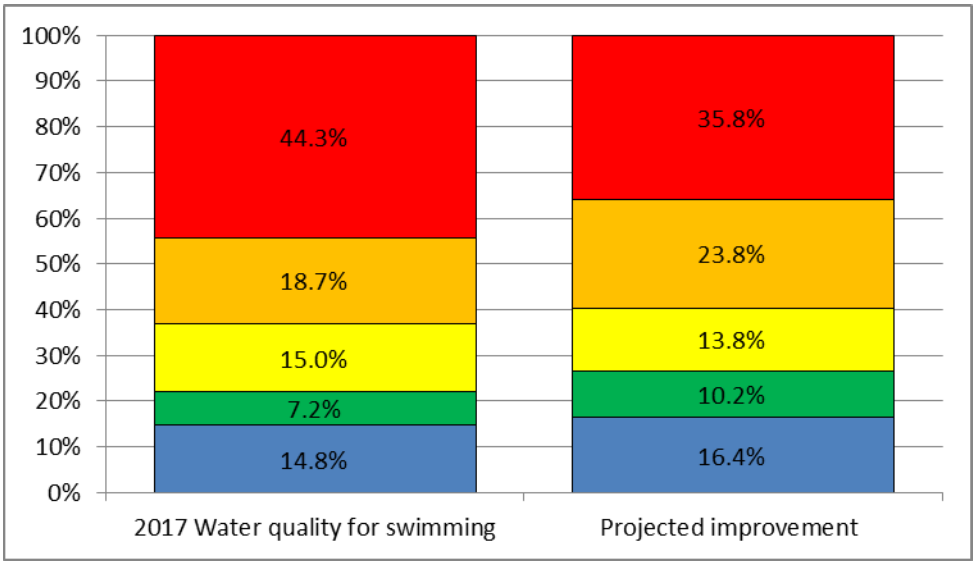

Figure 10: Projected improvement in water quality for swimming for Waikato's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Waikato region is $18.76 m. The rural costs of committed work are spread across the dairy (39%), dairy grazing (1%), sheep and beef (41%), deer (1%), and lifestyle (18%) sectors.

Region-specific modelling considerations

Nothing specific.

Bay of Plenty

Overview of swimmability now

Main activities

About half of the region is covered by native vegetation, a quarter in exotic plantation forestry, and 20 per cent in pasture, with the remainder divided among horticulture and urban areas. While there has been relatively little land-use change in recent years, intensification and urban growth in the Western Bay have placed increasing pressure on both water quality and quantity.[46]

Rivers in the region typically flow along fault lines northward from headwaters in the mountains and volcanic plateaus into the sea. The largest of these are the Wairoa, Kaituna, Tarawera, Rangitāiki, Whakatāne, Waioeka, Motu and Raukokore rivers. The 12 Rotorua Te Arawa lakes are the largest in the region and have cultural, recreational and economic significance. Hydro-electric dams on the Rangitāiki River have created two additional lakes. Wetlands were historically drained and destroyed to a greater extent than in other parts of the country, meaning only 3 per cent of the region's wetlands remain today. The region also encompasses all or part of 10 geothermal systems, including those around Kawerau, Rotorua, Tauranga and the Waimangu valley.[47]

Several regional rivers have elevated microbial levels that do not meet the minimum acceptable standard for swimming or other primary recreation.[48] As is common nationwide, quality is highest in catchments dominated by native forest and poorest in lower river reaches and areas of more intensive agriculture or urban development.

Lakes Rotoehu and Okaro have histories of algae blooms since the early 1990s. A combination of in-lake interventions, such as alum dosing, weed harvesting and land-use change have contributed to water quality improvements. However, the past two summer seasons have seen blooms that have resulted in health warnings.[49]

Point-source discharges in the region include stormwater and waste-water discharges, treated abattoir waste water, and discharges from wood-processing plants, a dairy factory and distillery.[50]

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46 Implementation Review

47 Implementation Review

48 Bay of Plenty Regional Council. 2015. *Freshwater in the Bay of Plenty – Comparison against the National Objectives Framework.* Environmental Publication 2015/04. Retrieved from www.boprc.govt.nz/media/433845/freshwater-in-the-bay-of-plenty-comparsion-against-the-national-objectives-framework.pdf (30 June 2017).

49 Survey response

50 Survey response

Main sources of *E. coli*

Microbial source tracking has been conducted for some bathing sites with high bacteria concentrations. Tracking information for the Kaiate Stream showed the dominant source of *E. coli* is from ruminants with some from avian sources. [51] In the Ngongotahā Stream, ruminant sources were identified. [52] Updated information for further sites (including Waiōtahe and Uretara, where ruminant and avian sources have been identified) will be provided in the next recreational water report.

Planned work

Point sources/urban

Upgrades are planned for the following:

- Western Bay of Plenty Council – discharge of treated effluent to Waiari Stream
- Rotorua Lakes Council – stormwater discharge (to water and land)
- Rotorua Lakes Council – discharge of treated effluent from wastewater treatment plant to land.

Rural

Bay of Plenty Regional Council has placed a focus on riparian management, providing financial assistance with fencing, planting and alternative stock water sources for many years. The Council's investment in fencing waterways has resulted in over 75 per cent protection along stream margins so far, and even more in our most vulnerable catchments.

Riparian fencing and planting, and providing general technical advice (in regard to water quality) are business-as-usual activities for the Council. The Council has information for each catchment about:

- how much more fencing is required
- areas where repairs are needed
- crossings and detention bunds required
- areas that may require land use changes.[53]

Lakes

Both Lake Rotoehu and Lake Okaro have had a raft of interventions to attempt to improve water quality. Interventions at Lake Rotoehu included land use and land management change, floating wetlands, weed harvesting, alum dosing and aeration. At Lake Okaro interventions have included land-use change and land management change, riparian planting, and stock

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[51] www.boprc.govt.nz/media/596365/recreational-waters-surveillance-report-2015_2016.pdf

[52] www.boprc.govt.nz/media/596365/recreational-waters-surveillance-report-2015_2016.pdf

[53] Survey response

exclusion, development of a catchment wetland, interception of water flows to settle sediment, and phosphorus and alum dosing.

The main focus of the Rotorua Lakes Programme is reducing nutrients that drive harmful algal blooms. To date the large investment in improving water quality has resulted in substantial improvements for the 12 lakes that are under active management. There are ongoing interventions in all the 12 lakes; however even with a range of interventions, Lake Rotoehu and Lake Ōkaro are not meeting the swimmability targets. The action plans for the lakes capture the list of interventions agreed with the local communities, and these are regularly reviewed.

State of swimming in Bay of Plenty

Overall swimmability for the Bay of Plenty is 95 per cent of rivers and 85 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in the Bay of Plenty is represented below.

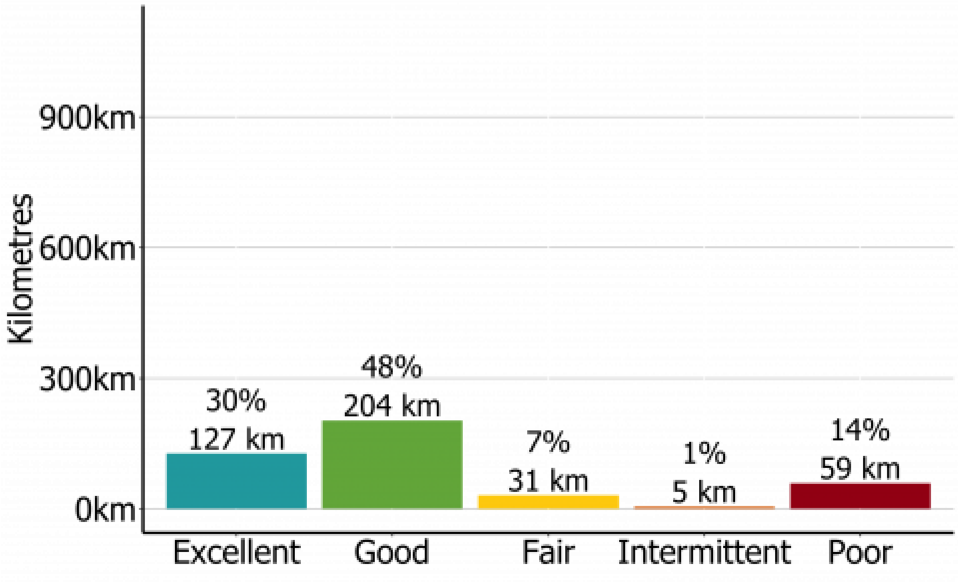

Figure 11: Percentage of Bay of Plenty lakes currently in each swimming category

Rivers

The modelling shows an increase in the overall swimmability of rivers from 94.5 per cent, to 95.7 per cent of rivers being swimmable.

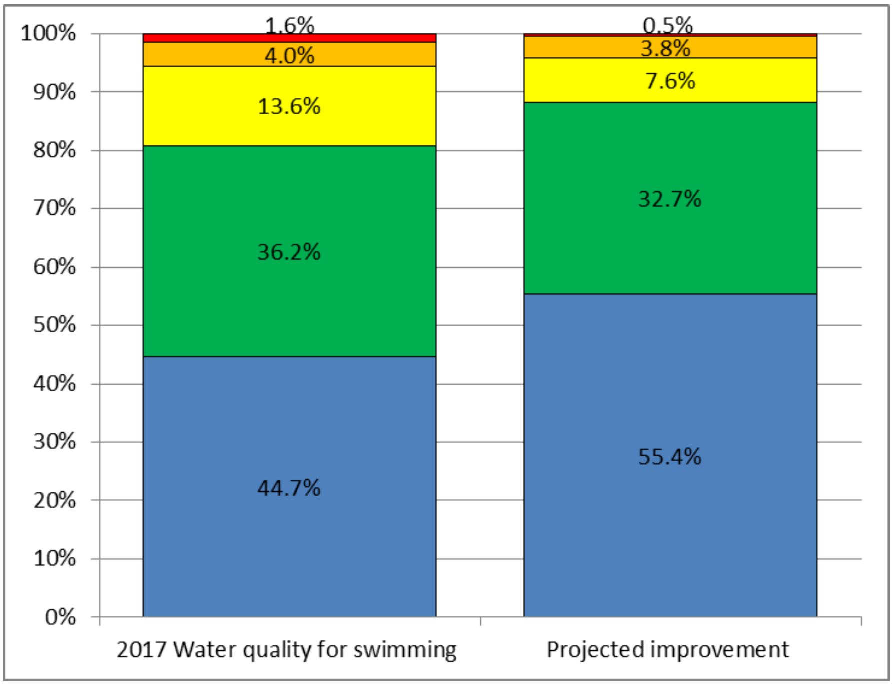

Figure 12: Projected improvement in water quality for swimming for Bay of Plenty's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Bay of Plenty region is $4.17 m. The rural costs of committed work are spread across the dairy (26%), dairy grazing (1%), sheep and beef (35%), deer (8%), and lifestyle (30%) sectors.

Region-specific modelling consideration

In modelling the planting and restoration activities planned by Bay of Plenty, we have assumed 50 per cent uptake of the activities from the current state of planting.

Approximately 40 per cent of riparian fencing in the region is set back more than 3 metres from the edge of the river or lake.

Gisborne

Overview of swimmability now

Main activities

Pastoral land and crops (42 per cent), plantation forest (20 per cent) and indigenous forest (22 per cent) account for most of the land cover within the region.[54] The region has two major river catchments:

- the Waipaoa, which feeds the Poverty Bay Flats where Gisborne City is located
- the Waiapu, which flows northeast from the Raukūmara Range and enters the Pacific Ocean north of Ruatoria, near the northern tip of the East Cape.

There is also an extensive groundwater system under the Poverty Bay Flats.

Gisborne's topography is naturally steep. Approximately 3 per cent of the land area is classified as flat, and this land is mainly used for horticulture. A lot of the hill country is steep land. There are five dairy farms in the region, with the balance of farming being 50/50 beef and sheep farming. Due to the topography, there is little water reticulation, and stock access streams and use stream gullies for shade.[55]

Sediment and *E. coli* are the main pressures for both urban and rural areas. *E. coli* levels frequently fail national bottom lines for both primary and secondary contact recreation, including at the popular Rere Falls and Rere Rockslide.[56] Both sediment and *E. coli* levels are strongly affected by rainfall events: rainfall flushes high levels of suspended solids and bacteria into local rivers.

Point-source discharges in Gisborne are mainly stormwater discharges from urban and rural activities to the estuarine areas in Gisborne City and the Gisborne plains. Emergency wastewater overflows currently occur several times a year in Gisborne City, usually as a result of heavy rain events. Council is working to minimise these overflows through wastewater pipe renewals and improvements, and other stormwater drainage solutions.

There is also a wastewater discharge into the Waipaoa River at Te Karaka.

Main sources of *E. coli*

The majority of *E. coli* in Gisborne's rivers is from ruminants. For the Wharekopae,[57] Te Arai,[58] and Waipaoa[59] rivers, ruminants contribute 100 per cent of the *E. coli* load. The Waimata has

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[54] Gisborne District Council. 2016. *The State of Our Environment: Land and Soil 2013–2015*. Gisborne District Council: Gisborne

[55] Emails Lois Easton to Sara Clarke, 5 and 12 September 2017

[56] Gisborne District Council. 2016. *The State of Our Environment: Fresh Water Resources 2013–2015*. Gisborne District Council: Gisborne.

[57] Faecal source tracking studies, Gilpin et al 2011, Devane et al 2014

[58] Faecal source tracking studies, Devane et al 2014

[59] Faecal source tracking studies, Devane et al 2014

ruminant and avian sources.[60] For the Taruheru[61] and Wainui[62] rivers, the ruminants are the main source in rural areas with avian and dog contributions in urban areas. In the Waikanae catchment almost all the *E. coli* is from unknown sources, and could be naturalised *E. coli*.[63]

Planned work

There are planned upgrades for Te Karaka Wastewater Treatment Plant, including tertiary treatment and land disposal. These will have a minimal impact on *E. coli* loads.[64]

The Council opened a new domestic wastewater treatment plant for Gisborne City in 2010 and is in the process of deciding how to approach further upgrades. Options include expansion of the new treatment facility and a proposed wetland treatment system; however, all of the proposed options will strain the council's budget. Simultaneously, the Council is overhauling regional stormwater to separate it from domestic wastewater and reduce strain on treatment facilities.[65]

The Proposed Regional Freshwater Plan (notified October 2015) establishes regional objectives, policies and rules to address water quality and quantity, include new rules for urban sewage and stormwater, stock exclusion and setbacks from waterways, and requirements for farm environment plans.[66]

Rural mitigations include plans to fence main stem rivers (Wharekopae and Totangi rivers).[67]

State of swimming in Gisborne

Overall swimmability for the Gisborne region is 77 per cent of rivers and 83 per cent of lakes.

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[60] Faecal source tracking studies, Devane et al 2014

[61] Faecal source tracking studies, Devane et al 2014

[62] Faecal source tracking studies 2016

[63] Faecal source tracking studies, Devane et al 2014

[64] Survey response

[65] Implementation Review

[66] Implementation Review

[67] Survey response

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Gisborne is represented below.

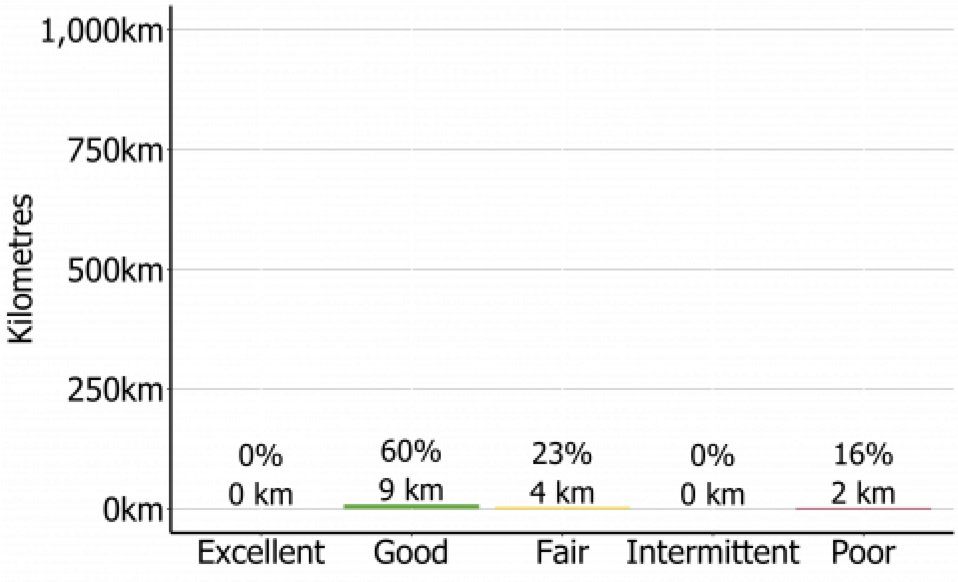

Figure 13: **Percentage of Gisborne lakes currently in each swimming category**

Rivers

The modelling shows an increase in the overall swimmability of rivers of 12.4 per cent, to 85 per cent of rivers being swimmable.

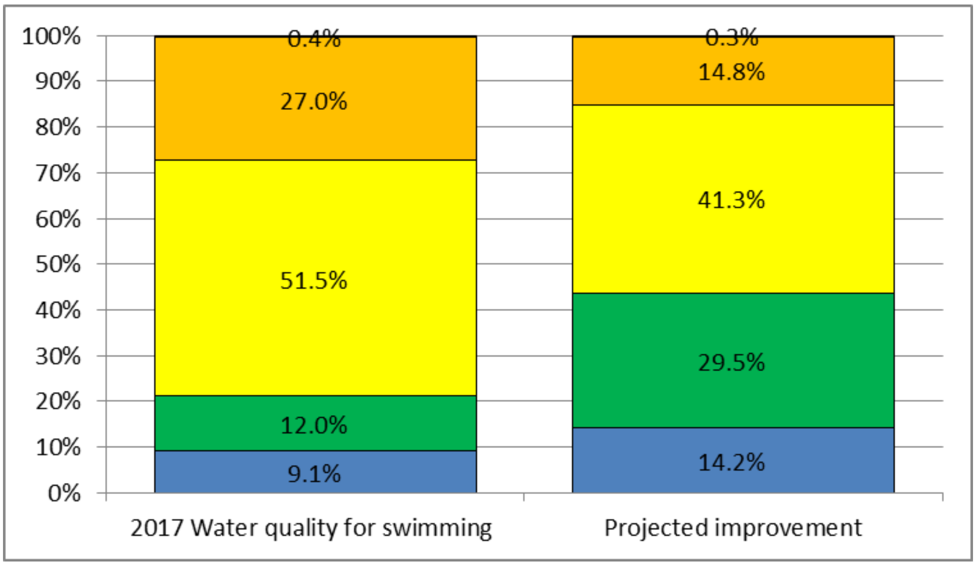

Figure 14: **Projected improvement in water quality for swimming for Gisborne's rivers**

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Gisborne region is $3.18 m. The rural costs of committed work are spread across the dairy grazing (1%), sheep and beef (82%), and lifestyle (17%) sectors.

Region-specific modelling considerations

Gisborne's planning provisions largely reflect the Sustainable Dairy Accord, and the proposed Stock Exclusion Regulations. As the Stock Exclusion Regulations are already modelled, we have not modelled this as it would result in double counting the reduction. It is worth noting that the stock exclusion rules will be limited in their application due to the topography of Gisborne (very little flat land).

Hawke's Bay

Overview of swimmability now

Main activities

Nearly half of the land area is used for pastoral farming, primarily sheep and beef with some dairy farms and deer.[68] One-third of the land cover is native vegetation, around 12 per cent is exotic forestry and the remainder is divided among horticulture, urban and industrial and other uses. Although they represent a relatively small proportion of the land area, the highly productive Heretaunga and Ruataniwha plains are essential to the region's strong horticulture industry, known for its orchards, vegetable growing and viticulture. Agriculture is the largest employer in the region, and also the basis of much related industry, including fruit and vegetable processing, wine production, and transport of produce.[69]

Hawke's Bay has several major river catchments, generally with headwaters in the inland mountains and hills, leading to fast-flowing gravel-bottomed rivers with braided lower reaches. The Wairoa and Mōhaka rivers drain catchments from the northern and western hills into northern Hawke's Bay. The Tūtaekurī and Ngaruroro rivers flow from the Kaweka and upper Ruahine ranges through the Heretaunga Plains, merging just before their mouth near Clive; and the Tukituki flows from the Ruahine Range across the Ruataniwha Plains towards Cape Kidnappers.

Lakes Whakaki, Rahui, Oingo, Runanga, Horseshoe, Tutira, Whatuma and Poukawa all have histories of algal blooms.

The main point-source discharges are sewage (Wairoa District Council and Central Hawke's Bay District Council (Waipukurau, Waipawa)) and waste water from an Affco meat works.

Main sources of *E. coli*

The main source of *E. coli* throughout the region is ruminant. The following table provides more detail on the sources of *E. coli* in different catchments.

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68 Ministry for the Environment. n.d. *Environmental Reporting: Area of land cover 1996–2012*. Retrieved from https://data.mfe.govt.nz/table/2478-land-cover-area-of-land-cover-1996-2001-2008-and-2012/data/ (10 July 2017).

69 www.lawa.org.nz/explore-data/hawkes-bay-region/river-quality/

Table 2: Sources of *E. coli* in different catchments

Catchment	Sources of *E. coli*
Karamu	ruminant (up to 10%), plant, avian[70]
Porangahau	ruminant up to 100%[71]
Kairakau	ruminant (up to 100%), some dog[72]
Wairoa	ruminant (10–50%), plant, avian[73]
Kopuawhara (Maungawhio)	ruminant 10–50%[74]
Kopuawhara (Te Mahia)	ruminant (up to 100%), avian[75]
Kopuawhara (Opoutama)	ruminant up to 100%[76]
Southern Coast (Waipuka stream)	ruminant (up to 50%), avian[77]
Waipatiki	ruminant (up to 10%), plant, wildfowl[78]

Planned work

Point sources

Ongoing upgrades at Waipukurau and Waipawa are expected to overcome existing problems around capacity and design issues. Takapau Waste Water Treatment Plant is looking to discharge to land, and upgrades are currently occurring at Otane, which will involve ultra-violet treatment. Consent renewal discussions are currently under way for the Wairoa Affco discharge.

Urban

Stormwater treatment wetlands for the Napier watershed (Ahuriri estuary, Purimu Stream) could reduce *E. coli* load by 80 per cent, depending on design.

Napier City is investigating options to increase capacity within the sewerage network to prevent blowouts during high-flow events.

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[70] ESR_CMB140853/0844

[71] ESR_CMB140853/0844

[72] ESR_CMB152236

[73] ESR_CMB160304/0305 & ESR_CMB160142_0143_0144

[74] ESR_CMB160142_0143_0144

[75] ESR_CMB160142_0143_0144

[76] ESR_CMB140059

[77] ESR_CMB130680

[78] ESR_CMB120996

Rural

Attention on dairy effluent management will continue, with measures in place to ensure effective storage and deferred irrigation measures are in place (using effluent pond storage calculator). Appropriate conditions are placed on all dairy consents, and each farm is visited and checked every year by compliance officers.

The Tukituki Plan is currently being implemented (from Plan Change 6), and includes a requirement for 1100 Farm Environmental Management Plans to be completed (240 done so far). Farm plans include designation of critical source areas, with appropriate mitigation measures identified and a plan of implementation outlined. Stock exclusion rules (excluding sheep) essentially apply to any flowing waterways that have formed beds, if stocking rate is above 18 stock units, or slope is less than 15 degrees. The Tukituki Plan is the region's first to give effect to the National Policy Statement for Freshwater Management (NPS-FM), but expectations are that some form of Farm Environmental Management Plan, as well as compulsory stock exclusion rules, will be developed and apply to the rest of the region.

Hawke's Bay have an ongoing soil conservation control programme which, among other things, has included 2.4 million poles being planted, resulting in the protection of 46,000 hectares of highly erodible land. This includes stream bank stabilisation by protecting about 50 kilometres of gullies with willow poles each year. Up to 20,000 native plants are planted along streams each year, with fencing subsidies available outside of the Tukituki (where stock exclusion is not mandatory and so no longer subsidised).

There is currently a major focus on five 'hotspots' in Hawke's Bay, which include initiatives to improve overall water quality, including swimmability. The hotspots include the Ahuriri, Tutira Lakes, Whakaki and Wairoa, Tukituki River and Lake Whatuma and the Karamu. Wide-scale stock exclusion and riparian planting will be a component of each workstream. Council have committed $1 million across these hotspots, and the Tutira Lakes and Whakaki Lake have received additional money from the Ministry for the Environment's Freshwater Improvement Fund.

Lakes

There is a project for Lake Tutira to develop an Integrated Catchment Management Plan, develop and implement farm environmental management plans throughout the catchment, reconnect Papakiri Stream to Lake Tūtira, install an oxygenation system, and implement a mauri monitoring programme.[79]

Work at Lake Whakaki will include a recirculating wetland, the establishment of 80 hectares of mānuka plantation, and complete stock exclusion from the lagoon's perimeter.[80]

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79 Survey response; www.mfe.govt.nz/more/funding/freshwater-improvement-fund/freshwater-improvement-fund-projects

80 Survey response; www.mfe.govt.nz/more/funding/freshwater-improvement-fund/freshwater-improvement-fund-projects

State of swimming in Hawke's Bay

Overall swimmability for the Hawke's Bay is 63 per cent of rivers and 68 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Hawke's Bay is represented below.

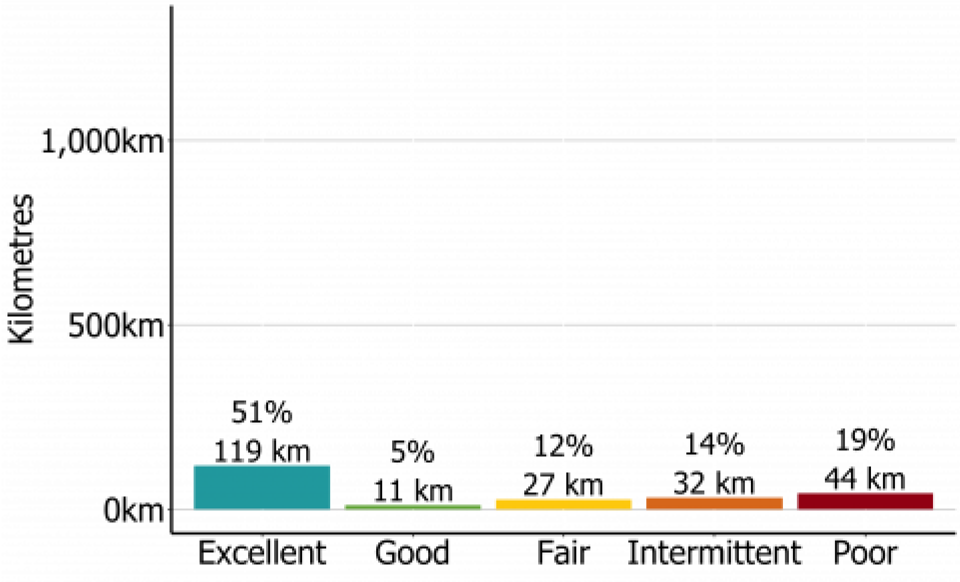

Figure 15: Percentage of Hawke's Bay lakes currently in each swimming category

Rivers

The modelling indicates an increase in the overall swimmability of rivers of 25.9 per cent, to 89.8 per cent of rivers being swimmable.

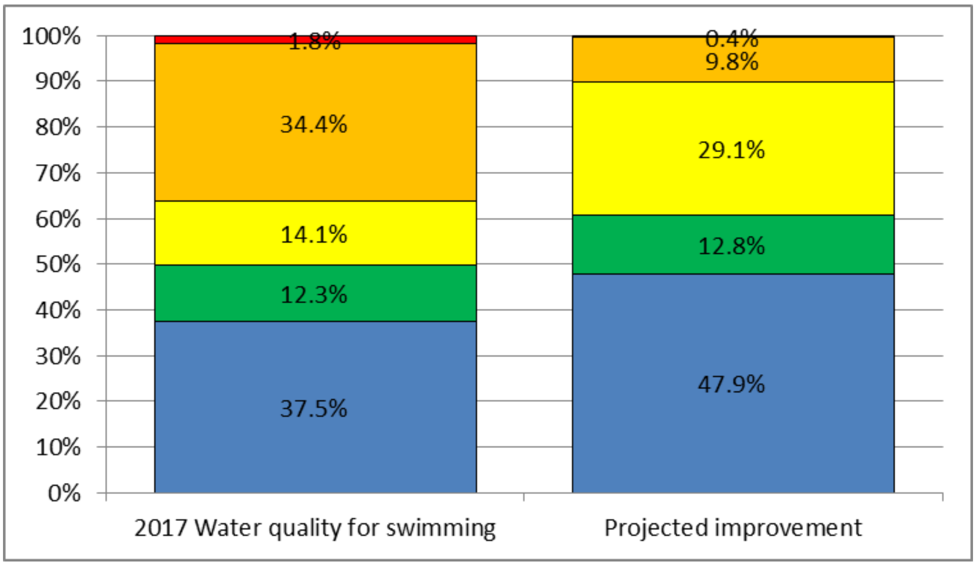

Figure 16: Projected improvement in water quality for swimming in Hawke's Bay rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Hawkes Bay region is $14.72 m. The rural costs of committed work are spread across the dairy (3%), dairy grazing (1%), sheep and beef (85%), deer (2%), and lifestyle (9%) sectors.

Region-specific modelling considerations

For modelling the implementation of activities in the Ahuriri catchment, the modelling has assumed uptake of 15–20 per cent riparian planting.

Fencing on slopes greater than 20 degrees will have a >3 metre setback. Eighty per cent of fencing on dairy farms have <3 metre setback, and 90 per cent of fencing on cropping land will have a <3 metre setback.

Where the regional plan focuses on stock exclusion or an extension to the Sustainable Dairy Accord, the modelling approach taken is to extend the stock exclusion provisions to all streams in that catchment.

Taranaki

Overview of swimmability now

Main activities

Around 60 per cent of the land is used for intensive farming – primarily dairying on the ring plains with sheep and beef farming in the eastern hill country.[81] Because the Taranaki region has had intensive dairying for a long time, the Taranaki Regional Council reports that the region is not seeing the same level of new conversion to, and intensification of, dairying that many other regions are.[82] Most of the remaining 40 per cent is indigenous vegetation with small pockets of urban and industrial land.

The ring plain is characterised by hundreds of short, steep, fast-flowing streams and rivers radiating from the native bush on Mount Taranaki, which flush comparatively quickly to the sea. The Pātea River is the longest of these. In the eastern hill country, rivers are generally longer and slower flowing, with short tributaries contained in narrow valleys.

