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Environmental Assessment of Farm Mitigation Scenarios in Southland

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EXECUTIVE SUMMARY

This report is part of a wider project to assess the impact of the proposed freshwater management reforms on the total economic value of freshwater in the Southland region. It describes an assessment of the water quality outcomes associated with different farm-level mitigation scenarios and evaluates the results in terms of levels of acceptability proposed by the National Objectives Framework (NOF). At the time of completion of this report, a more comprehensive evaluation of water quality in the Southland region was being carried out as part of the Environment Southland's Water Management Strategy (WMS). In particular, a spatially comprehensive assessment of a large number of water quality and condition indicators, was underway as part of identifying water management zones for the interim measures component of the WMS. The results of this assessment will be available by late 2013 and will provide a more thorough and representative picture of water quality in rivers, lakes, estuaries and aquifers in Southland than is provided by this report.

The mitigation scenarios represent a range of potential tools that can be applied on-farm to reduce the contribution of nitrogen, phosphorus and microbiological contaminants (*E. coli*) to freshwater. These water quality variables determine the state of environmental attributes: nitrate toxicity, periphyton (algae) abundance, and human health risk in rivers as well as the trophic status of estuaries (level of nutrients and associated algae abundance). These attributes are currently being considered for inclusion in the proposed NOF. The NOF attributes have associated thresholds of acceptability that comprise four bands: A, B, C and D. The D band defines a proposed "national bottom line", whereas bands A, B and C represent excellent, good and fair environmental conditions respectively. It is beyond the scope of this report to link predicted economic impacts to our findings – these are considered elsewhere.

This report completes the three stage modelling process that can be summarised as follows:

1. NZIER (2013) modelled 20 different farm-level mitigation scenarios that could be implemented in the Southland region. The 20 scenarios were divided into 7 groups (A – G) depending on the outcomes for farm contaminant loss rates.
2. NIWA (2013) modelled catchment loads and concentrations by combining the results from Step 1 (i.e. farm contaminant losses) with contaminant contributions from other sources, to establish contaminant loads at 73 water quality monitoring sites throughout the region's river systems. The model evaluated predicted annual loads and concentrations for 73 sites for 2012 (Baseline 2012 scenario) and in 25 years under the existing policy regimes (Baseline 2037 scenario), plus the 20 farm-level mitigation scenarios. In addition to this, the model was used to estimate the annual load of nitrogen for each of the nine estuaries in the Southland region.
3. This report assesses the environmental outcomes resulting from the water quality predictions resulting from NZIER's and NIWA's models (Steps 1 and 2). We converted the predicted river water quality to NOF attributes for each of the 73 river sites and nine estuaries for all scenarios and compared these to the acceptability thresholds (bands) proposed for the NOF. In addition, we evaluated the "reference state" (i.e. water quality in the absence of human pressures) as a means of assessing the suitability of the proposed NOF bands. We anticipated that all sites would comply with the "A" band (i.e. excellent outcome) when water quality was in the reference condition.

The performance of each scenario is summarised below by attribute, relative to the proposed NOF thresholds of acceptability. Results are presented as aggregations across the region. The predicted *E. coli* values for the mitigation scenarios indicate small improvements in meeting the proposed NOF bottom line compared to the Baseline 2012 scenario. Baseline 2012 levels suggest that 7% of sites could be below the NOF bottom line for *E. coli*. These levels are expected to improve to 0–4% of sites under the mitigation scenarios. The predicted nitrate toxicity values for the mitigation scenarios indicated small improvements in meeting the proposed NOF bottom line compared to the Baseline 2037 scenario. None of the scenarios predicted levels below the nitrate toxicity NOF bottom line. Baseline 2037 levels suggest that 8% of sites could be in the NOF "fair" category. These levels are expected to be between 0–8% of sites under the mitigation scenarios. The predicted periphyton levels for the mitigation scenarios indicated small improvements in outcomes for periphyton compared to both the Baseline 2012 and 2037 scenarios. None of the scenarios predicted levels below the periphyton NOF bottom line. Baseline 2037 levels suggest that 33% of sites could be in the NOF "fair" category. These levels are expected to improve to 8–22% of sites under the mitigation scenarios.

The results for all three river water quality attributes indicated that the current level of water quality would be maintained or improved in the future under nearly all the mitigation scenarios, with improvements increasing as mitigation becomes more stringent. However, at the regional level, these improvements are not large, as mitigation measures mainly impact dairy farming, which currently makes up only 17% of the region's agricultural land use and is only projected to increase to 28% by 2037.

The assessment of river water quality across the region that is based on the aggregate results is likely to be pessimistic because lowland pasture sites, a river category which has the most degraded water quality in the Southland region, is over-represented by the 73 modelled sites. In addition, the regional assessment of improvements in water quality resulting from mitigation are likely to be optimistic because water quality at the over-represented lowland pasture river category is more likely to be improved by mitigation than other categories.

Reference state results for the nine estuaries indicate that five fall within bands B or C, whereas we would expect these results to place all the estuaries in band A. This suggests the currently proposed NOF thresholds for estuaries may be too conservative. An alternative set of thresholds developed by Wriggle Coastal Management for Environment Southland produced reference state outcomes for which only two estuaries fell within the "poor" condition. For the Baseline 2012 results, six out of nine estuaries were in the NOF band D (i.e. below the bottom line). Only one estuary showed any improvement in terms of the grading bands under the mitigation scenarios. Wriggle's criteria were even more pessimistic, suggesting that all but one estuary had unacceptable water quality under both Baseline 2012 and Baseline 2037 scenarios. When considering the future mitigation scenarios, only one estuary improved using the NOF thresholds and two estuaries improved using the Wriggle criteria. The results suggest that the modelled mitigation measures do not significantly improve compliance with the NOF estuary objectives. We note that even the most stringent of the mitigation scenarios, which precludes dairy farming from the region, is unable to ensure that the region's estuaries are above the proposed NOF bottom line.

Dicyandiamide (DCD) is a chemical nitrification inhibitor that is a possible option for mitigating nitrogen discharge. DCD was not initially included as an option in this study because of potential trade concerns that arose in 2012. Subsequently, DCD has been included as a mitigation option. The NZIER (2013) study found that DCD is an effective mitigation option that can lower the cost of meeting the environmental objectives specified under the scenarios. The complete results for all mitigation scenarios that included DCD are provided in Appendix D of this report. In general terms, compliance with NOF thresholds for tools that included DCD were very similar to those that did not include DCD. This is because the scenarios were generally based on achieving specified nutrient caps; DCD simply provides another way of complying with the cap. The economic implications associated with the option of DCD are not the topic of this report and is discussed in the NZIER (2013) report.

There are three principal limitations to consider when reviewing the results of this report:

1. Uncertainties present in the NZIER and NIWA models inevitably impact upon this report – our results are subject to the limitations of these models.
2. Our results are based on proposed NOF attributes and associated thresholds, which are likely to be revised before being adopted.
3. The certainty of the model for evaluating periphyton abundance is limited by available data. In addition, in applying the model, we assumed that all sites are suitable for periphyton. However, not all rivers and streams have suitable habitats for periphyton growth.

We conclude that existing river quality in Southland achieves a high level of attainment against the proposed NOF attributes. The results indicate that the current level of water quality would be maintained or improved in the future under nearly all the mitigation scenarios, with improvements increasing as mitigation becomes more stringent. However, at the regional level these improvements are not large, as mitigation measures mainly impact dairy farming, which currently makes up only 17% of the region's agricultural land use and is only projected to increase to 28% by 2037.

We conclude that Southland's estuaries are likely to be more sensitive receiving environments than rivers and that contaminant loss from all farming activities in the region (not just dairy farming) has its most marked effect on estuaries. However, there is uncertainty about the degree to which estuaries are failing to meet realistic bottom lines and this study indicates that the currently proposed NOF thresholds may be environmentally conservative. Notwithstanding this caution, the study indicates that eight of the nine estuaries have total nitrogen loads in excess of the proposed NOF bottom-line thresholds. In addition, the study indicates that the mitigation scenarios had a minimal impact on the outcomes for the estuaries. This is consistent with the fact that the mitigation scenarios generally only reduced nitrogen losses from dairy farms and because these represented at most 28% of the region's agricultural land use, the reductions were insufficient to significantly benefit the estuaries.

1 INTRODUCTION

As part of a cost–benefit analysis of a package of measures to reform the management of freshwater in New Zealand, the Ministry for the Environment (MFE) and the Ministry of Primary Industries (MPI) have undertaken an evaluation of the Total Economic Value (TEV) of freshwater to the economy of the Southland region. In addition, the marginal impact to the TEV of changes associated with the proposed freshwater management reforms (MFE, 2013), including the introduction of resource use limits and compliance with the proposed National Objectives Framework (NOF), has been evaluated. Part of this work has been an assessment of the effectiveness and economic impacts of water quality mitigation measures undertaken by farms in Southland. The mitigation measures are aimed at reducing the contribution to freshwater of nitrogen, phosphorus and microbes from individual farms.

This report broadly describes the modelling steps undertaken to evaluate the water quality outcomes of a series of farm-level mitigation scenarios. A series of scenarios were assessed whereby farms reduce their loss rates of nitrogen, phosphorus and microbes to by increasing amounts. The environmental assessment has compared the water quality outcomes for the rivers and estuaries of Southland to a set of attributes that are currently being considered for inclusion in a proposed NOF.

The report details how the water quality outcomes were assessed in terms of the proposed NOF attributes. The results are discussed in terms of possible thresholds of acceptability (bands) that are being considered for a proposed NOF. When linked to the economic measures associated with the farm mitigations, the component studies will provide the basis for an assessment of the impact of resource use limits and the NOF on both the economy and surface water quality of the Southland region. It is beyond the scope of this report to link the results to any economic measures; economic implications are considered elsewhere.

2 BACKGROUND

The package of measures to reform the management of freshwater in New Zealand includes a proposal to limit water resource use to levels at which environmental outcomes will meet at least a minimum acceptable level. An important link between the desired environmental outcome and the resource use limit is the management objective, which is based on community values. The word “objective” is used in several Resource Management Act (RMA) instruments (national policy statements, national environmental standards, regional policy statements and regional plans) to describe the intended outcomes for each of those instruments. Broadly, environmental management objectives under the RMA are concerned with maintaining or improving environmental values such as human health, ecosystem health, and recreational and aesthetic values (Norton *et al*, 2010).

Objectives may be expressed at different levels of detail or precision, and this determines the extent to which the intended outcome is left open to interpretation (Norton *et al*, 2010). Thus, objectives can range from broad narrative objectives (e.g. suitable for recreation) to tight narrative objectives (e.g. swimmable) to numeric objectives (e.g. water clarity of 1.6 metres visibility and riverbed periphyton (algae) cover of less than 30% are often deemed as environmental states that are suitable for swimming). The specific environmental states that are associated with objectives, such as the water clarity and algae values in the previous example, are termed "attributes". From a scientific perspective, it is most helpful for management when objectives include measurable attributes (preferably numeric) and a value, or range of values, so that the acceptable environmental state is rigorously defined.

The reform of freshwater management in New Zealand includes a proposal for a National Objectives Framework (NOF). The purpose of the NOF is to define some nationally applicable objectives that would provide a basis for limiting resource use to levels that sustain environmental values. The NOF proposes a graduated range of acceptable numeric thresholds for attributes associated with the objectives that define bands denoted as A, B, C and D. These bands express the extent to which values are supported, including human health, ecosystem health, and recreational and aesthetic values. The NOF proposes a threshold for minimum acceptability (the "bottom line") at the bottom of the "C" band. Therefore "D" is considered to represent an unacceptable outcome, "C" is acceptable but only fair and B and A are viewed as good and excellent outcomes respectively.

This study used possible objectives, attributes and bands that are currently under consideration by the NOF. This is an on-going process and the variables and bands used here are likely to change before they are adopted.

3 METHODS

3.1 Approach to Assessment

Arguably, an ideal approach to assessing water quality limits would start by defining the desired outcomes in the receiving environments and determining the resource use limits that would achieve this. This approach is technically difficult from a scientific perspective, partly because there are many ways that catchment land use and land management could be organised to meet a desired water quality outcome presenting an almost infinite set of modelling scenarios. The approach used in this study was to work from the "source to receiving environment" in three steps.

The first step modelled the impacts of a range of farm-level mitigation scenarios that could be implemented in Southland using regulatory or non-regulatory tools. This work was undertaken by NZIER (2013) using multi-agent simulation modelling. The outputs described the economic costs and the loss rates for two key nutrients, total nitrogen (TN) and total phosphorus (TP), for all (~3000) farms in Southland for the current ("Baseline") policy settings and a range of 20 "tools" (Table 1). Tools 1 to 16 were based on requiring uniform nutrient "caps" (i.e. specified maximum allowable loss rates for TN and TP per hectare). Because the cap for a particular nutrient generally constrained the outcome, the farm-level mitigation tools have been grouped into five sets of outcome scenarios, labelled A to E. Tools 17, 18 and 19 (scenario F) were based on non-uniform caps and Tool 20 (scenario G) mandated mitigation measures that applied to all farms (NZIER 2013). We refer to these farm-level mitigation scenarios hereafter as "scenarios". This modelling work also produced information that allowed the loss of *Escherichia coli* (*E. coli*) to be estimated from farms at the next step (for details see NIWA, 2013).

Table 1: Summary of the 20 farm-level mitigation scenarios. The uniform discharge caps required mitigation to be applied to farms and outcomes were grouped into scenarios A, B, C, D and E based on the mitigation practices that needed to be applied to meet the caps.