Surface water quality in the upper reaches is generally very good; however, lowland rivers in catchments with urban areas or more intensive agriculture use are often degraded. Microbial levels sometimes exceed guidelines for swimming and other primary recreation in several sites, although Taranaki Regional Council reports this is often due to bird life.[83] Lakes Rotokare and Rotomanu are the only lakes that have had significant toxic blooms.[84] Lake Rotokare lies in a shallow basin that is entirely bush-clad, with no pastoral activity in its catchment.

The main remaining point-source discharges in the region are all wastewater treatment plants at Stratford, Kaponga, Patea and Waverley. The downstream *E. coli* loads of these treatment plants are:

- Stratford: 337 c.f. units/100mL
- Kaponga: 60 c.f. units/100mL
- Patea: 225 c.f. units/100mL
- Waverley: 1,833 c.f. units/100mL.

Other, larger wastewater plants (and associated sewer networks), together with large industrial facilities formerly discharging to fresh water, have already been upgraded and points of discharge altered to marine outfalls or to land.

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[81] Land, Air, Water Aotearoa. n.d. *Taranaki region*. Retrieved from www.lawa.org.nz/explore-data/taranaki-region (28 June 2017).

[82] Implementation Review

[83] Implementation Review

[84] Survey response

Main sources of *E. coli*

The main sources of *E. coli* in Taranaki are cattle and birds. In the Waimoku[85] and Wawhakaiho[86] catchments the main sources are birds – pukeko and seagulls respectively. The predominant source for the Waingongoro River, Timaru Stream and Kaupokonui River is cattle.[87]

Planned work

Point sources

Planned work on sewage pump stations includes providing emergency storage at all pump stations and some diversions and relocations to service new development and reduce the risks of overflows.

The load from Inglewood will be diverted to a new pump station to take load off the Mangati Stream pump station. The Connett Road pump station will be abandoned and the load diverted to a new pump station to service new residential development. The West Quay pump station will be relocated to reduce risk of overflow.

Kurapete Street will have a planned upgrade to reduce risk of overflow to Waionganaiti and Ngatoro Streams.

Rural

Riparian plan holders have planted 70 per cent of their waterways. Waterways planted in this scheme include drains, wetlands and waterways that are smaller and less significant than are required by the proposed stock exclusion regulations. The voluntary riparian management programme has resulted in around 4.3 million plants being supplied to land owners, 99.5 per cent of dairy farms having a riparian plan, and 84.4 per cent of plan holders fencing their streams. The programme covers 14,500 kilometres of stream bank. Completion of fencing and planting is set for around the end of the decade, when it is intended that a compliance regime will be put in place to ensure the completion and security of the programme into the future is maintained.[88] It should be noted that this is on the back of a substantial amount of collaborative work with the region's stakeholders to determine an appropriate and achievable completion and compliance regime that embraces the wide diversity of circumstances and landscapes. These expectations are already being driven through Council publications and communication plans.

Taranaki Regional Council released a draft *Freshwater and Land Management Plan for the Taranaki region* for pre-notification comment in 2016. The draft plan would establish freshwater management units and set objectives and maximum in-stream concentrations for water quality attributes. It also contained rules requiring stock exclusion and riparian planting on land used for intensive pastoral farming, effluent discharge to land, and forestry setback

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85 *Taranaki as One*, 2015 State of the Environment report, pg 77

86 Annual recreational water quality monitoring reports, eg doc 1671518

87 Annual recreational water quality monitoring reports, eg doc 1671518

88 Implementation Review; survey response

distances from waterways. Following comments received on the draft, the council is now carrying out further consultation and investigations, with the intention of notifying a proposed plan within five years.[89]

The transition from discharge of treated farm dairy to water, to discharges to land will occur over a 17-year period, ending in 2031. This requirement starts as consents are renewed or there are compliance issues.[90]

State of swimming in Taranaki

Overall swimmability for the Taranaki is 39 per cent of rivers and 97 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Taranaki is represented below.

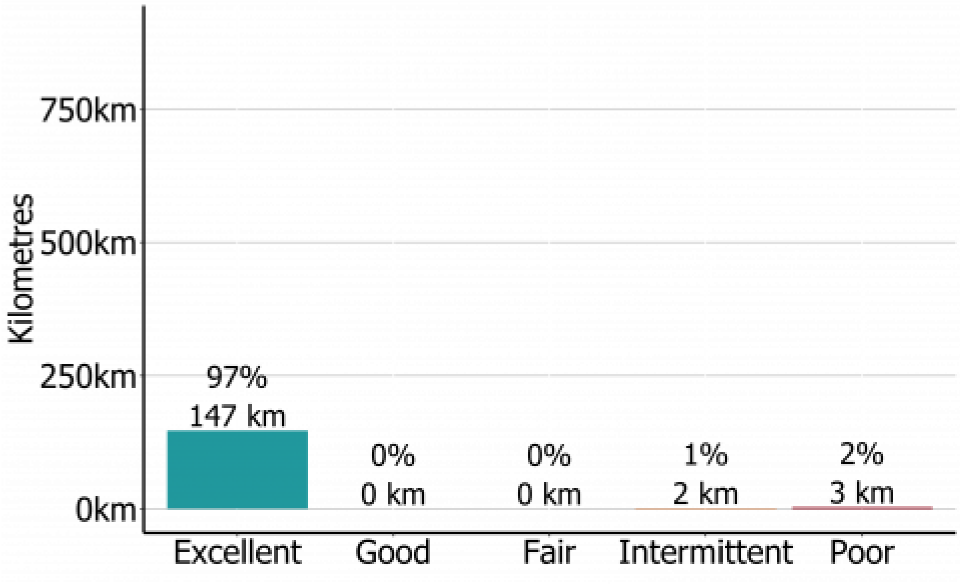

Figure 17: Percentage of Taranaki lakes currently in each swimming category

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[89] Implementation Review

[90] Implementation Review; survey response

Rivers

The modelling shows an increase in the overall swimmability of rivers of 26 per cent, to 65.4 per cent of rivers being swimmable.

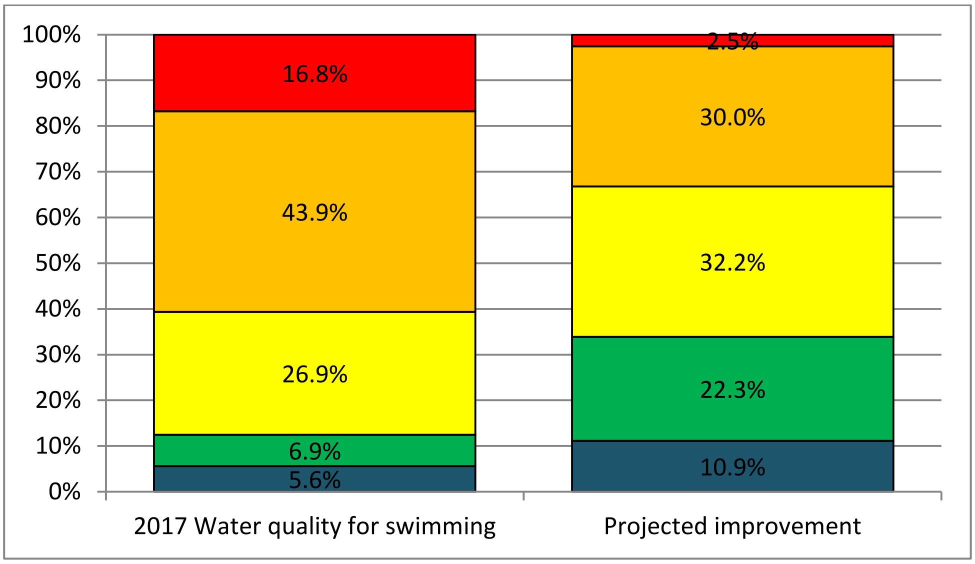

Figure 18: Projected improvement in water quality for swimming for Taranaki's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Taranaki region is $4.94 m. The rural costs of committed work are spread across the dairy (53%), sheep and beef (31%), deer (1%), and lifestyle (15%) sectors.

Region-specific modelling considerations

Taranaki has remaining two-pond effluent systems, essentially all of which are expected to be phased out by 2040. To model this, we have assumed that 40 per cent of farms currently use this method. For that percentage of farms we have applied a reduction of *E. coli* of 60 per cent in rivers (stream order 4 and above).

Seventy-six per cent of fencing on flat land in the region is set back greater than 3 metres. In steeper land this is approximately 2 per cent.

Taranaki Regional Council Reservations about the modelled results in this report

Taranaki Regional Council has expressed concerns that this report has critical flaws in methodology and quality. In particular, that the modelling that has been undertaken has not accurately represented and assessed the application of the NPS 95th%ile *E. coli* criterion to above-median flow conditions, that the modelled costs of riparian planting in the Taranaki region underestimate the investment that Taranaki farmers are making in riparian management, that the reductions in annual E. coli loadings from diverting farm dairy effluent from rivers are over-stated, and that the costs of completing farm dairy effluent conversion to land irrigation are under-stated. The economic model for costs may be re-run prior to councils setting their final regional targets later in 2018.

Manawatū–Whanganui

Overview of swimmability now

Main activities

About half of the region is used for sheep and beef farming, and a third is covered with native vegetation. The remainder is divided among dairy farming, exotic forestry, horticulture, urban areas and other land uses.[91] All dairy farms in the region have land-based effluent systems and none discharge to water.[92]

The Horizons region has 226 lakes, including volcanic, riverine, landslide, wetland-formed, beach lagoons, dune lakes and man-made reservoirs.[93] Major rivers include the Whanganui, Whangaehu, Turakina, Rangitīkei and Manawatū. Groundwater is often unconfined, meaning that it is closely connected with surface water.

Many areas, such as the Upper Rangitīkei River and Manganui o te Ao River, which are protected under Water Conservation Orders, have excellent quality across most measured attributes. However, water quality and ecosystem health decline as water flows towards the coast, largely because of diffuse discharges from agricultural and urban land uses. There are also some rivers affected by direct discharges from industrial sites or wastewater treatment plants.[94] High bacterial levels and occasional blooms of toxic algae are found in some lakes and in the middle and lower reaches of many rivers, making them unsafe for swimming or other primary recreation.[95]

Recent analysis carried out in the region shows there has been an improvement in *E. coli* levels in the decade ending 2016. This has resulted in an improvement in swimmability of rivers of between 5 – 8%.

The major point-source discharges in the region come from wastewater treatment plants, three meat-processing plants, and a wood-processing plant.[96]

Main sources of *E. coli*

Where faecal source tracking has been carried out, the main identified sources of *E. coli* are ruminants. The regional council measures the concentration of *E. coli* in the main point source discharges, and also upstream and downstream of these sources monthly to determine the relative input of point source discharges and to monitor changes over time.

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91 www.lawa.org.nz/explore-data/manawatu-Whanganui-region/

92 Implementation Review

93 www.lawa.org.nz/explore-data/manawatu-Whanganui-region/lakes/

94 Horizons Regional Council. 2013. *2013 State of the Environment*. Palmerston North: Horizons Regional Council. Retrieved from www.horizons.govt.nz/CMSPages/GetFile.aspx?guid=725c8a67-ff40-4962-b728-62430f38e82c&disposition=attachment (11 July 2017).

95 Implementation Review

96 Survey response

At Waikawa (Horowhenua) ruminants (cows) make up 50–100 per cent (greater at the top of catchment, up to 50 per cent at the bottom of catchment) of the *E. coli* source with some avian sources. Ruminants make up 10–50 per cent of the *E. coli* load in the Makotuku River (Raetihi), 1–10 per cent at Mowhanau (Whanganui) and 50–100 per cent in the Whanganui River at Town Bridge.[97]

Planned work

The Manawatū River Leaders' Accord, signed in 2010, galvanised leaders from local government, iwi and stakeholders after significant publicity about the poor quality of the river. Horizons Regional Council reports that six years after establishment "it is still going strong" and a second action plan was released in March 2016. It has been effective in motivating actions to improve water quality in the catchment – more than $46 million has been spent on sewage treatment improvements and farm management in this catchment, and around 120 farms consented for land use and discharges.[98]

Point sources

Upgrades are planned for a number of wastewater treatment plants. Upgrades (planned and potential) include wetland treatment systems (Eketahuna, Pahiatua, Raetihi,[99] Ohakune[100]), infrastructure upgrades (Palmerston North[101]), ultra-violet treatment (Pahiatua, Raetihi[102]), removing discharges from water and discharging to land (Shannon, Tokomaru,[103] Bulls,[104] Feilding,[105] Dannevirke, Foxton, Foxton Beach, Ratana[106]), and piping to other treatment plants (Marton,[107] Awahuri, Halcombe, Kimbolton, Rongotea, Sanson).

The Horizons Regional Council is working with territorial authorities to identify opportunities to improve stormwater discharges.[108]

Riverlands industrial wastewater may join Bulls/Marton upgrades if the Freshwater Improvement Fund application is successful, and discharge to land at times.

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97 Survey response

98 Implementation Review

99 Overview of the Nga Ora o te Whangaehu Freshwater Improvement Project (2017)

100 Overview of the Nga Ora o te Whangaehu Freshwater Improvement Project (2017)

101 Overview of the Manawatu Awa: Freshwater Improvement Project (2017)

102 Overview of the Nga Ora o te Whangaehu Freshwater Improvement Project (2017)

103 Overview of the Manawatu Awa: Freshwater Improvement Project (2017)

104 Overview of the Rangitikei Awa: Freshwater Improvement Project (2017)

105 www.mdc.govt.nz/Services_Information/Council_Projects/Infrastructure/Feilding_Waste_Water_Treatment_Plant_Upgrade

106 Overview of Lake Waipu Freshwater Improvement Fund Project Ratana (2017)

107 Overview of the Rangitikei Awa: Freshwater Improvement Project (2017)

108 Survey response

Urban

In 2013, the Muaūpoko owners and four other governing partners developed and signed the Lake Horowhenua Accord. The parties agreed to work together to provide leadership, halt the degradation of the water body, and put in place remedial measures. This will involve riparian fencing and planting, improvements to stormwater, mechanically removing the weeds and installing a sediment trap and fish pass.[109] This project has been granted co-funding from the Fresh Start for Freshwater, Te Mana o to Wai and Freshwater Improvement Fund. The Freshwater Improvement Fund will have a large focus on stormwater remediation.

At Lake Waipu, and Tokomaru, there is planned work to remove the direct discharge of treated wastewater to the lake and apply wastewater to land. Monitoring will enable assessment of whether additional interventions are required to restore lake health.[110]

Rural

A number of mitigation measures are under way or planned for rural areas, including:[111]

- dairy effluent pond upgrades
- land use consents in target catchments identified in the One Plan
- stream fencing
- riparian planting
- best/good practice effluent management
- education/awareness programmes
- sustainable land use initiative – this was established after the 2004 floods and uses non-regulatory methods to incentivise paddock-scale best land management to minimise hill country erosion. These measures include voluntary land retirement and revegetation. This project has planted over 13.6 million trees over 11 years and is projected by Landcare Research to be on track to deliver a 27 per cent improvement in sediment loads in the region by 2043.[112]

State of swimming in Manawatū–Whanganui

Overall swimmability for the Manawatū–Whanganui region is 43 per cent of rivers and 55 per cent of lakes.

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[109] Implementation Review

[110] Survey response; www.mfe.govt.nz/more/funding/freshwater-improvement-fund/freshwater-improvement-fund-projects

[111] Survey response

[112] Implementation Review

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Manawatū–Whanganui is represented below.

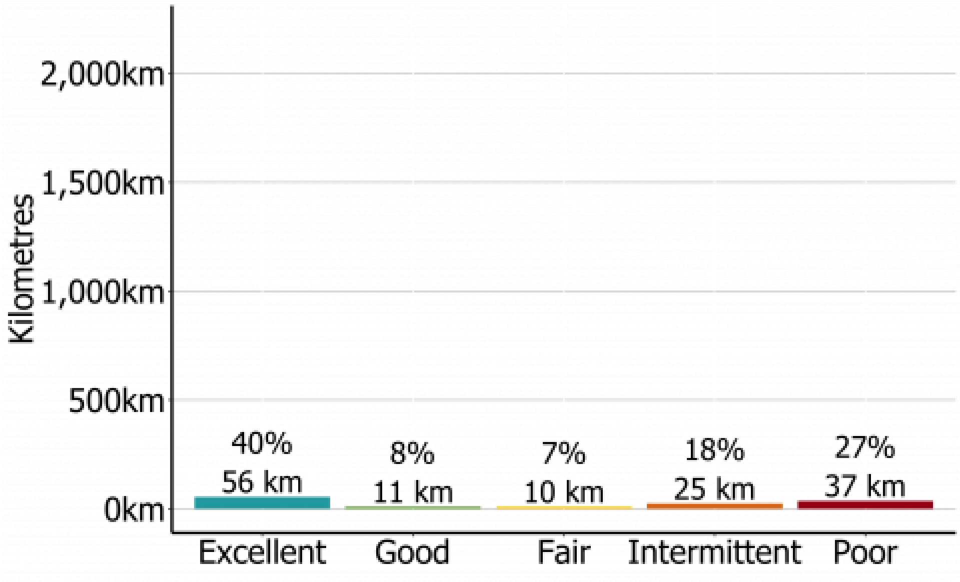

Figure 19: Percentage of Manawatū–Whanganui lakes currently in each swimming category

The modelling indicates an increase in the overall swimmability of rivers of 16.7 per cent, to 59.7 per cent of rivers being swimmable.

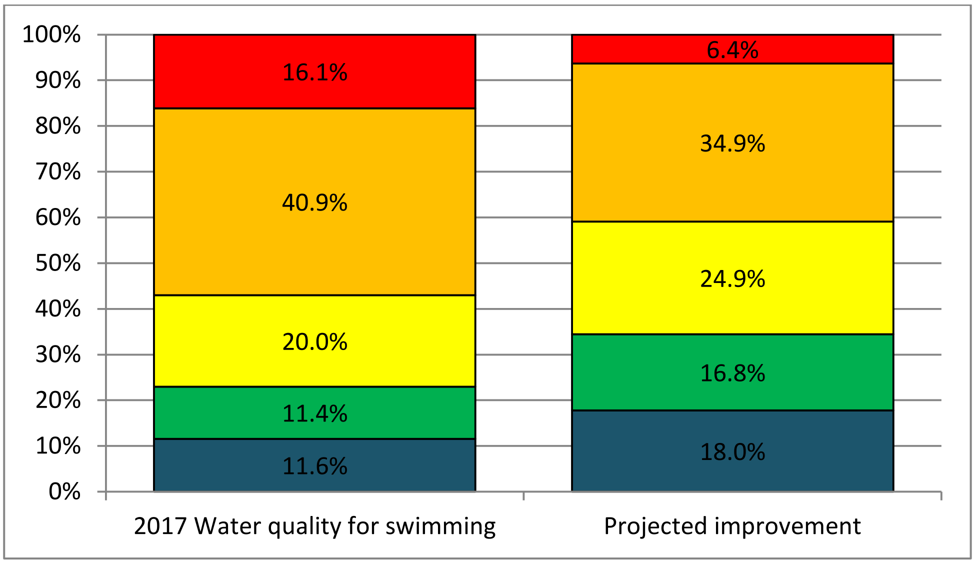

Figure 20: Projected improvement of water quality for swimming in Manawatū–Whanganui rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Horizons Manawatu-Whanganui region is $12.59 m. The rural costs of committed work are spread across the dairy (13%), dairy grazing (1%), sheep and beef (70%), deer (2%), and lifestyle (14%) sectors.

Region-specific modelling considerations

Planning provisions for excluding stock largely reflect the proposed Stock Exclusion Regulations. As the Stock Exclusion Regulations are already modelled, we have not modelled this, as it would result in double counting the reduction.

We have no data on the proportion of fencing in the region likely to be set back greater than 3 metres.

Wellington

Overview of swimmability now

Main activities

Around half of the region's land is used for pastoral sheep and beef farming, one-third is native vegetation, around 8 per cent is exotic plantation forestry, 5 per cent is dairy farming, and the remainder is urban, industrial and other uses.[113]

Of the 14 lakes in the region, by far the largest is Lake Wairarapa and the surrounding wetlands. A major flood control project in the 1960s and 1970s diverted the Ruamāhanga River away from the lake and drained much of the surrounding wetland system for farmland. Other major lakes include Lake Waitawa on the Kāpiti Coast, lakes Kohangapiripiri and Kohangatera on the south coast, and lakes Pounui and Ōnoke in the Wairarapa. The region also contains several human-made reservoirs.[114]

Wellington water quality and ecosystem health are best in the upper reaches of catchments and in areas with native vegetation or forestry.[115] However, quality tends to decline in lower river reaches, in urban and town areas, or catchments dominated by intensive farming. High levels of nutrients, sediment and bacteria, and poor clarity are common issues in these areas.[116]

Most Wellington rivers are considered safe for swimming and other primary recreation most of the time.[117] However, urban stormwater or wastewater overflows and run-off from agricultural areas have increased microbial levels in several rivers, particularly following rain and flooding events. As a result, a number of river sites monitored for recreational health often do not meet guidelines for primary recreation. In addition, toxic algal blooms are common in the lower Hutt, Ruamāhanga, Wainuiomata and Waipoua rivers, particularly during the late summer when temperatures are higher and water levels are low.[118]

Water quality in lakes Wairarapa, Ōnoke and Waitawa is degraded, with high levels of nutrients, poor clarity, poor ecological health, and occasional toxic algal blooms.[119] In contrast,

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113 www.lawa.org.nz/explore-data/wellington-region/

114 Implementation Review; www.lawa.org.nz/explore-data/wellington-region/lakes/

115 Greater Wellington Regional Council. 2016. *Rivers State of the Environment monitoring programme: Annual data report 2015/16*. Retrieved from www.gw.govt.nz/assets/Our-Environment/Environmental-monitoring/Environmental-Reporting/Rivers-State-of-the-Environment-monitoring-programme-Annual-data-report-2015-16.pdf (30 June 2017).

116 Implementation Review

117 Greater Wellington Regional Council. 2016. *Is it safe to swim? Recreational water quality monitoring results for the 2015/16 summer*. Retrieved from www.gw.govt.nz/assets/Our-Environment/Environmental-monitoring/Environmental-Reporting/Recreational-Water-Quality-Annual-Report-2016-web.pdf (30 June 2017).

118 Implementation Review

119 Greater Wellington Regional Council. 2012. *Lake Water Quality and Ecology in the Wellington Region*. Retrieved from www.gw.govt.nz/assets/Our-Environment/Environmental-monitoring/Environmental-Reporting/Lake-water-quality-and-ecology-SoE-report.pdf (30 June 2017); Greater Wellington Regional

lakes Kohangapiripiri and Kohangaterai, , which draw from catchments covered mostly in native forest, have much better water quality and ecological health.[120]

Point-source discharges include stormwater from urban areas, discharges from wastewater treatment plants (including Paraparaumu, Martinborough, Featherston, Greytown, Carterton and Masterton), wet weather overflows from wastewater networks and treatment plants to surface water bodies and discharges from human-made lakes (Henley Lake, Queen Elizabeth II Park Lake). [121] In Wairarapa and the Kāpiti Coast all dairy farms discharge to land.[122]

Main sources of *E. coli*

E. coli is predominantly from agriculture in the rural areas, and human sources in the urban areas, including the Porirua, Karori, Kaiwharawhara, Waiwhetu, Taupo, Onepoto, Owhiro and Wainuiomata streams.[123]

Planned work

Point sources

Most of the wastewater treatment plants have planned upgrades. The Featherston, Martinborough, Greytown and Carterton wastewater treatment plants all have plans for a series of staged upgrades through to 2035, to increase the proportion of wastewater discharged to land. At Martinborough and Greytown this will see 100 per cent discharge to land. The Homebush wastewater treatment plant has already undergone upgrades under the existing consent, and additional upgrades may be undertaken through review of discharge to land options.[124]

Stormwater discharges are currently or soon to be re-consented, or in some urban areas if the proposed requirements of the new proposed Natural Resources Plan go ahead, be consented for the first time. These consents will likely be for five-year durations. More targeted monitoring of stormwater effects is required under the Proposed Natural Resources Plan, and remediating or mitigating any acute effects discovered through monitoring.[125]

Council. 2016. *Lakes Water Quality and Ecology monitoring programme: Annual data report 2015/16*. Retrieved from www.gw.govt.nz/assets/Our-Environment/Environmental-monitoring/Environmental-Reporting/Lakes-Water-Quality-and-Ecology-monitoring-programme-Annual-data-report-2015-16.pdf (30 June 2017).

120 Implementation Review

121 Survey response

122 Survey response

123 Survey response

124 Survey response

125 Survey response

Rural

The Proposed Natural Resources Plan includes provisions for stock exclusion. Stock must be excluded from:[126]

- waterways classified as containing sites of significance; there are 210 sites throughout the region incorporating 1,050 kilometres of waterway, and current projections are that half will require fencing
- waterways classified as lowland streams greater than 1 metre wide (Category 2)

On land that carries stock, 3,365,060 metres of waterways fencing is required: 2,103,162 metres is completed and 1,261,897 metres of fencing remains to be completed – the target date for completion is July 2022.

An investigation is planned for Lake Waitawa, which will investigate the effects of cyanobacteria blooms, establish or confirm causality, and develop an appropriate remediation and/or containment programme.[127]

State of swimming in Wellington

Overall swimmability for the Wellington region is 65 per cent of rivers and 75 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Wellington is represented below.

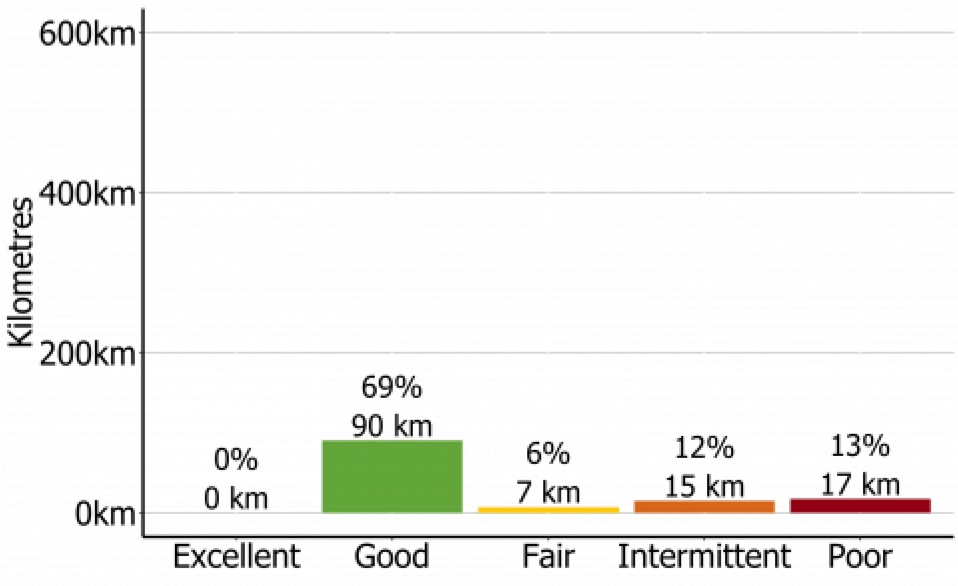

Figure 21: Percentage of Wellington lakes currently in each swimming category

[126] Survey response

[127] Survey response

Rivers

The modelling shows an increase in the overall swimmability of rivers of 10 per cent, to 75.2 per cent of rivers being swimmable.

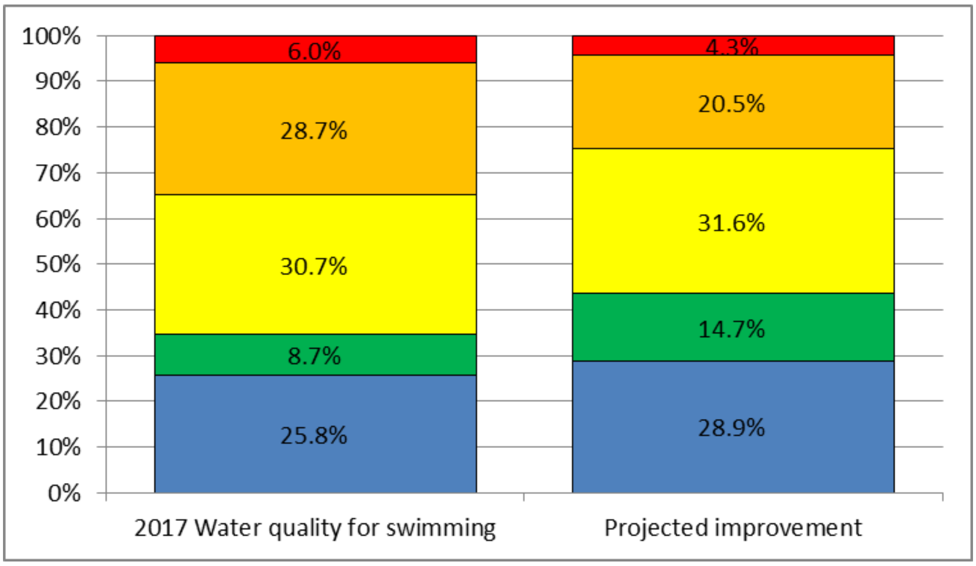

Figure 22: Projected improvement in water quality for swimming for Wellington's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Wellington region is $4.24 m. The rural costs of committed work are spread across the dairy (14%), dairy grazing (1%), sheep and beef (62%), deer (1%), and lifestyle (22%) sectors.

Region-specific modelling considerations

Current committed work for the Wellington region excludes their whaitua committee process which is the community collaborative process they are using to set objectives and limits as directed by the NPSFM.

Planning provisions for excluding stock largely reflect the proposed Stock Exclusion Regulations. As the Stock Exclusion Regulations are already modelled, we have not modelled this, as it would result in double counting the reduction.

Tasman

Overview of swimmability now

Main activities

Land cover consists primarily of native forest (60 per cent), pasture (17 per cent) and exotic forest (9 per cent).[128] Around 70 per cent of the district is protected conservation land, including the Abel Tasman, Kahurangi, and Nelson Lakes national parks. Most pasture land, viticulture and horticulture is in the Waimea, Moutere, Aorere and Tākaka valleys.[129]

The district has five major river catchments:

- Aorere and Tākaka in the northwest
- Motueka
- Waimea on the border with Nelson City
- headwaters of the Buller River, which flows westward to the West Coast.

Nearly two-thirds of the Tākaka catchment lies within the Kahurangi National Park. The catchment is also home to the famous Te Waikoropupū Springs, the largest cold-water spring in the southern hemisphere.

The largest lakes in the district are:

- Lake Rotoiti and Lake Rotoroa in Nelson Lakes National Park
- Cobb Reservoir
- Lake Otuhie
- Lake Matiri
- Lake Stanley in Kahurangi National Park.

Because such a large portion of the district is covered in protected native vegetation, water quality is generally high and most monitored sites are in the excellent or good (A or B bands) for most measures of water quality and ecosystem health.[130] Moreover, monitoring indicates water quality is being maintained or improved at most sites. However, quality decreases in lower river reaches and in lowland stream catchments with more intensive agriculture or

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128 James T, McCallum J. 2015. *State of the Environment Report: River Water Quality in the Tasman Region 2015*. Prepared for Tasman District Council. Nelson: Tasman District Council. Retrieved from www.tasman.govt.nz/policy/ reports/environmental/river-water-quality-reports (30 June 2017).

129 Implementation Review

130 James T, McCallum J. 2015. *State of the Environment Report: River Water Quality in the Tasman Region 2015*. Prepared for Tasman District Council. Nelson: Tasman District Council. Retrieved from www.tasman.govt.nz/policy/reports/ environmental/environmental-monitoring-reports/?path=/EDMS/Public/Other/Environment/ EnvironmentalMonitoring/WaterMonitoring (30 June 2017).

urban areas.[131] There are no longer any dairy shed effluent discharges direct to water and so the current significant point sources that are known are all municipal wastewater discharges. Septic tank discharges are all supposed to be to land but from time to time some have been found to be failing, with a resulting discharge to water. However, owners of failing septic tanks have been required to upgrade their system when these situations are discovered. Assessments of environmental effects at wastewater treatment plants show downstream *E. coli* levels are either usually or always no different to upstream levels (depending on the site).[132]

Main sources of *E. coli*

The council has undertaken microbial source tracking at all monitoring sites, and some investigation sites, where they have found high *E. coli* concentrations.[133]

About 85 per cent of these had ruminant animals as a significant source. Ruminant sources of *E. coli* in rural areas include effluent from:

- dairy sheds
- around stock drinking troughs sited close to streams
- feed pads and stand-off pads
- winter cropping
- raceways/laneways.

All regular dairy farm stock crossings in the district have been bridged since about 2012, and stock are excluded from almost all waterways over 1 metres wide and 300 millimetres deep. Humans are a significant source currently at only one catchment that they know of (Tasman Valley Stream, south-east of Motueka). While the council has known about this risk for some time, and individual sites as they are identified are fixed, it has not been a priority to undertake a full septic tank survey of the catchment. As the catchment increasingly urbanises it will become a higher priority.

A human source was found in Murchison (Ned's) Creek, Little Sydney Creek, and Tukurua Stream, but this source is no longer present due to a septic tank survey and upgrades to failing septic tanks.

Wildfowl are a significant source in the following waterways:

- Jimmy-Lee Creek
- Reservoir Creek
- Seaton Valley Stream
- Tasman Valley Stream
- Powell Creek/Lower Motupipi

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[131] Implementation Review

[132] Survey response

[133] Survey response

- occasionally at Tukurua Stream and Murchison Creek.

In-line ponds in the catchment (particularly the Moutere Hill country and urban streams) are often frequented by ducks.

Planned work

Implementation of the National Policy Statement for Freshwater Management (NPS-FM) will involve the roll out of a water quality management framework to the whole region, beginning with Tākaka and Waimea in 2018 and urban catchment management plans by 2020. A review of rules for contaminant discharges will also be carried out in 2017 for completion in 2019.[134]

Point sources

No significant upgrades are planned for wastewater treatment plants, these having been progressively upgraded in recent years.[135]

Urban

Stormwater upgrades across the district are planned over the next 10 years. The Council supports urban riparian initiatives and supports the Waimaori project, which provides educational awareness at the streamside in urban areas.[136] Applications for resource consents to discharge contaminants from urban stormwater in the district's two largest settlements (Richmond and Motueka) are likely to be lodged in 2018.

Rural

Each year there is an expectation that a minimum of 20 kilometres of fencing materials are provided to prevent stock access to waterways. Historically the fund has provided 27 kilometres per year on average.[137] A project has been initiated with Landcare Trust and other parties to support farmers in the Sherry and Aorere/Kaituna valleys to refresh their farm environmental plans.

Compliance action undertaken includes:[138]

- assessed compliance with effluent rules at almost every dairy farm
- two prosecutions are in process for dairy effluent discharges
- prior to the bathing season a feed-pad on a dairy run-off block was moved well away from Tukurua Stream (a swimming hole in the lower reaches); *E. coli* results show a marked improvement on previous years

[134] Implementation Review

[135] Survey response

[136] Survey response

[137] Survey response

[138] Survey response

- a fly-over of the region has identified some areas , such as winter cropping, standoff and feed pads, that need attention
- wastewater treatment plant monitoring reports have been audited.

State of swimming in Tasman

Overall swimmability for the Tasman region is 97.5 per cent of rivers and 100 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Tasman is represented below.

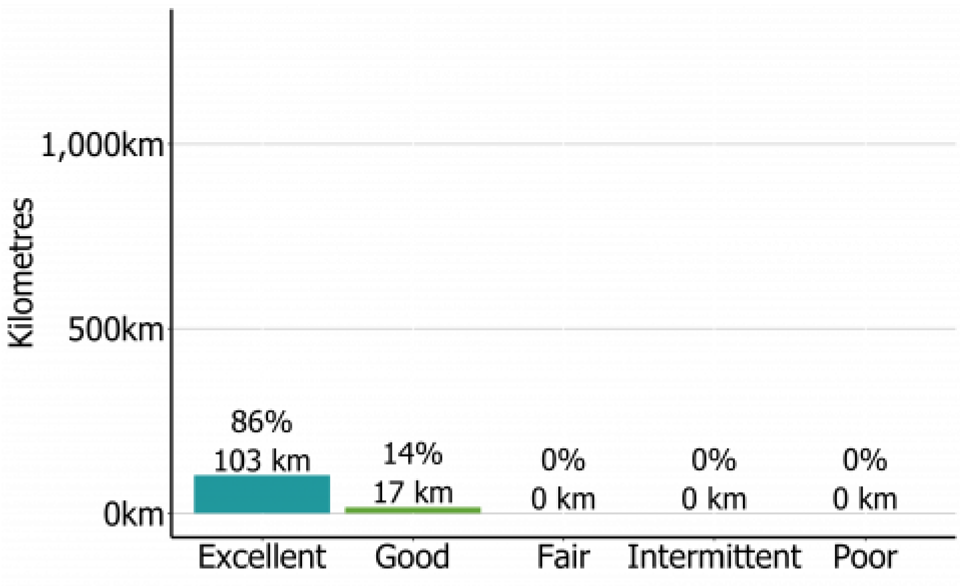

Figure 23: Percentage of Tasman lakes currently in each swimming category

Rivers

The modelling shows an increase in overall swimmability of rivers in Tasman of 0.2 per cent to 97.7 per cent.

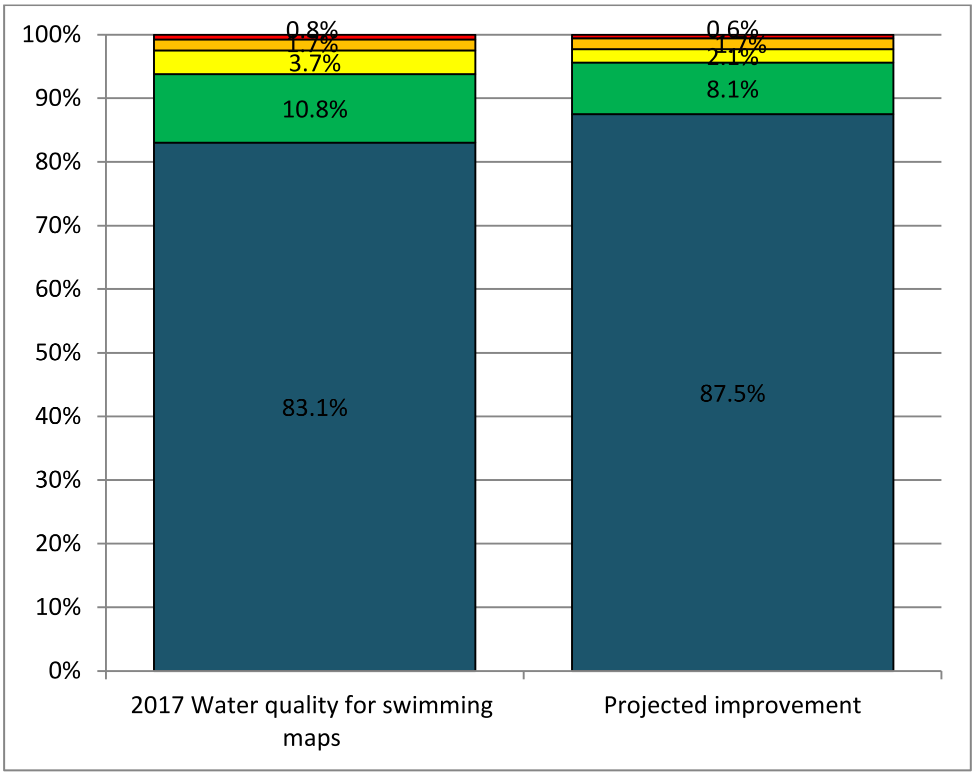

Figure 24: Projected improvement in water quality for swimming for Tasman's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Tasman region is $1.54 m. The rural costs of committed work are spread across the dairy (18%), dairy grazing (2%), sheep and beef (40%), deer (5%), and lifestyle (35%) sectors.

Region-specific modelling considerations

Planning provisions for excluding stock largely reflect the proposed Stock Exclusion Regulations. As the Stock Exclusion Regulations are already modelled, we have not modelled this, as it would result in double counting the reduction.

We have no data on the proportion of fencing set back by greater than 3 metres.

Nelson

Overview of swimmability now

Main activities

Nelson City Council is a Unitary Authority, with the Nelson City urban area making up just 6 per cent of land, concentrated towards the southern end of the territory. Most of the area is sparsely populated and covered in protected native forests and regenerating bush (42 per cent), exotic plantation forestry (22 per cent) or farm land (13 per cent).[139]

The largest rivers, the Whangamoa, Wakapuaka, Maitai and Roding, have their headwaters in the Bryant Range, which is largely in conservation land or plantation forestry. The first three of these catchments drain directly into Tasman Bay, while the Roding drains into Tasman District and joins the Waimea River. Several smaller streams drain catchments in the coastal hills and flats. Most aquifers are unconfined and connected hydrologically to surface water.[140] There are no major point-source discharges to rivers.[141]

Water quality and ecosystem health are best in the upper river reaches and in catchments with less urban area or intensive agriculture, such as the Whangamoa catchment. Most river monitoring sites have microbial levels that are generally safe for swimming and other primary contact recreation, and the overall swimmability for the Nelson region is 100 per cent of rivers based on the criteria used for this report.

Main sources of *E. coli*

The sources of *E. coli* vary over time and have included ruminant, human, wildfowl, gull, possum and dog.[142]

Table 3: Sources of *E. coli* in the Maitai catchment

Report date	Sources of *E. coli*
April 2008[143]	Ruminant &/or possum, human
March 2011	Ruminant, wildfowl, gull, human
November 2014	Wildfowl, gull, human
March 2015	Ruminant, wildfowl, human, possum, gull, dog
October 2016	Human/possum, wildfowl, faint traces dog, faint traces ruminant

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139 www.lawa.org.nz/explore-data/nelson-region/river-quality/

140 The Catalyst Group. 2015. *Aquatic Sites of Significance: Document in support of the Nelson Plan water management framework*. Report No 2015/031. Retrieved from https://drive.google.com/file/d/0B8uhqenEodmicnFEc21rMGhJelU/view?usp=sharing (30 June 2017).

141 Survey response

142 Survey response

143 Cawthron Report 1447

Table 4: Sources of *E. coli* in the Wakapuaka catchment

Report date	Sources of *E. coli*
March 2011	Ruminant, wildfowl
March 2015	Ruminant, wildfowl, possum, sheep, human (inconclusive)

Planned work

Urban

Renewal of wastewater infrastructure is planned for the next one to three years. This is primarily driven by the need to maintain a level of service, and to reduce stormwater infiltration to allow capacity for urban growth, but will also reduce exfiltration.[144]

There is an inflow and infiltration project to reduce stormwater and groundwater ingress into the piped network. The work programme is broken into two components:

- for investigations and some small spot repairs
- to advise a more extensive programme of relining or replacement of aging services.

In addition to inflow and infiltration, a further project has been established to evaluate the storage capacity of the current network and identify areas where either larger inline detention tanks can be installed or network reticulation upgrades undertaken, to address in part the current wet weather overflows experienced by the city. As the integrity of the network is improved it will also prevent wastewater escaping. There is also an exfiltration project to investigate specific areas where sampling identifies high counts of *E. coli* that may be attributed to the wastewater network.[145]

There are planned wastewater network fixes as a result of CCTV work in Bishopdale, driven by high State of the Environment *E. coli* readings at the York at Bishopdale site. This will happen in the next one to two years.[146]

The Nelson Nature and Project Maitai/Mahitahi urban streams projects have included public education campaigns to reduce dog poo in streams since 2015. The 10-year Nelson Nature programme uses an extensive and targeted approach to care for the region's natural environment, boosting the conservation and ecological work carried out on both public and private land. In relation to fresh water, Nelson Nature aims to protect and enhance the aquatic biodiversity of Nelson's freshwater streams and rivers, through:

- protecting and enhancing riparian margins and habitat for fish spawning
- removing fish barriers
- facilitating stock exclusion from waterways
- advocating for reduction in contaminants and sediments into freshwater.[147]

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[144] Survey response

[145] Survey response

[146] Survey response

Project Maitai/Mahitahi has seen Nelson City Council work in partnership with iwi, the community and other regional agencies, on a four-year project to improve the water quality of the Maitai River. This will be achieved through several initiatives, including extensive riparian planting, removing barriers to fish movement, and identifying and addressing pollution, nutrient and sediment sources.[148]

There is also ongoing low-level public education regarding not putting wipes and other materials down the toilet, where they can cause blockages and wastewater overflows.[149]

Rural

The Nelson Nature rural streams project includes planned work with land owners to revegetate riparian margins, increase stock fencing, and reduce cattle crossings. Land Management Plans are being progressed where appropriate, and work with land owners will identify a range of issues, including:

- stock exclusion
- erosion issues
- cattle crossings
- riparian management
- contamination through fertiliser use
- septic tank maintenance.[150]

A rural waterways project specifically focused on enhancing the Wakapuaka River is beginning in the 2017/18 year, in partnership with Landcare Trust, land owners, community and iwi.

Nelson Nature is also planning programmes to control browsers and predators, to protect native vegetation and wildlife, which as a by-product may reduce *E. coli* from ungulates and possums entering waterways.

A project to identify 'good management practices' in a Nelson context is near completion, including development of a good management plan template, supported by an example plan in a catchment with high *E. coli*. This will be used to inform the Nelson Plan freshwater management framework, including plan methods.[151]

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[147] Survey response, Implementation Review

[148] Survey response, implementation review

[149] Survey response

[150] Survey response

[151] Survey response

State of swimming in Nelson

Overall swimmability for the Nelson region is 100 per cent of rivers. Swimmability of rivers stays at 100 per cent, with 99.4 per cent in the blue or green category.

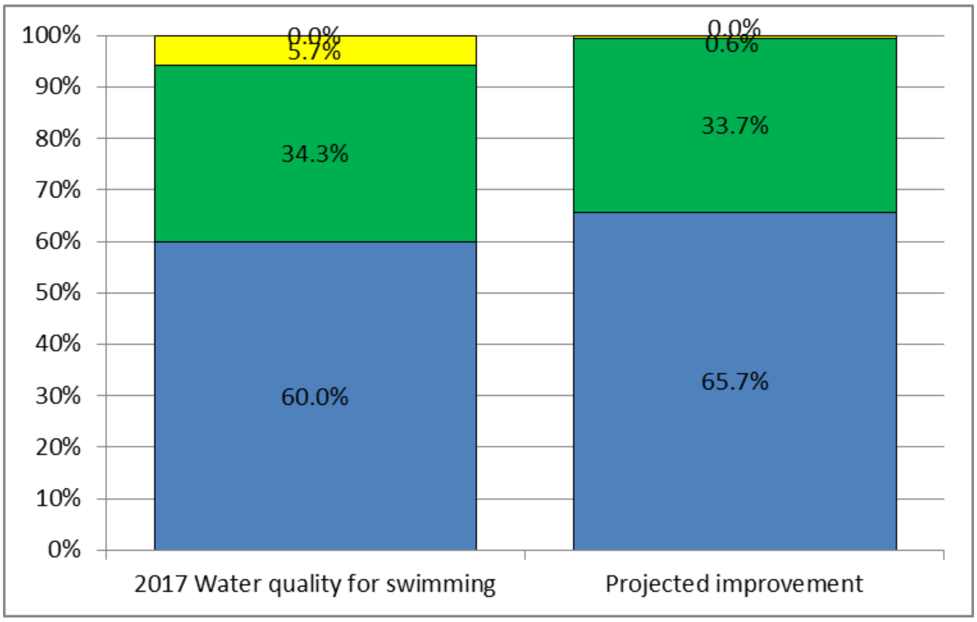

Figure 25: Projected improvement in water quality for swimming of Nelson's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Nelson region is $0.05 m. The rural costs of committed work are spread across the dairy (6%), dairy grazing (1%), sheep and beef (25%), and lifestyle (68%) sectors.

Region-specific modelling considerations

Nothing specific.

Marlborough

Overview of swimmability now

Main activities

Northwest of the Wairau Fault is hill country around the Richmond and Bryant ranges, and the Marlborough Sounds with their glacial mountain valleys and short, steep rivers and streams. The hill country is largely covered in native and exotic forests, while the valleys are mostly dairy farms and other agriculture.

To the southeast of the Wairau Fault lies a mixture of valleys, mountain ranges, and complicated fault systems. This area includes the Wairau Plains and Wairau Valley, with Marlborough's famous viticulture industry, as well as the Blenheim urban area. Over the past few decades, the growing viticulture industry has taken over from sheep and beef farming and horticulture to be the dominant land use in the plains area.[152]

There are four main rivers in the region: the Wairau, Awatere, Clarence and Pelorous. The Wairau and Awatere rivers both flow along faults and down from headwaters in the western mountains to the Cook Strait at Cloudy Bay, west of Blenheim.

While most regional rivers are safe for recreation most of the time, bacterial contamination occasionally exceeds guideline values for safe swimming and other primary contact recreation in some rivers.[153] The worst of these is the Taylor River in Blenheim, which often has high bacteria levels even during dry periods.[154]

Only one urban wastewater treatment plant discharges to fresh water. The Seddon treatment plant discharges into Starborough Creek, a tributary of the Awatere River. However, the creek is often dry so actual discharges into the river are only occurring occasionally.[155] All dairy effluent in the region is applied to land.[156]

Main sources of *E. coli*

In the Rai and Brown rivers, ruminants are the dominant source of *E. coli*, making up 50–100 per cent of the total *E. coli* load. In both rivers contamination corresponds with rainfall. Detection of the bovine marker in the Rai River indicates cows may be the main ruminant source. In the Taylor River and tributaries the *E. coli* sources include wildfowl, ruminants,

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[152] Implementation Review

[153] Marlborough District Council. 2016. *Recreational Water Quality Report 2015–16*. MDC Technical Report No: 16-003. Blenheim: Marlborough District Council. Retrieved from www.marlborough.govt.nz/repository/libraries/id:1w1mps0ir17q9sgxanf9/hierarchy/Documents/Recreation/Swimming%26Boating Recreational Water List/A2015-16 Recreational Water Quality Report.pdf (12 July 2017).

[154] Implementation Review

[155] Survey response

[156] Survey response

human and dog. In Doctors Creek and tributaries the sources are wildfowl, ruminants and human.[157]

Planned work

Point source

An application for a short-term (five-year) consent has been submitted for the Seddon sewage treatment plant, with a proposal to investigate land disposal options.[158]

Urban

There is a planned upgrade of Blenheim sewerage infrastructure to increase capacity and reduce and better control wet weather overflows to surface water.[159]

Rural

Catchment enhancement plans are to be developed and implemented in co-operation with affected land owners in the Doctors Creek, Tuamarina River, Cullen Creek, and Ada Creek areas. Investigation of contamination sources is planned to begin this year, with the aim of developing a catchment enhancement plan in the Flaxbourne River catchment.[160]

State of swimming in Marlborough

Overall swimmability for the Marlborough region is 98 per cent of rivers and 100 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Marlborough is represented below.

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[157] Survey response

[158] Survey response

[159] Survey response

[160] Survey response

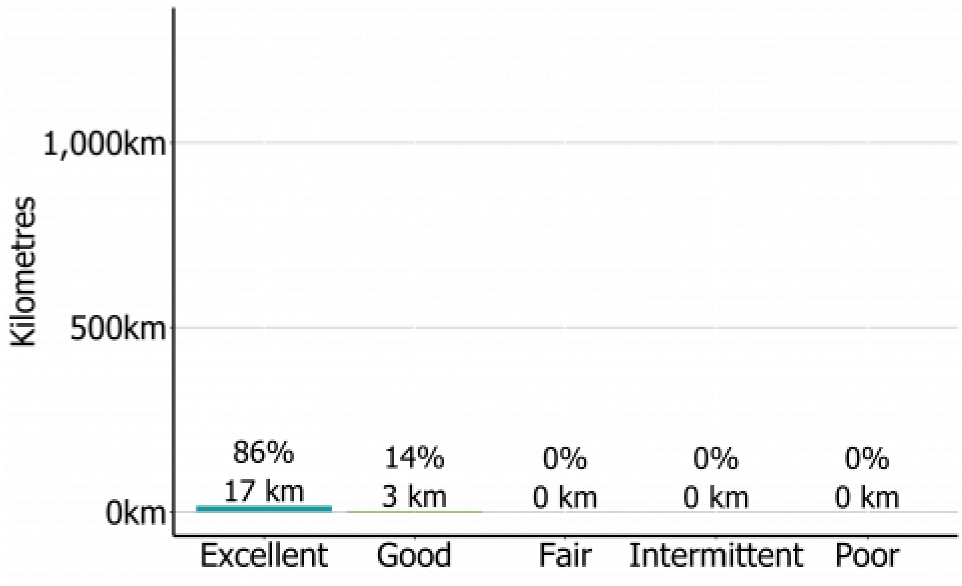

Figure 26: **Percentage of Marlborough lakes currently in each swimming category**

Rivers

The modelling shows an increase in the overall swimmability of rivers of 1 per cent, to 98.7 per cent of rivers being swimmable.

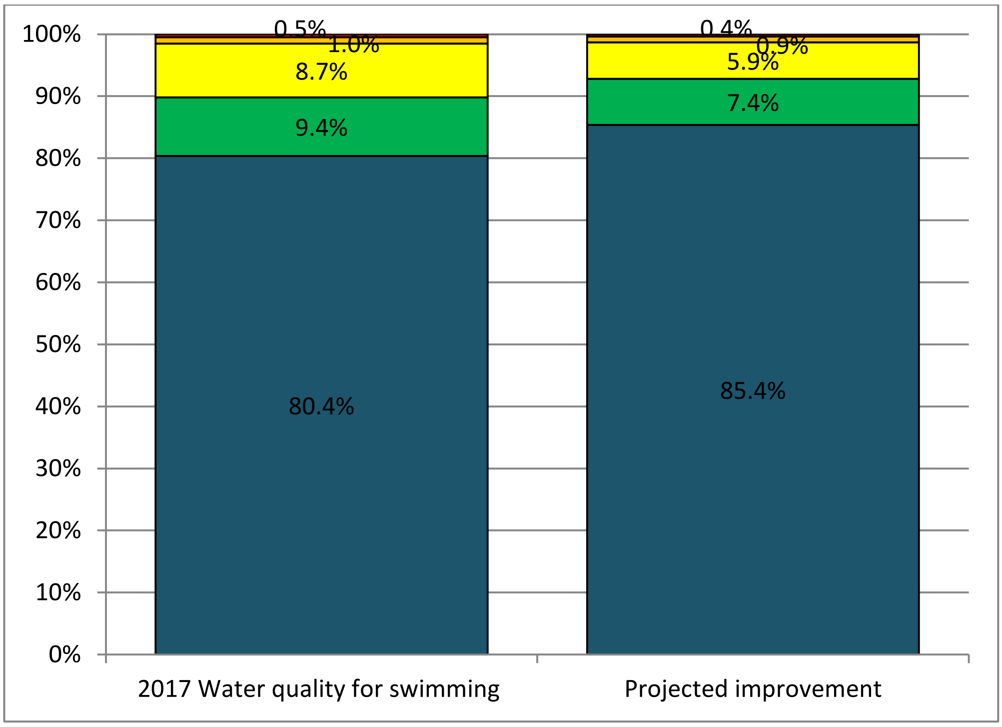

Figure 27: **Projected improvement in water quality for swimming for Marlborough's rivers**

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Marlborough region is $2.64 m. The rural costs of committed work are spread across the dairy (4%), dairy grazing (4%), sheep and beef (68%), deer (1%), and lifestyle (23%) sectors.

Region-specific modelling considerations

Planning provisions for excluding stock largely reflect the proposed Stock Exclusion Regulations. As the Stock Exclusion Regulations are already modelled, we have not modelled this, as it would result in double counting the reduction.

We have no data on the proportion of fencing set back by greater than 3 metres.

West Coast

Overview of swimmability now

Main activities

The southern half of the West Coast forms a narrow strip of land falling westward from the Southern Alps down to the coast. This strip alternates between alluvial plains and low moraine formed hill country. The northern half of the West Coast is more complicated geographically with multiple ranges, valleys, and catchments from east to west.

Indigenous cover including forest, shrub, tussock, and rock, makes up 87% of the region's total cover. [161] Both exotic pasture and forests account for 7% and 2%, respectively.

More than 80 per cent of the region is held in public trust, including all or part of five national parks (Arthur's Pass, Mount Aspiring, Kahurangi, Paparoa, and Westland Tai Poutini) and part of the Te Wāhipounamu – South West New Zealand World Heritage Area.

Most medium to large rivers in the region have headwaters originating in hill and mountain country, covered by indigenous vegetation. The largest rivers are the Karamea, Buller, Grey, Hokitika, and Haast. The West Coast region also has multiple lakes, which are highly valued for recreation of which most have catchments dominated by native forest.

Most monitored sites score in the A band for microbiota and are considered excellent quality for swimming and other primary immersion recreational activities. However, a few are in bands C and D for *E. coli*.[162]

Problem cyanobacterial blooms in rivers and lakes have not been observed by the Council to date, and there is no formal monitoring of cyanobacterial abundance. The following conditions are typical and beneficial for improving swimmability:

- low inorganic nutrient status
- high-coloured dissolved organic carbon loads leading to reduced light penetration
- cool temperatures.[163]

Point-source discharges in the region include:[164]

- treated dairy effluent
- stormwater
- treated sewage from wastewater treatment plants

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[161] See Statistics New Zealand. n.d. Agricultural area in hectares by usage and region. Retrieved from http://stats.govt.nz/~/media/Statistics/browse-categories/industry-sectors/agriculture-horticulture-forestry/ag-census-2012/ag-areas-hect-by-usage-region.xls (22 June 2017).

[162] Implementation Review

[163] Survey response

[164] Survey response

- untreated sewage during storm overflow events
- wastewater from hydro-electric power generation
- treated wastewater from meat processing plant and a dairy factory

Main sources of *E. coli*

There has been little in the way of conclusive investigations that pinpoint the main sources of *E. coli* in specific catchments. Specific studies have identified human and ruminant *E. coli* in the Orowaiti River[165], and a drain adjacent to the Hokitika River, beside Hokitika township.[166] Pastoral agriculture is the obvious source of elevated *E coli*, where this occurs intensively, but birds also have potential as a significant source in certain areas and at certain times.

Planned work

Point source

Improvements are being made to the Runanga sewerage scheme. Historically stormwater has been entering the system causing frequent overflows into Raleigh Creek, which flows into Seven Mile Creek. This is used for contact recreation. A new pump is going in, which has more capacity than the old one, to direct discharges to the treatment plant. There will be fewer overflows of sewerage to Raleigh Creek/Seven Mile Creek in future and these measures will reduce *E. coli* levels in this catchment.[167]

In Greymouth, *E. coli* readings in Sawyer's Creek are within the National Objectives Framework D band. The Grey District Council is implementing a $48 million sewerage system upgrade, which should reduce *E coli* levels sufficiently to climb above the national bottom line within two years.[168]

Marrs and Shingle beaches near the Buller river mouth at Westport are popular for recreational use and have had regular exceedances of *E. coli* for a number of years. Source/s of the raised contaminant levels have been difficult to identify. A working group of community and organisation representatives is being formed to investigate the issues and options for managing water quality at these swimming beaches.[169]

Rural

A lot of work has been done in the Lake Brunner catchment in the last ten years. This work was not designed to address problems with *E. coli* specifically, but many of the initiatives undertaken will result in a reduction in *E. coli*. Work is still ongoing in the Lake Brunner catchment and further improvements are anticipated. Initiatives include:

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[165] Survey response, ESR analysed sample from 4 Dec 2015

[166] Survey response, ESR analysed sample from 28 November 2006. WCRC Hokitika Beach faecal source investigation reports.

[167] Survey response

[168] Implementation Review

[169] Implementation Review

- stock exclusion
- dairy effluent storage and low rate application
- riparian fencing and planting
- requirements for consents for stock crossings without bridges or culverts.[170]

State of swimming in West Coast

Overall swimmability for the West Coast region is 99 per cent of rivers and 99 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in the West Coast is represented below.