Scenario	Farm level tool	N kg/ha	P kg/ha	Type of 'tool'	Dairy practices	Comment
Baseline 2012					No Change	The current situation. Dairy farmland constitutes 17% of the total agricultural area, with sheep/beef and forestry comprising 80% and 3% of the remainder.
Baseline 2037						The situation in 2037, if the current dairy practices and policy settings continue. Dairy farmland constitutes 28% of the total agricultural area, with sheep/beef and forestry comprising 64% and 8% of the remainder.
A	1	60	2	Uniform discharge caps	No change	No change in land use from Baseline 2037 or dairy practices.
	2	60	1.5			
B	3	60	1.0		64% of farms adopt mitigation bundle M2	No change in land use from Baseline 2037, but some change in dairy practices.
	5	45	2.0			
	6	45	1.5			
	7	45	1.0			
C	4	60	0.5		All farms adopt mitigation bundle M2	Some land use change from Baseline 2037 – dairy farmland decreases to 20% of the total agricultural area, sheep/beef increases to 73%, and forestry remains about the same (7%). Change in dairy practices to middle mitigation option.
	8	45	0.5			
D	9	30	2.0		All farms adopt mitigation bundle M3	Land use change as for Tool Set C. Change in dairy practices to highest mitigation option.
	10	30	1.5			
	11	30	1.0			
	12	30	0.5			
E	13	15	2.0		Dairying unable to comply with discharge caps	Change in land use away from dairy. Sheep/beef and forestry constitute 88% and 12% of the total agricultural area respectively.
	14	15	1.5			
	15	15	1.0			
	16	15	0.5			
F	17			Non-uniform discharge caps		No change in land use from Baseline 2037.
	18					
	19					No change in land use from Baseline 2012.
G	20			Mandated farm practices	All farms adopt mitigation bundle M3.	No change in land use from Baseline 2037. All sheep/beef farms also adopt mitigation bundle M3.

The second step modelled catchment loads and concentrations by combining the modelled farm losses with other catchment contaminant contributions, both natural and human derived, and accumulated these down the region's river systems (river networks). This work was undertaken by NIWA (2013). The catchment model estimated the annual loads of *E. coli*, TN and TP at 73 long-term State of Environment (SOE) river monitoring sites in Southland (Figure 1). The catchment model was calibrated to the observed loads at these 73 sites. The farm losses estimated by the NZIER model were then used as input to the NIWA model. The NIWA modelling predicted loads for the 73 SOE sites for the Baseline scenario in 2012 and 25 years in the future in 2037 and for the 20 policy scenarios in 2037. The annual loads for all scenarios were used to calculate the corresponding median concentrations of *E. coli*, TN and TP plus nutrient species of nitrogen and phosphorus, including dissolved inorganic nitrogen (DIN), nitrate (NO_3N) and dissolved reactive phosphorus (DRP) at the 73 SOE sites. These concentrations were calculated based on the assumption that the observed ratio of the annual load to the concentrations would be preserved for all scenarios (NIWA, 2013). The catchment modelling was also used to estimate the annual load of TN for each of 9 estuaries in the Southland region (Figure 2). We note that NIWA (2013) have discussed various sources of uncertainty and assumptions that were associated with the catchment modelling step. These uncertainties are therefore inherent in the subsequent modelling that is the subject of this report, because these analyses used the NIWA (2013) results.

The third step, which is the subject of this report, comprises the assessment of environmental outcomes for water quality. This step uses the predicted river water quality (concentrations of *E. coli* and nutrients at the 73 SOE sites) and predicted estuary water quality (annual loads) to evaluate performance against some of the objectives that are currently under consideration as part of the proposed National Objectives Framework (NOF). These objectives concern human health, aquatic ecosystem health and recreation and aesthetic values. For most of the objectives assessed by this study, the predicted concentrations or loads could be directly compared with attributes and bands that are currently under consideration as part of the NOF process. For rivers, we converted the concentrations to periphyton biomass (i.e. the amount of algae growing on the bed of rivers) and compared these estimates to the proposed bands for this environmental variable. The environmental assessment also compared the annual load of TN for each of nine estuaries to criteria that have been proposed as part of the NOF process.

In addition to the concentration and loads estimated by NIWA, we estimated concentrations and loads that could be expected in the absence of human pressures. These estimates of "reference state" water quality (i.e. water quality in the absence of human pressures) provided a basis for verifying that the objectives proposed by the NOF would be met under natural conditions and were therefore well-grounded. We used the method of McDowell *et al* (In press) to estimate the reference state median concentrations of the nutrients and *E. coli* at the 73 SOE sites. In addition, the concentrations were combined with predictions of mean flow made by Woods *et al* (2006) to estimate the reference state annual loads of TN and TP to the estuaries. Reference concentrations were converted to loads by multiplying the concentration of each stream or river discharging to an estuary by the total annual volume and summing all streams or rivers for each estuary. This method is likely to underestimate the reference state loads because it does not account for the large component of the total load that may be associated with high flows.

Dicyandiamide (DCD) is a chemical nitrification inhibitor that is a possible option for mitigating nitrogen discharge. DCD was not initially included as an option in this study because of potential trade concerns that arose in 2012. Subsequently, DCD has been included as a mitigation option. We present results of analyses that included DCD in a separate section of the results.

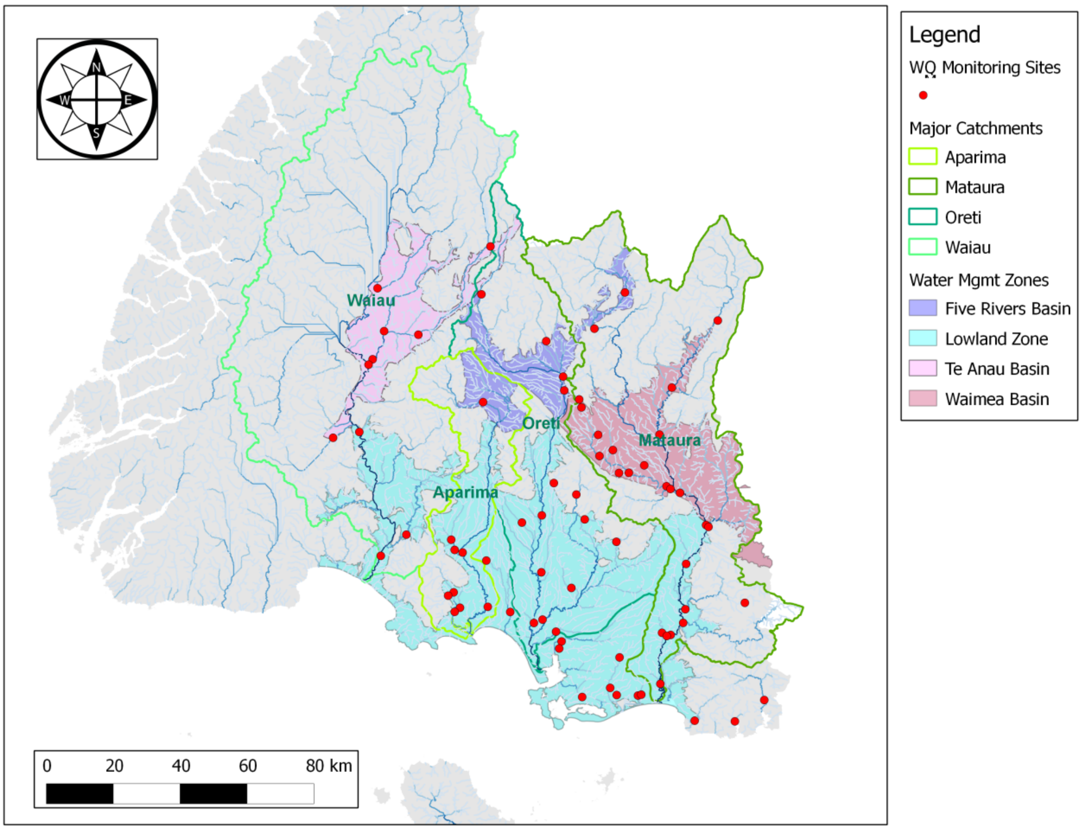


Figure 1: *Location of the 73 SOE river sites for which the loads and concentrations of nutrients and E. coli were estimated and environmental assessments were made. The map also shows the boundary of the four major catchments and the proposed water management zones.*

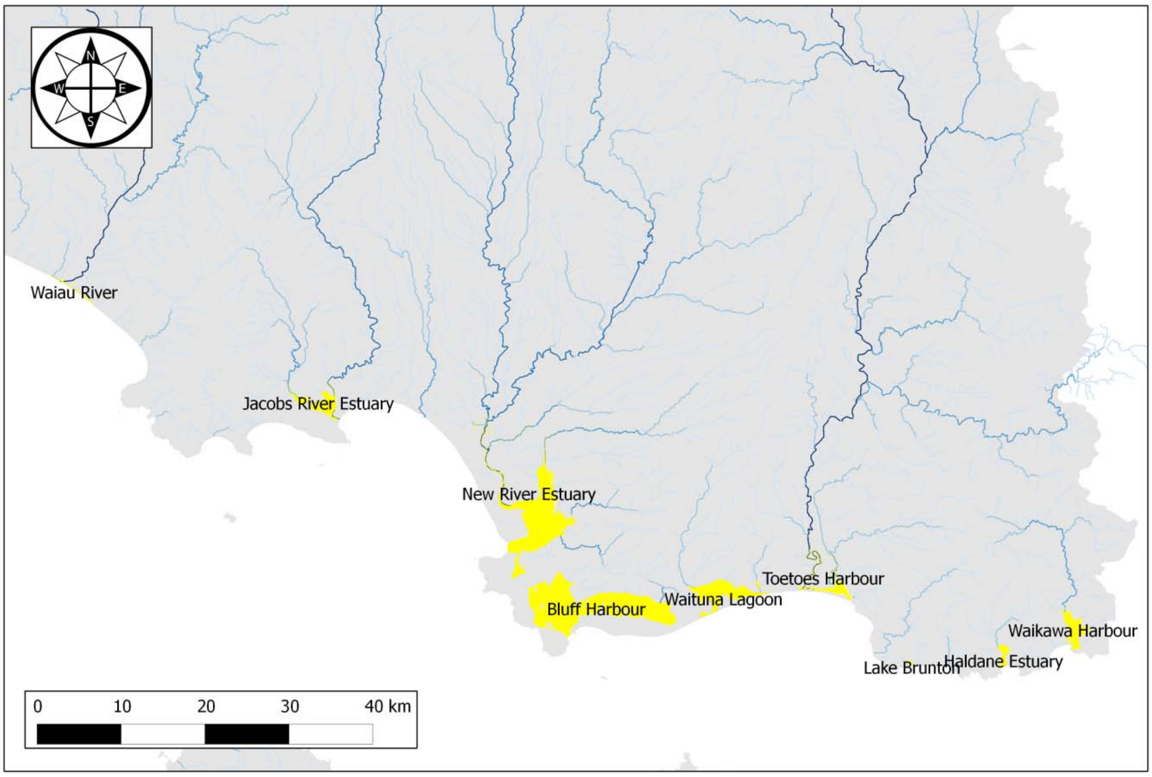


Figure 2: Location of the nine estuaries for which the loads of total nitrogen were estimated and environmental assessments were made.

3.2 Summary of Results by Grouping of Sites and Analysis of Representativeness

We aggregated results for Southland's river SOE sites based on three groupings:

1. the whole region
2. the four major catchments (Mataura, Oreti, Aparima and Waiau; Figure 1)
3. proposed water quality management zones (Lowland and three Inland Basins; Figure 1).

For each grouping, we summarised the results by counting the number of sites in the possible NOF bands (A, B, C and D). Aggregation of the results in this manner has two advantages. First, it allows broad conclusions to be drawn about the consequences under each scenario. Second, the water quality predictions for individual sites are associated with uncertainties; however, as a group, the predictions were strongly correlated with the observations (NIWA, 2013). This means the broad conclusions drawn from the aggregate results can be treated with greater confidence than predictions for individual sites.

However, a disadvantage with drawing conclusions from aggregated data in this way concerns how representative the sites are of regional water quality. For example, if SOE sites were all located in lowland areas under intensive land use, we would draw different conclusions about water quality in Southland than if the sites all represented mountain catchments in natural land cover. To better understand if aggregation of sites provided a reasonable overview of the regional implications of the scenarios, we performed an analysis of the regional representativeness of the network of SOE river monitoring sites, which was designed to identify water quality issues within the region. The purpose was to determine how well the 73 SOE sites represented particular types of catchments for the region's rivers as a whole, and, for exemplary purposes, for two of the proposed water quality management zones (Lowlands and Inland Basins). The analysis therefore considered the actual environmental variability within these groupings based on "river types" and compared this actual variability to the representation of these types by the 73 SOE monitoring sites.

We defined river types by combining two categories of the River Environment Classification (REC); Snelder and Biggs (2002). The REC is based on a digital representation of the New Zealand river network comprising segments with a mean segment length of ~700 m. Each segment is associated with its unique upstream catchment. The REC groups rivers that share similar environmental characteristics and which therefore tend to have similar physical biological and water quality characteristics (Snelder and Biggs, 2002). REC *Topography* and *Land-cover* categories classify rivers according to the dominant topography and land cover of their catchments (Table 2). Such groupings are commonly used to provide insights into the causes of spatial patterns of water quality states and trends in relation to environmental and human factors, and to describe how well a network of sites represents the overall environmental variation within a region (e.g. Ballantine *et al*, 2010).