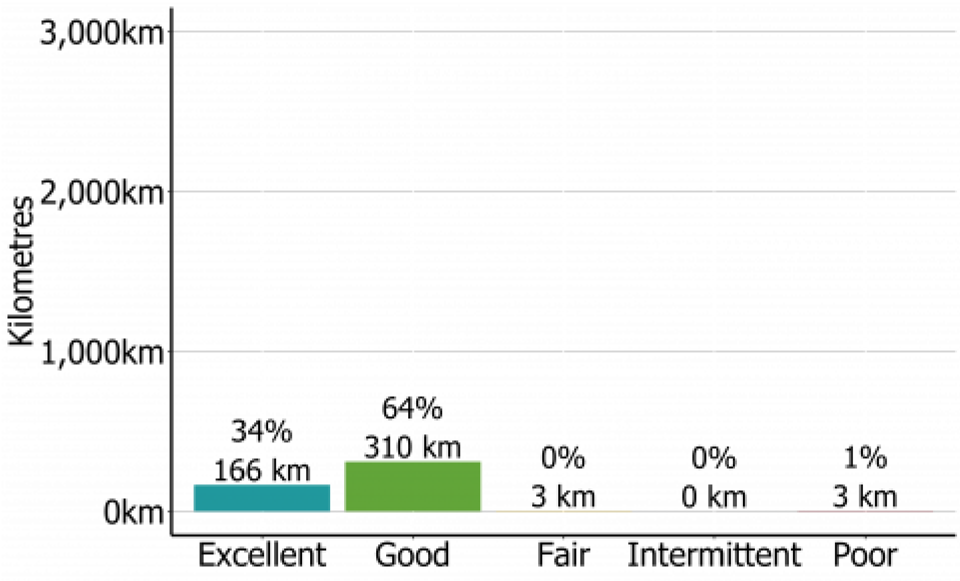

Figure 28: Percentage of West Coast lakes currently in each swimming category

[170] Survey response

Rivers

The modelling shows an increase in the overall swimmability of rivers of 0.3 per cent, to 99.3 per cent of rivers being swimmable.

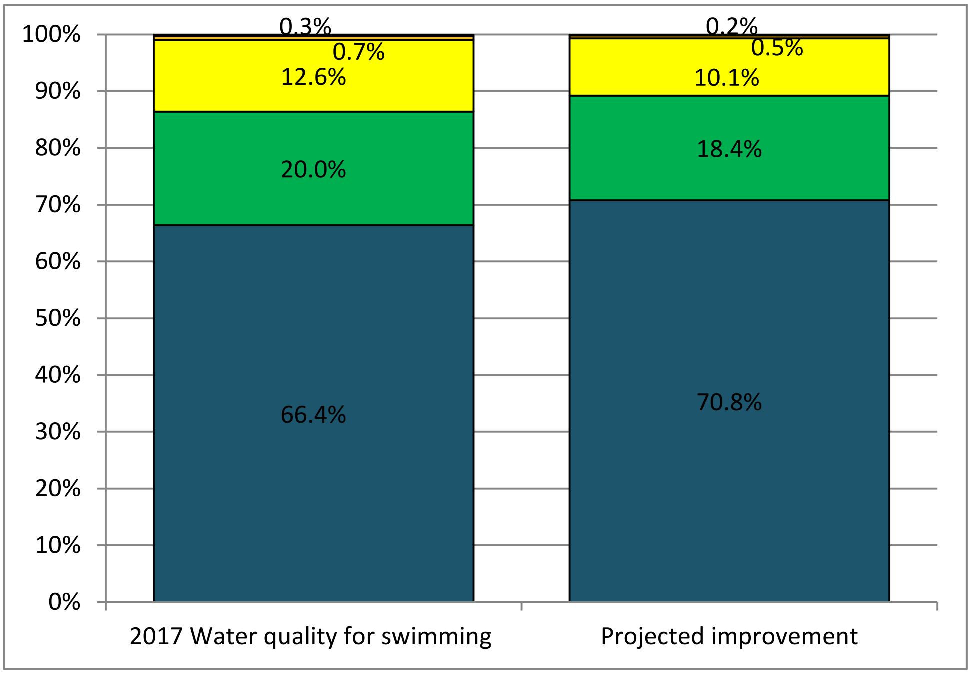

Figure 29: Projected improvement in water quality for swimming for West Coast rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the West Coast region is $3.5 m. The rural costs of committed work are spread across the dairy (35%), dairy grazing (2%), sheep and beef (28%), deer (3%), and lifestyle (32%) sectors.

Region-specific modelling considerations

Planning provisions for excluding stock largely reflect the proposed Stock Exclusion Regulations. As the Stock Exclusion Regulations are already modelled, we have not modelled this as it would result in double counting the reduction.

We have no data on the proportion of fencing set back by greater than 3 metres.

Canterbury

Overview of swimmability now

Main activities

Canterbury includes large areas of productive farmland, more than 4,700 lakes and tarns, and over 78,000 kilometres of rivers and streams. The region ranges from the Southern Alps and foothills in the west to the wide Canterbury plains to the east in the middle of the region; in the north and south of the region the foothills have only a narrow coastal plain. Around half of Canterbury land is pasture, a third is native forest and vegetation, and the remainder is divided among horticulture, exotic forestry, urban area and other land uses.[171]

In recent years, the productive flatter areas in the region have undergone agricultural intensification, with widespread dairy conversion. Between 2006 and 2016, the estimated number of dairy cattle in Canterbury nearly doubled from 656,000 to 1,271,000 while numbers of sheep and beef have fallen.[172]

Microbial levels in the lower reaches of many streams and rivers frequently do not meet standards for swimming and other primary contact recreation.[173] Water quality and ecosystem health in the majority of lakes is very good but lowland and coastal lakes suffer from degradation with elevated levels of nutrients, poor water clarity, and toxic cyanobacteria blooms. Te Waihora/Lake Ellesmere and Wairewa/Lake Forsyth are both severely degraded and routinely have blooms of toxic cyanobacteria.

The majority of problems around primary contact recreation are derived from diffuse sources but there are some areas where substantial improvements have been made (e.g. Pahau River winner of 2017 national Most Improved River). The main point-source discharges are storm- and wastewater. Over the past 20 years there has been a concerted effort to remove discharges from wastewater treatment plants into rivers (for example, the Lower Waimakariri, Otukaikino, Temuka and Opihi rivers), which has led to water quality improvements (for example, Otukaikino River winner of 2014 national Most Improved River[174]).

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[171] Ministry for the Environment. n.d. *Environmental Reporting: Area of land cover 1996–2012*. Retrieved from https://data.mfe.govt.nz/table/2478-land-cover-area-of-land-cover-1996-2001-2008-and-2012/data/ (10 July 2017).

[172] Statistics New Zealand. 2017. *Agricultural Production Statistics: June 2016*. Retrieved from www.stats.govt.nz/browse_for_stats/industry_sectors/agriculture-horticulture-forestry/AgriculturalProduction_final_HOTPJun16final.aspx (10 July 2017).

[173] Environment Canterbury. 2016. *Water Quality Monitoring for Contact Recreation: Summary of the 2015–2016 Season*. Retrieved from www.ecan.govt.nz/document/download?uri=3060272 (10 July 2017).

[174] Morgan Foundation Awards, 2014. www.lawa.org.nz/get-involved/news-and-stories/otago-regional-council/2015/november/the-new-zealand-river-awards/#improved

Main sources of *E. coli*

There are two significant studies of animal sources of faecal matter in Canterbury. In the urban environment the sources of *E. coli* in the Avon River were found to be human, bird, and dog.[175] In a predominantly rural catchment (the Jed River) sources were cow, sheep, and human.[176]

Planned work

Point source

In the past 20 years many wastewater treatment plants have been consolidated into larger, upgraded plants. For example, the Belfast sewage and separate abattoir wastewater treatment plants used to discharge into rivers. These have been closed and waste is treated at the larger Bromley treatment plant, which has better treatment and an ocean discharge. This leaves the two issues of point-source discharge being small urban settlements and overflow wastewater discharges during storm events (that is, sewage system overloaded with stormwater).

In terms of smaller urban settlements:

- The primary point-source discharge from the Otematata Wastewater treatment plant was removed through upgrades a few years ago when subsurface infiltration trenches were installed. The discharge now is only during extreme rainfall events.
- There is an upgrade planned for Omarama stream to remove point discharge by December 2019. The upgrade involves installing sub-surface irrigation on an adjoining piece of land.

In terms of overflow discharges in Christchurch, four projects are currently under way at the wastewater overflow points to the Avon River, Heathcote River and Avon/Heathcote Estuary to reduce wet weather overflows. These are the Riccarton Road, lower Riccarton Interceptor, Colombo Street and Beckenham Street wastewater network upgrades.

Urban stormwater

While stormwater treatment devices are being installed across Christchurch, the ability of these to reduce faecal contamination is unknown. Starting in 2019 the city and regional councils will undertake a long-term education programme about valuing water. It will include public education about measures to reduce faecal contamination of waterways.

The Christchurch City Council Dog Control Bylaw 2016 requires dog owners to carry plastic bags or other effective means to remove and dispose of any fouling (dog faeces) when in public places with their dog, and must remove and appropriately dispose of any fouling (dog faeces) produced by their dog in public places or on land that is not their own land.

Rural

The Land and Water Regional Plan has new rules for farming activities relating to nutrient management. All farmers in Canterbury need to operate within the farming activity rules

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[175] Moriarty & Gilpin, ECan report R09/67; Gilpin & Moriarty (2015) ESR Client report: CSC15022

[176] Done by ESR as part of their Ministry of Business, Innovation and Employment work (Elaine Moriarty)

unless sub-regional plan changes establish different rules. In general, farms are required to operate at Good Management Practice (GMP).

Under the Land and Water Regional Plan rules introduced in 2015, farmed cattle, deer and pigs are prohibited from:

- all access to spring-fed streams (mainly lowland)
- using and disturbing the bed and banks of other waterbodies.

Under Plan change 4 (Stock in Waterways), non-intensively farmed stock can stand in some high country lakes without requiring a resource consent. This change limits the application of the rule with respect to the type of lakes that non-intensively farmed cattle are to be excluded from. The stock exclusion rules now define braided riverbeds, to make it easier to understand how to comply with the rules. Rules prohibit farmed cattle, deer and pigs from inanga-spawning habitat (more lowland waterbodies than is currently the case).

Overall the current stock exclusion rules in Canterbury, although expressed in different ways, achieve all of the 2017 stock exclusion rules proposals for the National Policy Statement on Freshwater Management (NPS-FM).

To continue to farm within nutrient management rules, most intensive agriculture farms will require a:

- farming activity resource consent
- nitrogen baseline
- farm environment plan.

Plan Change 5 proposes new rules that restrict (as a permitted activity) the area of a property that may be irrigated or used for winter grazing of cattle.

In addition, permitted farming activities will be required to prepare a Management Plan and register with their farming activity on the Farm Portal. Where these requirements are not met, a resource consent will be required, and farming activities will be restricted to nitrogen loss limits that represent Good Management Practice.

Farming activities that require a resource consent will need to include with their application for resource consent a Farm Environment Plan that describes the practices to be implemented on farm, and include a report from the Farm Portal, a web-based tool that estimates the nitrogen loss rate for a farming activity if operated at Good Management Practice.

State of swimming in Canterbury

Overall grading of primary contact recreation for the Canterbury region shows 86 per cent of rivers and 81 per cent of lakes are considered swimmable.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Canterbury is represented below.

Figure 30: Percentage of Canterbury lakes currently in each primary contact recreation category

Rivers

The modelling shows an increase in the overall swimmability of rivers of 5.0 per cent, to 91.2 per cent of rivers being swimmable.

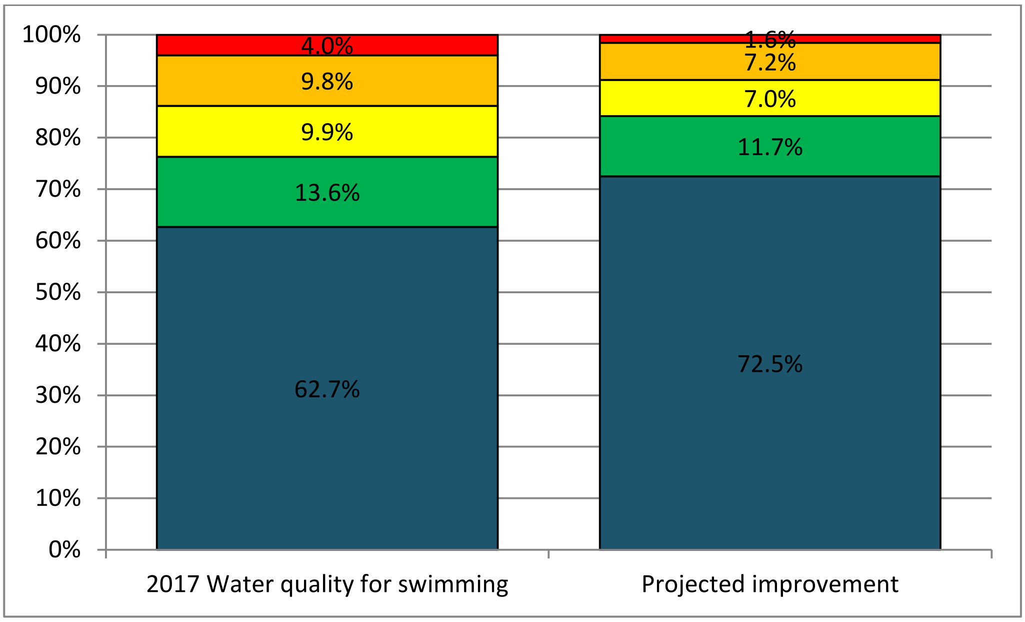

Figure 31: Projected improvement in water quality for swimming for Canterbury's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Canterbury region is $32.62 m. The rural costs of committed work are spread across the dairy (8%), dairy grazing (5%), sheep and beef (62%), deer (6%), and lifestyle (19%) sectors.

Region-specific modelling considerations

The modelling approach taken for planning provisions in Canterbury is to extend the stock exclusion provisions to all streams in the relevant catchments.

We have no data on the proportion of fencing set back by greater than 3 metres.

Otago

Overview of swimmability now

Main activities

Otago covers around 32,000 square kilometres from the south-eastern coastland to the iconic dry central areas, and includes alpine landscapes and large lakes. The great majority of the land is used for pastoral farming. Fresh water is a feature of western Otago, where its many lakes are valued for their recreational uses, including fishing.

Water quality and ecosystem health are high in many parts of Otago, such as the upper Clutha and Taieri river catchments and Lake Wakatipu, Lake Wānaka and Lake Hāwea.[177] However, stormwater contamination in urban areas and intensive farming are putting pressure on water quality and aquatic ecosystems, particularly in the lower river reaches. Lower reaches of rivers towards the coast tend to have higher *E. coli* levels, with many sites exceeding the national bottom line for *E. coli* in the National Policy Statement for Freshwater Management (NPS-FM).[178] Lake Waihola and Tomahawk Lagoon have sporadic cyanobacteria blooms.[179]

The main point-source discharges in the region are wastewater treatment plants and the Mt Cooee Landfill.[180]

Planned work

Point sources

A number of upgrades are planned for wastewater treatment plants. These include:[181]

- emergency overflow and high-flow management
- overflow mitigation
- nutrient removal
- sludge processing upgrade
- treatment and disposal improvements
- storage
- electrical and instrumentation renewals, mechanical plant renewals

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177 Otago Regional Council. 2016. *Water Quality and Ecosystem Health in Otago*. Retrieved from www.orc.govt.nz/Documents/Publications/Research%20And%20Technical/surface-water-quality/2016/2016%20SOE%20report%20card.pdf (13 July 2017).

178 Implementation Review; www.lawa.org.nz/explore-data/otago-region/

179 Survey response

180 Survey response

181 Survey response

- extensions
- new wastewater schemes
- capacity upgrades
- new pump stations.

Planned work at Mt Cooee Landfill includes pipeline remediation.[182]

Urban

Work planned for urban areas includes:[183]

- road drainage renewals
- stormwater renewals, extensions and upgrades
- trade waste bylaws
- waste minimisation education and initiatives
- household hazardous waste amnesty
- management of all waste at transfer stations
- closed landfill maintenance monitoring.

Rural

Otago Regional Council has set targets for *E. coli* for the region in their Regional Plan: Water under Schedule 15. Comparison of Schedule 15 limits of *E. coli* data collected throughout the region from the State of Environment monitoring network to the 4 separate statistical tests within the NPSFM has shown:

- That the *E. coli* limits set in Schedule 15 for Receiving Water Group 3 (Upper Clutha upstream of the Southern Great Lakes) provides compliance against the four separate statistical tests in the NPSFM and as a minimum, will provide a blue (A grade) or green (B grade) swimmability category. The minimum requirement is an orange or C grade.
- With the exception of some catchments in the Pomahaka catchment, the *E. coli* limits set in Schedule 15 for Receiving Water Group 1 and 2 (that covers the remainder of the Otago region), will provide good compliance against the four separate statistical tests in the NPSFM, and as a minimum, will provide a blue (A grade), green (B grade) or in some cases an orange (C grade) category. The Orange, C grade category being the minimum requirement.
- In the case of the Pomahaka catchment, monitoring sites in some catchments return high 95th percentiles at all flows, even though they may be compliant with the Schedule 15 limit. This is believed to be due to effluent storage issues and a prevalence of mole and tile drains through areas of the catchment resulting in very high *E. coli* peaks under high flow

[182] Survey response

[183] Survey response

conditions. ORC are working actively throughout the Pomahaka catchment with groups such as the Pomahaka Watercare Trust, the Landcare Trust and the Clutha Development Trust to address water quality issues. A large part of this effort is focused on improving bacterial water quality.

State of swimming in Otago

Overall swimmability for the Otago region is 79 per cent of rivers and 70 per cent of lakes.

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Otago is represented below.

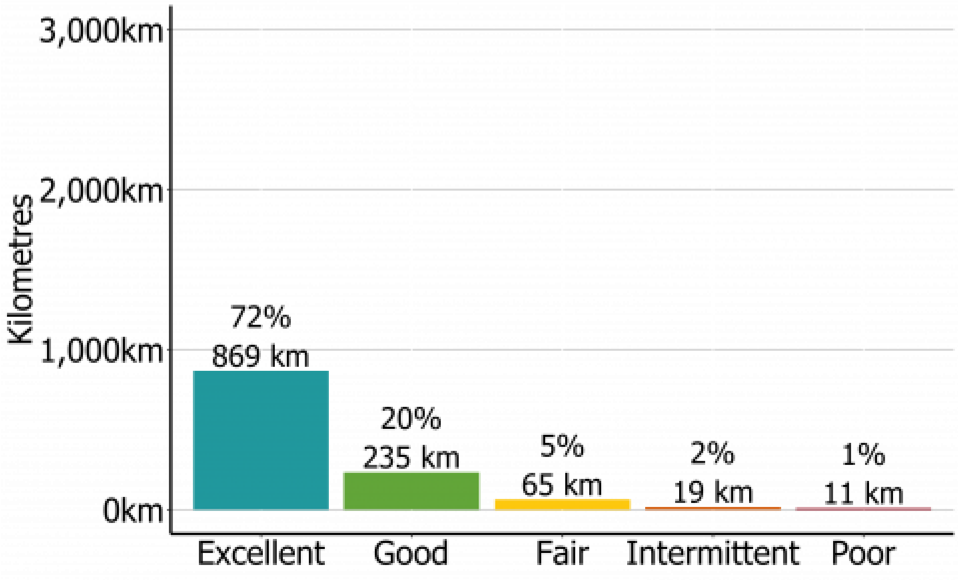

Figure 32: Percentage of Otago lakes currently in each swimming category

Rivers

The modelling shows an increase in the overall swimmability of rivers of 3.2 per cent, to 81.5 per cent of rivers being swimmable.

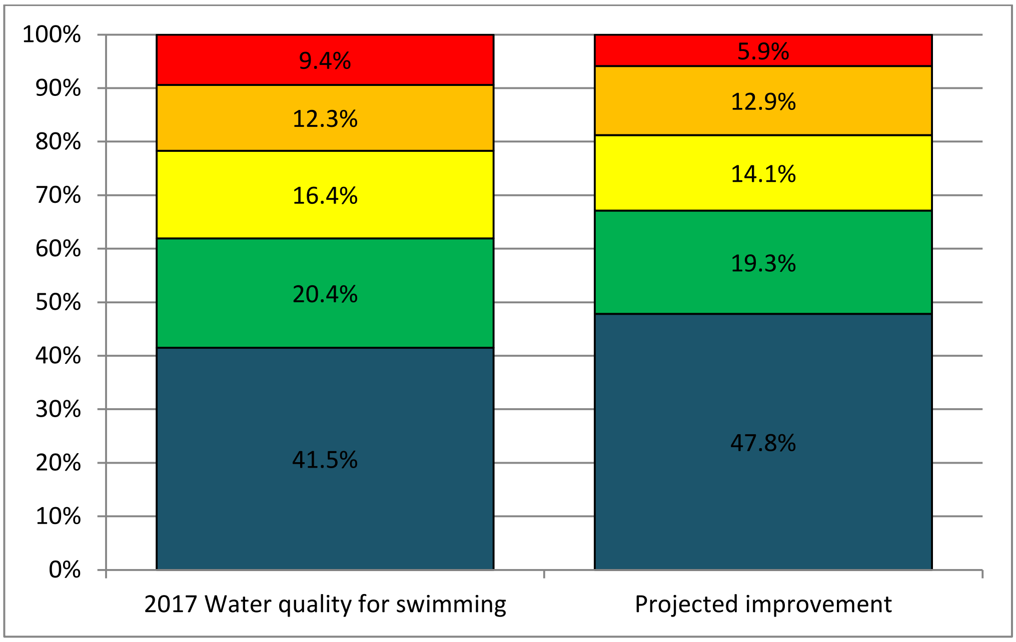

Figure 33: Projected improvement in water quality for swimming of Otago's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Otago region is $13.03 m. The rural costs of committed work are spread across the dairy (7%), dairy grazing (5%), sheep and beef (71%), deer (2%), and lifestyle (15%) sectors.

Region-specific modelling considerations

Nothing specific

We have no data on the proportion of fencing set back by greater than 3 metres.

Southland

Overview of swimmability now

Main activities

The Southland region covers an area of approximately 2.3 million hectares, with just over half that area in conservation estate (including Fiordland and the Catlins). The western portion is largely indigenous forest and the east is alpine areas and rolling farmland. There are five main catchments, which all drain into the lowland, highly modified southern part of Southland. Primary production has long been a major contributor to the region's economy, and pasture accounts for 85 per cent of the non-conservation land.[184] Sheep and beef farming remain the dominant form of farming, but the introduction of irrigation and high milk prices have seen a rapid change in land use to dairying and dairy support over the past 25 years.

Water quality and ecosystem health in most of Fiordland and Stewart Island/Rakiura are exceptionally high.[185] Although there is localised pressure from tourism, the high volume of water flowing through the system and minimal human development minimises the overall impact. Water quality is also generally high in the upper reaches of catchments across the region. Overall, most monitored sites are within the A band for most attributes listed in Appendix 2 of the National Policy Statement for Freshwater Management (NPS-FM).[186] All monitored lakes and 80 per cent of monitored rivers are in the A or B bands for *E. coli*, and considered generally safe for swimming or other primary contact recreation.[187]

In some parts of the region, however, water quality and ecosystem health are under pressure, primarily due to diffuse discharges from intensive agricultural run-off and ageing urban stormwater and sewage systems. As a result, water quality and ecosystem health generally decrease as water flows from the northern and western hills to the eastern and southern lowlands, particularly in the lower Ōreti and Mataura rivers. *E. coli* levels measured at 10 river sites do not meet the minimum acceptable state for primary contact recreation; six of these are below the national bottom line set in Appendix 2 of the NPS-FM, and do not meet the minimum acceptable state for secondary contact recreation.[188]

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184 www.lawa.org.nz/explore-data/southland-region/

185 Environment Southland. 2015. *Water and Land 2020 and Beyond: Water Quality in Southland 2014*. Retrieved from www.es.govt.nz/Document Library/Factsheets/Other factsheets/Water Quality in Southland web.pdf (14 June 2017).

186 Environment Southland. 2017. *Water Quality in Southland: Current State and Trends – Technical Report*. Publication No 2017-04. Dunedin: Environment Southland. Retrieved from www.es.govt.nz/Document Library/Consultations/2016/Proposed Southland Water and Land Plan/Supporting Documents/7 - Water Quality in Southland - Current State and Trends - April 2017.pdf (14 June 2017).

187 Implementation Review

188 Environment Southland. 2017. *Water Quality in Southland: Current State and Trends – Technical Report*. Publication No 2017-04. Dunedin: Environment Southland. Retrieved from www.es.govt.nz/Document Library/Consultations/2016/Proposed Southland Water and Land Plan/Supporting Documents/7 - Water Quality in Southland - Current State and Trends - April 2017.pdf (14 June 2017).

The main point-source discharges in the region are from industry, including meat- and milk-processing operations, sewage and stormwater systems.[189]

Main sources of *E. coli*

As a case study, sampling in the Aparima catchment detected ruminant faecal pollution in most samplings, generally dominated by sheep signature though cow markers were also detected. Wildfowl markers were consistently present, with intermittent detection of human indicative markers. However, occurrence varies with time and space.[190]

In the Mataura catchment ruminant faecal pollution was also present in most samplings, mostly dominated by sheep signature but cow markers were often detected, with possible deer sources at times. Wildfowl markers were consistently present, with intermittent detection of human indicative markers. Occurrence varies with time and space.[191]

Ruminants are the dominant source in the upper Otepuni catchment above the Otepuni Dam. Human source *E. coli* was the dominant source in the lower Otepuni catchment below the dam, with no human contamination present above the dam. The catchment below Otepuni is predominantly urban.[192]

Planned work

Point source and urban

Upgrades are planned to meat-processing operations as part of a new consent to reduce the discharge contaminants including *E. coli* over time. Wastewater for the Te Anau area is currently authorised to be discharged to the Upukerora River, but work is under way to look at alternatives as part of the consent process.

Investigations will be undertaken to remove cross-contamination of stormwater in Gore and Invercargill, and very old stormwater and sewer pipes in Invercargill will be replaced.[193]

An urban ‘Three Waters’ work programme has started with Environment Southland, Gore District Council, Southland District Council, and Invercargill City Council, to coordinate, programme and improve the maintenance and upgrading of all wastewater, stormwater and potable water supplies. This work programme seeks to improve consent compliance, streamline the re-consenting process, and create a forum to explore how the urban environment can comply with its NPS-FM obligations.[194]

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[189] Survey response

[190] *Sources of Microbial Pollution in the Aparima Freshwater Management Unit*. 2017. Prepared by ESR for Environment Southland.

[191] *Sources of Microbial Pollution in the Matuara Freshwater Management Unit*. 2017. Prepared by ESR for Environment Southland.

[192] Otepuni Faecal Source Investigation 2012

[193] Survey response

[194] Implementation Review

Rural

Under the Proposed Southland Water and Land Plan as notified, all farmers would need to complete a farm environmental management plan and implement good management practices. Once those are completed, however, most would not need a resource consent to farm. Further dairy conversion and intensification would be strongly discouraged and be a non-complying activity in some physiographic zones.[195]

The Proposed Southland Water and Land Plan as notified included the following provisions:

- All stock except sheep and deer must be excluded from waterbodies (including artificial water courses) by 1 May 2018. Deer must be excluded by 1 May 2020. No exclusion for sheep, or for any stock on slopes greater than 16 degrees in the bedrock/hill country physiographic zone.[196]
- Intensive winter grazing provisions: all stock types covered by these rules, all stock excluded from waterways when on forage crops from May to September, buffer widths determined by slope immediately adjacent to waterways, consent requirement considers a number of criteria including area grazed and physiographic zone.[197]
- Cultivation on sloping ground rule: all stock types, cultivation has specific definition, buffers and good management practices required, otherwise consent needed.[198]
- Wetlands: rule relating to modification of any wetlands, grazing not allowed without consent, intent is to maintain integrity of wetlands.[199]
- Farming rules: a suite of rules to manage existing and new farming practices, primarily via a Farm Environment Plan (details specified in Appendix N of plan, but includes riparian management plan and wintering plan and nutrient budget. Specific criteria outlined for who requires a farm plan (most farms), and by when.[200]
- Installed subsurface drains (nova flow, tile and mole drains): for existing drains and associated discharge, must not cause significant erosion/deposition/flooding. No visible different in colour/clarity 20 metres downstream, or make water unsuitable for stock to drink (etc).[201]

At the time of writing this report, the Proposed Southland Water and Land Plan was progressing through the hearing and deliberations process. The Council has now made its final decision on the Plan and a revised version will be released on 4 April 2018.

State of swimming in Southland

Overall swimmability for the Southland region is 62 per cent of rivers and 98 per cent of lakes.

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[195] Implementation Review

[196] Rule 70 Proposed Southland Water and Land Plan

[197] Rule 23 Proposed Southland Water and Land Plan

[198] Rule 25 Proposed Southland Water and Land Plan

[199] Rule 74 Proposed Southland Water and Land Plan

[200] Rules 20, 21, 22 Proposed Southland Water and Land Plan

[201] Rule 13 Proposed Southland Water and Land Plan

Lakes

This work has not modelled the projected improvement in water quality for swimming in lakes, but the current state of water quality for lakes in Southland is represented below.

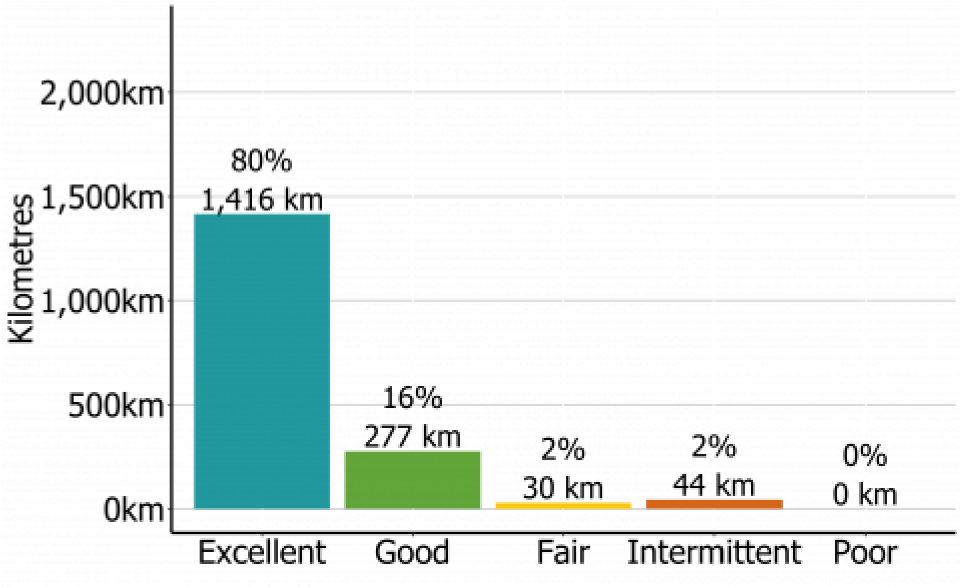

Figure 34: Percentage of Southland lakes currently in each swimming category

Rivers

The modelling shows an increase in the overall swimmability of rivers of 3.9 per cent, to 65.7 per cent of rivers being swimmable.

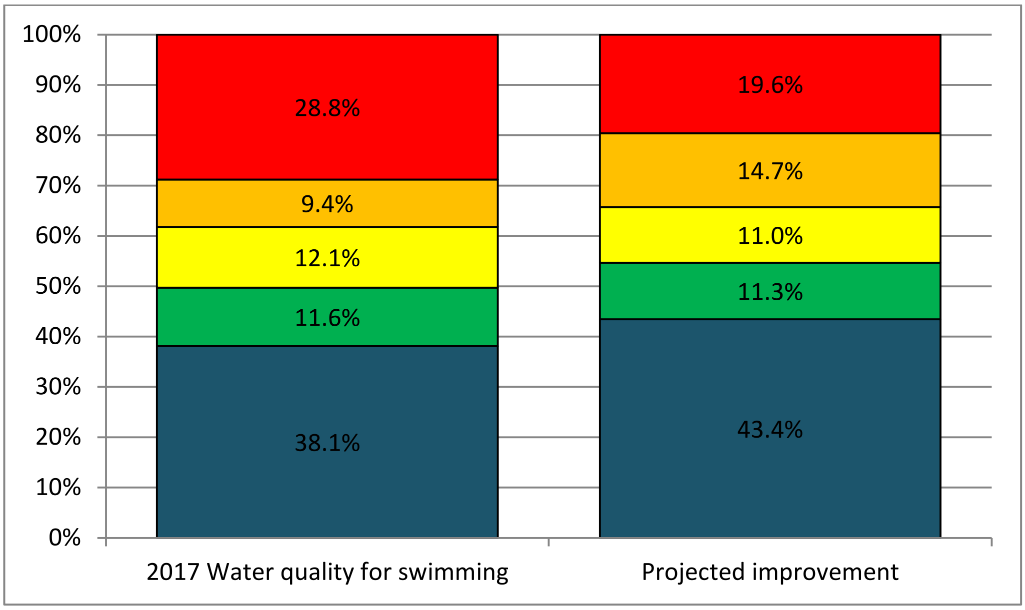

Figure 35: Projected improvement in water quality for swimming of Southland's rivers

See Figure 2, page 11, for a key to the categories used to describe state of a river.

The total annual cost of committed work in the rural area of the Southland region is $10.16 m. The rural costs of committed work are spread across the dairy (16%), dairy grazing (8%), sheep and beef (55%), deer (6%), and lifestyle (15%) sectors.

Region-specific modelling considerations

Nothing specific.

We have no data on the proportion of fencing set back by greater than 3 metres.

Appendix A: Approach to scientific modelling

Definition of national swimming maps

The water quality for swimming maps for *E. coli* in rivers are based on the regression modelling approach outlined in Snelder et al (2016).[202] A separate model was constructed for each of the four statistics outlined in the National Policy Statement for Freshwater Management 2014 updated August 2017 (NPS-FM) *E. coli* attribute table human health:

- percentage of exceedances over 540 *E. coli*/100ml
- percentage of exceedances over 260 *E. coli*/100ml
- median *E. coli*/100ml
- 95th Percentile *E. coli*/100ml.

The models were used to predict the values of each statistic for each segment of a digital representation of the national river network.[203] These predictions are the basis for the river water quality for swimming maps. However, the 95th percentile model was excluded from the swimming maps because subsequent analysis showed that these predictions were unreliable. The uncertainty of the 95th percentile predictions is associated with the imprecision of values of the 95th percentile calculated from monitoring site data.[204] This imprecision cannot be reduced because it is inherent to the available data and varies between sites in association with the level of variability in the individual *E. coli* measurements. The grades shown on the swimming maps were derived by applying the criteria (tests) defined by the NPS-FM *E. coli* attribute table to the predicted values of the three retained statistics.

The final step adjusted the mapped grades to account for areas where the predicted *E. coli* statistics were not providing accurate swimming grades, and to ensure that grades at network segments that represent monitoring sites were brought into line with the 95th percentile values calculated for those sites.

Adjustments were made based on:

- expert opinion from freshwater scientists
- fact-checking with regional councils
- actual data at a monitoring site.

River network segments were adjusted to be consistent with all four *E. coli* statistics calculated from monitoring site data. Changes were made at and upstream of the monitoring site if a category was incorrectly assigned (that is, a grade had been assigned based on the three retained predicted statistics compared to the grade implied by the calculated values of the four statistics for the monitoring site). The calculated value of the 95th percentile was included

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[202] www.mfe.govt.nz/publications/fresh-water/strategic-assessment-of-new-zealand%E2%80%99s-freshwaters-recreational-use-human

[203] River Environment Classification version 1

[204] https://data.mfe.govt.nz/document/12871-stats-nz-2017-technical-note-on-initial-assessment-of-modelled-e-coli-data/

in the grade assignment for segments representing monitoring sites, provided the site had five years of data. The maps were adjusted to match the monitoring site category.

The values for network segments adjacent to monitoring sites. If one segment was surrounded by segments with higher or lower category, the reach was changed to the predominant category to account for model error (that is, the reach was only just over or under a category threshold).

It was necessary to adjust the modelled data in places before making the information public, because the statistics calculated for a site from the monitoring data are the best measure of the swimming grade at that site and are a more accurate assessment than the model predictions. Since the map is a public health indicator, it is important that they communicate the most reliable information. The modelled data provides the best estimate of the broad scale pattern of water quality for swimming. However, monitoring site data should always be relied on as a first preference for understanding local-scale water quality.

Modelling effect of mitigation on *E. coli* statistics

Modelling the effect of mitigation on *E. coli* statistics undertaken using a national standalone version of the *E. coli* sub-model from the Catchment Land Use for Environmental Sustainability model (CLUES; Elliott et al, 2016). CLUES comprises several models that together predict the mean annual loads of total nitrogen, total phosphorus, sediments and *E. coli* throughout New Zealand at a spatial resolution of 0.5 square kilometres. The details of CLUES differ according to the water quality variable being considered. For *E. coli*, the key underlying model is SPARROW (SPAtially-Referenced Regression On Watershed attributes) (Elliott et al, 2005, 2016). It was the SPARROW model that was used to model the effect of mitigation on *E. coli* statistics in this study, and we refer to the model as SPARROW for the remainder of this section.

SPARROW is an annual steady state model that predicts annual *E. coli* loads for every reach in the River Environments Classification version network. While dynamic models are able to predict a time series of *E. coli* concentrations by representing the temporal dynamics of transport and attenuation in more detail (for example, Collins and Rutherford, 2004; Muirhead et al, 2011; Wilkinson et al, 2011), this type of modelling is not feasible for the present study within the given timeframe, the available national datasets, and the models readily available.[205]

SPARROW was calibrated to loads of *E. coli* (number of organisms per year) observed at state-of-environment (SoE) water quality monitoring sites distributed throughout New Zealand. The SPARROW model calibrates several parameters that represent key processes involved in the production, transport and attenuation of *E. coli* (see section on Error! Reference source not found.). A key calibration parameter represents the diffuse source yields of *E. coli* generated by different types of land use per year (see section on Error! Reference source not found.). The contributions from individual land areas are accumulated downstream to calculate the total *E. coli* at any point in the catchment drainage system. In addition to representing the

[205] A more detailed explanation is that firstly, most of the available data for model calibration are monthly observations at state of environment monitoring sites. These data are sufficient to estimate annual loads of *E. coli* but are insufficiently frequent to calibrate dynamic models. Second, dynamic models require data describing the input of *E. coli* at a frequency that is consistent with the temporal dynamics represented by the model. However, the temporal dynamics of *E. coli* production from land areas has not been described with sufficient detail or accuracy in New Zealand. Third, such calculations would entail considerable setup effort and computational cost to run nationally. Therefore, *E. coli* production at the land unit level has to be inferred from the annual loads at monitoring sites, and this is carried out by the SPARROW calibration process.

accumulation and transport of *E. coli* loads, a SPARROW parameter represents attenuation (by die off and sequestration) in the drainage network.

For the current project, SPARROW was modified to represent loading occurring in base-flow conditions only, calibrating the model parameters to loads determined from the measured median concentration times the measured median flow. This was to avoid the influence of storm flows, which can carry a large proportion of *E. coli* loads. The calibration used the same data and calibration method adopted for the Ministry for Primary Industries (MPI) stock exclusion study (Semadeni-Davies and Elliot, 2016); however, the earlier work used a different set of calibrated parameters and yields. There were 204 SoE monitoring sites located throughout the country with suitable data available for baseflow load calculation, but the number of sites regionally is variable and some regions are better represented in the national calibration dataset than others.

As noted above, the primary contact ('swimming') grades are based on four statistics: the annual median and 95th percentile concentrations (Q_{50}, Q_{95}), and the proportion of time concentration thresholds of 260 and 540 *E. coli* 100mL^{-1} are exceeded (G_{260}, G_{540}). However, the SPARROW model predicts annual loads of *E. coli*. Therefore, the changes in the SPARROW annual load predictions were used to adjust the four statistics their current, or baseline, values in the following manner. The values of the four statistics representing the current baseline conditions for sites that have monitoring data are derived from available monitoring site concentration data. For a scenario, it is assumed the values of Q_{50} and Q_{95} at the monitoring sites change by the same factor as the change in the current baseline and scenario loads. Scenario values of G_{260} and G_{540} are calculated by assuming the full range of concentrations at a site change by the same factor as the change in the current baseline and scenario loads. The values of G_{260} and G_{540} for the new scenario are recalculated from the modified concentrations.

For locations that do not have monitoring data, the current baseline values of all four statistics are predicted using regression models fitted to monitoring site data (for example, Larned et al (2016)). The scenario values of Q_{50} and Q_{95} at these locations are calculated in the same manner as described above for monitoring sites (Semadeni-Davies and Elliot, 2016). The calculation of scenario values of G_{260} and G_{540} for locations without data is more complicated. This calculation uses predicted values of an additional statistic, the standard deviation of the concentrations, so that the full range of concentrations (that is, the distribution) can be modelled for every location (see Elliot and Whitehead (2016) for details).

Supplementary material related to *E. coli* modelling

A technical report of supplementary material to support setting draft regional targets for swimmable rivers is attached as Appendix E.

Appendix B: Economic assessment of committed work to reduce *E. coli* loads to New Zealand streams and rivers

Graeme Doole, Waikato University (19/10/2017, revised 20/03/2018)

The total cost of committed work, including existing fencing, is represented (Doole et al, 2016). It is customary to assess only the cost of marginal changes in the national stock of stream fencing. However, the costing of both existing and new fences is estimated here. This approach is motivated by the fact that many stream fences exist currently, but will require replacing over time given that they vary in age and condition. Moreover, this scenario is intended to represent a baseline to which future scenarios involving alternative ways to reach proposed swimmability targets will be compared. This assessment focuses on estimating an initial level of total cost, to which marginal changes will be estimated once further work is performed.

An implication of this assumption is that the assessment of the cost of stream fencing presented below considers that existing fences have been financed in a way that new fences are also assumed to be financed. This introduces consistency, while also recognising that existing fences are durable but will not exist in perpetuity. Essentially, the analysis represents that existing fences are continually being replaced, with the cost being the same as if a new fence is being constructed. An alternative approach would be to consider a depreciation cost for different age classes of fence. This method is not used due to data limitations and the fact that the two approaches will yield similar results in most relevant cases.

Overall, a conservative approach is taken. This is justified because there is broad data uncertainty, especially given that modelling is undertaken at a national scale (Woodward and Shaw, 2008). The assessment uses a variety of methods to ascertain the cost of each committed action.

Five land uses are represented. These are dairy, dairy grazing, sheep and beef, deer, and other. For simplicity, the 'other' class is represented as 'lifestyle blocks' throughout, given that this land use is likely to dominate this miscellaneous category. It also improves the integration of the economic assessment with the biophysical analysis performed by NIWA.

The economic assessment of stream fencing loosely follows the work conducted by the Ministry of Primary Industries (MPI) for the stock exclusion study (Grinter and White, 2016; Agribusiness Group, 2017; Semadini-Davies and Elliott, 2017). Various assumptions are central to this application; these are described below.

All capital costs are converted into an annual amount using a discount rate of 6 per cent (New Zealand Treasury, 2016) and a 25-year payback period (Grinter and White, 2016). Conceptually, this is comparable to converting large capital costs into annual payback equivalents, akin to determining the annual payments required to service a loan (Damodaran, 2014). This method is used to reduce bias associated with representing large costs in individual years.

New fencing involves the exclusion of stock from both sides of the waterway (Semadini-Davies and Elliott, 2017).

Stream length present in each land use is weighted according to the proportion of the catchment that consists of that land use (Semadini-Davies and Elliott, 2017). This assumption is driven by a lack of alternative information.

Stream fencing is assumed to consist of two-wire electric fences, constructed to exclude cattle only (Muirhead, 2017). There appears to be no policies currently that seek to exclude sheep as well (R Muirhead, AgResearch, pers. comm., 16 October 2017). Two-wire electric fences are represented on flat, rolling, and steep land. Grinter and White (2016, p 20) assume that eight-wire conventional fencing is chiefly utilised on steep land for beef and dairy cattle. Two-wire electric fences are represented here given their cost-effectiveness, their reduced cost if damaged through erosion and/or flood, and no need to exclude sheep.

The cost of fencing varies by region, as set out by Agribusiness Group (2016, p 18). Maintenance costs are 1 per cent of total material costs in flat and rolling land, and 2 per cent in steep land (Grinter and White, 2016). Material costs are presented by Agribusiness Group (2016, p 18).

A riparian buffer of 3 metres width on each side of the waterway is assumed, where riparian buffers are part of committed work (Muirhead, 2017). This is assumed to consist of pasture and one row of native plants (flax or sedges) with 1.5 metre spacing; the cost is $3.67/m of waterway (Agribusiness Group, 2017).

The opportunity cost of land within each buffer is considered. Earnings before Interest, Tax, Depreciation, and Amortisation (EBITDA) is determined for each land use. EBITDA is determined for New Zealand dairy farms using data from DairyNZ (2017). Values for 2011/12 to 2015/16 are adjusted for inflation using PPI data from Statistics NZ (2017). The mean EBITDA is $2,274/ha. There is a pertinent lack of information pertaining to the national profitability of dairy grazing. Farm accounts presented for the Waikato by Olubode-Awasola (2015) are used to determine EBITDA for dairy grazing activity. This value is adjusted for inflation using PPI data from Statistics NZ. The EBITDA value is $385/ha.

EBITDA is determined for New Zealand sheep and beef farms using data from Beef and Lamb New Zealand (2017). Values for 2011/12 to 2015/16 are adjusted for inflation using PPI data from Statistics NZ (2017). The mean EBITDA is $305/ha.

A lack of historical information related to profit of deer land means that an average of several point estimates of deer farm profit in the North Island and South Island in 2014 are utilised. EBITDA is determined from Thompson (2014), and then adjusted for inflation using PPI figures from Statistics NZ (2017). The mean EBITDA is $614/ha.

No opportunity cost of lost land is represented for lifestyle blocks, given their diversity and the central importance of off-farm income to most of these units (Andrew and Dymond, 2012).

Excluding stock from streams can motivate a need for providing water troughs and reticulating water to these structures. The cost of water reticulation varies greatly across New Zealand due to high diversity in landscape, land use, and regional costs (Journeaux and van Reenan, 2016). The weighted average of the capital and operating cost generated to establish and maintain water reticulation on eleven representative case-study farms in Journeaux and van Reenan (2016) is used. This is converted to a per-metre cost in a consistent way to that used in the stock-exclusion report of Grinter and White (2016). It is done so through assuming that each 50-hectare block extends 350 metres on either side of the waterway, and 71.42 metres along it. The cost of additional water reticulation with more stream fencing is not represented on dairy farms because of the presence of intensive rotational grazing on these farms, which requires a high number of troughs under standard management (Doole and Romera, 2013).

The total length of stream under each classification in the committed work scenario is presented in table B.1. The 'no fencing' category is the length of stream that will not be fenced under the committed-work scenario. The 'fencing' category is the length of stream that will be fenced under this scenario, consisting of both existing fences and new fences. The 'fencing and riparian buffer' category is the length of stream that is expected to be both fenced and have riparian buffers, under the committed-work scenario. Hence, the 'total' length of fence represents the length of streams across all land uses nationally. (The motivation to include current fencing in this assessment is outlined above.) The "fencing" and "fencing and riparian buffer" partitions represent additional activities that are predicted to occur because of committed work. A total stream length of 168,592 kilometres is represented. Sixty per cent of this is present in sheep and beef land, while around 20 per cent of this is present on dairy land. Around 80, 68, 61, 77, and 77 per cent of streams will be fenced under committed work in the dairy, dairy grazing, sheep and beef, deer, and lifestyle sectors, respectively.

Table B.1: Length of stream (km) in each classification under the committed work scenario

Classification	Dairy	Dairy grazing	Sheep and beef	Deer	Lifestyle
No fencing	7,093	1,716	39,822	366	5,649
Fencing	27,540	3,664	61,834	1,228	19,363
Fencing and riparian buffer	112	5	92	2	106
Total	34,745	5,385	101,748	1,596	25,118

The annual cost of stream fencing in each land use is presented in table B.2. These figures include maintenance costs. All fences are 2-wire electric fences (see above). However, the costs vary across each land use according to their placement on different slope classes, the alternative value of each land use that determines opportunity cost, and the needs of each with regards to water reticulation.

Table B.2: Annual cost of stream fencing ($/metre) in each land use

Classification	Dairy	Dairy grazing	Sheep and beef	Deer	Lifestyle
Fencing	0.8	0.93	1.05	3.16	1.04
Water reticulation	-	0.24	0.24	0.24	0.24
Fencing total	0.8	1.17	1.29	3.4	1.28
Riparian vegetation	0.29	0.29	0.29	0.29	0.29
Opportunity cost	0.11	0.02	0.01	0.03	-
Fencing + riparian total	1.2	1.48	1.59	3.72	1.57

Establishment costs are annualised at a rate of 6 per cent over a period of 25 years. The fencing cost is a national average given that it varies by region and slope class (Agribusiness Group, 2016)

Table B.3 presents the annual and total cost of stream fencing in the committed-work scenario. The total cost is computed through summation of annual cash flows over a 25-year payback period, after each cash flow has been discounted using a discount rate of 6%. The annual cost is projected to be $135 million, with 59 per cent of that occurring in the sheep and beef industry, 20 per cent in the dairy industry, and around 15 per cent in the lifestyle sector. Table B.3 is not generated simply through multiplication of the length of stream fencing (Table B.1) and the annual cost of stream fencing (Table B.2). Rather, the annual cost across each land use is computed for each of the individual 576,296 streams considered in the NIWA assessment, with the per-unit cost of fencing varying according to the incidence of riparian margins, land use, level of existing fencing, opportunity cost, slope, and need for water reticulation.

Table B.3: Annual cost of stream fencing ($million) under committed-work scenario

Land use	Annual cost ($ mil.)	Total cost ($ mil.)
Dairy	22.03	298.51
Dairy grazing	4.3	58.27
Sheep and beef	79.76	1,080.78
Deer	4.17	56.5
Lifestyle	24.82	336.32
Total	135.08	1,830.38

Several regions plan to move away from the pond treatment of farm dairy effluent (FDE) to land application in the committed-work scenario. This is planned to occur on 230,167 hectares of land across the Auckland, Manawatū, Taranaki, and Whanganui regions. Using regional average stocking rates from LIC/DairyNZ (2017), this would stand to affect land containing around 641,090 cows or around 12 per cent of the national herd. No cost is represented for this transition from pond treatment to land discharge in the assessment. This is because the total cost of labour and extra infrastructure required for land-based application of FDE is closely equivalent to the money saved through not having to apply additional nutrients through fertiliser application (Doole, 2015).

Some remediation of wastewater systems is planned in several regions. This is focused on reducing leaks and overflows from wastewater systems. Limited information is available with respect to the cost of such remediation. Indeed, little suitable data has been identified in the council responses, published literature, and unpublished literature. A conservative approach is justified given the level of uncertainty that exists with respect to this facet of the data. Accordingly, a replacement cost is determined per square kilometre, using data from Watercare (2016). These assumptions involve 25 kilometres of wastewater pipe per square kilometre of urban land use and a replacement cost of $595,346 per kilometre. The cost of improved wastewater infrastructure is annualised at a discount rate of 6 per cent over a 50-year period. This yields an annual cost of $37,771 per kilometre of pipe or $944,275 per square kilometre. Wastewater systems are improved over 87 square kilometres of urban land in committed work. Thus, the total annual cost of this remediation is computed as $82.15 million.

The annual costs of the committed work therefore consist of $135.08 million to the rural sector and $82.15 million to the urban sector. This yields a total annual cost of $217.23 million.

It is accepted that several key limitations exist with regards to these estimates.

A certain type of stream fencing and riparian buffer has been assumed to be feasible across each sub-catchment, though this is often limited by existing infrastructure and difficult terrain (for example, hard subsoil layers, slope).

A key assumption is that stream density has been assumed to be the same across each land use, with stream length weighted proportionally according to the incidence of land-use coverage across each sub-catchment. This may underestimate the cost on sheep and beef farms given their placement on more highly-dissected landscapes, relative to dairy farms. Conversely, it may also elevate the cost on dairy farms, given their location typically on flatter parts of a catchment.

Poor information exists with relation to the current location and cost of fencing streams on lifestyle blocks.

A standard, stylised form of water reticulation has been assumed to exist across all landscapes. This is based on the best information available, but does not reflect the heterogeneity between land uses and landscapes across New Zealand's rural sector.

The cost of reducing wastewater overflows and leaks is likely overestimated. It is accepted that this estimate is based on poor data, so it would be particularly useful to ask regional council staff how it can be improved.

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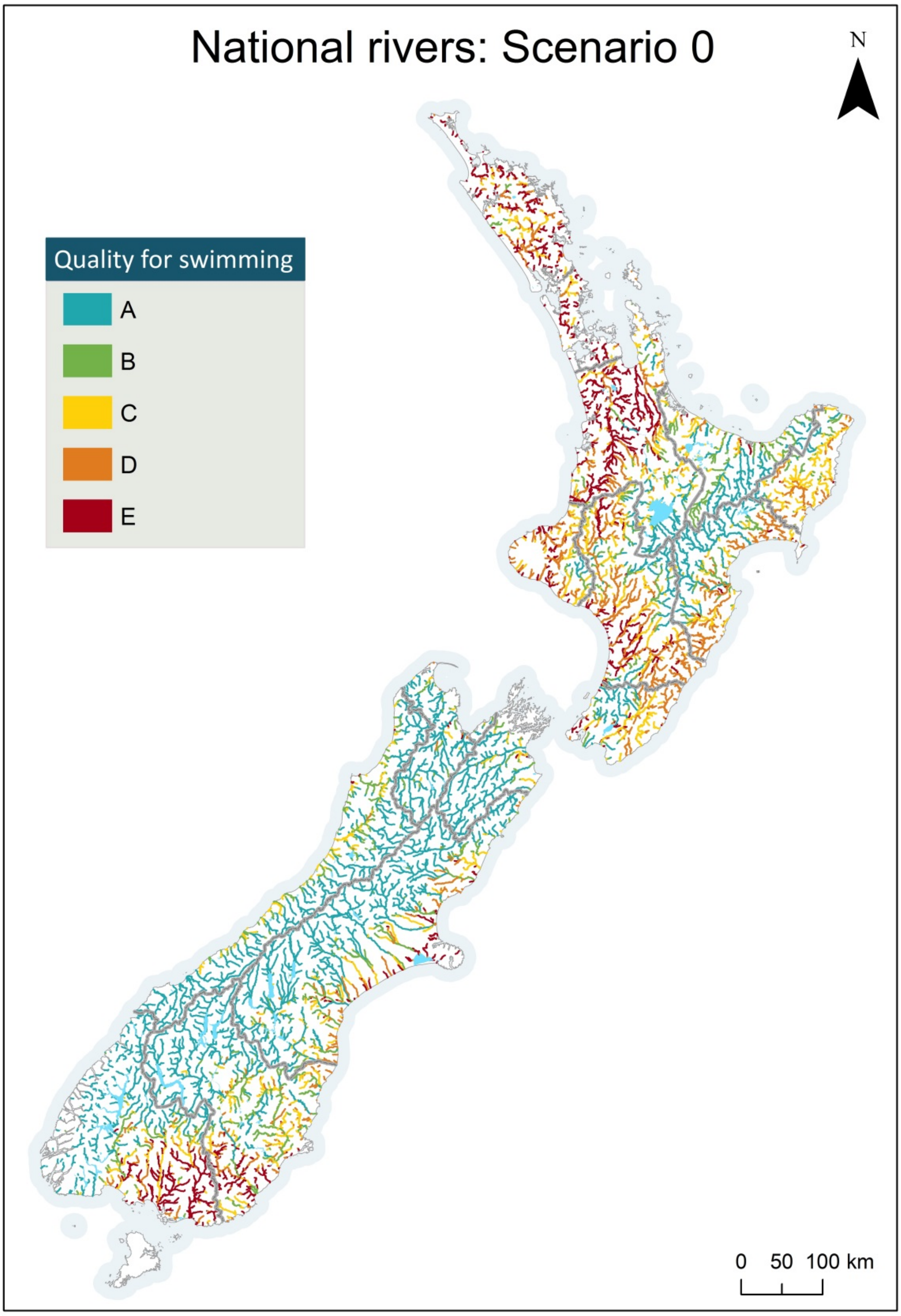
Peer review summary

The economic analysis in Appendix B of the draft report clearly states the sources of the data used and any assumptions made. The peer reviewer of the economics work (Phil Journeaux, March 2018) expressed overall comfort with the analysis. His main comments included the NIWA database/spreadsheet being very large, making it difficult to readily check the base data and calculations. However, the calculations that he did check were correct. He also queried whether there should be more variation in the cost of fencing relative to land use. The reviewer highlighted that the depreciation method could have been used for annualising costs, but felt that the equilibrium method used was equally valid. Appendix B was updated in response to the review.

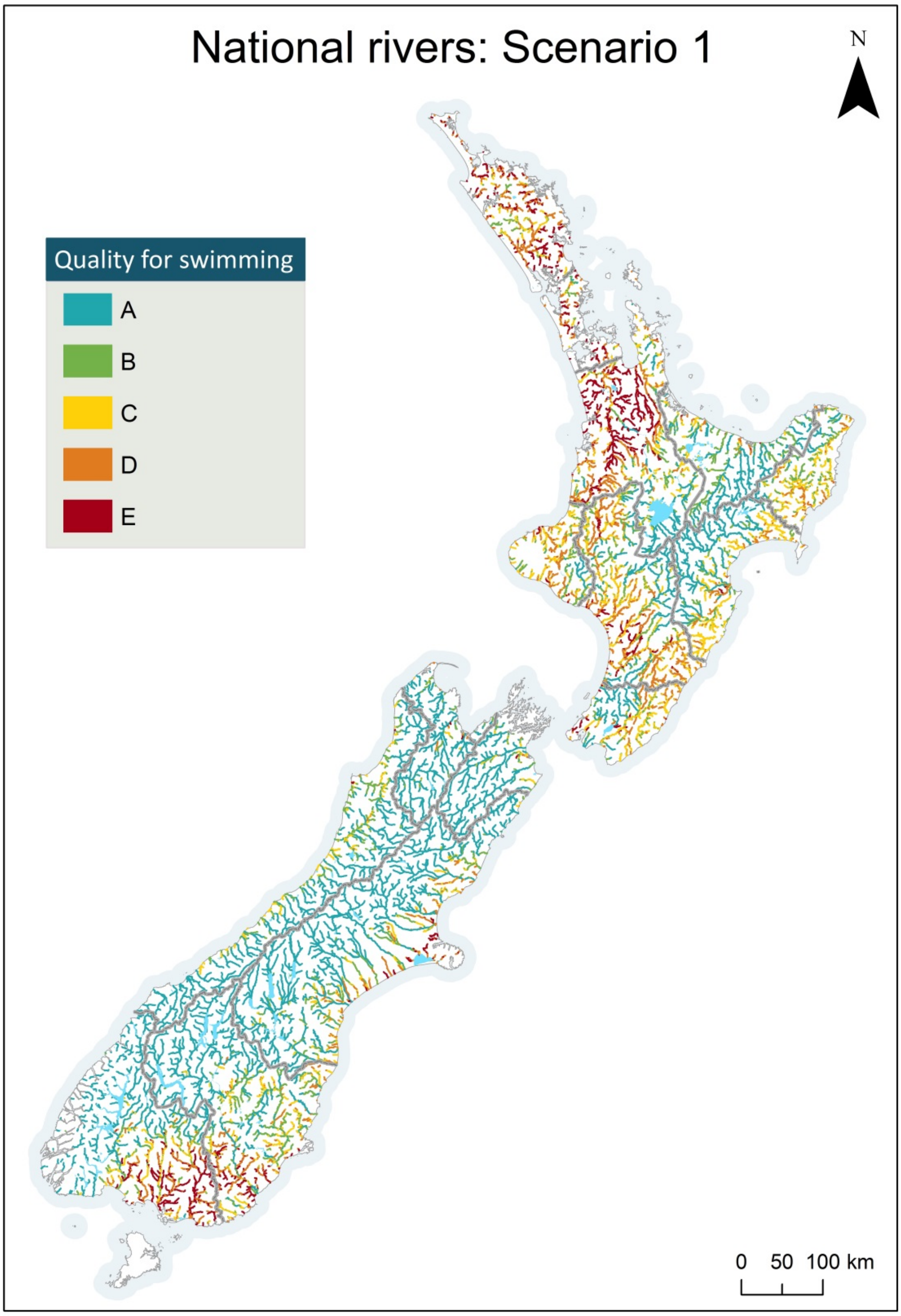
Two regional councils have registered concerns about how the economic analysis portrays costs in their regions. Northland Regional Council referred to a recent Kaipara Harbour economic study which indicated mitigation costs would be more than twice those suggested by the economic analysis in the draft report. Taranaki Regional Council had a number of concerns about the science and economics used in the report. They also felt the analysis resulted in an underestimation of the costs of riparian planting and of transitioning to land irrigation.

Economic analyses are only as accurate as the data used to inform them. Consequently, it is reasonable to assume that testing the results on the ground at a catchment or regional level may provide different results, as indicated by Northland and Taranaki Regional Councils. Undertaking targeted data gathering, while significantly more expensive, could result in a model which more accurately reflects this regional variation.

Appendix C: Map showing current quality for swimming



Appendix D: Map showing projected quality for swimming



Appendix E: National *E. coli* modelling, supplementary material to support setting draft regional targets for swimmable rivers

National *E. coli* modelling

Supplementary material to support setting draft regional targets for swimmable rivers

Prepared for Ministry for the Environment

March 2018

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Quality Assurance Statement		
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Ken Becker Regional Manager, Auckland.	Approved for release by:	K. B

21 March 2018 11.28 AM

Contents

Tables

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Executive summary

This report documents the set up and application of the SPAtially-Referenced Regression on Watershed attributes (SPARROW) model to estimate the capacity of planned national and regional water quality measures to reduce annual loads of *E. coli* in rivers. The modelling was undertaken by NIWA for the Ministry for the Environment (MfE) as part of work underway to improve water quality in terms of effects on human health so that regional councils can set draft targets for swimmable lakes and rivers.