We first evaluated the proportion of SOE sites in each river type and then compared this with the total number of REC river network segments belonging to each type within the groupings under consideration (i.e. the region as a whole followed by the Lowlands and then the Inland Basin water quality management zones). The implicit assumption here was that the number of segments (or approximately the length of the river) is an appropriate weighting of a river type's 'representativeness'. This assessment, therefore, provides an indication of how representative the SOE sites are of these groupings in relation to river length for various river types. We acknowledge there are other physically and ecologically meaningful ways of both defining river types and assessing representation rather than by the number of segments (e.g. by flow or riverbed area) that also could have been used. We used the method described here as it involves the fewest sources of error and because it is consistent with previous studies (e.g., NIWA, 2010).

Table 2: REC Topography *and* Land-cover *categories used to define the river types used by the representativeness analysis. The criteria used to define each are shown (see Snelder and Biggs, 2002 for details).*

Category Grouping	Category	Symbol	Criteria
Topography	Low-elevation	L	Majority of catchment draining land lower than 400 m
	Hill	H	Majority of catchment draining land between 400 and 1000 m
	Mountain	M	Majority of catchment draining land greater than 1000 m
	Glacial Mountain	GM	More than 2 per cent of catchment covered by glacier
	Lake	Lk	Flow strongly influenced by upstream lakes
Land-cover	Urban	U	The spatially dominant land-cover category unless P exceeds 25 per cent of catchment area, in which case category = P, or unless U exceed 15 per cent of catchment area, in which case category = U.
	Pasture	P	
	Exotic Forest	EF	
	Scrub	S	
	Indigenous Forest	IF	
	Tussock	T	
	Wetland	W	

The river types that were most common (by REC segment) in Southland as a whole were low-elevation pasture and hill indigenous forest, followed by mountain tussock, low-elevation indigenous forest and hill tussock (Table 3). The analysis of representativeness indicated that the river SOE sites (i.e. the sites for which the water quality assessments were made) over-represented some of these river types and under-represented others (Table 3). This is an expected outcome because SOE networks are often concentrated in locations where there is significant human pressure and are not necessarily aiming to be a representative sample of the region. Taken over the region as a whole, the SOE sites over-represented the low-elevation pasture, hill pasture, lake indigenous forest and low-elevation wetland types outside of the national parks. The SOE sites under-represented the mountain tussock, hill indigenous forest, low-elevation indigenous forest and hill tussock types (Table 3). Some river types are not represented by any SOE sites (shown as zero in Table 3), generally because the type represents only a small proportion of the actual river network.

Studies, both in Southland and nationally, have shown that the low-elevation pasture type has the poorest water quality (NIWA, 2010). Low-elevation pasture environments make up a significant part of the Southland region and are also likely to be subject to high-intensity land use, in particular dairy farming, and are expected to be strongly affected by the mitigation scenarios. As a result, the aggregate results (i.e for low-elevation pasture sites) are likely to be pessimistic in terms of overall regional water quality (i.e. regional average water quality is likely to be better in reality than that represented by the SOE sites) and optimistic in terms of the benefits of mitigation (i.e. mitigation is unlikely to improve water quality regionally to the extent represented by the SOE sites). However, this situation is not necessarily the case for the aggregate results within either the management zones or the river catchments.

Table 3: Proportion (%) of river segments and SOE water quality monitoring sites (shown in brackets) belonging to each river type in Southland. The types are defined by the REC Topography *and* Land-cover *categories. Shading reflects the degree of difference between the proportion of SOE sites in each type versus the proportion of the actual river network (red = over-represented, green = under-represented by the SOE sites). NA indicates that the type does not occur within the region.*

		Landcover								
		Indigenous Forest	Scrub	Tussock	Bare	Misc.	Pasture	Wetland	Exotic Forest	Urban
Topography	Low elevation	9.9 (6.8)	2.8 (0)	0.4 (0)	0 (0)	0 (0)	25.6 (56.2)	0.2 (2.7)	0.9 (0)	0.3 (1.4)
	Hill	20.2 (4.1)	2.1 (0)	8.3 (5.5)	0.2 (0)	NA	5.1 (13.7)	0 (0)	0.6 (1.4)	NA
	Mountain	1.5 (0)	0.2 (0)	12.4 (1.4)	2.5 (0)	NA	0 (0)	NA	0 (0)	NA
	Glacial Mountain	0.1 (0)	NA	0.4 (0)	1.3 (0)	NA	NA	NA	NA	NA
	Lake	3.1 (5.5)	0.1 (0)	0.7 (1.4)	0.1 (0)	0.9 (0)	0.1 (0)	NA	NA	0 (0)

The river types that were most common (by REC segment) in the Lowland water quality management zone were low-elevation pasture and low-elevation indigenous forest followed by low-elevation exotic forest (Table 4). Within the Lowland water quality management zone, the SOE sites over-represent the low-elevation indigenous forest, hill pasture and lake indigenous forest, and under-represent the low-elevation pasture (Table 4). Assuming the low-elevation pasture type has the poorest water quality and is subject to high-intensity land use, this result suggests that the aggregate results for the Lowland zone may be optimistic in terms of overall water quality and pessimistic in terms of the benefits of mitigation.

Table 4: Proportion (%) of river segments and SOE water quality monitoring sites (shown in brackets) belonging to each river type within the Lowland water quality management zone (see Figure 1). The types are defined by the REC Topography *and* Land-cover *categories. Shading reflects the degree of difference between the proportion of SOE sites in each type versus the proportion of the actual river network (red = over-represented, green = under-represented by the SOE sites). NA indicates that the type does not occur within the zone.*

		Landcover								
		Indigenous Forest	Scrub	Tussock	Bare	Misc.	Pasture	Wetland	Exotic Forest	Urban
Topography	Low elevation	4.5 (10)	2.1 (0)	0.2 (0)	0 (0)	NA	84.5 (70)	1.2 (5)	2.2 (0)	1.6 (2.5)
	Hill	0.2 (0)	0 (0)	0.2 (0)	NA	NA	2 (7.5)	NA	0.2 (0)	NA
	Mountain	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Glacial Mountain	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Lake	1.2 (5)	NA	NA	NA	NA	0.1 (0)	NA	NA	NA

The river types that were most common (by REC segment) in the Inland Basins water quality management zone (a combination of the Te Anau, Five Rivers and Waimea Basins, Figure 1) were low-elevation pasture, hill pasture, hill tussock and hill indigenous forest (

Table 5). As with the Lowland zone, within the Inland Basins water quality management zone the SOE sites over-represented the hill pasture, hill tussock and hill indigenous forest, and under-represented the low-elevation pasture (

Table 5). Assuming the low-elevation pasture type has the poorest water quality and is subject to high-intensity land use, this result suggests that the aggregate results for the Inland Basins zone may also be optimistic in terms of overall water quality and pessimistic in terms of the benefits of mitigation.

Table 5: Proportion (%) of river segments and SOE water quality monitoring sites (shown in brackets) belonging to each river type within the Inland Basins water quality management zone (see Figure 1). The types are defined by the REC topography and land cover categories. Shading reflects the degree of difference between the proportion of SOE sites in each type versus the proportion of the actual river network (red = over-represented, green = under-represented by the SOE sites). NA indicates that the type does not occur within the zone.

		Landcover								
		Indigenous Forest	Scrub	Tussock	Bare	Misc.	Pasture	Wetland	Exotic Forest	Urban
Topography	Low elevation	2.4 (0)	0.5 (0)	0.6 (0)	0 (0)	0 (0)	63 (37.5)	0.4 (0)	0.9 (0)	0.2 (0)
	Hill	5.3 (8.3)	0.5 (0)	5.6 (16.7)	NA	NA	15.5 (25)	0 (0)	0.5 (0)	NA
	Mountain	0.1 (0)	NA	1.7 (0)	0 (0)	NA	0 (0)	NA	NA	NA
	Glacial Mountain	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Lake	1.9 (8.3)	0 (0)	0.2 (4.2)	NA	0.3 (0)	0.2 (0)	NA	NA	0 (0)

3.3 Comparing Water Quality to NOF Objectives

This study took as inputs the water quality predictions made by NIWA (2013) and tested these against numerical thresholds of acceptability for specific attributes that are currently being considered by officials as part of the development of the NOF. These thresholds are under development and are very likely to change. In addition, we had to nominate thresholds for the periphyton biomass attribute for reasons that are discussed below in section 3.3.3 of this report. The results are sensitive to all of the thresholds used here and therefore the possible water quality outcomes should be regarded as indicative and subject to revision.

3.3.1 River Human Health: Microbiological Contamination

The NOF objectives for human health seek to protect people from infection by waterborne pathogens such as the protozoan *Cryptosporidium parvum*. The associated attribute that is proposed by the NOF is the concentration of the indicator bacterium *E. coli*. This microbe is not generally a pathogen itself but the concentration of *E. coli* has been linked through studies to the risk of infection from waterborne pathogens (MFE & MoH, 2003).

The concentration bands proposed by the NOF are for human "secondary contact". Secondary contact implies being in contact with the water but not immersion in it (e.g.

fishing, boating, and wading, but not swimming, which has a more stringent threshold). The bands are defined in terms of the risk of contracting an illness given a secondary contact occasion, and are shown in Table 6.

Table 6: Thresholds that define the NOF bands for E. coli *and the associated risk of infection.*

Thresholds (*E. coli*/100ml)	Band	Infection risk
<260	A	<0.1%
<540	B	0.1-1%
<1000	C	1-5%
>1000	D	>5%

3.3.2 River Ecosystem Health: Nitrate Toxicity

The NOF objectives for ecosystem health seek to support biological communities and ecological processes. An associated attribute that is proposed by the NOF is the concentration of nitrate. Nitrate is toxic to some species when its concentration exceeds specific thresholds.

The concentration bands proposed by the NOF are defined in terms of the proportion of test species that are protected at that concentration (Table 7). These bands are based on the “grading concentrations” provided by Hickey and Martin (2012), which were based on a meta-analysis of nitrate toxicity tests. The bands are based on thresholds for concentration of nitrate, which are compared to the median concentration of nitrate in the water body under consideration.

Table 7: Thresholds that define the NOF bands for nitrate toxicity and the associated proportion of test species that are protected.

Thresholds (mg Nitrate m^{-3})	Band	Species Protected
<1000	A	99%
<2400	B	95%
<6900	C	80%
>6900	D	>80%

3.3.3 River Ecosystem Health: Periphyton

The NOF objectives for ecosystem health seek to support biological communities and ecological processes. A key attribute of rivers with suitable substrate is the abundance of algae growing on the bed. Algae growing on the bed of rivers are known as periphyton and are a primary source of food for invertebrate insects, which in turn are food for fish and birds. The growth of periphyton is determined primarily by light, temperature and the concentration of nitrogen and phosphorus. If nutrient concentrations exceed certain values, the abundance of algae can become excessive. Excessive or ‘nuisance’ growth of periphyton can smother habitat, alter invertebrate communities, and produce adverse fluctuations in dissolved oxygen and pH. Excess periphyton can also cause changes to water colour, odour and the general physical nature of the river bed, which has resultant detrimental effects on aesthetics and human uses of a river (MFE, 2000). We note that not all rivers have suitable physical conditions for the growth of conspicuous periphyton. In particular soft- (i.e. muddy) bottomed lowland streams are often not a suitable habitat for periphyton. In this analysis we were unable to account for this and therefore assumed that periphyton would grow at all SOE sites.

The periphyton abundance bands proposed by the NOF are defined by an index that measures the proportion of the riverbed covered by periphyton. To use these bands in this study we needed to convert the predicted nutrient concentrations to this index. We attempted to use a national scale model of periphyton cover (Snelder *et al*, In press) to estimate the mean annual maximum cover of the bed by periphyton at the 73 SOE sites. However, when we tested the model against periphyton cover observations made by Environment Southland we found the model performed poorly. The reasons for this are unclear but further investigation was beyond the scope of this study.

Environment Southland also monitor the concentration of benthic Chlorophyll-*a*, which is an alternative measure of periphyton abundance. We were able to use this data to develop a predictive model of mean monthly summer-time Chlorophyll-*a* as a function of nutrient concentration (for details see Appendix A). Previous work (e.g. Biggs, 2000; Snelder *et al*, In press), has shown that, apart from nutrient concentrations, hydrological regime (e.g. the magnitude of low flows and the frequency of change in flow) is an important determinant of periphyton abundance. The model developed for the present study included variables that describe the flow regime at sites to maximise the accuracy of the regional predictions. Because flow regimes are spatially variable, the periphyton abundance is a function of both nutrient concentrations and the variables used to describe variation in flow regimes.

The mean annual maximum of benthic Chlorophyll-*a* is used to measure the abundance of periphyton by the New Zealand periphyton guidelines (MFE, 2000). We have adopted thresholds for acceptability based on Chlorophyll-*a* that are presented in this guideline as a basis for developing periphyton bands for this study (Table 8). The model developed from the Environment Southland Chlorophyll-*a* data predicted mean monthly summer-time concentrations, not the mean annual maximum used by the MFE (2000) guidelines. Therefore, we converted the guideline values to mean summer values based on the assumption that Chlorophyll-*a* concentrations observed at a site over time are exponentially distributed. This assumption is based on the finding by Snelder *et al* (In press) that periphyton cover is approximately exponentially distributed. This assumption is untested for Chlorophyll-*a*, but appears reasonable. The Chlorophyll-*a* concentration bands we adopted are shown in Table 8.

Table 8: Periphyton biomass thresholds for mean summer Chlorophyll-a and equivalent mean annual maximum thresholds.

Thresholds *for* mean monthly summer-time Chlorophyll-*a* (mg m^{-2})	**Band**	**Equivalent mean annual maximum threshold Chlorophyll-*a*** *(mg m^{-2})*
<31	*A*	<50
<75	*B*	<100
<124	*C*	<200
>124	*D*	>200

3.4 Estuary Health: Nitrogen Load

The NOF objectives for estuary ecosystem health seek to support biological communities and ecological processes. For estuaries, the load of Total Nitrogen (TN) is a key attribute that determines ecosystem health. We note that the load of sediment entering estuaries is also a key attribute but that there are not currently guidelines for acceptable sediment loads. The load of nitrogen largely determines the trophic state of estuaries and excessive N loading (particularly of inorganic N) can lead to potential estuarine concentrations that will maximise growth of phytoplankton and nuisance macro-algae (i.e. numerous forms of leafy or branching marine algae). This in turn results in detrimental environmental impacts within the estuary, including oxygen depletion, sulphide accumulation, smothering and habitat modification.

The TN loading bands used in the present study are based on expert opinion concerning the relationship between estimated TN loading rates and macro-algal/algal response monitoring data from typical NZ estuaries (*personal communication:* Robertson, 2013; Zeldis, 2013). Two alternate sets of loading rates are shown in Table 9 and Table 10. Table 9 are preliminary loading rates that have been suggested to underpin the NOF. Table 10 shows alternative nitrogen and phosphorus loading rates that were provided to Environment Southland by Wriggle Coastal Management (2012). The Wriggle (2012) loading rates do not specify bands and define only a single threshold above which the estuary is considered to be unacceptably impacted by nutrients (i.e. equivalent to the threshold between bands C and D).

The bands for both sets of nutrient loading rates are specified as areal loading rates (i.e. loads per unit area of the estuary). For both sets of bands the loading rates differ by estuary type. Estuary type discriminates different hydrodynamic conditions and is important because this affects the residence time of water in estuaries and therefore the potential uptake of nutrients by plants. There are three estuary types defined for the Southland Region: Tidal River Estuaries, Tidal Lagoons and intermittently closed and open lagoons/lakes (ICOLLs). Tidal River Estuaries export most of their nutrients to the sea, hence the loading bands nominated for them are relatively high. Tidal Lagoons (mudflat-dominated with large intertidal areas) are unlikely to be light-limited for much of the year because they are shallow. They have large amounts of suitable substrate for macro-algal growth (but may still have short residence times for micro-algal growth). Therefore, the loading rates for Tidal Lagoons are intermediate to the level of the other estuary types. ICOLLs, which are open very infrequently, represent the extreme of eutrophic sensitivity, being shallow (therefore, well lit) and often with high residence times and poor flushing; hence, they are ascribed low loading bands.

The loading rate bands shown in Table 9 and Table 10 were converted to actual loads for each estuary by multiplying the values by the estimated estuary surface areas. The surface areas were obtained from the New Zealand Estuary Environment Classification (EEC) database (Hume *et al* 2007) and were checked using data provided by Robertson and Stevens (2008).

Table 9: Thresholds that define the NOF bands for annual total nitrogen load criteria for estuaries by estuary type. These are preliminary loading rates that have been proposed to underpin the NOF.

Estuary type	**A**	**B**	**C**	**D**
Shallow ICOLL	8	18	38	>38
Shallow tidal lagoon	30	100	200	>200
Shallow tidal river estuary	100	500	1000	>1000

Table 10: Total annual nitrogen and phosphorus load rates by estuary type. These are loading rates proposed by Wriggle (2012).

Estuary type	**TN**	**TP**
Shallow ICOLL	30	1.5
Shallow tidal lagoon	50	NA
Shallow tidal river estuary	750	NA

4 RESULTS

4.1 Rivers

4.1.1 River Human Health: Microbiological Contamination

The analysis of the river human health objective (microbiological contamination: secondary contact) under “reference state” water quality (i.e. water quality in the absence of human pressures) indicated that all SOE sites would be in the A (i.e. excellent) state (Figure 3). The regionally aggregated results for the Baseline 2012 scenario indicated 4 sites (5%) had *E. coli* values in the D category (i.e. below the bottom line) and 6 were in the C (i.e. above the bottom line but only in a fair state). The remaining 62 sites (i.e. 85% of the SOE sites) were in either an A or B category. Results for the Baseline 2037 scenario showed little change to the Baseline 2012 results, with a slight decrease in the number of sites in the D category and increases in sites in the C and A categories (Figure 3). This outcome occurs because the percentage of agricultural land area (either dairy or sheep/beef) was lower for Baseline 2037 (dairy 28%, sheep/beef 65%; total of 93%) than Baseline 2012 (dairy 15%, sheep/beef 82%; total of 97%), and the *E. coli* yields for dairy and sheep/beef were equal (NIWA, 2013). The reduction in sheep/beef area was partly accounted for by forestry, which has very low yields of *E. coli*. The dairy yields for TN and TP are greater than those for sheep/beef, so that the increase in dairy land area for Baseline 2037 leads to greater TN and TP concentrations and loads when compared to the 2012 baseline (NIWA, 2013).

The predicted *E. coli* values for the mitigation scenarios indicated small improvements in meeting the proposed NOF bottom line compared to the Baseline 2012 scenario (Figure 3). The improvements are small because for most scenarios the mitigations have most impact on loss of contaminants from dairy farms, but *E. coli* loss rates from sheep/beef farms are assumed to be equivalent by the NZIER (2013) model; therefore, non-dairy pasture produces a large proportion of the loading, and change in land-use between dairy and non-dairy has little effect. Scenario 20, however, was associated with a large improvement in *E. coli* values across the region (Figure 3). This is because this scenario mandates mitigations to all pastoral farm types within the model and therefore reduces the loads from sheep/beef farming, which represents the dominant source of *E. coli* regionally (NZIER, 2013).

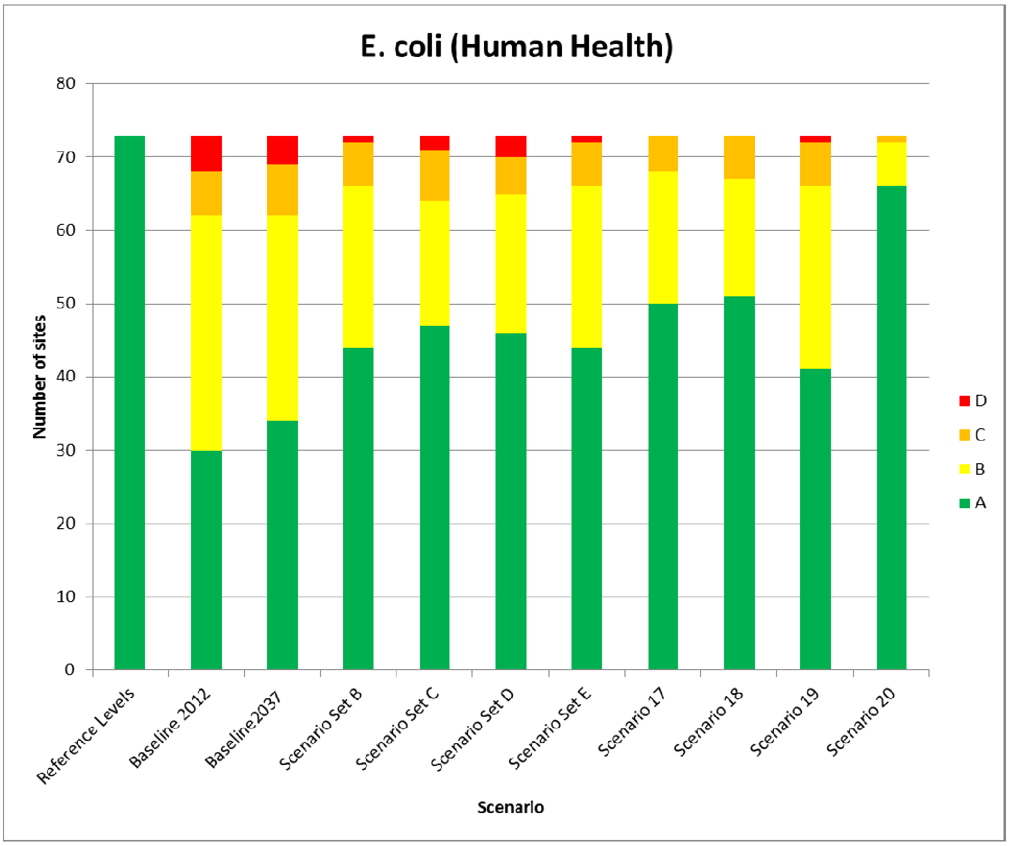


Figure 3: Regionally aggregated results of the analysis the river human health objective based on predicted E. coli *concentrations and proposed NOF bands (see Table 6).*

When aggregated by water quality management zone, the analysis of the river human health objective showed some regional variation in both the existing water quality and the predicted outcomes under the scenarios.

Figure 4 and Figure 5 show exemplary results for the lowland water quality management zone and the Waimea Basin, which is a part of the Inland Basins water quality management zone. The results for these specific groupings contrast to the region as a whole. A complete set of results for all water quality management zones and the four major catchments of the region are appended to this report (Appendix B) and tables and figure are contained within a spread sheet that is associated with this report. In addition, tables for all zones and catchments are appended to this report.

The lowland water quality management zone showed a similar pattern to the regional aggregation for both existing (Baseline 2012) and future outcomes (
Figure 4). This reflects the strong representation of lowland pasture sites in the regional SOE network, which are predominantly the sites that represent the lowland water quality zone. Because the lowland pasture-type sites are under-represented within the Lowland water quality zone (Table 4), this result is probably optimistic in terms of water quality and pessimistic in terms of the benefits of mitigation. In contrast, the Waimea Basin water quality management zone had better water quality (all sites in either the A or B band; Figure 5). The other inland basin water quality management zones had all sites in the A band for all scenarios (see Appended tables B2). Again, because the lowland pasture type sites are under-represented within the Inland Basins water quality zone (

Table 5), this result is probably optimistic in terms of water quality and pessimistic in terms of the benefits of mitigation.

When the *E. coli* results were aggregated by the four major catchments, there were two sites below the bottom line (i.e. in the D band) in the Oreti Catchment, whereas the Matura and Aparima catchments had only one site each in the D band and the Waiau had no sites in the D band (see Appendix B). The pattern of improving water quality (*E. coli* attribute) for the management scenarios relative to the baseline was consistent for all catchments, with the best *E. coli* outcomes occurring for Scenario 20.

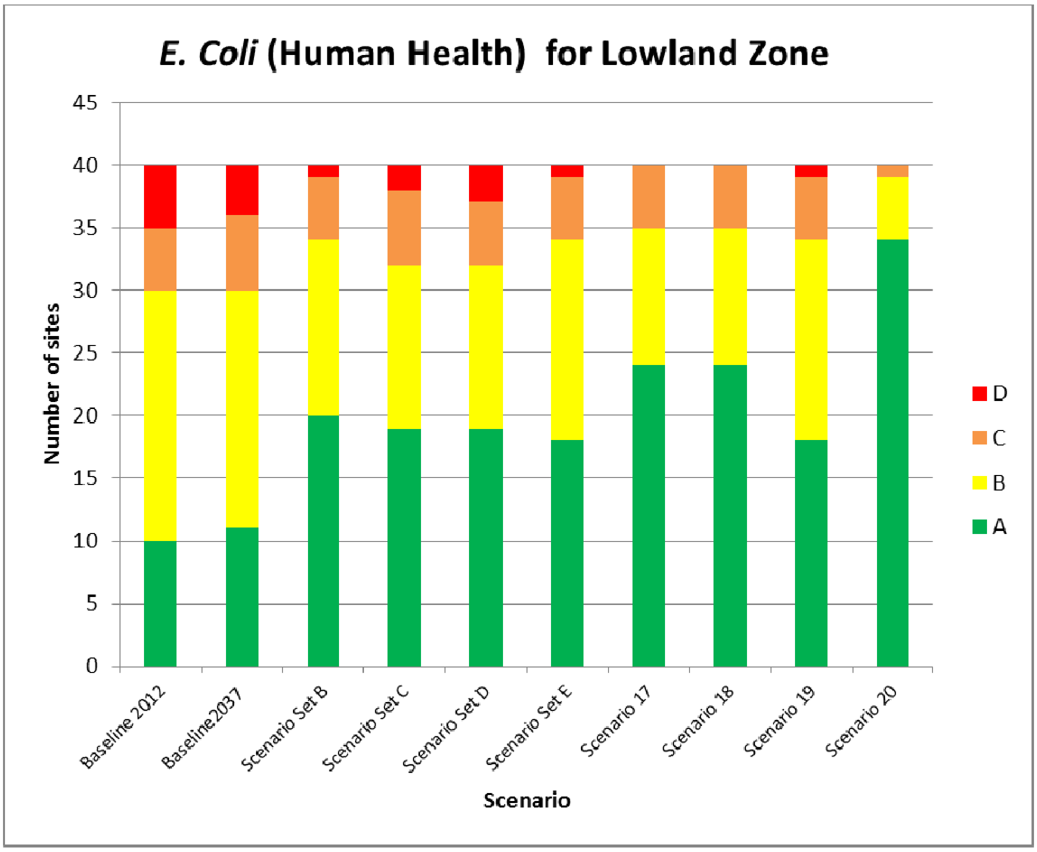


Figure 4: Lowland water quality management zone results of the analysis the river human health objective based on predicted E. coli concentrations and proposed NOF bands (see Table 6).