SPARROW is a steady state annual load model that operates at the catchment scale. It determines the loads from diffuse and point sources that are discharged from each river sub-catchment and then routes these loads down the river network accounting for both instream and lake attenuation. SPARROW was calibrated for *E. coli* loads in 2014; here we use a model calibration for baseflow conditions under the assumption that rivers at full flow, which are likely to have the highest *E. coli* concentrations (at least initially), are unsafe for swimming.

SPARROW was run for two scenarios relating to the current or 2017 level of water management (Scenario 0) and a future state after planned national and regional measures for improving water quality have been implemented (Scenario 1).

To be considered suitable for swimming, a river reach must have a stream order of 4 or greater and must have an *E. coli* attribute state of A, B or C (i.e. excellent, good or fair) as defined for "human health for recreation" in the National Policy Statement for Freshwater Management (NPS-FM; MfE, 2014). Since the SPARROW *E. coli* outputs are estimates of mean annual loads (or organism counts), the outputs had to be related to the concentration metrics used to determine the attribute state. To do this, the Scenario 1 model outputs were compared to the Scenario 0 model outputs (equated to the current attribute state data from the MfE swimmability maps dataset) to estimate the degree of change associated with the mitigation measures. The baseline attribute state data set was altered accordingly to give a new future attribute state dataset.

The report is arranged in five sections, these are:

1. Background including the report scope;
2. Description of the model including spatial input data and representation of the attribute states;
3. Scenario development including estimation of current and future levels of mitigation and point sources;
4. Model limitations including sources of model error and uncertainty; and
5. Summary of model outputs.

In addition to these section, there are seven appendices, these are:

A. SPARROW model algorithms;

B. SPARROW calibration

C. Method for adjusting exceedance frequencies;

D. Representation of the effectiveness of *E. coli* mitigations for agricultural runoff;

E. Representation of the effectiveness of *E. coli* mitigations for urban runoff; and

F. A list of point sources of *E. coli* included in the model.

G. Model output tables by region.

1 Background

The Ministry for the Environment (MfE) commissioned NIWA to model the effects of national and regional mitigation measures that are either already in place or have been proposed, to improve water quality in terms of the annual loads and concentrations of *Escherichia coli (E. coli)* in rivers. *E. coli* is used as an indicator of freshwater faecal contamination and is one of the attributes of the "Human health for recreation" water quality value in the National Policy Statement for Freshwater Management (NPS-FM; MfE, 2014). This model will inform policy designed to meet the national targets for swimming in New Zealand's rivers and lakes, which were added to the NPS-FM in August 2017. This report provides a description of the *E. coli* model including its calibration and limitations, as well as overviewing the input data, including point sources and policy information provided by regional councils that are used to derive the current and future scenarios. The model outputs will supplement information provided by MfE to regional councils about improvements to water quality in terms of *E. coli* attribute states that are projected to occur as a result of works committed in each region.

1.1 Report scope

The *E. coli* modelling steps covered in this report are shown in Figure 1-1 along with key data sources. The modelling was undertaken using a customised version of the United States Geological Survey SPARROW model (SPAtially-Referenced Regression On Watershed attributes; Smith *et al.* 1997; Schwarz *et al.* 2006a; Schwarz *et al.* 2006b). The modelling method is overviewed in Section 2 along with model input data. A full description of the model algorithms is given in Appendix A and the calibration is detailed in Appendix B.

Two scenarios have been developed for the modelling relating to the current (Scenario 0) and future (Scenario 1), post policy implementation, states.

To be considered suitable for swimming, a river reach must have a stream order of 4 or greater and must have a "human health for recreation" *E. coli* attribute state of A, B or C (i.e. blue, green or yellow). Since the SPARROW *E. coli* outputs are estimates of mean annual loads (or organism counts), the outputs had to be related to the concentration metrics used to determine the attribute state. To do this, the Scenario 1 model outputs were compared to the Scenario 0 model outputs (equated to the current attribute state data from the MfE swimmability maps dataset) to estimate the degree of change associated with the mitigation measures. The baseline attribute state data set was altered accordingly to give a new future attribute state dataset. The methodology used is overviewed in Section 2.3 and detailed in Appendix C.

Scenario development is discussed in Section 3. The effectiveness of mitigation measures with respect to *E. coli* removal are summarised in Appendix D for agricultural runoff and in Appendix E for urban runoff. Point sources under both scenarios are listed in Appendix F.

Model limitations and sources of error and uncertainty are addressed in Section 4. Finally, the model results are summarised in Section 5 and given in full in Appendix G.

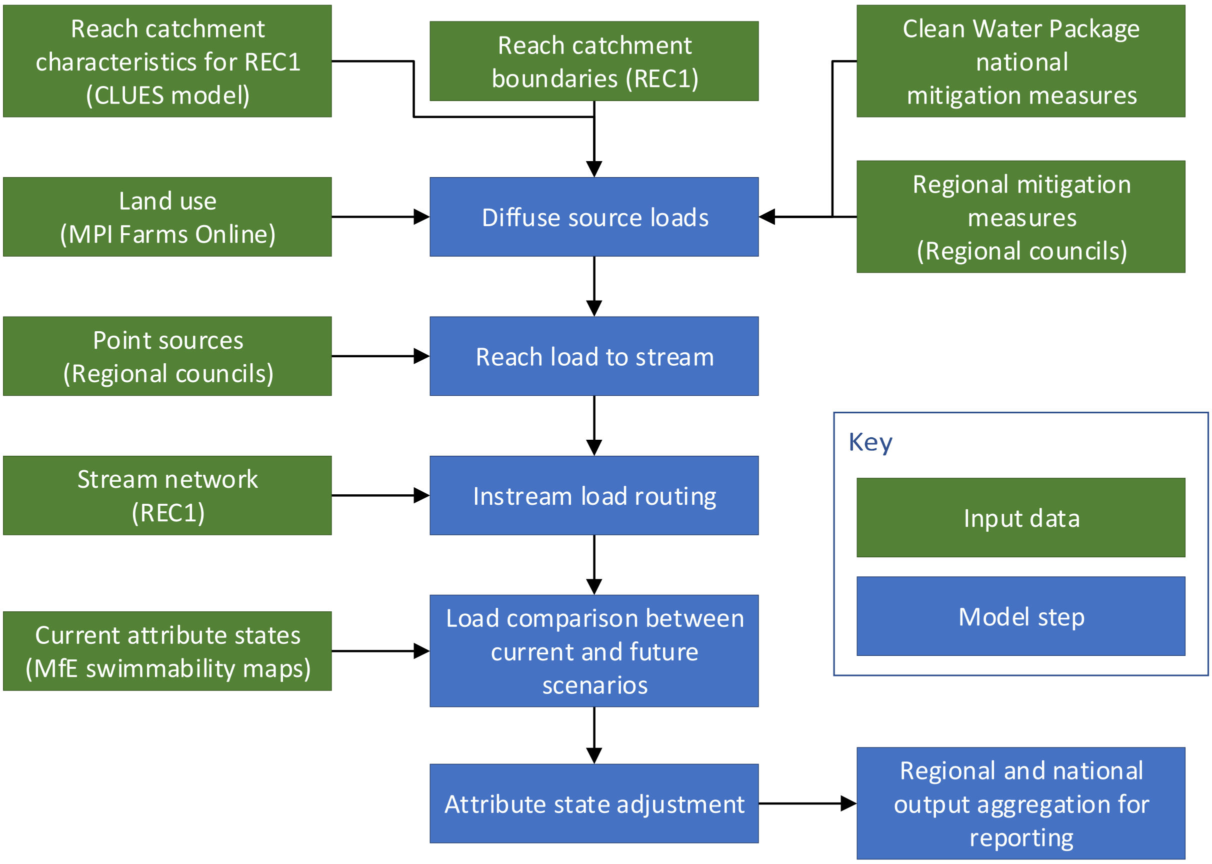

Figure 1-1: Flow chart showing the modelling steps and data sources used to model the effect of mitigation measures on *E. coli* attribute states .

2 SPARROW model description

SPARROW is a catchment-scale, steady state, annual load water quality model with a spatial resolution of around 0.5 km^2. While dynamic models (rather than steady-state) can predict a time series of *E. coli* concentrations by representing the temporal dynamics of transport and attenuation in more detail (for example, Collins and Rutherford, 2004; Muirhead et al, 2011; Wilkinson et al, 2011), this type of modelling is not feasible for the present study within the given timeframe, the available national datasets, and the models readily available.[1]

The SPARROW model was originally developed for the United States and has been modified and calibrated for use in New Zealand (Elliott *et al.* 2005; Elliott *et al.* 2008). In New Zealand, SPARROW is generally run as part of the Catchment Land Use for Environmental Sustainability (CLUES) modelling framework (Elliott *et al.* 2016; Semadeni-Davies *et al.* 2016). The SPARROW *E. coli* modelling method is documented in Elliott *et al.* (2016) and is reproduced here in Appendix A. However, to enable SPARROW to be run nationally rather than regionally, and to adjust the model outputs to represent attribute states rather than annual loads, a customised version of SPARROW was developed as a stand-alone Python script specifically for this project.

SPARROW calculates annual input loads from diffuse and point sources and routes these loads down the drainage network taking into account decay or attenuation within streams and lakes (including hydro-dam reservoirs). For the current project, SPARROW was modified to represent loading occurring during base-flow conditions only on the assumption that people generally swim during these conditions. This was to avoid the influence of storm flows, which can carry a large proportion of *E. coli* loads. The calibration was undertaken as part of CLUES model maintenance in 2014 and used the same data and calibration method adopted for the Ministry for Primary Industries (MPI) stock exclusion study (Grinter and White 2016; Semadeni-Davies and Elliott 2017); however, the earlier work used a different set of calibrated parameters and yields. There were 204 SoE monitoring sites located throughout the country with suitable data available for baseflow load calculation (i.e., with concurrent flow data), but the number of sites regionally is variable, and some regions are better represented in the national calibration dataset than others. Baseflow loads were estimated for the calibration sites as the product of the median annual concentration estimated from the SoE data and the median annual flow rate. The calibration procedure and results are described in Appendix B.

The model set up is similar to that run for the earlier MPI study. However, in addition to a different calibration, in the current model the river network is represented by the River Environments Classification version 1 (REC1) drainage network, rather than version 2, in order to be compatible with maps of the current swimmability of New Zealand rivers and lakes[2] produced for MfE (Snelder *et al.* 2016).

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[1] A more detailed explanation is that firstly, most of the available data for model calibration are monthly observations at state of environment monitoring sites. These data are sufficient to estimate annual loads of *E. coli* but are insufficiently frequent to calibrate dynamic models. Second, dynamic models require data describing the input of *E. coli* at a frequency that is consistent with the temporal dynamics represented by the model. However, the temporal dynamics of *E. coli* production from land areas has not been described with sufficient detail or accuracy in New Zealand. Third, such calculations would entail considerable setup effort and computational cost to run nationally. Therefore, *E. coli* production at the land unit level must be inferred from the annual loads at monitoring sites, and this is carried out by the SPARROW calibration process.

[2] http://www.mfe.govt.nz/fresh-water/state-of-our-fresh-water/water-quality-swimming-maps (date of access, 8 March 2018)

2.1 Representation of the drainage network and catchment characteristics

The REC1 data set represents the national drainage network as a series of nodes or confluences linked by network reaches. The network was generated from a digital terrain model (DEM) with a 30 m resolution. Each reach has a contributing area, referred to as the reach sub-catchment. The median reach length is 530 m, and reach sub-catchments have a median area of 30 ha. There are some 600,000 reaches nationally. While the model was run for all reaches in the REC1, here we only present model outputs for reaches with a Strahler stream order of 4 or greater because the targets for swimmable rivers only apply to rivers of this size.

Catchment characteristics that are required to model *E. coli* using SPARROW are the mean annual rainfall and temperature (from the NIWA virtual climate station network; Tait and Turner 2005), soil drainage class (derived from the Land Resources Information Fundamental Soils Layer)[3] and slope (derived from the same 30 m DEM used for network delineation). These characteristics have been spatially averaged to REC1 sub-catchments and are included as part of the CLUES model dataset.

2.2 Land use data

Land use has been taken from the MPI Farms Online dataset that has been developed for biosecurity purposes and relates to the period 2010–15. This dataset is more representative of current land use and was used in preference to the CLUES default land use, which has a baseline of 2008. The land uses included are:

- dairy (platform, runoff and third-party grazing)
- sheep and beef (lowland intensive, hill and high country)
- deer
- other stock
- horticulture and crops
- urban areas
- forest and scrub
- tussock
- other, non-specified, land uses.

A description of the dataset and how it was adapted for modelling is given in Semadeni-Davies and Elliot (2016). The only difference in the land use used for the MPI modelling is that the data were provided by MPI for this study aggregated to REC 1 reach sub-catchments rather than for REC2.

2.3 Representing attribute states

There are five *E. coli* attribute states (i.e. A - blue, B - green, C -yellow, D - orange and E - red) under the NPS-FM human health for recreation value, each of which has four criteria, or 'statistical tests', given in Table 2-1, that need to be satisfied for water quality to be in that attribute state. These are the annual median and 95th percentile concentrations (Q_{50}, Q_{95}), and the proportion of time concentration thresholds of 260 and 540 *E. coli* 100mL^{-1} are exceeded (G_{260}, G_{540}). All four criteria

[3] https://soils.landcareresearch.co.nz/index.php/soil-data/fundamental-soil-layers/ (date of access, 9 March 2018)

must be met to establish an attribute state; if one or more criteria cannot be satisfied in an attribute state, a lower attribute state must apply. For the purposes of the targets, a river must have a Strahler stream order of 4 or greater and an attribute state of A, B or C.

Table 2-1: Criteria used to define the *E. coli* attribute states for the NPS-FM human health for recreation value. Shading refers to the attribute classification colour.

Criteria	A	B	C	D	E
Median *E. coli*/100ml (Q_{50})	≤130	≤130	≤130	>130	>260
95th Percentile *E. coli*/100ml (Q_{95})	≤540	≤1000	≤1200	>1200	>1200
Proportion of exceedances over 260 *E. coli*/100ml (G_{260})	<0.2	≥0.2, ≤0.3	≥0.2, ≤0.34	>.34	>0.5
Proportion of exceedances over 540 *E. coli*/100ml (G_{540})	<0.05	≥0.05, ≤0.1	≥0.1, ≤0.2	≥0.2, ≤0.3	>0.3

As noted above, the SPARROW model predicts annual loads of *E. coli*, not concentrations or attribute states. Therefore, the changes in the SPARROW annual load predictions were used to adjust the current, or baseline, attribute states taken from the underlying MfE swimmability maps data to their future, post mitigation, state. That map data uses the values of the four statistics derived from monitoring site concentration data where available. For locations that do not have monitoring data, the current baseline values of all four statistics are predicted using regression models fitted to monitoring site data (for example, Larned et al (2016)).

The future scenario values of Q_{50} and Q_{95} are calculated using a delta-change method similar to that used by Semadeni-Davies,Elliott (2017). That is, the *E. coli* loads simulated for Scenario 0 were equated to the current attribute state values. The percentage difference in the loads simulated for Scenario 1 was used to adjust the Q_{50} and Q_{95} values proportionally. The calculation of scenario values of G_{260} and G_{540} use an additional statistic, the standard deviation of the concentrations, so that the full range of concentrations (that is, the distribution) can be modelled for every location (Elliott and Whitehead 2016). The method followed to calculate these values is described in Appendix C.

3 Scenario development

The model was used to predict *E. coli* loads for two scenarios. Scenario 0 represents the baseline (i.e. 2017) including the current level of on-farm fencing and land use. Scenario 1 represents the future after the proposed national Clean Water Package (CWP; MfE, 2017)for stock exclusion has been implemented, in tandem with other regional committed works.

3.1 Scenario 0

The current level of fencing was taken from the MPI study (Semadeni-Davies and Elliott 2017) and was estimated on the basis of industry evaluations (for example, Dairy NZ) and the Landcare Research Survey of Rural Decision Makers 2015 (SRDM 2015; Brown 2015)[4]. Since the data were provided by super regions, the current estimates were applied at this level. The super regions are Northern North Island (NNI: Northland, Auckland, Waikato, Bay of Plenty, Gisborne), Southern North Island (SNI: Taranaki, Manawatu-Whanganui, Hawke's Bay, Wellington) and the South Island (SI). It is assumed that only stream reaches that meet the dairy accord are fenced, that is, with an estimated width of 1 metre and a sub-catchment slope of < 15 degree. The estimated width has been taken from Booker,Hicks (2013). The current level of fencing for accord streams by super region and stock type is given in Table 3-1.

Table 3-1: Current level of stock exclusion (% of accord stream length fenced) estimated by super region and stock type.

Stock type	Northern North Island	Southern North Island	South Island
Dairy	97%	93%	94%
Sheep and beef	60%	44%	49%
Deer	65%	54%	46%

While there may be other mitigations in place, these are assumed to be implicit within the swimmability model.

3.2 Scenario 1

Scenario 1 represents the level of stock exclusion and riparian planting for the nominal year 2030 when the CWP rules have been implemented assuming that the effects of the measures have been realised and water quality has attained a new attribute state. Scenario 1 also includes the impact of regional committed work (that is, work already committed to by councils in their policy plans, or planned infrastructure investment) in regions that have committed to mitigation beyond the CWP.

Scenario 1 represents the CWP as all stock types[5] excluded from all reaches with either:

- an estimated width of 1 metre or more where the reach sub-catchment has a slope of greater than 3 degrees;
- a sub-catchment slope of 3 degrees or less.

[4] www.landcareresearch.co.nz/science/portfolios/enhancing-policy-effectiveness/srdm/srdm2015 (date of access, 9 March 2018)

[5] Note that while sheep are exempt from the CWP, it is not possible in the modelling to separate sheep from the sheep and beef land use class. For this reason, Scenario 1 was also applied to sheep.

The regional committed mitigation measures were reported to the taskforce for regional swimming targets by the regional councils and generally follow one of three general strategies for agricultural runoff that were simulated:

- extension of the CWP to all reaches irrespective of slope (Table 3-2),
- riparian planting in addition to fencing (Table 3-3),
- land disposal of farm dairy effluent (FDE, Table 3-4).

The mitigation measures are represented by a percentage removal based on removal efficiencies for stock-exclusion by fencing or riparian planting reported in the literature. These reduce the diffuse loads calculated for each of the affected land uses in reaches were the mitigation is applied. The fencing removal efficiencies are the same as those that were adopted for the MPI study (Muirhead 2016; Semadeni-Davies and Elliott 2017). The riparian planting assumes an extra 10 % removal (Muirhead, pers. comm., reproduced in Appendix D). The mitigation efficiencies for stock exclusion by fencing and stock exclusion with an assumed 3-metre-wide riparian planting set-back are given in Table 3-5. Note that since sheep are not required to be fenced in the CWP, the mitigation efficiencies for sheep and beef are low compared to dairy and deer. This is because the SPARROW model does not distinguish between sheep and beef. FDE was simulated for dairy platform by a 40 % reduction in *E. coli* loads for Horizons (Manawatu-Whanganui) and Taranaki and a 20 % reduction for Auckland, which has a lower density of dairying.

Table 3-2: Summary of commitment to water quality mitigation measures beyond the CWP for each regional council. Information provided by MfE.

Region	Rivers	Scenario 1 proposed response
Northland	All	None (covered by Clean Water Package)
Auckland	All	Extend Clean Water Package to all streams
Waikato	All	None (covered by Clean Water Package)
Bay of Plenty	All	Extend Clean Water Package to all streams
Gisborne	All	None (covered by Clean Water Package)
Taranaki	All	None
Horizons	All	None (covered by Clean Water Package)
Hawke's Bay	All	Extend Clean Water Package to all streams
Wellington	All	None (covered by Clean Water Package)
Nelson	All	None (covered by Clean Water Package)
Marlborough	All	None (covered by Clean Water Package)
Tasman	All	None*
West Coast	All	None (covered by Clean Water Package)
Canterbury	All	Extend Clean Water Package to all streams
Otago	All	None
Southland	All	None (covered by Clean Water Package)

*Since the modelling was undertaken, it has been reported by the Tasman District Council that approximately 23 km of river is fenced in the district per year. This fencing was not included in the modelling.

Table 3-3: Summary of committed riparian planting work for each regional council.

Region	Rivers	Scenario 1 proposed response	Council information on setbacks	Comment
Northland	All	None		
Auckland	Hoteo, Henderson Creek (upper), Kaipara, Mahurangi, Wairoa	Assume that 50% of streams with order 3 or more are planted	Assuming a minimum of 3m and an average of 5m is okay	Assume all planted streams have a minimum 3m setback
Waikato	All	None		
Bay of Plenty	All	Assume an additional 10% of streams with order 3 or more are planted	Approximately 40% of fences in the region are set back more than 3m from the river. Council are actively encouraging land owners to increase both the margin and percentage.	This represents an additional 10% from existing planting to bring the total up to our proposed response of 50% of streams with order 3 or more planted. Assume all planted streams have a minimum 3m setback.
Gisborne	All	None	Dairy farms and break-feeding farms have a 5m setback requirement. Deer have no setback requirements. Council has no riparian planting requirements, but estimate 25% of pastoral-farmed streams have riparian cover in the hill country but none on flat land.	No effect as proposed response assumes no additional riparian planting
Taranaki	All	Assume an additional 5% of streams on plains with order 3 or more are planted	Estimate 75.6% of total riparian streambank length on the ring plain is 3m or wider. Maybe an increase to 80% over the next 10 years.	Assume all planted streams have a minimum 3m setback.
Horizons	All	None		
Hawke's Bay	Third order streams feeding into Ahuriri Estuary	Assume that 15% of streams of order 3 or more are planted		Assume all planted streams have a minimum 3m setback.

Region	Rivers	Scenario 1 proposed response	Council information on setbacks	Comment
Wellington	All	10% new planting on lowland streams of order 3 or more	Programme to incentivise riparian planting with a recommended 5m setback on high value sites and lowland streams. Generally, most riparian setbacks on dairy farms would be 3m or less. Other land uses would be variable but probably average out to 3m.	Assume all planted streams have a minimum 3m setback.
Nelson	All	None		
Marlborough	All	None		
Tasman	All	None		
West Coast	All	None	Regional Land and Water Plan only requires stock exclusion in the Lake Brunner catchment. Estimated that 73% of streams fenced on dairy farms. Lake Brunner catchment requires a minimum 1m setback. Proportion of intensely farmed area in the region managed by Landcorp who have fenced the majority of waterways with a minimum 3m setback requirement.	No effect as proposed response does not include riparian planting.
Canterbury	All	None		
Otago	All	None	Council does not require specific setback distances	No effect as proposed response does not include riparian planting.
Southland	All	None		

Table 3-4: Summary of committed FDE management for each regional council.

Region	Rivers	Scenario 1 proposed response	Comment
Northland	All	None	
Auckland	Mahurangi, Hoteo, Rangitopuni, Kaukapakapa, Wairoa, Makarau, Kaipara, Henderson Creek	Apply land surface disposal of FDE to 75% of all dairy land use in these streams	This represents a 75% increase in uptake of FDE controls (assuming 25% already in place). For Auckland, assume FDE controls are 50% as effective as in Taranaki and Horizons, due to low dairy density in the region.
Waikato	All	None	
Bay of Plenty	All	None	
Gisborne	All	None	
Taranaki	All	Apply land surface disposal of FDE to 75% of all dairy land use in region	This represents a 75% increase in uptake of FDE controls (assuming 25% already in place).
Horizons	All	Apply land surface disposal of FDE to 75% of all dairy land use in region	This represents a 75% increase in uptake of FDE controls (assuming 25% already in place).
Hawke's Bay	All	None	
Wellington	All	None	
Nelson	All	None	
Marlborough	All	None	
Tasman	All	None	
West Coast	All	None	
Canterbury	All	None	
Otago	All	None	
Southland	All	None	

Table 3-5: Percentage removal efficiencies for stock exclusion by modelled stock type and super region.

Stock type	Northern North Island		Southern North Island		South Island	
	Fencing	Riparian	Fencing	Riparian	Fencing	Riparian
Dairy	62%	72%	62%	72%	62%	72%
Sheep and beef	53%	63%	44%	54%	40%	50%
Deer	62%	72%	62%	72%	62%	72%

For urban land use, there are several options for stormwater treatment to remove *E. coli* including bioretention in raingardens and grassed swales and in ponds and wetlands (see memo reproduced in Appendix E). The removal efficiencies reported in the literature for these options ranges between 10 and 80%. Here, Scenario 0 assumed no current urban *E. coli* removal; a flat removal efficiency of 50% was used for Scenario 1.

3.3 Point sources

The *E. coli* loads from point sources for both Scenario 0 and Scenario 1 are listed in Appendix F. Point sources included in this SPARROW implementation represent mean annual *E. coli* discharges from around 150 sources. These represent, for example, sewage treatment plants in larger towns, dairy factories, piggeries and freezing works. Coastal discharges were specifically excluded from this summary. Loads from septic tanks, urban sewer overflows, sewage treatment of smaller towns and dairy effluent ponds are not modelled. It is assumed that loads from these sources are adequately accounted for by the land use description in SPARROW.

The discharge point data were provided to MfE for this study by regional councils, and data included were the type of source, the location, consented loads or concentrations, and, where available, monitored estimates of average loads concentrations and flow rates. For sites where loads could not be estimated from the provided information, loads were estimated based on population (NZ 2013 Census data) and the type of treatment. For non-human effluent sites, *E. coli* loads were based on historical data, or from similar wastewaters in New Zealand. For Scenario 1, changes to loads due to planned changes at the sources (for example, upgrades to sewage treatment plants) were considered. These were based on information provided by regional councils. For instance, where a site was being upgraded by addition of sand filters and UV treatment to existing oxidation ponds, estimates were based on known concentrations of discharges from similar systems. Where the type of upgrade was not specified, the likely upgrade water quality (e.g. from secondary treatment to advanced secondary or to tertiary) was based on budgeted costs supplied by the site operating authority. Input data values used to estimate loads are listed in Appendix F.

4 Model limitations

Like all models, SPARROW contains inherent error and uncertainty. In the modelling context, uncertainty refers to the limitations of the model due to, for instance, the choice and representation of model input and outputs; model structure and the simplification of complex physical, chemical and biological processes; and the choice and calibration of model parameters. Model error is separate from uncertainty and can refer to errors in the model code as well as errors in the input, calibration and validation data, due to, for example the accuracy and precision of data capture, data processing methods and storage. This section overviews the sources of model error and uncertainty identified for this implementation of SPARROW.

4.1 Spatial scaling

The SPARROW model operates at the catchment-scale and is therefore subject to smoothing of data inputs which have been averaged over time (e.g., variation in *E. coli* seasonally and due to weather events) and space (e.g., variation due to terrain, soil, slope and other catchment characteristics). In addition, the variation in data availability and data collection from region to region may mean that some regions are not as well represented in model calibration as others.

The smallest spatial unit in the SPARROW model is the river reach sub-catchment. Spatial data within each sub-catchment are lumped together and there are no linkages between potentially dependant data types (e.g., slope and land use). Land use within each sub-catchment is split into proportional areas while rainfall and slope have been spatially-averaged. This means that, for example, within a sub-catchment there can be differences in slope from the stream channel to the sub-catchment boundaries that could influence the location of land use types.

The underlying data sets, such as the Farms Online land use data provided by MPI, soil drainage class and slope, also contain inherent error. For example, in the case of Farms Online, the data were not purpose collected and included land use classes not supported by the model that needed to be reassigned (e.g., lifestyle blocks).

Climate data comes from NIWA's VPSN and the estimates of rainfall and temperature are therefore highly dependent on the distance to the nearest climate gauge, the length of the climate records at each gauge and the complexity of the terrain (personal communication, Dr Andrew Tait, NIWA principal climate scientist).

4.2 Temporal scaling

Use of the SPARROW model in this project is a limitation as it is a steady state model, and predicts the mean annual load that would occur once equilibrium conditions have been achieved. Thus, it cannot show how *E. coli* statistics would change through time if implementation was progressive, or if the effects took some time to be fully realised. Moreover, the effects of seasonal changes in *E. coli* generation (e.g., over-wintering dairy cattle versus milk production), die-off and transport (summer low flow versus winter peak flows) are not captured by the model. While a dynamic model would not have these limitations, for reasons specified above, such a model was deemed to be unsuitable for national *E. coli* modelling.

4.3 Drainage representation

The SPARROW model is based on a representation of the surface water drainage network and does not explicitly include aquifer systems. Thus, the effect of groundwater storage or transport on *E. coli* loads is not explicitly represented. In addition, the SPARROW model represents attenuation as an exponential decay rate, which is a function of the estimated travel time in the river network.

4.4 Point sources

E. coli point source data used in the model include industrial and municipal waste. These point sources are variable over time making it difficult to assess mean annual loads.

4.5 Current level of fencing

The current level of fencing was estimated based on the preliminary results of the SRDM 2015. The SRDM is a voluntary survey and is subject to bias including self-selection of respondents and response bias (see de Leeuw *et al.* 2012, for information on survey design and bias). While the survey does include questions on mitigation practices including fencing, its primary purpose is to provide a snapshot of the current rural landscape to give an insight into the future of New Zealand's primary industries. The SRDM is currently the leading source of information on fencing practices, at this level of detail, in New Zealand and is undertaken every 1-2 years by Landcare Research.

Results were provided by super-region and contain no information on the underlying spatial distribution of fencing with respect to regions or catchment characteristics. The assumption was made that only Water Accord streams on land with a slope of less than 16°are currently fenced, however, other considerations, such as elevation or soil type, were not taken into account. The level of fencing was estimated as the product of the number of farms with fencing and the approximate percentage of Accord streams on farms that are fenced. In comparison with dairy farming which is largely restricted to flat-to-rolling countryside, this percentage had higher variability for other stock types. For sheep and beef, this variability may be due to the range of catchment conditions associated with the three sheep and beef classes.

It was also assumed that the length of a particular reach accessible to stock was proportional to the percentage coverage for each stock type in the reach sub-catchment. However, it is likely that some stock types may have greater access than others, particularly if there is a high elevation gradient in the reach sub-catchment which favours dairying and intensive sheep and beef near the stream channel.

4.6 Calibration error

The *E. coli* SPARROW model was calibrated in 2014 as part of CLUES model maintenance and used the CLUES default land use data rather than the MPI Farms Online land use data. For the calibration, monthly *E. coli* concentration data held in the National River Water Quality Network was used to estimate mean annual loads for calibration. Suitable flow and concentration data required to estimate loads were available from 204 monitoring sites nationally, which is roughly one third of the sites where *E. coli* is monitored. These data are subject to potential errors in sampling and analysis and the methods used vary from region to region.