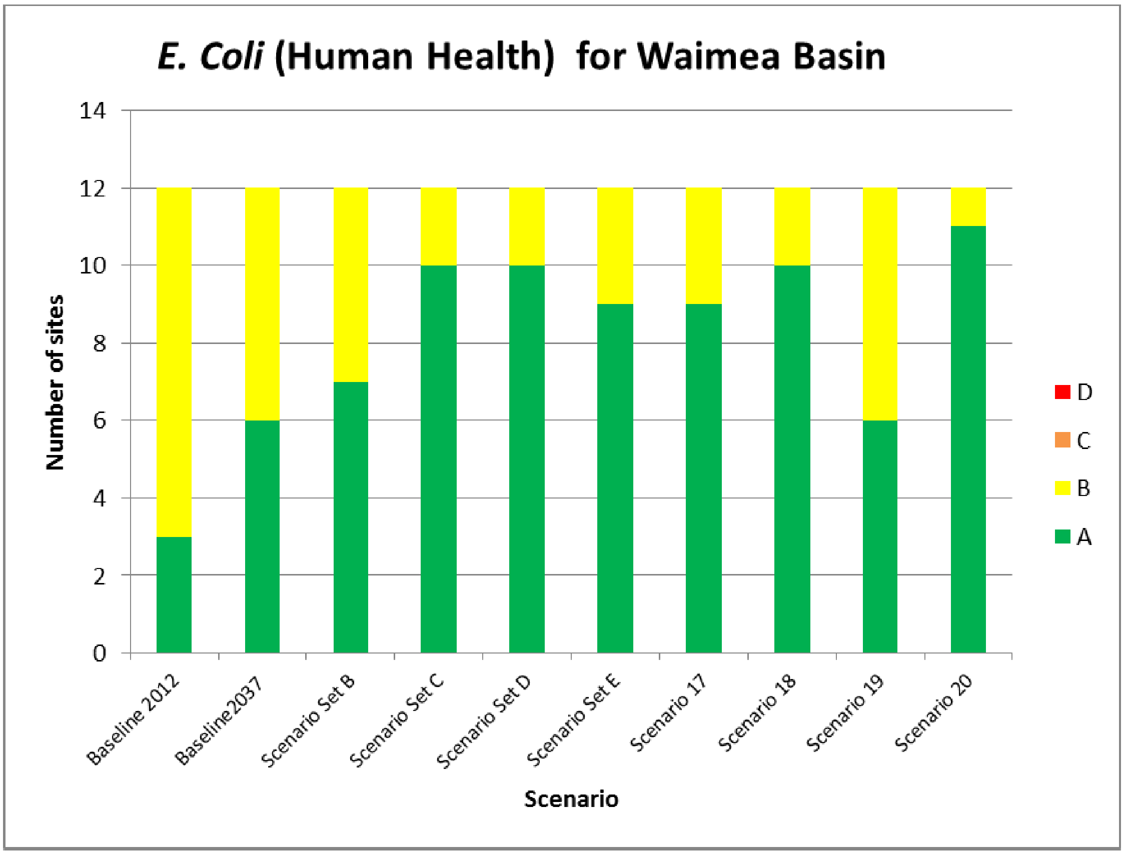


Figure 5: Waimea basin water quality management zone results of the analysis the river human health objective based on predicted E. coli *concentrations and proposed NOF bands (see Table 6).*

In addition to the aggregation by region, Appendix B provides tables of results for the results aggregated by water quality management zone and by catchment.

4.1.2 River Ecosystem Health: Nitrate Toxicity

All SOE sites were predicted to be in the A (i.e. excellent) condition for the river ecosystem health objective (nitrate toxicity attribute) under “reference state” water quality (i.e. water quality in the absence of human pressures) (Figure 6). The regionally aggregated results for the Baseline 2012 scenario indicated that no sites were in the D category, 5 sites (7%) had nitrate concentrations in the C category (i.e. above the bottom line but in only fair condition). Of the remaining sites, 74% and 19% were in the A and B categories respectively.

The regionally aggregated results for nitrate toxicity for the Baseline 2037 scenario showed a general decline in water quality, with an increase in the number of sites in the C and B categories to 8% and 25% respectively and a decrease in sites in the A category (Figure 6). This water quality outcome is expected because the Baseline scenario envisages further intensification of land use with a continued growth in dairying and no change to mitigation practices.

Scenario Set B showed no difference in the river ecosystem health outcome based on nitrate toxicity over the Baseline 2037 scenario and indicated some degradation of water quality relative to the Baseline 2012 scenario. The remaining scenarios indicated an increase in attainment of the river ecosystem health outcome relative to the Baseline 2012 scenario (Figure 6). This suggests that the land use intensification envisaged under these scenarios could occur with improvements in overall water quality outcomes if the mitigation measures were adopted. In addition to the aggregation by region, Appendix B provides tables of results for the results aggregated by water quality management zone and by catchment.

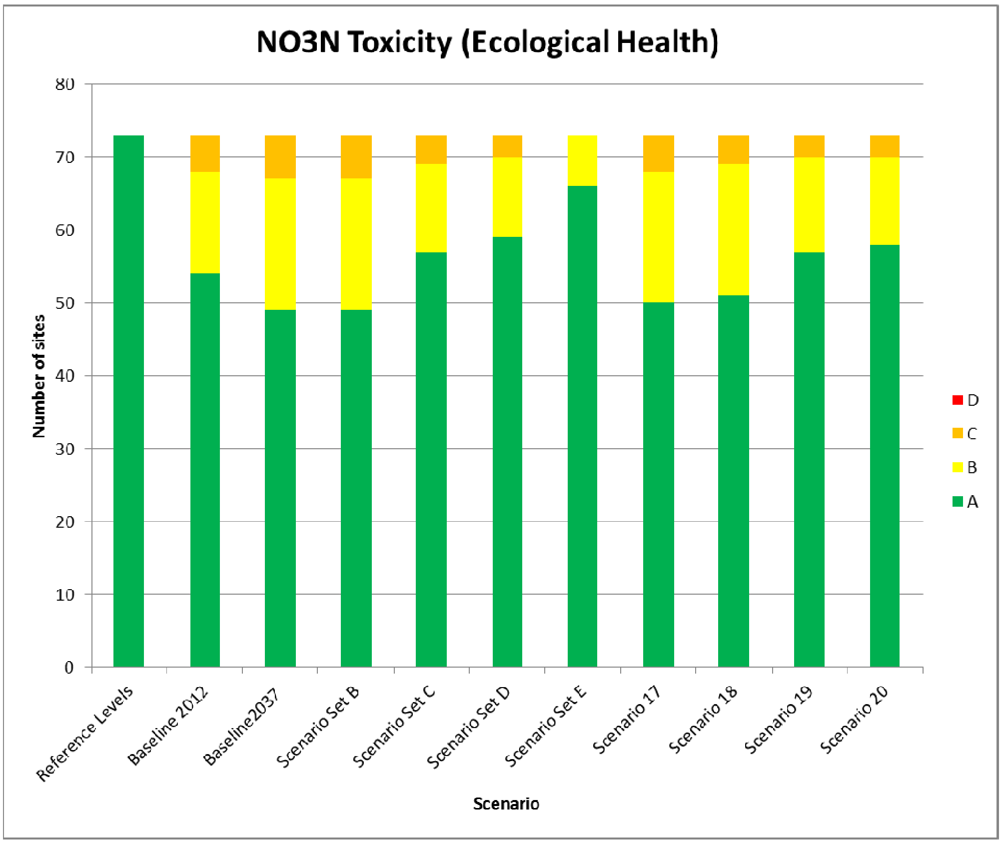


Figure 6: Results of the analysis of the river ecological health objective based on predicted nitrate concentrations and proposed NOF bands (see Table 7).

4.1.3 River Ecosystem Health: Periphyton

The analysis for the other river ecosystem health objective (periphyton attribute) under "reference state" water quality (i.e. water quality in the absence of human pressures) indicated that the majority of SOE sites (62%) would be in the A band (i.e. excellent) condition and the remainder would be in the B band (Figure 7). The regionally aggregated results for the Baseline 2012 scenario indicated that no sites were in the D category, 4 sites (5%) had Chlorophyll-*a* concentrations in the C category (i.e. above the bottom line but in only fair condition). Of the remaining sites, 37% and 58% were in the A and B categories respectively.

The regionally aggregated results for the Baseline 2037 scenario showed an increase in the number of sites in the C category from 5 to 10% and a decrease in the number of sites in the A category (Figure 7). This outcome indicates a small decrease in attainment of the river ecosystem health outcome based on periphyton relative to the Baseline 2012 scenario. This is expected because the baseline scenario envisages further intensification of land use with a continued growth in dairying and no change to mitigation practices.

The regionally aggregated results for all scenarios that included mitigation measures indicate either maintaining river ecosystem health outcomes relative to the Baseline 2012 scenario or improving the attainment of these objectives (Figure 7). This suggests that the land use intensification envisaged under these scenarios could occur while either maintaining or improving the water quality outcomes if the mitigation measures were adopted. In addition to the aggregation by region, Appendix B provides tables of results for the results aggregated by water quality management zone and by catchment.

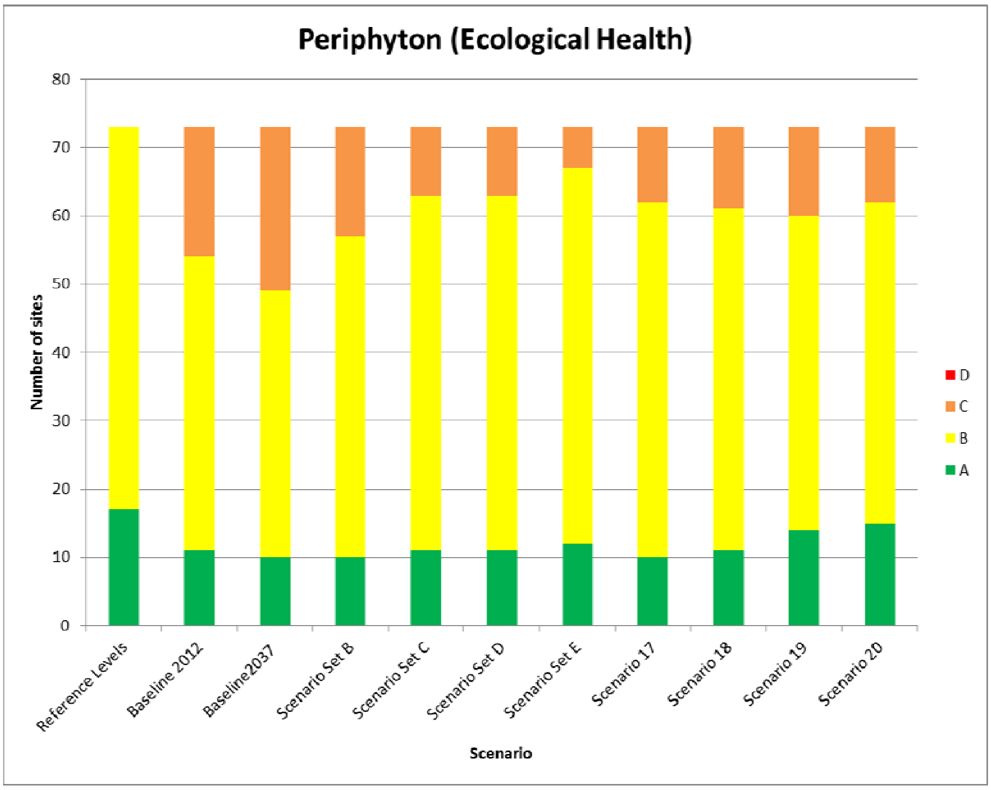


Figure 7: Results of the analysis of the river ecological health objective based on predicted Chlorophyll-a concentrations (i.e. measure of periphyton biomass) and nominated bands (Table 8).

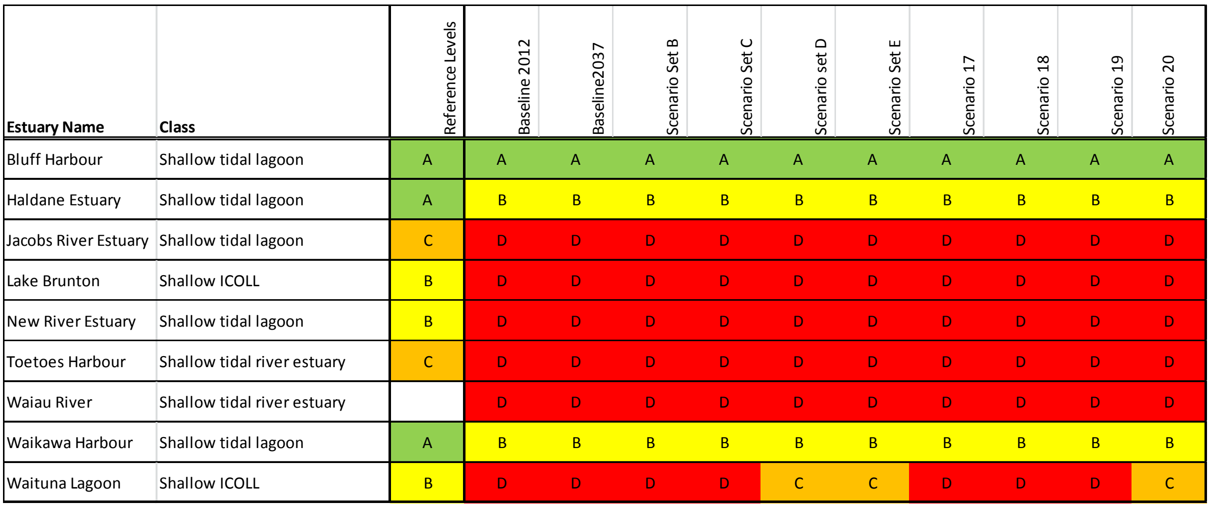
4.2 Estuaries

The analysis of the estuary ecosystem health objective (total nitrogen load attribute) under “reference” (i.e. natural) state water quality (i.e. water quality in the absence of human pressures) indicated that only the Bluff Harbour, Haldane Estuary and Waikawa Lagoon would be in the A band (i.e. excellent) condition (Figure 8). Of the remainder, two estuaries were predicted to be in the C band and three in the B band (Figure 8). The expectation is that all estuaries would be able to achieve the A band under the reference state. Therefore, these results suggest that the total nitrogen load criteria that are currently suggested (Table 9) are conservative.

For estimated loads under the reference state, only two of eight estuaries were in a poor state based on the total nitrogen and total phosphorus loading rates developed by Wriggle Coastal Management (2012) (Figure 9). These results suggest that the Wriggle threshold may be a more realistic definition of the A or B bands (i.e. excellent or good condition) than those being considered under the NOF.

Based on the proposed NOF estuary loading rates, six out of the nine estuaries were below the bottom line (D band) for total nitrogen load for the Baseline 2012 scenario (Figure 8). All of these, apart from the Waituna Lagoon, remained in this band under all other scenarios. Only the Waituna Lagoon had an improved water quality outcome under some of the mitigation scenarios, relative to the Baseline 2012 scenario. The results for the analysis based on the loading rates developed by Wriggle Coastal Management (2012) (Figure 9) were even more pessimistic, indicating that all estuaries, except Bluff Harbour, were in a poor state for Baseline scenarios for 2012 and 2037. Most estuaries remained in the poor state for all scenarios with mitigation measures, with only the Haldane Estuary and Waituna Lagoon improving to the good state under scenario set E (Figure 10).

Figure 10 shows the TN loads for each scenario normalised by the proposed NOF load required to achieve at least a C band outcome (i.e. fair condition). For those estuaries below the bottom line for all scenarios, the TN loads ranged from 1 to 9 times greater than the C band loading. Notwithstanding that the proposed criteria are possibly conservative, these results suggest the estuary loading rates are high. The results suggest that the mitigation measures, as modelled, may not decrease total nitrogen loads sufficiently to have significant benefits for the ecological health of the estuaries. The raw data on which these assessments were made are provided in Appendix C, in tabulated form.

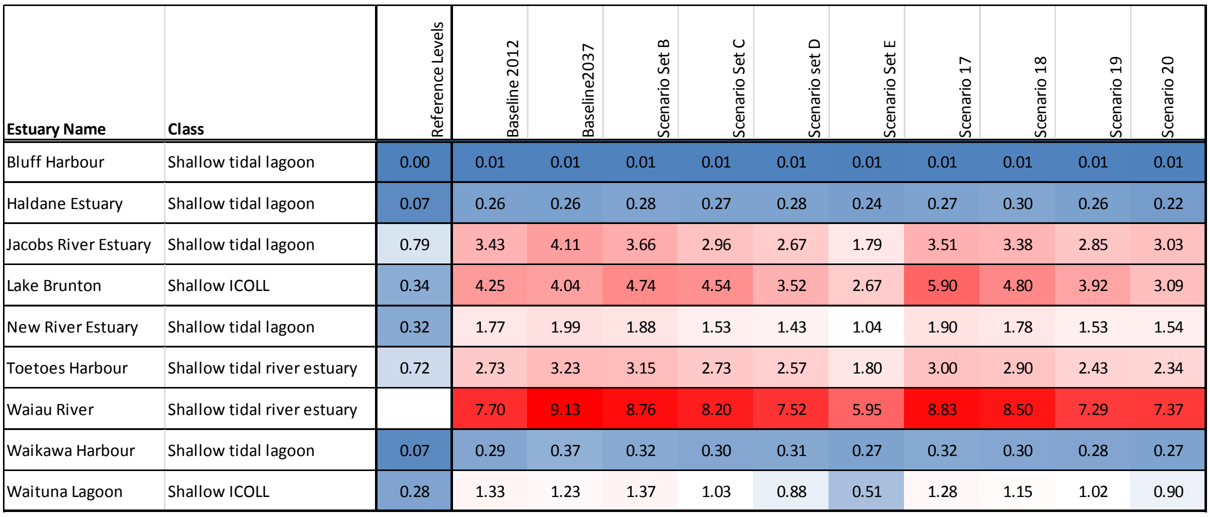


Estuary Name	**Class**	Reference Levels	Baseline 2012	Baseline2037	Scenario Set B	Scenario Set C	Scenario set D	Scenario Set E	Scenario 17	Scenario 18	Scenario 19	Scenario 20
Bluff Harbour	Shallow tidal lagoon	A	A	A	A	A	A	A	A	A	A	A
Haldane Estuary	Shallow tidal lagoon	A	B	B	B	B	B	B	B	B	B	B
Jacobs River Estuary	Shallow tidal lagoon	C	D	D	D	D	D	D	D	D	D	D
Lake Brunton	Shallow ICOLL	B	D	D	D	D	D	D	D	D	D	D
New River Estuary	Shallow tidal lagoon	B	D	D	D	D	D	D	D	D	D	D
Toetoes Harbour	Shallow tidal river estuary	C	D	D	D	D	D	D	D	D	D	D
Waiau River	Shallow tidal river estuary		D	D	D	D	D	D	D	D	D	D
Waikawa Harbour	Shallow tidal lagoon	A	B	B	B	B	B	B	B	B	B	B
Waituna Lagoon	Shallow ICOLL	B	D	D	D	D	C	C	D	D	D	C

Figure 8: Results of the analysis of the estuary ecological health objective based on predicted total nitrogen loads and the currently proposed NOF bands (see Table 9).

Estuary Name	Class	Reference Levels	Baseline 2012	Baseline2037	Scenario Set B	Scenario Set C	Scenario set D	Scenario Set E	Scenario 17	Scenario 18	Scenario 19	Scenario 20
Bluff Harbour	Shallow tidal lagoon	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
Haldane Estuary	Shallow tidal lagoon	GOOD	POOR	POOR	POOR	POOR	POOR	GOOD	POOR	POOR	POOR	GOOD
Jacobs River Estuary	Shallow tidal lagoon	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Lake Brunton	Shallow ICOLL	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
New River Estuary	Shallow tidal lagoon	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Toetoes Harbour	Shallow tidal river estuary	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Waiau River	Shallow tidal river estuary		POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Waikawa Harbour	Shallow tidal lagoon	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Waituna Lagoon	Shallow ICOLL	GOOD	POOR	POOR	POOR	POOR	POOR	GOOD	POOR	POOR	POOR	POOR

Figure 9: *Results of the analysis of the estuary ecological health objective based on predicted total nitrogen loads and loading rate thresholds proposed by Wriggle (2012) (see Table 10).*



Estuary Name	Class	Reference Levels	Baseline 2012	Baseline2037	Scenario Set B	Scenario Set C	Scenario set D	Scenario Set E	Scenario 17	Scenario 18	Scenario 19	Scenario 20
Bluff Harbour	Shallow tidal lagoon	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Haldane Estuary	Shallow tidal lagoon	0.07	0.26	0.26	0.28	0.27	0.28	0.24	0.27	0.30	0.26	0.22
Jacobs River Estuary	Shallow tidal lagoon	0.79	3.43	4.11	3.66	2.96	2.67	1.79	3.51	3.38	2.85	3.03
Lake Brunton	Shallow ICOLL	0.34	4.25	4.04	4.74	4.54	3.52	2.67	5.90	4.80	3.92	3.09
New River Estuary	Shallow tidal lagoon	0.32	1.77	1.99	1.88	1.53	1.43	1.04	1.90	1.78	1.53	1.54
Toetoes Harbour	Shallow tidal river estuary	0.72	2.73	3.23	3.15	2.73	2.57	1.80	3.00	2.90	2.43	2.34
Waiau River	Shallow tidal river estuary		7.70	9.13	8.76	8.20	7.52	5.95	8.83	8.50	7.29	7.37
Waikawa Harbour	Shallow tidal lagoon	0.07	0.29	0.37	0.32	0.30	0.31	0.27	0.32	0.30	0.28	0.27
Waituna Lagoon	Shallow ICOLL	0.28	1.33	1.23	1.37	1.03	0.88	0.51	1.28	1.15	1.02	0.90

Figure 10: *Modelled total nitrogen loads to the estuaries compared to the load required to achieve at least a NOF C band (i.e. fair condition). The loading rates are based on the nominated thresholds shown in Table 9.*

4.3 DCD Results

The NZIER (2013) study found that DCD is an effective mitigation option that can lower the cost of meeting a given environmental objective (for example the nutrient caps specified under Scenarios B–E). The specific implications of using DCD for each scenario depend on the caps and mitigation tools and their interaction with farm practices. For a few uniform caps – tools 9, 10 and 11 – DCD makes the difference between dairy farming being compliant and not being compliant for large areas. The result is a small increase in nitrogen loss from these areas relative to the non-DCD tools.

The scenarios for mitigations that included DCD are shown in Table 11. The farm-level tools that these scenarios are based on are the same as the ‘without DCD’ mitigations (Table 1). We note that tool numbers that produced similar outcomes were grouped into a smaller number of scenarios (Scenarios B–G) for the ‘without DCD’ mitigations (Table 1). For ‘with DCD’ (Table 11), the interaction between mitigations and nutrient caps changes, so that tools do not group the same way. Therefore, the results are presented just by farm-level mitigation tool numbers.

Table 11. Farm-level mitigations tools for mitigations that include DCD. The NZIER (2013) model results for farm-level mitigation tools 1 and 2 were the same as for Baseline 2037, so were not included in this table. The Farm-level mitigation results for Tools 13, 14, 15 and 16 with DCD were the same as those for without DCD, so not included in this table.

Tool numbers	Type of tool	Dairy practices	Comment
1,2	Uniform discharge caps	No change	
3, 5, 6, 7		64% of farms adopt mitigation bundle M1 or M2	No change in land use from Baseline 2037 or dairy practices.
4, 8, 12*		All farms adopt mitigation bundle M1 or M2	Some land use change from Baseline 2037 - dairy farmland decreases to 20% of the total agricultural area, sheep/beef increases to 73%, and forestry remains about the same (7%). Change in dairy practices to low and middle mitigation options.
9, 10, 11		All farms adopt mitigation bundle M2 or M3	No change in land use from Baseline 2037. Change in dairy practices to middle and high mitigation options.
13, 14, 15, 16		Dairying unable to comply with discharge caps	No change in land use from Baseline 2012.
17	Non-uniform discharge caps	All farms adopt mitigation bundle M1 or M2	No change in land use from Baseline 2037. Change in dairy practices to low and middle mitigation options.
18			
19	Mandated farm practices	All farms adopt mitigation bundle M3.	
20		All farms adopt mitigation bundle M3.	No change in land use from Baseline 2037. All sheep/beef farms also adopt mitigation bundle M3.

*Scenario 12 moves from the D group to the C group. The P cap becomes binding in a way that the N caps no longer are.

The complete results for all mitigation scenarios that included DCD are provided in Appendix D of this report. In general terms, compliance with NOF thresholds for tools that included DCD were very similar to those that did not include DCD. This is because the scenarios were generally based on achieving specified nutrient caps; DCD simply provides another way of complying with the cap. The economic implications associated with the option of DCD are not the topic of this report and is discussed in the NZIER (2013) report.

5 DISCUSSION

5.1 Limitations of this Study

The analysis undertaken for this study is subject to considerable uncertainty and limitations. First, this study was contingent on the model results and assumptions that were produced by the catchment modelling (NIWA, 2013), which were in turn based on the farm-scale modelling (NZIER, 2013). The uncertainties and limitations of these component studies are therefore inherent in the results presented here; for example, how wintering is dealt with, and a lack of water quality data around high flows, which carry the bulk of nutrient loads. In particular, it was assumed that the observed nitrogen loads (at the SOE sites) represent the steady-state response to the existing land use. If there are significant lags in the groundwater system then this assumption will not be true. The growth in intensive land use in Southland since 2000 will not be fully evident in the Baseline 2012 scenario, and the future loads (i.e. the predictions for the scenarios) will be underestimated (NIWA, 2013). Little is yet known about lag times in groundwater in the Southland region (Clint Rissmann, Environment Southland, *personal communication, 2013*). Data collection and modelling are currently underway, and the results from this work could improve scenario predictions in the future.

A second limitation of this study is the degree to which we are able to have confidence in the thresholds that have been used to judge acceptability of the water quality outcomes for the various attributes. We comment below about the apparently conservative thresholds for the estuary loading rates in particular. These thresholds are under development and are likely to be revised. Therefore, the results of this study should be regarded as indicative and subject to change.

A third significant limitation of this study is our confidence in the periphyton model. We developed this model using the available data, but this was limited. We had to make an assumption that periphyton biomass data is exponentially distributed. Although this has been shown to be largely true for periphyton cover data, it is untested for the biomass (Chlorophyll-*a*) data used in this study. We also note that some rivers and streams in Southland do not have substrates that are suitable for periphyton growth. Our analysis did not account for this and made the assumption that all the SOE sites have periphyton habitats.

5.2 Rivers

The representativeness analysis of the 73 SOE sites used as a basis for the modelling indicates that the sites over-represent the lowland pasture category of rivers at a regional level. This category represents the rivers in Southland that are generally the most degraded from a water quality perspective (NIWA, 2010). These river types also drain the landscapes that are most likely to undergo intensification of land use. This means that the overall results (i.e. the regionally aggregated results presented as bar charts in Figure 3, Figure 6 and Figure 7) are likely to give pessimistic estimates of overall water quality across the region (i.e. on average, water quality is better than that represented by the SOE sites). In addition, the results are likely to give optimistic estimates of any improvement in regional water quality under any of the scenarios.

This is because the SOE sites over-represent the areas in which intensification is likely to occur and where mitigation measures are likely to be applied.