It is assumed that monthly data are representative of the full range of *E. coli* concentrations at the monitoring sites and that the median *E. coli* concentrations calculated from these data are representative of the median annual concentrations for each site respectively. As pointed out by

Davies-Colley *et al.* (2011), this is not necessarily the case, highlighting the need for national protocols around the collection of water quality data in order to standardise monitoring and to provide data that is purpose-collected for modelling.

Baseflow *E. coli* loads for each site were estimated by multiplying the median annual concentrations determined from the concentration data by the estimated mean annual flow rate for that site. There is a possibility that this method could skew results to be lower than the actual median loads. The method also assumes that a proportional change in load produces an equivalent proportional change in concentration. This assumption has not been tested.

SPARROW was calibrated to minimise the root mean square error between the modelled and measured loads (see below for a discussion on calibration data). A single national set of parameters was calibrated, incorporating each of the model parameters as described in Appendix A. At the regional or catchment level, these parameters may not necessarily reflect the regional characteristics that drive *E. coli* generation and transport.

A key simplification of SPARROW model is that production rates of *E. coli* (that is, source yields) are homogeneous within three land use/cover categories (pastoral land use - all stock types; urban; and all other land uses). The model was found to be insensitive to stock type, which was not an expected outcome of the calibration. While the urban land use yield was found to be highly uncertain, this land use class was retained due to its special nature and to allow urban mitigation measures to be simulated. The available calibration dataset included comparatively few urban calibration sites and therefore the predictions may be less reliable for urban catchments or catchments with a significant urban component. Moreover, SPARROW does not distinguish between types of urban land use (that is, residential, industrial or commercial), sewer network (that is, separate or combined) or stormwater treatment. It is noted that the main sources of *E. coli* in urban runoff are sanitary sewer overflows during high intensity rainfall events, or wash-off of animal excrement (e.g., dogs, water fowl).

The model calibration results, as represented by the root mean square error and coefficient of determination (0.823 and 0.82, respectively; Appendix B), reflect the difficulty in modelling *E. coli* as the yield of microbes from diffuse and point sources is highly variable in time and space (Wilcock 2006; Muirhead 2015) making determination of average annual catchment loads and concentrations difficult. The model errors and uncertainty are compounded by potential errors in the input data and assumptions made in processing that data for use in the model. Thus, load prediction for individual segments should be considered indicative only.

However, if the modelling is unbiased (that is, no systematic error), the model errors for individual segments cancel out so that the aggregated predictions will be reliable. For example, the proportion of rivers of a given swimming grade within a region will be accurately represented. The models underlying the swimming maps used to represent the current attribute states were shown to have low bias (Snelder *et al.* 2016) and the SPARROW calibration also indicated low bias. Therefore, it is reasonable to assume that the model predictions aggregated over large areas (that is, regions or nationally) are reliable.

5 Model outputs

This section provides a summary of the model outputs at a national level. Full model results are given in Appendix G. Note that there are some 1300 km of eligible stream reaches in the REC1 for which there are no swimmability data provided in the MfE suitability for swimming maps.

Table 5-1 gives the total length of streams with a Strahler stream order of 4 or greater nationally that are in each of the respective human health for recreation *E. coli* attribute state bands. From the table, 69 % of eligible rivers are currently in bands A-C; this increases to an estimated 76% of eligible rivers for Scenario 1, an improvement of 7% swimmability nationally.

Table 5-1: Length of rivers with a stream order > 4 estimated to be in each *E. coli* attribute state band for Scenario 0 and Scenario 1. Current state taken from swimmability maps, future state estimated using SPARROW *E. coli* modelling. The percentage of the total length of eligible rivers in each class is in parentheses. Shading refers to the attribute classification colour.

Scenario	A	B	C	D	E
Scenario 0	17121 (39%)	6044 (14%)	7193 (16%)	7804 (18%)	6115 (14%)
Scenario 1	19820 (45%)	6823 (15%)	7004 (16%)	6713 (15%)	3916 (9%)
Percentage change in lengths	16%	13%	-3%	-14%	-36%

Figure 5-1 shows the percentage of river lengths suitable for swimming by region for Scenario 0 and Scenario 1. Five regions (Nelson, West Coast, Marlborough, Tasman, and Bay of Plenty) have upwards of 90 % their river lengths suitable for swimming, that is, they are above the national and therefore have little capacity for improvement. The regions that have the lowest percentage of swimmable rivers currently (< 30%) are Auckland and Northland, followed by Waikato and Taranaki that have less than 40% swimmable rivers. Of these, under Scenario 1, Taranaki has a capacity for an increase in swimmability of around 26%. Hawke's Bay has a similar level of potential improvement followed by Manawatu-Whanganui (Horizons) with an estimated improvement of 16%. Auckland has an estimated improvement on par with the national average (~7%), while Northland and Waikato have an estimated improvement of between 2 and 4%.

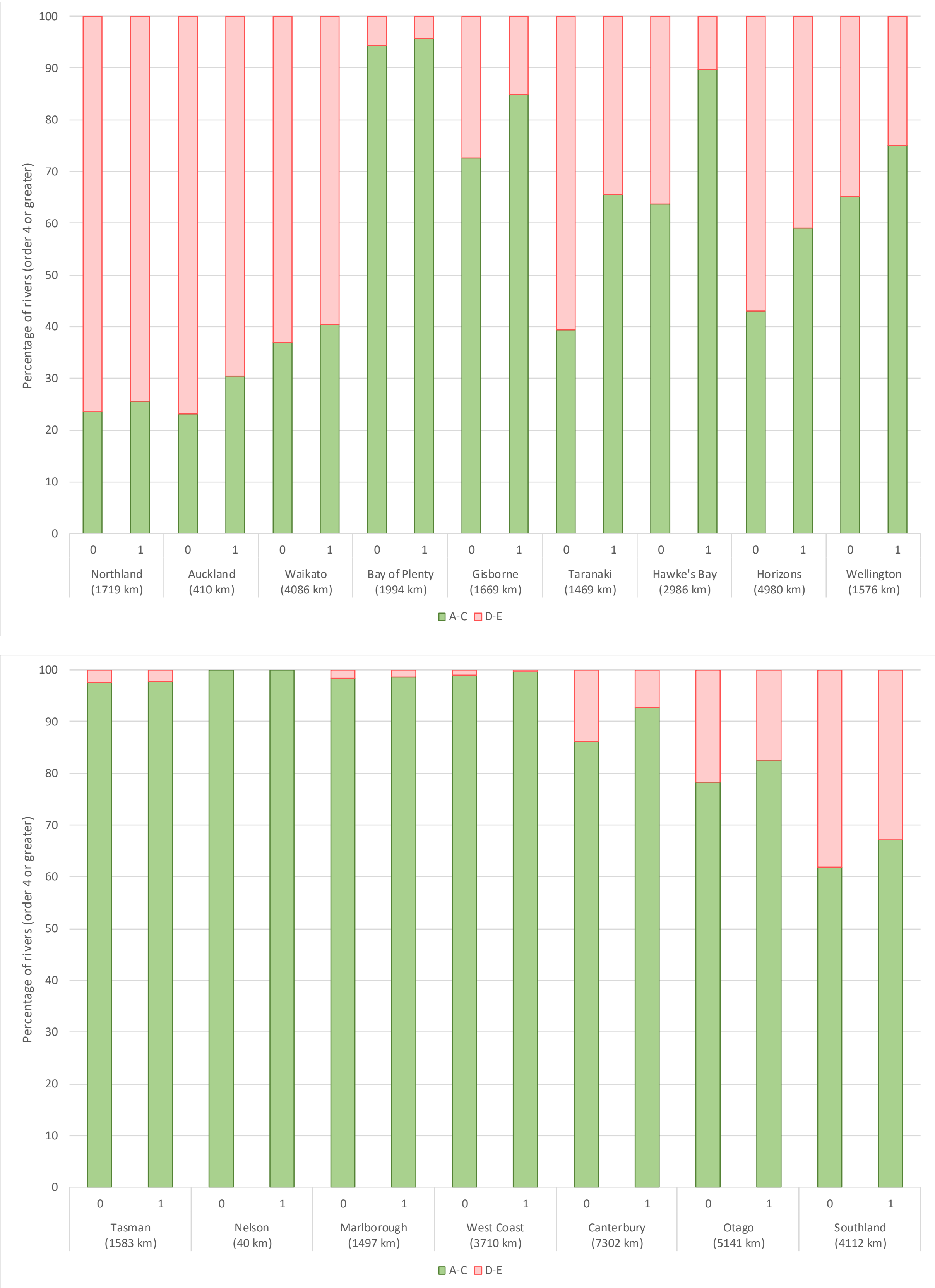

Figure 5-1: Estimated percentage of river reaches suitable for swimming by region for Scenarios 0 and 1. Top - North Island, Bottom - South Island. Attributes bands are grouped according to their suitability for swimming. The total length of eligible rivers (i.e., with an order of 4 or greater) in each region is indicated. Horizons refers to Manawatu-Whanganui.

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Appendix A SPARROW *E. coli* modelling procedure

SPARROW is a steady state annual load model that operates at the catchment scale. It determines the loads from diffuse and point sources that are discharged from each river sub-catchment and then routes these loads down the river network accounting for both instream and lake attenuation. The following description of the model algorithms has been amended from Appendix 1 of:

Elliott A.H., Semadeni-Davies A.F., Shankar U., Zeldis J.R., Wheeler D.M., Plew D.R., Rys G.J., Harris S.R. (2016) A national-scale GIS-based system for modelling impacts of land use on water quality. Environmental Modelling & Software 86:131-144. DOI: http://dx.doi.org/10.1016/j.envsoft.2016.09.011.

The diffuse sources of *E. coli* were broken into areal loading for a number of land use classes and point sources. Initially all 19 land use classes represented in the CLUES model were used, but this number was reduced during calibration as described below. Three land-water delivery factors were investigated. Increased rainfall is expected to increase the losses, due to increased percolation and surface runoff of faecal matter. Infiltration of *E. coli* varies with soil properties (McLeod et al. 2008)[6], with greater bypass flow in clay soils and greater filtering in well-drained soils (high drainage class, D). Poor drainage is also expected to lead to greater surface runoff of faecal matter. Temperature may also affect microbial survival and persistence (e.g., Blaustein et al. 2013)[7].

The calculation of diffuse loads from each land use is given in equation 1:

$$S_i = A_i y_i \exp\big(a_R(R - 1.85) + a_D(D - 4.2) + a_T(T - 10.1)\big) \quad (1)$$

(1)

where S_i is the source (organisms/day) for land use i, A_i is the area of land use i (km^2), y_i is the source coefficient or yield associated with the source, R is the mean annual rainfall (m/y), D is the drainage class (dimensionless indicator ranging between 1-5, increasing from poorly drained to well drained), and T is the mean annual air temperature (°C). The coefficients 1.85, 4.2, and 10.1 are the mean across all sub-catchments of R, D and T respectively, determined directly from input data. The exponents *a* relate to the relevant delivery factor.

Once delivered to the stream network, the total loads from diffuse and point sources is routed downstream such that the instream load for a reach is the total of the upstream load and the reach load less attenuation. Decay in streams is modelled as a first-order function of stream length, with the decay coefficient varying as a power function of flow (Elliott et al., 2005)[8]. The expression for the decay factor, D_{stream} is:

$$D_{stream} = 1 - e^{\left(k_{stream} L Q^{k_{flow}}\right)} \quad (2)$$

Where k_{stream} and k_{flow} are calibrated parameters, L is the reach length (km) not in a lake and Q is the estimated mean annual flow rate from the CLUES model. The total load from each reach sub-

6 McLeod, M., Aislabie, J., Ryburn, J., McGill, A., 2008. Regionalizing potential for microbial bypass flow through New Zealand soils. Journal of Environmental Quality 37(5) 1959-1967.

7 Blaustein, R.A., Pachepsky, Y., Hill, R.L., Shelton, D.R., Whelan, G., 2013. Escherichia coli survival in waters: Temperature dependence. Water Research 47(2) 569-578.

8 Elliott, A., Alexander, R., Schwarz, G., Shankar, U., Sukias, J., McBride, G., 2005. Estimation of nutrient sources and transport for New Zealand using the hybrid mechanistic-statistical model SPARROW. Journal of Hydrology (New Zealand) 44(1) 1-27.

catchment discharged to the reach is multiplied by the decay factor while the load routed from upstream reaches is multiplied by the square-root of the decay factor.

Decay in lakes is applied only to the lake outlet reach and is a function of the lake area and depth of outflow calculated as:

$$D_{lake} = \frac{O}{O + k_{res}} \qquad (3)$$

where D_{lake} is the decay factor for the outlet reach of the lake, $O$is the reservoir overflow (m/year) for the outlet reach taken from the CLUES model and k_{res} is a calibrated coefficient representing the loss of *E. coli* within the reservoir.

Appendix B SPARROW calibration

Calibration was undertaken as part of CLUES maintenance in 2014 and used CLUES default land use data. The calibration minimised the root mean square error (RMSE) calculated for the residuals between the modelled and measured *E. coli* log-transformed base-flow loads for the 204 water quality monitoring sites from the National River Water Quality Network for which *E. coli* loads could be determined. The RMSE is used as a standard statistical metric to measure model performance in many fields, including meteorology, air quality, climate research and agriculture and assumes the errors are unbiased and follow a normal distribution (Chai and Draxler 2014)[9]. The calibrated RMSE represents the standard deviation of the differences between the natural log of predicted and natural log of observed values (that is, model residuals in log space).

Based on initial model exploration, the 19 land uses represented in CLUES were simplified into three main lumped categories of pastoral (i.e., stock) land use, urban areas, and all other land uses for the *E. coli* calibration. The model was not able to discriminate between source coefficients at finer levels for land use. Interestingly, the calibration was not able to distinguish between dairy and sheep and beef pastoral land uses, where we might have expected some difference. Urban land use was retained as a separate term despite the uncertainty, due to the interest in separating out this source and the generally large yields compared with other non-pasture source.

The calibration results are shown in Table B-1 and the calibrated parameters, along with their associated standard errors, are shown in Table B-2.

Table B-1: Calibration results for the base-flow SPARROW *E. coli* calibration. The RMSE, and R2 values were calculated in log space. Calibration undertaken with for base-flow conditions.

Number of observations	Number of calibrated parameters	RMSE	Load R2	Yield R2
204	8	0.823	0.82	0.64

Table B-2: SPARROW calibrated parameters and their associated standard errors. Calibration undertaken with for base-flow conditions.

Parameter	Unit	Calibrated value	Standard error
Source yield y_i: Pasture	10^{15} organisms/km^2/year	0.0091	0.0025
Source yieldy_i: Urban	10^{15} organisms/km^2/year	0.0166	0.0075
Source yield y_i Other land uses	10^{15} organisms/km^2/year	0.0002	0.0001
Rainfall delivery coefficient a_r	dimensionless	0.4906	0.1408
Temperature delivery coefficient a_t	dimensionless	0.1269	0.0271
Drainage delivery coefficient a_d	dimensionless	Removed from the calibration	
Decay coefficient k_{stream}	/year	0.1190	0.0268
Flow coefficient k_{flow}	/year	-0.6681	0.0727
Reservoir attenuation coefficient k_{res},	/year	75.226	58.54

[9] Chai, T. and Draxler, R.R. (2014) Root mean square error (RMSE) or mean absolute error (MAE)? – Arguments against avoiding RMSE in the literature. Geosci. Model Dev., 7(3): 1247-1250. 10.5194/gmd-7-1247-2014

Similarly, the drainage coefficient was dropped from the calibration as it had only a small influence on the model results.

The calibration uses the CLUES default land use data for the baseline year of 2008, while the Farms Online data used in this study was collected between 2010 and 2015 with a nominal baseline of 2012. For this reason, the yields from pastoral land uses (0.0091 for all stock types from Table B-2) were adjusted to the change in the level of fencing estimated between 2008 and 2012 for each of the stock types modelled. The adjustment method is described in detail in Semadeni-Davies and Elliot (2016). The adjusted pastoral yields for each stock type and for fenced and unfenced streams are given in Table B-3.

Table B-3: Adjusted source yields determined for each stock type modelled.

Pastoral land use	Yield (10^{15} organisms / km2 /year)
Dairy – Platform (milking cows on dairy farms)	0.0152
Dairy – Runoff (non-milking dairy cattle, e.g., calves, grazing on dairy farms)	0.0152
Dairy - Third (grazing of non-milking dairy cattle on non-dairy farms)	0.0152
Sheep and Beef Intensive	0.0108
Sheep and Beef Hill	0.0108
Sheep and Beef High Country	0.0108
Deer	0.0125
Other Animals	0.0002

Appendix C Future adjustment of exceedance frequencies

This appendix outlines the method used adjust the current attribute states (i.e., Scenario 0), to the future attribute states under Scenario 1.

For each reach, the new non-exceedance frequencies are calculated assuming that the concentrations are characterized by a log-normal distribution with μ = ln(median) and σ = ln(standard deviation). We use a fixed value of σ = 1.34 (Elliott and Whitehead, 2016)[10]. The calculations are as follows:

1. Calculate the non-exceedance frequencies for the baseline as:

   $$F_{260.0} = 1 - G_{260,0}$$
   or
   $$F_{540.0} = 1 - G_{540,0}$$
   respectively.

2. Calculate an estimate of μ from the current non-exceedance frequency for each F_{260} and F_{540}, of using:
   $$\mu_{260} = \ln(260) - \sqrt{2}\sigma \operatorname{erf}^{-1}(2F_{260,0} - 1)$$
   or
   $$\mu_{540} = \ln(540) - \sqrt{2}\sigma \operatorname{erf}^{-1}(2F_{540,0} - 1)$$
   respectively, where erf^{-1} is the inverse error function from the Python Scipy library[11]

3. Calculate the new non-exceedance frequency using
   $$F_{260,1} = \frac{1}{2} + \frac{1}{2}\operatorname{erf}\left(\frac{\ln 260 - \mu - \ln D}{\sqrt{2}\sigma}\right)$$
   or
   $$F_{540,1} = \frac{1}{2} + \frac{1}{2}\operatorname{erf}\left(\frac{\ln 540 - \mu - \ln D}{\sqrt{2}\sigma}\right)$$
   respectively, where $D = L_1/L_0$ is the ratio of loads between Scenario 1 and Scenario 0 and the erf is the error function from the Python SciPy library[12]

4. Convert the non-exceedance frequencies back into exceedance frequencies for reporting using $1 - F_{260,1}$ and $1 - F_{540,1}$

[10] Elliott S., Whitehead A. (2016) Effect of *E. coli* Mitigation on the Proportion of Time Primary Contact Minimum Acceptable State Concentrations Are Exceeded: Technical Note. .

[11] https://docs.scipy.org/doc/scipy-0.14.0/reference/generated/scipy.special.erfinv.html (date of access, 9 March 2018)

[12] https://docs.scipy.org/doc/scipy-0.14.0/reference/generated/scipy.special.erf.html (date of access, 9 March 2018)

Appendix D E. *coli* mitigations for MfE modelling

From	**Richard Muirhead, AgResearch**
To	Sharleen Yalden
Date	September 2017

Background

NIWA have set up national models to predict the effects of applying mitigations will have on achieving the governments Swimmability targets in the "Clean Water" plan released earlier this year. This work is to provide the mitigation effectiveness inputs for the agricultural land. NIWA have already compiled the mitigation data for urban land use.

Mitigations to model

There seems to be four strategies councils are relying on, which are:

1. Extend fencing to all reaches irrespective of width or slope.
2. Riparian planting (or buffers) along main streams in some catchments/regions. NIWA will need associated mitigation factors for stock exclusion with riparian planting with the assumption that the streams are also fenced as per Clean Water.
3. Land use change to retire pasture on steep land.
4. Management of dairy effluent. NIWA will need a bundle with mitigation factors and some rules, eg. only apply to dairy platform.

Mitigation (3) on land use change can be modelled using the source factor already in the SPARROW model developed by NIWA. So what is needed is tables of mitigation effectiveness for (1) stream fencing, (2) stream fencing + riparian planting and (4) stream fencing + riparian planting + FDE management applied to dairy platforms.

Applying the mitigations

Applying the mitigations in the SPARROW model require 2 separate input factors. The first is the effectiveness of the mitigation factor and the second is the proportion of land that the mitigations have already been applied to i.e. if 97% of the streams on dairy farms are already fenced then the mitigation of stream fencing will only apply to the 3% of streams that remain unfenced. This will significantly reduce the impact of the fencing mitigation for achieving the Swimmability targets. The challenge for this analysis is both a lack of data on the effectiveness of mitigations for reducing *E. coli* losses and on accurate data on current level of mitigations already applied on farms.

Proposed Tables

The tables below are proposed for each of the 3 mitigations needed. Super region codes are Northern North Island (NNI), Southern North Island (SNI) and South Island (SI) as used in the previous fencing analysis for the Clean Water plan. Table D-1 is based on the same data as used for the National fencing study.

Table D-1: Input tables for the effectiveness of the stream fencing mitigation.

Land use	Sub-land use	Super Region	Mitigation effectiveness	Mitigation levels already applied
Dairy	Platform	NNI	62%	97%
Dairy	Platform	SNI	62%	93%
Dairy	Platform	SI	62%	94%
Dairy	Runoff	NNI	62%	60%
Dairy	Runoff	SNI	62%	89%
Dairy	Runoff	SI	62%	72%
Sheep & Beef	Intensive	NNI	53%	60%
Sheep & Beef	Intensive	SNI	44%	44%
Sheep & Beef	Intensive	SI	40%	49%
Sheep & Beef	Hill	NNI	53%	60%
Sheep & Beef	Hill	SNI	44%	44%
Sheep & Beef	Hill	SI	40%	49%
Sheep & Beef	High	NNI	53%	60%
Sheep & Beef	High	SNI	44%	44%
Sheep & Beef	High	SI	40%	49%
Deer	Deer	NNI	62%	65%
Deer	Deer	SNI	62%	54%
Deer	Deer	SI	62%	46%

The literature review used for the National Fencing study identified a median effectiveness of 62% for dairy farms and slightly less for mixed sheep and beef farms. These numbers where higher than expected and also higher than figures of ~40% used in previous modelling studies (e.g. Whangarei Harbour). This provides an issue with adding extra mitigations on top of the fencing pushing the effectiveness values to >60% reductions at the farm-scale, which is much greater than would be applied for other contaminants such as N or P. This makes me nervous in applying extra effectiveness for other mitigation options. Fencing + riparian planting provides the additional complexity in that fencing alone will help reduce *E. coli* loads deposited during base-flow but the riparian planting will only affect storm-flow generated run-off. We have little understanding of how the relative loads generated during base- or storm-flow conditions will impact on stream water quality metrics. So the suggestion is we just add an extra percentage reduction value to fencing values to represent the fencing + riparian planting mitigations (Table D-2). The challenge here will be identifying the proportion of land that is fenced with <5m buffer that can be improved by expanding the fenced area and planting and applying the 10% mitigation to that land.

The FDE management mitigations will only apply to the dairy milking platforms. Again we are adding an additional mitigation to the fencing and riparian planting mitigations applied (Table D-3). Again I propose just adding an extra percentage value to represent this amount. The challenge will be getting representative data of the current levels of application of GMP FDE management.

Table D-2: Input tables for the effectiveness of the stream fencing + riparian planting mitigations.

Land use	Sub-land use	Super Region	Mitigation effectiveness
Dairy	Platform	NNI	Table 1 + 10%?
Dairy	Platform	SNI	Table 1 + 10%?
Dairy	Platform	SI	Table 1 + 10%?
Dairy	Runoff	NNI	Table 1 + 10%?
Dairy	Runoff	SNI	Table 1 + 10%?
Dairy	Runoff	SI	Table 1 + 10%?
Sheep & Beef	Intensive	NNI	Table 1 + 10%?
Sheep & Beef	Intensive	SNI	Table 1 + 10%?
Sheep & Beef	Intensive	SI	Table 1 + 10%?
Sheep & Beef	Hill	NNI	Table 1 + 10%?
Sheep & Beef	Hill	SNI	Table 1 + 10%?
Sheep & Beef	Hill	SI	Table 1 + 10%?
Sheep & Beef	High	NNI	Table 1 + 10%?
Sheep & Beef	High	SNI	Table 1 + 10%?
Sheep & Beef	High	SI	Table 1 + 10%?
Deer	Deer	NNI	Table 1 + 10%?
Deer	Deer	SNI	Table 1 + 10%?
Deer	Deer	SI	Table 1 + 10%?

Table D-3: Input tables for the effectiveness of the stream fencing + riparian planting + FDE management mitigations to dairy farms..

Land use	Sub-land use	Mitigation effectiveness	Mitigation levels already applied
Dairy	Platform	60%?	25%
Dairy	Runoff	0%	-

Questions regarding regional differences.

One of the questions being asked in this analysis is about regional differences in effectiveness of mitigation options. The reality is there is insufficient data on effectiveness from different regions to put into the models. Furthermore, there is the bigger issue in that the current levels of mitigations applied in each region is likely to be different and we have no data on those levels. However, the SPARROW model set up by NIWA will already take into account a number of regional differences such as rainfall, temperature and soil drainage classes.

Appendix E *E. coli* in stormwater and options for urban mitigations

From	**Jennifer Gadd**
To	Annette Semadeni-Davies Sandy Elliot
Date	17 August 2017

Introduction

This memo outlines the methods used to develop yields for *E. coli* in urban areas, and the potential effect of various mitigation measures, for use in the MfE swimmability project.

Derivation of urban yields

E. coli data from urban streams was collated in an existing dataset, comprised of sites in Auckland, Wellington and Christchurch. Only sites with more than 15% urban land cover (based on LCDB4) in their upstream catchment were included, following Larned et al. (2016). The stream sites were then categorised as either stormwater, wastewater-affected, wildfowl-affected or rural-affected. Sites were put in the wastewater category if they had known inputs of wastewater, either from overflows (from either combined or separated wastewater systems), or from illegal cross-connections. Wildfowl influences were based on the presence of an upstream lake known for wildfowl, or from faecal source tracking studies that had identified wildfowl as the major source. Sites were put into the rural category if there were large areas of rural land use. The remaining sites were classified as stormwater.

For Auckland, this categorisation was based on information in Watercare's Network Discharge Consent Application Documents and the Central Interceptor Application Documents. For Wellington, the categorisation was based on experience (Juliet Milne) and where possible, information provided by Wellington Water Ltd. For Christchurch, no local information could be provided in time, so the categorisation was made based on publicly available reports on wastewater overflow locations, and from aerial photographs to identify major rural areas.

E. coli data from monthly monitoring over the period from January 2013 to December 2015 was used in the assessment. The median *E. coli* concentrations over this period were calculated for each site. The median flow for each monitoring site was obtained from the NZ River Maps tool, as most of the water quality monitoring sites do not have associated flow monitoring. The median load at each site was calculated from the median concentration multiplied by the median flow. This was converted to an annual load, by multiplying by 60 x 60 x 24 x 365.25. The annual load was then converted to an annual yield by dividing by the catchment area obtained by GIS analysis.

These yields (Table E-1 and Table E-2) are an order of magnitude lower than the yields for urban areas generated by Sparrow runs at low flows and 2 orders of magnitude lower than the yields in CLUES. The difference is probably due to two reasons:

- The yields generated in this memo are for baseflow (median concentrations and median flows, excludes the high concentrations that are released at high flows);
- The yields account for attenuation in the stream and between source and stream, as they are based on stream data rather than land-based source data.

If the MfE model is to be run with in-stream attenuation, then these yields should not be used as the calculated in-stream concentrations will be incorrectly low.

Table E-1: Representative concentrations and yields of *E. coli* from urban sources.

Category	No. of sites	Mean of median *E. coli* (No./100mL)	Mean annual yield *E. coli* (Peta / km^2/ yr)
Stormwater	13	437	0.0010
Stormwater and rural sources	11	439	0.0007
Stormwater with wastewater sources	20	815	0.0019
Wildfowl	9	361	0.0007

Table E-2: Comparison of *E. coli* yields derived in this memo with other estimates.

Source	Mean annual yield *E. coli* (Peta / km^2/ yr)	Comment
Stormwater – this memo	0.0010	Baseflow
Stormwater with wastewater – this memo	0.0019	Baseflow
MPI / MfE project – Sparrow run	0.014	Baseflow
CLUES - urban	0.147	All flows
Porirua - urban	0.080	All flows

The relative effect of wastewater inputs on urban yields may be of use for this project. The yield for wastewater-influenced urban areas is 1.9 times higher than the yield for urban areas without wastewater influences.

Mitigations

The following mitigations have been reviewed to assess their potential for reducing *E. coli* counts in urban freshwater during baseflow:

- reducing wastewater inputs (overflows and cross-connections);
- stormwater treatment devices;
- street sweeping and catch-basin cleaning;
- effects of wildfowl removal;
- effects of dog waste removal.

This review was undertaken through searches of journal abstracting services and the internet (for grey literature).

Wastewater inputs

The stream monitoring data reviewed as part of developing the yields suggested that removing wastewater sources could reduce in-stream concentrations to ~50% of original concentrations. Based on monitoring data from Invercargill City (MWH 2016), where there are dry weather leakages and cross-connections of wastewater, there can be very high counts in the stream, such as over 10,000 *E. coli*/100ml. In such locations, much larger reductions can be expected, perhaps up to 95%. However, these reductions are most likely to occur only in some specific locations, e.g., just downstream of the outfall and are not expected to be catchment-wide. Therefore, a percentage removal of 50% seems reasonable.

There are several studies internationally discussing reductions in *E. coli* or other indicator bacteria due to removal of wastewater inputs and some suggest around 95-99% removal rates. However, these are generally rates based on total annual loads and therefore include storm events, which is when the majority of the load from wastewater occurs if it is from overflows.

Stormwater devices

Stormwater treatment devices have the potential to reduce bacteria through a mixture of UV disinfection, filtration and infiltration. The International Stormwater Best Management Practice (BMP) Database is a web-based resource that collates the data from over 600 BMP studies. The most recent review of the data was undertaken this year for data available up to December 2016 (Clary et al. 2017), and the reduction in *E. coli* was included (Table E-3).

Table E-3: Removal of bacteria by stormwater treatment devices. From Clary et al. (2017).

BMP Category	Influent EMC	Effluent EMC	Percentage Removal
Bioretention	1,200	240	80%
Grass swale	3,500	4,400	-26%
Retention pond	2,000	80	96%
Wetland basin	2,800	1,000	64%
Wetland basin / retention pond	2,300	450	80%

Street sweeping and catch-basin cleaning

Street sweeping, and catch-basin cleaning have been suggested as non-structural methods to reduce pollutant loads, including indicator bacteria. There were two studies that looked at these methods in some depth using modelling to estimate reduction (Pitt 1983; Zarriello 2002).