Overall the analysis suggests that, as expected, the SOE sites were predicted to be in the A band (i.e. excellent) condition for the attributes considered under "reference state" water quality. The analysis indicates that the existing river water quality in Southland achieves a high level of attainment of the proposed NOF bottom lines that were considered in this analysis (i.e. *E. coli*, nitrate toxicity and periphyton). We note that the bands used in this study were preliminary and are subject to on-going revision as part of the process of developing the NOF. These results should therefore be treated as indicative. The Baseline 2012 scenario suggests that a few sites are below the bottom line for the human health objective (*E. coli*) and all sites are at present above the bottom line for the ecosystem health objectives (nitrate toxicity and periphyton).

Overall the analysis indicates that the current level of attainment of the proposed NOF water quality objectives included in this study would be maintained or improved under the scenarios, with improvements increasing as the contaminant loss rates decreased. However, the analysis indicated that the improvements in water quality at the regional level under all scenarios would not be large. This is because the mitigation measures mainly affect dairy farming (NZIER, 2013). Dairy farming makes up only 17% of the region's agricultural land use and is projected to increase to 28% by 2037 (NZIER, 2013). This means that mitigations are making reductions in contaminant losses in only a relatively small proportion of the agricultural landscape. A particular exception to this general pattern was Scenario 20, for which large improvements in the human health objective (reductions in *E. coli*) were predicted. This occurs because Scenario 20 mandates specific mitigations for all farm types. The *E. coli* loss rates are assumed to be the same for sheep/beef and dairy farms, and the mitigation measures are also assumed to be equally effective (NZIER, 2013).

5.3 Estuaries

The analysis suggests that many of Southland's estuaries have total nitrogen loads in excess of the bottom-line thresholds that are currently under consideration for the NOF objectives, as well as those independently derived for Environment Southland by Wriggle Coastal Management (2012). The analysis also indicates that some Southland estuaries would not be in the proposed A band even given a total nitrogen load representing the reference (natural) state. This unexpected result suggests that the current bands for the total nitrogen load attribute may be environmentally conservative. We note that the application of the proposed bands is dependent on assigning estuaries to one of three estuary types and that results are likely to be very sensitive to these somewhat subjective decisions. Yet the analysis also shows that existing and future total nitrogen loads exceed the proposed environmental bottom line (at least a C band or fair condition) by a factor of more than two for many of the region's estuaries. Furthermore, the mitigation scenarios generally had little effect on the bands that estuaries were assigned to. The reason for the relatively minor decreases in predicted total nitrogen loads with decreasing nutrient loss rates from farms is because the scenarios have most impact on loss rates of contaminants from dairy farms and these make up a relatively small component of the contributing area of most catchments.

6 CONCLUSION

At the time of completion of this report, a more comprehensive evaluation of water quality in the Southland region was being carried out as part of the Environment Southland's Water Management Strategy (WMS). In particular, a spatially comprehensive assessment of a large number of water quality and condition indicators was underway as part of identifying water management zones for the interim measures component of the WMS. The results of this new assessment will be available by late 2013 and will provide a more thorough and representative picture of water quality in rivers, lakes, estuaries and aquifers in Southland than is provided by this report.

The results of this study suggest that Southland's estuaries are more sensitive receiving environments than rivers and that contaminant loss from farming activities in the region has its most marked effect on estuaries. The results suggest that contaminant loads for many estuaries are significantly higher than is acceptable (i.e. they do not meet the proposed bottom lines). We note that even the most stringent of the mitigation scenarios, which precludes dairy farming from the region, is unable to ensure that the region's estuaries are above the proposed NOF bottom line. On the other hand, the study results suggest that rivers and streams are less impacted and that, apart from a small proportion of locations, they are above the proposed bottom lines.

This study indicates that the mitigation measures that were modelled will be effective in at least maintaining river and stream water quality in the future, even given projected increases in dairy farming. Greater improvements in water quality are attributable to the most effective mitigation scenarios, but these are more costly to implement. The results indicate that the mitigation scenarios reduce the load of TN to the impacted estuaries; however, the reductions under all mitigation scenarios are unlikely to be sufficient to appreciably change the environmental outcomes in the estuaries (i.e. few estuaries change the quality band they are associated with under the current (2012) scenario).

7 REFERENCES

Akaike H. Information theory and an extension of the maximum likelihood principle. Second International Symposium on Information Theory. 1973. (B. N. Petrov & F. Csaki, eds.), 267–281. ed. Akademiai Kiado: Budapest: Springer Verlag.

Ballantine D, Booker D, Unwin M, Snelder T. Analysis of National River Water Quality Data for the Period 1998–2007. 2010. NIWA Client Report: CHC2010-038. 72 p.

Biggs BJF. Eutrophication of streams and rivers: dissolved nutrient-chlorophyll relationships. *Journal of the North American Benthological Society* 2000;**19**:17–31.

Hickey CW, Martin ML. Site-specific nitrate guidelines for Hawkes Bay. 2012. NIWA client report (draft) HAM2012–127.

Hume TM, Snelder TH, Weatherhead M, Liefting R. A controlling factor approach to estuary classification. *Ocean & Coastal Management* 2007;50: 905–929.

Jowett IG, Richardson J. Microhabitat preferences of benthic invertebrates in a New Zealand river and the development of in-stream flow-habitat models for Deleatidium spp. *New Zealand Journal of Marine and Freshwater Research* 1990;**24**:19–30.

Leathwick J, Snelder T, Chadderton W, Elith J, Julian K, Ferrier S. Use of generalised dissimilarity modelling to improve the biological discrimination of river and stream classifications. *Freshwater Biology* 2011;**56**(1):21–38.

Ministry for the Environment (MFE). *New Zealand Periphyton Guideline: Detecting, Monitoring and Managing Enrichment of Streams*. Wellington: Ministry for the Environment. 2000. Available from: http://www.mfe.govt.nz/publications/water/nz-periphyton-guide-jun00.html (Accessed April 2013.)

Ministry for the Environment (MFE). *Freshwater reform 2013 and beyond.* Wellington: Ministry for the Environment. 2013.

Ministry for the Environment (MFE) & Ministry of Health (MoH). *Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas*. Ministry for the Environment, Wellington, 2003. p159 . .

National Institute of Water and Atmospheric Research (NIWA). *Freshwater quality monitoring by Environment Southland, Taranaki Regional Council, Horizons Regional Council and Environment Waikato*. 2010. NIWA Client Report CHC2010-141, prepared for the Office of the Auditor General.

National Institute of Water and Atmospheric Research (NIWA). *Water Quality Modelling for the Southland Region*. Report to the Ministry for the Environment. 2013.

Norton N, Snelder T, Rouse H. *Technical and Scientific Considerations When Setting Measurable Objectives and Limits for Water Management*. 2010. NIWA Client Report. Christchurch. 49p. Available from: http://www.mfe.govt.nz/publications/water/technical-scientific-considerations-setting-measurablehttp://www.mfe.govt.nz/publications/water/technical-scientific-considerations-setting-measurable (Accessed April 2013.)

New Zealand Institute of Economic Research. *The impact of water quality policies in Southland. Impacts on the agricultural economy and nutrient discharges*. 2013. Report to the Ministry for the Environment.

Robertson B, Stevens L. *Southland Coast Te Waewae to the Catlins Habitat Mapping, Risk Assessment and Monitoring Recommendations*. 2008. Report prepared for Environment Southland. 130pp

Snelder TH,; Biggs BJF. Multi-scale river environment classification for water resources management. *Journal of the American Water Resources Association* 2002;38(5):1225-40.

Snelder TH Booker JD. Natural flow regime classifications are sensitive to definition procedures. *River Research and Application*s. Article first published online: 25 May 2012.

Snelder TH, Booker DJ, Quinn, J, Kilroy C. Predicting periphyton cover frequency distributions across New Zealand's rivers. (In press).

Unwin M, Snelder T, Booker D, Ballantine D, Lessard J. *Predicting water quality in New Zealand rivers from catchment-scale physical, hydrological and land cover descriptors using random forest models*. 2010. NIWA Client Report: CHC2010-0.

Wriggle Coastal Management. *Preliminary Guidance Document: Nutrient Load Criteria to Limit Eutrophication in Typical NZ Estuary Types - Tidal Lagoon and Tidal River Estuaries*. 2012. Prepared by Wriggle Coastal Management for Environment Southland .

Appendix A: Periphyton Abundance Model for the Southland Region

Introduction

The aim of the analysis was to use a model to predict periphyton abundance in the rivers of the Southland region as a function of nutrient concentration. A national scale model of periphyton cover as a function of nutrient concentration and various other environment factors was available (Snelder *et al*, In press). However, tests of this model with Southland Regional Council's (SRC) observations of cover at State of Environment (SOE) monitoring sites showed that the model had poor performance. The reasons for this are unclear and further investigation was beyond the scope of this study.

A new Southland-specific model was therefore developed from data representing periphyton abundance as Chlorophyll-*a* that had been collected at SOE sites. Previous work (e.g. Biggs, 2000) has shown that, apart from nutrient concentrations, flood frequency is an important determinant of periphyton abundance. More recently Snelder *et al* (In press) has shown that other hydrological indices, substrate, temperature and light explained significant additional variation in mean or mean annual maximum periphyton abundance between sites. The present study investigated the inclusion of these additional variables and subsequently used regional information concerning these variables to maximise the accuracy of the regional predictions.

Data

Chlorophyll-*a* (Chl-*a*) and ash free dry weight (AFDW) data for 102 river sites across Southland were obtained from the SRC. The number of sample occasions varied between sites and sample dates spanned the period 2002 to 2012. Samples had mostly been collected between November and March (78%; Figure 11). We retained all samples taken during this five month period and assumed that the mean of these for each site was a reliable estimate of the mean monthly summer-time *Chlorophyll-a* and mean monthly summer-time AFDW.

Most sites were able to be located on specific segments of the GIS-based River Environment Classification (REC) digital river network. Of these located sites, 58 that had been sampled on at least 4 occasions were retained for analysis (Figure 12).

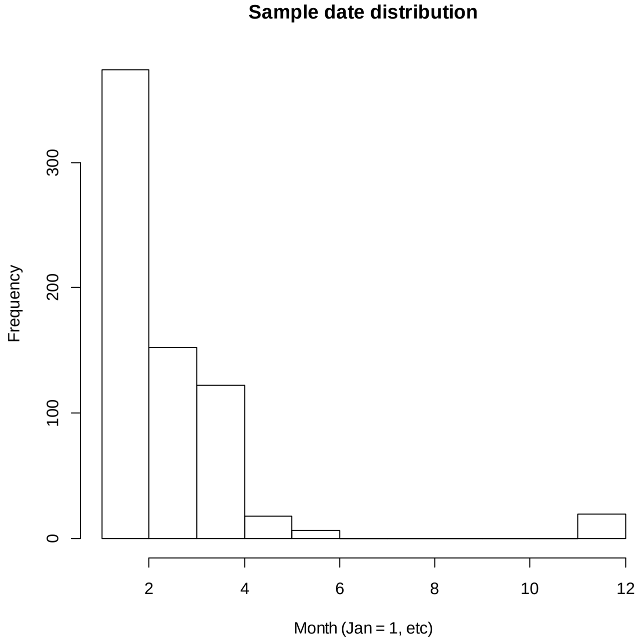


Figure 11: Frequency distribution of sample dates (months) for 102 river sites across Southland.

The retained sites were associated with potential predictor variables describing site water quality, flow regime and substrate (an index describing sediment grain size). All the predictor variables were produced for the REC network using national models in a variety of previous studies. Predictions of clarity (black disc visibility), ammoniacal nitrogen, nitrate nitrogen, total nitrogen (TN), dissolved reactive phosphorus (DRP) and total phosphorus (TP) were derived from the model of (Unwin *et al*, 2010). Predictions for ammoniacal nitrogen and nitrate nitrogen were added to estimate dissolved inorganic nitrogen (DIN). The proportion of bed covered by several substrate size classes was represented by single substrate index, as described by (Jowett & Richardson, 1990). Predictions of this index were derived using a national model developed as part of species distribution modelling (Leathwick *et al*, 2011).

Predictions for four hydrological indices, which describe aspects of the flow regime, were obtained for each site from predictions made by Snelder and Booker (2012). The frequency of floods was represented by the number of events per year that exceeded a multiple (n) times the long-term median flow (FREn) where n = 2, 3, and 4. The frequency of changes of flows was represented by hydrological reversals (Reversals). Sites with frequent reversals have many hydrograph peaks. Rates of increase of flow were represented by the number of days on which flow was less than that of the previous day (nNeg). Sites with steep rising limbs have large values of nNeg. The mean annual 7-day low flow divided by the mean flow was used to represent the low flow magnitude (LowFlow). The expected relationship with periphyton abundance of these indices was calculated and details of their calculation are set out in Snelder *et al.* (In press).