Pitt (1983) used measured faecal coliform yields from various sources (roofs, paved areas, streets) to come up with overall yields of faecal coliforms for different sub-catchments in the Rideau River catchment. Removal rates for bacteria with different street cleaning equipment and frequency was reviewed and the percentage removal for each sub-catchment was estimated. For the case-study catchment (Figure E-1), there was a maximum reduction of 10-30%, depending on the size of the rainfall event, but this requires sweeping approximately 3 times per week (~90 per six months). For sweeping once a week, there would be a maximum of around 10% reduction.

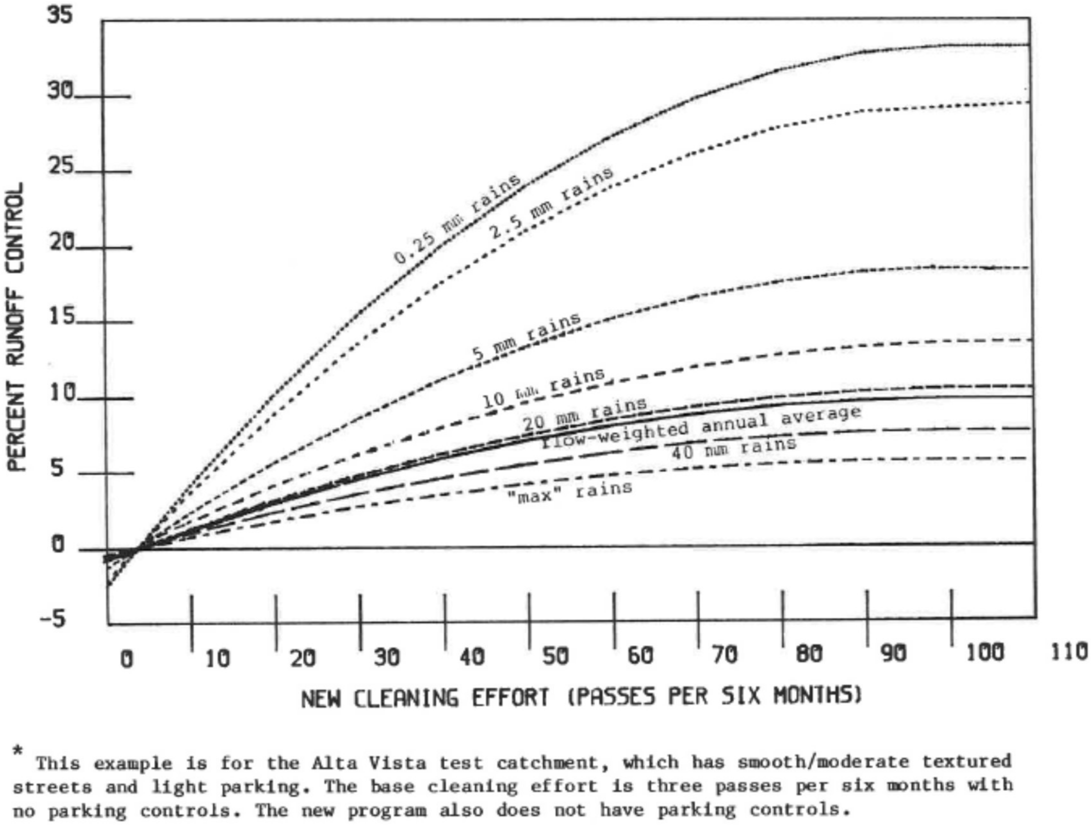

Figure E-1: Potential reduction in faecal coliform bacteria from street sweeping. From Pitt (1983).

The more recent study also modelled removal rates for faecal coliform bacteria based on storm flows only (Zarriello et al. 2002). Under these conditions, there was a less than 5% reduction in faecal coliform bacteria, even with the most efficient street sweeping equipment, with sweeping once per week (Figure E-2). More frequent sweeping provided minimal increased reduction and is unlikely to be feasible or cost-effective.

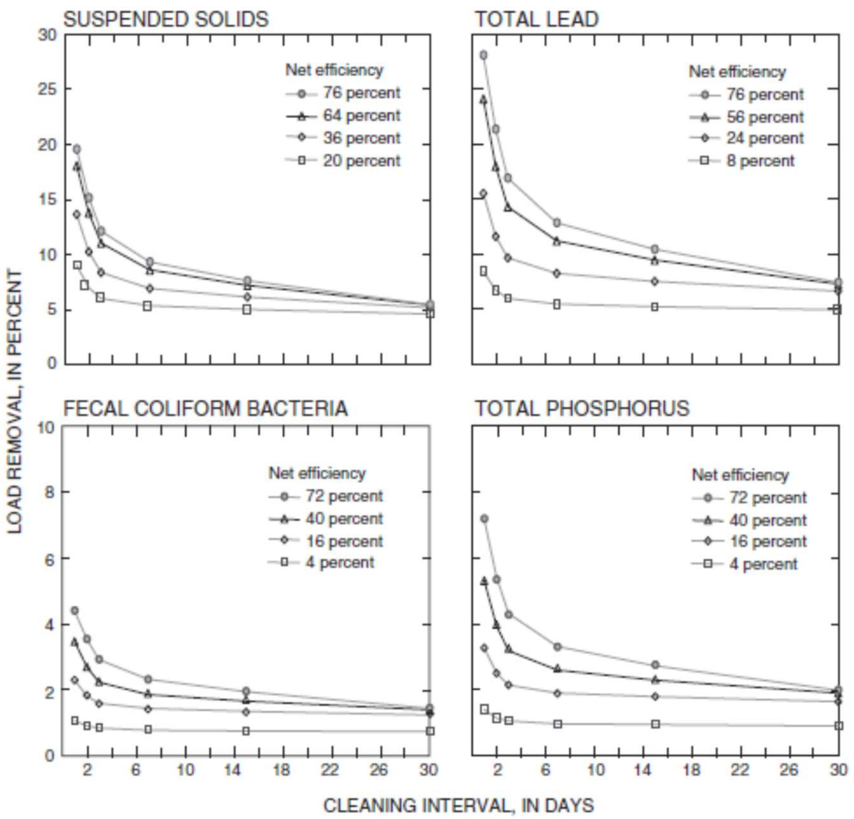

Figure 8. Simulated constituent-load removal for various sweeper efficiencies at selected sweeping intervals in the single-family land-use subbasin, lower Charles River Watershed, Massachusetts, 2000 water year.

Figure E-2: Potential load reduction in faecal coliform bacteria from street sweeping. From Zarriello et al. (2002).

Wildfowl and dogs

The mitigation effectiveness of the reduction in faecal material from wildfowl (predominantly ducks and geese) and dogs depends on their contribution to the total loads in urban areas. Some estimates of these contributions are presented in Table E-4.

The study by Ervin et al. (2014) measured the *E. coli* concentrations in several streams that discharged onto the beach. The major source of faecal bacteria in one of the streams was dogs. An education programme was undertaken to educate pet owners of the effect of dog faeces on the water quality. Before the programme, the median *E. coli* counts were ~200 MPN/100ml and after the programme the median concentrations were ~100 MPN/100ml, suggesting that the bacteria counts can be reduced to 50% where dogs are a dominant source.

Methods to reduce bird numbers include installing nets or bird spikes on the underside of bridges to reduce bird roosting directly above the water; and methods to reduce Canadian geese populations such as nest disturbance or oiling of eggs to prevent hatching. A reduction in bird numbers thereby results in a reduction in faecal material from birds.

Table E-4: Contribution of birds and dogs to bacteria in urban areas.

Location	Contribution	Method of investigation	Reference
Avon River, NZ	Dogs had a large contribution at many sites, especially under wet weather conditions. Under dry weather conditions wildfowl were strong contributors (no % quantification)	PCR	Moriarty & Gilpin (2015)
Onehunga Lagoon, NZ	Dogs were predominant source of *E. coli* for many inflows, particularly during wet weather	PCR	Walker et al. (2014)
Four Mile River, USA	9% canine sources; 37% waterfowl; 17% human sources	DNA fingerprinting	Simmons et al. (2000)
Rideau River catchment, Canada	Dog contribute 19% of total faecal coliform loads; Pigeons on land contribute 7%; pigeons on bridge contribute 54% and ducks on the river contribute 16%	Estimates from population and faecal content	Pitt (1983)
Wisconsin, USA	Dog faeces accounted for about 12 percent of the total bacteria at the storm-sewer outfall	Not stated	Cited in Zarriello et al. (2002)
Beach in Santa Barbara, USA	Humans, birds and canines major sources	Microbial source tracking	Ervin et al. (2014)

Summary

Table E-5 outlines the mitigation methods and their potential to reduce *E. coli* counts.

Table E-5: Summary of mitigation measures and possible reductions in concentrations / yields.

Mitigation measure	Possible reduction	Comment
Stormwater treatment devices	60-80%	Depending on the type of device, there may be no reduction at all
Removing wastewater overflows and leaks	50%	Based on the difference in concentrations and yields between the wastewater impacted sites and non-wastewater
Street sweeping	< 5% or 10%	Requires at least weekly street cleaning
Removing birds / reducing bird numbers	Up to 50%	Lincoln Urban Pollutant reduction strategies
Removing dog mess / education on dog mess	10-50%	Based on Waye (2000) and Ervin et al (2014). More important during high flows and depends on relative significance of canine as a source
Catchbasin cleaning	<10%	Lincoln Urban Pollutant reduction strategies

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Zarriello P.; Breault R.; Weiskel P. (2002). Potential effects of structural controls and street sweeping on stormwater loads to the Lower Charles River, Massachusetts. Water-Resources Investigations Report 02-4220. United States Department of the Interior, United States Geological Survey.

Appendix F Point source data

Table F-1 gives estimates of annual *E. coli* loads estimated from point source data provided to MfE by regional councils, and NIWA generated estimates of other known sources. Table F-2 gives the default input values that were used to estimate the average *E. coli* discharge concentrations and annual loads from data supplied by the regional councils.

Table F-1: Estimates of *E. coli* annual loads (10^{12} organisms per year) for point sources identified by regional councils.

Region	Point source	REC1 reach ID	Scenario 0	Scenario 1	Reduction (%)
Auckland	Wellsford WWTW	2001055	0.432163	0.432163	0
Auckland	Warkworth WWTW	2001734	0.392511	0	100
Bay of Plenty	AFFCO Rangiuru	4002830	3.3215	3.3215	0
Bay of Plenty	Murupara WWTP	4022385	0.936225	0.936225	0
Bay of Plenty	Tāneatua	4010794	0.174251	0.174251	0
Bay of Plenty	Edgecumbe WWTP	4006554	3.99675	3.99675	0
Bay of Plenty	Te Puke WWTP	4002596	6.57	6.57	0
Bay of Plenty	Fonterra Edgecumbe	4006879	0.313262	0.219284	30
Canterbury	Hanmer Springs	13012766	0.184573	0.184573	0
Canterbury	Hummocks Lake Coleridge	13040971	0.252945	0.252945	0
Canterbury	Hawarden	13024411	0.632363	0.632363	0
Canterbury	Greta Valley	13026345	0.252945	0.252945	0
HBRC	Wairoa District Council CD940404W	8014558	10.13804	7.603527	25
HBRC	AFFCO DP070670Wb	8013530	44.12151	44.12151	0
HBRC	Waipukurau	8013209	14.6	1.46	90
HBRC	Waipawa	8030676	7.1	0.71	90
Horizons	Feilding Meatworks	7036806	21.52413	16.14309	25
Horizons	Awahuri Wastewater Treatment Plant	7038167	0.625676	0	100
Horizons	Bulls Wastewater Treatment Plant	7035710	1.342207	1.342207	0
Horizons	Dannevirke Wastewater Treatment Plant	7036883	0.206219	0	100
Horizons	Eketahuna	7047175	0.412392	0	100
Horizons	Feilding WWTP	7037436	1.947742	0.973871	50
Horizons	Foxton	7042502	2.592548	0	100

Region	Point source	REC1 reach ID	Scenario 0	Scenario 1	Reduction (%)
Horizons	Halcombe Wastewater Treatment Plant	7034546	2.734868	0	100
Horizons	Hunterville Wastewater Treatment Plant	7030743	0.118065	0.118065	0
Horizons	Kimbolton Wastewater Treatment Plant	7033139	0.09855	0	100
Horizons	Mangaweka Wastewater Treatment Plant	7027525	0.508419	0.508419	0
Horizons	Marton Wastewater Treatment Plant	7033767	12.4646	12.4646	0
Horizons	National Park Wastewater Treatment Plant	7008712	0.064029	0.064029	0
Horizons	Norsewood Wastewater Treatment Plant	7033682	0.17658	0.17658	0
Horizons	Ohakune Wastewater Treatment Plant	7016830	0.01602	0.01602	0
Horizons	Ormondville Wastewater Treatment Plant	7034342	0.046538	0.046538	0
Horizons	Pahiatua	7041617	0.357434	0.035743	90
Horizons	Palmerston North Wastewater Treatment Plant	7040210	11.86691	11.86691	0
Horizons	Pongaroa Wastewater Treatment Plant	7044816	0.041537	0.041537	0
Horizons	Raetihi Wastewater Treatment Plant	7017619	2.534509	2.534509	0
Horizons	Rangataua Wastewater Treatment Plant	7017318	1.677869	1.677869	0
Horizons	Ratana Wastewater Treatment Plant	7032364	0.411536	0	100
Horizons	Riverlands Industrial wastewater	7035710	0.391462	0.293596	25

Region	Point source	REC1 reach ID	Scenario 0	Scenario 1	Reduction (%)
Horizons	Rongotea Wastewater Treatment Plant	7038035	0.605296	0	100
Horizons	Sanson Wastewater Treatment Plant	7036362	2.300691	0	100
Horizons	Taihape	7024391	7.336456	7.336456	0
Horizons	Taumarunui	7005367	1.180101	1.180101	0
Horizons	Tokomaru WWTP	7042204	0.121291	0.121291	0
Horizons	Waiouru	7018474	0.019395	0.019395	0
Horizons	Woodville Wastewater Treatment Plant	7039335	0.635915	0.635915	0
Marlborough	Outlet of Seddon Sewage Treatment plant	11023219	0.119777	0.119777	0
Northland	Affco NZ Ltd	1010200	44.12151	44.12151	0
Northland	Kawakawa WWTP	1009625	0.88476	0.88476	0
Northland	Kaikohe WWTP	1010804	9.667558	9.667558	0
Northland	Kaeo WWTP	1003906	0.096085	0.056402	41
Northland	Taipa WWTP	1002562	4.636482	4.636482	0
Northland	Dargaville WWTP	1022582	0.94374	0.94374	0
Northland	Te Koporu WWTP	1024278	1.145841	1.145841	0
Northland	Kaiwaka WWTP	1026102	1.487317	1.487317	0
Northland	Maungaturoto WWTP	1025525	0.5475	0.05475	90
Northland	Kaitaia WWTP	1004102	12.44489	12.44489	0
Northland	Hikurangi WWTP	1015523	0.305366	0.030537	90
Otago	Alexandra	14039789	12.14136	1.214136	90
Otago	Bannockburn WWTP	14030647	0.318711	0.318711	0
Otago	Cromwell	14029808	10.4871	1.04871	90
Otago	Omakau	14031506	0.632363	0.316181	50
Otago	Ranfurly WWTP	14034973	0.232535	0.232535	0
Otago	Balclutha	14070611	9.910385	0.859501	91
Otago	Clinton	14069681	0.743658	0.371829	50
Otago	Heriot	14062859	0.252945	0.126473	50
Otago	Kaitangata WWTP	14070966	2.048855	1.024427	50
Otago	Lawrence	14063118	0.053698	0.053698	0

Region	Point source	REC1 reach ID	Scenario 0	Scenario 1	Reduction (%)
Otago	Milton	14067846	0.248401	0.124201	50
Otago	Owaka WWTP	14072618	0.822071	0.822071	0
Otago	Stirling WWTP	14070514	1.01178	1.01178	0
Otago	Tapanui	14064004	5.7	2.85	50
Otago	Waihola WWTP	14064699	0.629833	0.314917	50
Otago	Middlemarch WWTP	14049235	0.758835	0.758835	0
Otago	Queenstown /Frankton	14027443	2.92292	0.292292	90
Otago	Moeraki WWTP	14042764	0.054933	0.054933	0
Otago	Oamaru	14026122	0	0	#DIV/0!
Otago	Palmerston	14047610	0	0	#DIV/0!
Southland	Alliance: Lorneville	15057697	6.82	6.82	0
Southland	Alliance: Mataura	15053089	7961.789	7961.789	0
Southland	Mataura WWTP	15054037	3.9347	3.9347	0
Southland	Gore	15050094	51.246	51.246	0
Southland	Waikaka WWTP	15041725	0.099189	0.099189	0
Southland	Nightcaps	15047085	4.07778	4.07778	0
Southland	Tokanui WWTP	15062094	0.695599	0.695599	0
Southland	Gorge Road WWTP	15061101	0.015494	0.015494	0
Southland	Wyndham and Edendale WWTP	15057604	0.9636	0.9636	0
Southland	Balfour WWTP	15038420	114.0233	114.0233	0
Southland	Winton WWTP	15052712	3.28427	3.28427	0
Southland	Browns WWTP	15051292	0.009214	0.009214	0
Southland	Tuatapere WWTP	15052799	0.12709	0.12709	0
Southland	Manapouri oxidation pond	15028200	0.074596	0.074596	0
Southland	Te Anau WWTP	15020633	1.665666	1.665666	0
Southland	Riversdale	15039756	0.425458	0.425458	0
Southland	Ohai WWTP	15044161	0.036333	0.036333	0
Taranaki	Stratford	6008178	66.6	66.6	0
Taranaki	Kaponga	6009745	0.59879	0.59879	0
Taranaki	Waverley	6015843	7.243425	7.243425	0
Tasman	Collingwood wastewater treatment plant	10000596	0.051553	0.051553	0

Region	Point source	REC1 reach ID	Scenario 0	Scenario 1	Reduction (%)
Tasman	Takaka wastewater treatment plant	10002421	0.252059	0.252059	0
Tasman	Tapawera wastewater treatment plant	10014462	0.088846	0.088846	0
Tasman	Murchison wastewater treatment plant	12011296	0.108809	0.108809	0
Tasman	St Arnaud wastewater treatment plant	12010792	0.096963	0.096963	0
Waikato	Hamilton	3016614	743.14	557.355	25
Waikato	Tuakau/PP	3006510	83.95977	62.96983	25
Waikato	Te Awamutu	3022460	49.51098	49.51098	0
Waikato	Cambridge	3020349	78.0735	58.55513	25
Waikato	Te Kuiti	3030722	815.1537	815.1537	0
Waikato	Tokoroa	3027829	0.351249	0.351249	0
Waikato	Huntly	3012631	32.60334	32.60334	0
Waikato	Ngāruawāhia	3014648	78.46187	78.46187	0
Waikato	Otorohanga	3026044	264.3795	264.3795	0
Waikato	Te Kauwhata	3010099	0.839493	0	100
Waikato	Meremere	3007650	5.054056	5.054056	0
Waikato	Kinleith	3032654	1.825	1.825	0
Waikato	Te Rapa dairy	3016182	87.6	51.42138	41
Waikato	Te Awamutu dairy	3022604	0.151148	0.088724	41
Waikato	Horotiu meatworks	3015715	10.25199	10.25199	0
Waikato	Hautapu dairy	3020349	0.567087	0.567087	0
Waikato	Tuakau rendering	3007039	8.056873	8.056873	0
Waikato	Morrinsville	3015051	2.185607	2.185607	0
Waikato	Thames	3004855	23.29862	23.29862	0
Waikato	Te Aroha	3012421	44.94597	44.94597	0
Waikato	Paeroa	3009393	0.670253	0.670253	0
Waikato	Matamata	3018774	11.32604	11.32604	0
Waikato	Waihi	3010378	0.126938	0.126938	0
Waikato	Putaruru	3023358	1.06169	1.06169	0
Waikato	Ngatea	3007167	5.791967	5.791967	0
Waikato	Tirau	3022101	0.016175	0.016175	0

Region	Point source	REC1 reach ID	Scenario 0	Scenario 1	Reduction (%)
Waikato	Kerepehi	3007748	0.471596	0.471596	0
Waikato	Turua	3006257	1.09438	1.09438	0
Waikato	Waihou	3013292	32.96483	32.96483	0
Waikato	Tahuna	3011917	0.361176	0.361176	0
Waikato	Waitakaruru	3005937	0.36113	0.36113	0
Waikato	Waitoa dairy	3014083	0.365	0.365	0
Waikato	Tirau dairy	3022141	0.365	0.365	0
Waikato	Te Aroha meat	3013367	124.0848	124.0848	0
Waikato	Waitoa poultry	3014297	0.03152	0.03152	0
Waikato	Waitoa meatwork	3014540	77.745	0.305357	100
Waikato	Morrinsville dairy	3015245	0.365	0.365	0
Waikato	Tatuanui dairy	3014083	0.365	0.365	0
Waikato	Paeroa meatworks	3010020	0.46894	0.46894	0
Waikato	Waharoa dairy	3017357	0.0146	0.0146	0
Wellington	Paraparaumu Wastewater Treatment plant	9004327	0.078615	0.078615	0
Wellington	Martinborough	9012599	0.206035	0	100
Wellington	Featherston	9010254	5.15088	0.309053	94
West Coast	Contaminants to Water (other than CMA)	12010411	0.929919	0.929919	0
West Coast	Contaminants to Water (other than CMA)	12020164	2.678688	2.678688	0
West Coast	Contaminants to WW	12026261	0.632363	0.632363	0
West Coast	Contaminants to WW	12027966	24.66214	24.66214	0
West Coast	Contaminants to Water (other than CMA)	12028515	975.7676	975.7676	0
West Coast	Contaminants to WW	12033274	0.313262	0.313262	0
West Coast	Contaminants to Water (other than CMA)	12051382	1.092722	1.092722	0

Table F-2: Default input values used to estimate *E. coli* concentrations and loads.

Parameter	Input value	Reference	Notes
Ratio of *E. coli* to faecal coliforms (FC)	0.63 (126/200)	USEPA (1986). Ambient water quality criteria for bacteria Criteria and Standards Division, U S Environmental Protection Agency No. EPA440/5-84-002. 18 p.	
Faecal coliforms after UV treatment	280 cfu/100 ml	Kay, D.; Crowther, J.; Stapleton, C.M.; Wyer, M.D.; Fewtrell, L.; Edwards, A.; Francis, C.A.; McDonald, A.T.; Watkins, J.; Wilkinson, J. (2008). Faecal indicator organism concentrations in sewage and treated effluents. Water Research 42 (1): 442-454.	Limited NZ data gave median of 241 cfu/100 ml
E. coli after UV treatment	176.4 cfu/100 ml		Derived from above data.
Water use per person	200 L/d	ARC (2004). TP58: On-site Wastewater Systems: Design and Management Manual, Third Edition. Auckland Regional Council Technical Publication. http://www.arc.govt.nz/environment/water/wastewater/wastewater-technical-publications-fact-sheets.cfm.	For on-site treatment
Average FC from 2 pond systems	5500 cfu/100 ml	Hickey, C.W.; Quinn, J.M.; Davies-Colley, R.J. (1989). Effluent characteristics of domestic sewage oxidation ponds and their potential impacts on rivers. New Zealand Journal of Marine and Freshwater Research 23: 585–600.	
Average *E. coli* from 2 pond systems	3465 cfu/100 ml	Hickey, C.W.; Quinn, J.M.; Davies-Colley, R.J. (1989). Effluent characteristics of domestic sewage oxidation ponds and their potential impacts on rivers. New Zealand Journal of Marine and Freshwater Research 23: 585–600.	Faecal coliform value x USEPA ratio above.
Average FC from trickling filter	477 cfu/100 ml	Kay, D.; Crowther, J.; Stapleton, C.M.; Wyer, M.D.; Fewtrell, L.; Edwards, A.; Francis, C.A.; McDonald, A.T.; Watkins, J.; Wilkinson, J. (2008). Faecal indicator organism concentrations in sewage and treated effluents. Water Research 42 (1): 442-454.	
Average FC from activated sludge	261 cfu/100 ml	Kay, D.; Crowther, J.; Stapleton, C.M.; Wyer, M.D.; Fewtrell, L.; Edwards, A.; Francis, C.A.; McDonald, A.T.; Watkins, J.; Wilkinson, J. (2008). Faecal indicator organism concentrations in sewage and treated effluents. Water Research 42 (1): 442-454.	
Average FC from oxidation ditch	35 cfu/100 ml	Kay, D.; Crowther, J.; Stapleton, C.M.; Wyer, M.D.; Fewtrell, L.; Edwards, A.; Francis, C.A.; McDonald, A.T.; Watkins, J.; Wilkinson, J. (2008). Faecal indicator organism concentrations in sewage and treated effluents. Water Research 42 (1): 442-454.	
Average FC from trickling/ sand filter	11 cfu/100 ml	Kay, D.; Crowther, J.; Stapleton, C.M.; Wyer, M.D.; Fewtrell, L.; Edwards, A.; Francis, C.A.; McDonald, A.T.; Watkins, J.; Wilkinson, J. (2008). Faecal indicator organism concentrations in sewage and treated effluents. Water Research 42 (1): 442-454.	

Average FC from Rotating Biological Contactor	80 cfu/100 ml	Kay, D.; Crowther, J.; Stapleton, C.M.; Wyer, M.D.; Fewtrell, L.; Edwards, A.; Francis, C.A.; McDonald, A.T.; Watkins, J.; Wilkinson, J. (2008). Faecal indicator organism concentrations in sewage and treated effluents. Water Research 42 (1): 442-454.	
Average *E. coli* from secondary treatment	301	This value is derived from Kay et al trickling filter x USEPA ratio. The average of all secondary treatment systems has not been used as this was below the UV treated value, which was implausible.	
Average *E. coli* concentration for NZ meatworks	76381 cfu/1oo ml	Supplied NZ data	From sites which included concentration only
Average *E. coli* load for NZ meatworks	0.0441 x 1015 CFU	Supplied NZ data	From sites which included load only
Average *E. coli* load for NZ dairy factories	0.000313 x 1015 CFU	Supplied NZ data	Derived from 7 sites.

Appendix G Model output tables

This appendix gives the swimmability bands by region for both Scenario 0 and Scenario 1. The outputs are provided as the length of eligible stream reaches (i.e., with a stream order of 4 or more) in each band for each region and as the percentage of the total eligible stream lengths in each region. To be considered suitable for swimming, a stream must be in band A (blue), B (green) or C (Yellow). Shading in the tables refers to the band suitability colour.

Scenario 0 – current state

Table G-1: Length of eligible steams (km) in each swimmability band by region - Scenario 0.

Super region and region		A	B	C	D	E	Total length
NNI	Northland	0	69	337	487	827	1719
NNI	Auckland	0	0	95	60	256	410
NNI	Waikato	605	295	612	764	1810	4086
NNI	Bay of Plenty	892	721	270	79	32	1994
NNI	Gisborne	152	200	860	451	6	1669
SNI	Taranaki	82	101	395	645	246	1469
SNI	Hawke’s Bay	1119	366	420	1027	54	2986
SNI	Manawatu-Whanganui	576	567	998	2036	803	4980
SNI	Wellington	407	137	484	453	95	1576
SI	Tasman	1316	170	58	27	12	1583
SI	Nelson	24	14	2	0	0	40
SI	Marlborough	1204	141	130	14	8	1497
SI	West Coast	2463	743	468	25	12	3710
SI	Canterbury	4581	991	723	716	291	7302
SI	Otago	2136	1050	844	630	481	5141
SI	Southland	1565	479	497	389	1182	4112

Table G-2: Percentage of eligible steams in each swimmability band by region - Scenario 0.

Super region and region		A	B	C	D	E
NNI	Northland	0	4	20	28	48
NNI	Auckland	0	0	23	15	62
NNI	Waikato	15	7	15	19	44
NNI	Bay of Plenty	45	36	14	4	2
NNI	Gisborne	9	12	51	27	0
SNI	Taranaki	6	7	27	44	17
SNI	Hawke's Bay	37	12	14	34	2
SNI	Manawatu-Whanganui	12	11	20	41	16
SNI	Wellington	26	9	31	29	6
SI	Tasman	83	11	4	2	1
SI	Nelson	60	34	6	0	0
SI	Marlborough	80	9	9	1	1
SI	West Coast	66	20	13	1	0
SI	Canterbury	63	14	10	10	4
SI	Otago	42	20	16	12	9
SI	Southland	38	12	12	9	29

Scenario 1 – Future state

Table G-3: Length of eligible steams (km) in each swimmability band by region - Scenario 0.

Super region and region		A	B	C	D	E	Total length
NNI	Northland	3	161	275	685	596	1719
NNI	Auckland	9	68	47	130	156	410
NNI	Waikato	669	417	564	972	1463	4086
NNI	Bay of Plenty	1105	651	152	77	10	1994
NNI	Gisborne	236	492	689	248	5	1669
SNI	Taranaki	159	331	474	464	42	1469
SNI	Hawke’s Bay	1429	383	868	294	13	2986
SNI	Manawatu-Whanganui	894	831	1215	1710	331	4980
SNI	Wellington	455	232	498	323	68	1576
SI	Tasman	1405	112	31	26	9	1583
SI	Nelson	26	14	0	0	0	40
SI	Marlborough	1280	114	83	13	7	1497
SI	West Coast	2804	640	251	12	3	3710
SI	Canterbury	5442	829	493	469	68	7302
SI	Otago	2527	967	754	641	253	5141
SI	Southland	1825	508	433	763	584	4112

Table G-4: Percentage of eligible steams in each swimmability band by region – Scenario 1.

Super region and region		A	B	C	D	E
NNI	Northland	0	9	16	40	35
NNI	Auckland	2	17	12	32	38
NNI	Waikato	16	10	14	24	36
NNI	Bay of Plenty	55	33	8	4	0
NNI	Gisborne	14	29	41	15	0
SNI	Taranaki	11	23	32	32	3
SNI	Hawke's Bay	48	13	29	10	0
SNI	Manawatu-Whanganui	18	17	24	34	7
SNI	Wellington	29	15	32	21	4
SI	Tasman	89	7	2	2	1
SI	Nelson	66	34	1	0	0
SI	Marlborough	86	8	6	1	0
SI	West Coast	76	17	7	0	0
SI	Canterbury	75	11	7	6	1
SI	Otago	49	19	15	12	5
SI	Southland	44	12	11	19	14