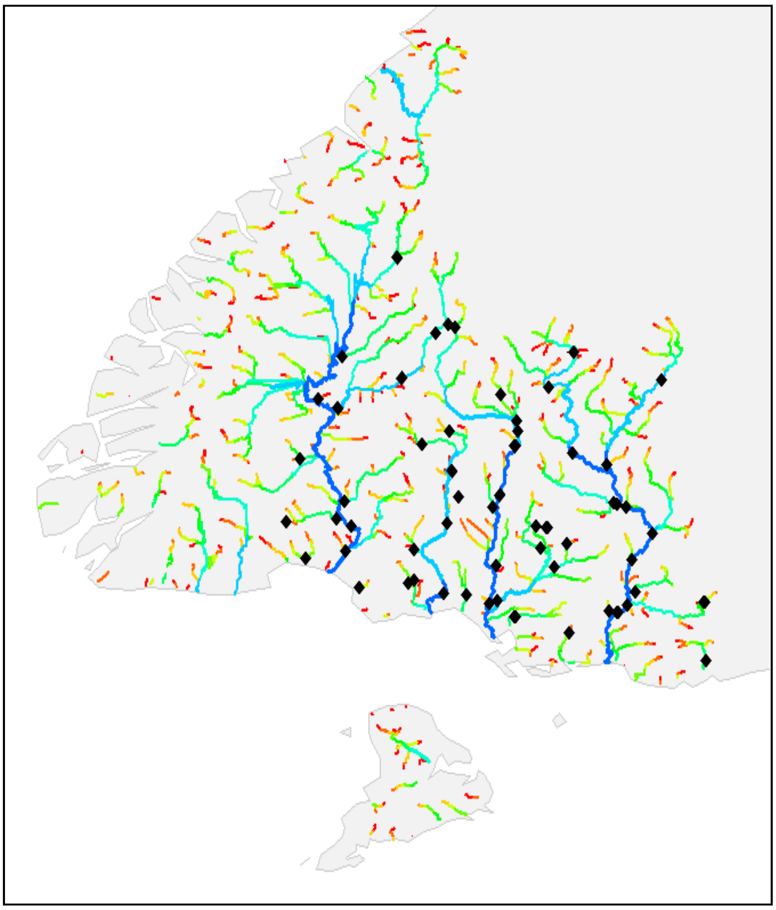


Figure 12: Location of the 58 sites retained for analysis. River lines are coloured by catchment area (red= small, blue = large).

Analysis

Regression modelling was used to define empirical relationships between mean monthly summer-time periphyton abundance (Chl-*a* and AFDW) at sites and the potential explanatory variables. Standard forwards and backwards stepwise linear regression was used to identify the minimal adequate additive linear combinations of the explanatory variables the potential explanatory variables for each response. The Akaike information criterion (AIC) (Akaike, 1973) was used to apply a penalised log likelihood method to evaluate the trade-off between degrees of freedom and fit of the model as the explanatory variables were added or removed. Model fit was evaluated using the coefficient of determination (r^2). The relationships represented by the empirical models also evaluated by comparing the model coefficients with expectations according to a conceptual model of the environmental factors controlling periphyton abundance (Snelder *et al*, Submitted).

Results

Mean monthly summer-time Chl-*a* and AFDW varied between 1.2 and 140 mg m^{-2} and 1.5 and 72.3 g m^{-2}. Most pairs of the candidate explanatory variables had low correlation (Table 1). However, many nutrient variables were strongly correlated ($r > 0.7$). With the exception of FRE2 and 3, which were highly correlated, the hydrological indices were only moderately correlated indicating that they comprised unique information about the hydrological regimes at the sites.

The nutrient variables (TN, TP, DIN, DRP) had skewed distributions and were log (base 10) transformed to approximate normality.

Table 12: Correlations between the potential explanatory variables.

	log$_{10}$TN	log$_{10}$TP	log10DIN	log$_{10}$DRP	log$_{10}$DINDRP	FRE2	FRE3	Reversals	nNeg	BFI
log10TP	0.85									
log10DIN	0.98	0.77								
log10DRP	0.82	0.95	0.75							
log10DINDRP	0.77	0.35	0.85	0.29						
FRE2	-0.32	-0.13	-0.33	-0.19	-0.33					
FRE3	-0.07	0.19	-0.12	0.1	-0.26	0.9				
Reversals	-0.16	0.1	-0.24	0.05	-0.39	0.37	0.4			
nNeg	-0.2	-0.19	-0.17	-0.02	-0.23	0.18	0.09	-0.36		
BFI	-0.41	-0.54	-0.37	-0.56	-0.09	-0.42	-0.59	-0.11	-0.31	
Substrate	-0.1	-0.05	-0.13	-0.13	-0.09	0.23	0.28	0.02	-0.09	0.1

The mean monthly summer-time Chl-*a* model explained 37% of the between-site variation, and included Reversals, nNeg and DIN, ration of DIN to DRP and substrate. The fitted coefficients were consistent with the conceptual model of factors controlling periphyton biomass (Table 13). For example, biomass decreased with increasing values of BFI, nNeg and Reversals, indicating that biomass is lower at sites that have high base flows, high rates of change of flows and frequent changes in flow. Biomass was positively related to DIN concentrations (note this was strongly correlated with DRP, TP and TN). The model also included DIN:DRP as a negative influence indicating that low DRP, relative to DIN can have a limiting effect on biomass.

Table 13: Coefficients for the mean summer Chl-a model.

	Coefficient	SE	Pr(>|t|)
(Intercept)	902.174	286.2026	0.00264
Reversals	-2.9526	0.9099	0.00202
nNeg	-1.9459	0.7469	0.01184
log10DINDRP	-40.5348	20.3427	0.05137
BFI	-245.513	111.9466	0.03262
log10DIN	28.8748	14.2692	0.04797

The mean monthly summer-time AFDW model explained 24% of the between-site variation and included FRE3, Reversals, nNeg, BFI, DIN and DRP. The fitted coefficients in this model were not consistent with the conceptual model of factors controlling periphyton biomass. For example, the coefficient for FRE3 was positive and for DIN was negative indicating biomass increases with increasing flood frequency and decreases with increasing nitrogen. This model was therefore not explored further.

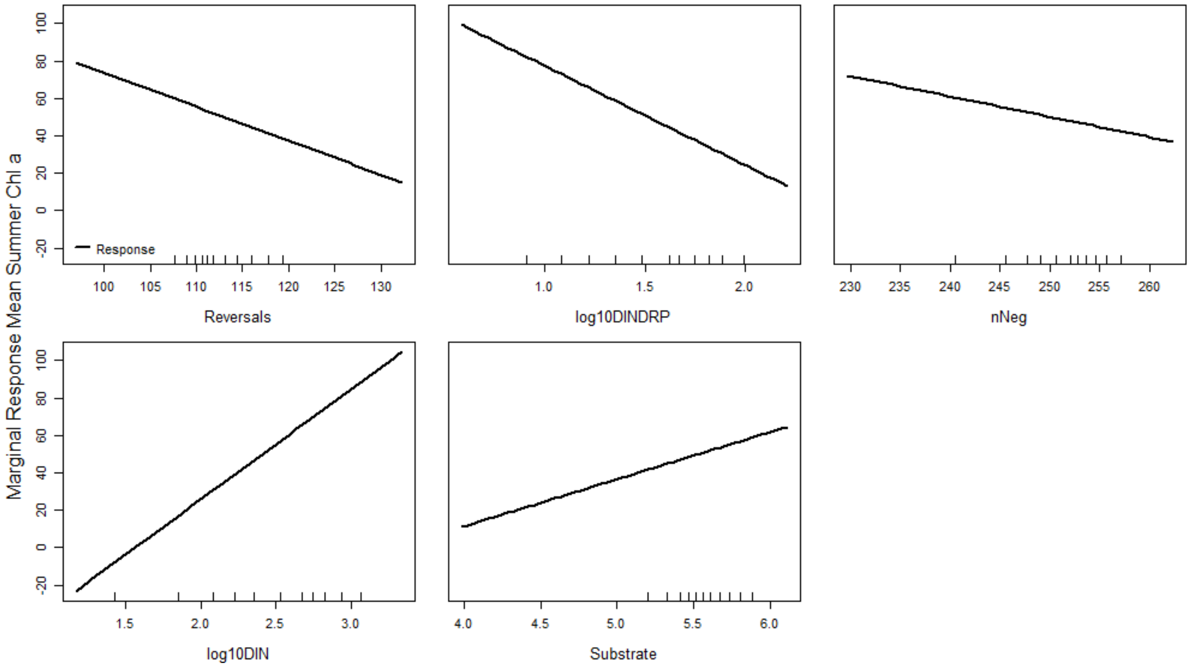


Figure 13: Marginal contribution of the predictors to estimated mean monthly summer-time Chl-a. The plots show the response (change in mean Chl-a along the total range of each variable) with the other variables held at their mean value. Negative values should be regarded as zero or very low biomass. The amplitude of the response is an indication of the relative sensitivity of Chl-a to changes in the variable.

Predictions of mean monthly summer-time *Chlorophyll-a* were made for the whole of the Southland Region river network using the fitted model (Figure 14:). The pattern of the predictions were consistent with expectations, with biomass being low in the west, where rivers have low nutrients and frequent high flows, and high in the Southland Plains streams. Care with interpreting the predictions is needed. For example, not all streams will have substrates that support periphyton, and the predictions will therefore be misleading in these cases.

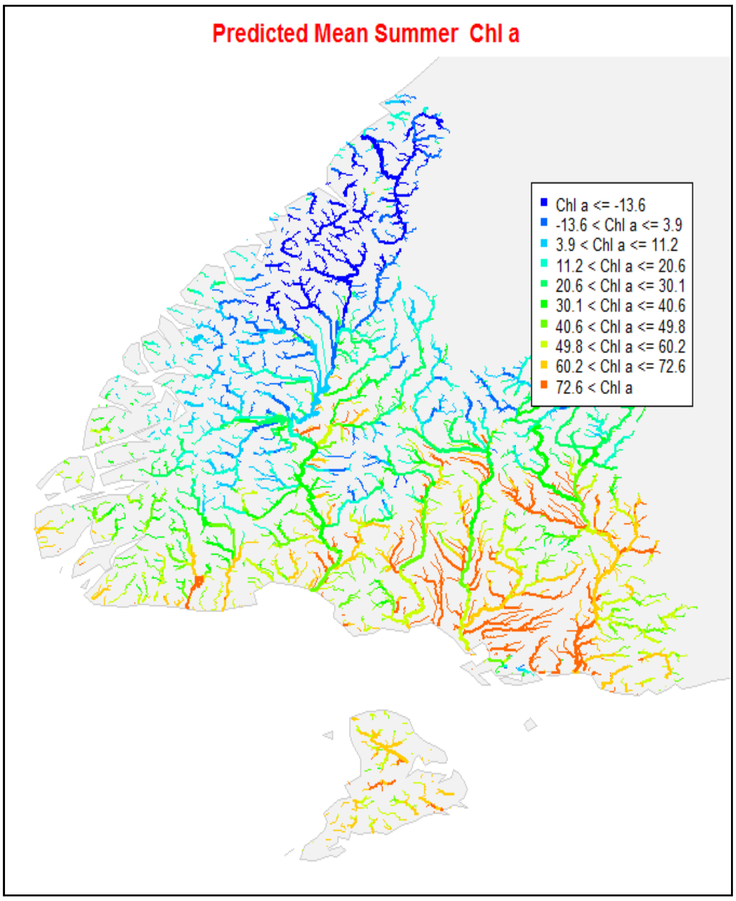


Figure 14: Predictions of mean monthly summer-time Chlorophyll-a for the whole of the Southland Region.

Appendix B: Tabulated Results: Rivers

B.1: Regionally Aggregated Results

B.1.1: River ecological health objective based on predicted Chlorophyll-a concentrations and nominated bands

Scenario	A	B	C	D
Baseline2037	25	41	7	0
Scenario Set B	28	39	6	0
Scenario Set C	27	45	1	0
Scenario Set D	29	43	1	0
Scenario Set E	32	40	1	0
Scenario 17	29	41	3	0
Scenario 18	29	41	3	0
Scenario 19	27	43	3	0
Scenario 20	25	46	2	0
Baseline 2012	27	42	4	0
Reference Levels	45	28	0	0

B.1.2: River ecological heath objective based on predicted nitrate concentrations and proposed NOF bands

Scenario	A	B	C	D
Baseline2037	49	18	6	0
Scenario Set B	49	18	6	0
Scenario Set C	57	12	4	0
Scenario Set D	59	11	3	0
Scenario Set E	66	7	0	0
Scenario 17	50	18	5	0
Scenario 18	51	18	4	0
Scenario 19	57	13	3	0
Scenario 20	58	12	3	0
Baseline 2012	54	14	5	0
Reference Levels	73	0	0	0

B.1.3: River Human Heath objective based on predicted E. coli concentrations and proposed NOF bands

Scenario	A	B	C	D
Baseline2037	34	28	7	4
Scenario Set B	44	22	6	1
Scenario Set C	47	17	7	2
Scenario Set D	46	19	5	3
Scenario Set E	44	22	6	1
Scenario 17	50	18	5	0
Scenario 18	51	16	6	0
Scenario 19	41	25	6	1
Scenario 20	66	6	1	0
Baseline 2012	30	32	6	5
Reference Levels	73	0	0	0

B.2: Management Zone Aggregated Results

B.2.1: River ecological health objective based on predicted Chlorophyll-a concentrations and nominated bands

	Scenario	A	B	C	D
Five Rivers Basin	Baseline 2012	5			
	Baseline2037	5			
	Scenario Set B	5			
	Scenario Set C	5			
	Scenario Set D	5			
	Scenario Set E	5			
	Scenario 17	5			
	Scenario 18	5			
	Scenario 19	5			
	Scenario 20	4	1		
Lowland Zone	Scenario	A	B	C	D
	Baseline 2012	8	28	4	
	Baseline2037	8	27	5	
	Scenario Set B	10	26	4	
	Scenario Set C	10	29	1	
	Scenario Set D	10	29	1	
	Scenario Set E	13	26	1	
	Scenario 17	10	27	3	
	Scenario 18	10	27	3	
	Scenario 19	8	29	3	
	Scenario 20	9	30	1	1
Te Anau Basin	Scenario	A	B	C	D
	Baseline 2012	6	1		
	Baseline2037	5	2		
	Scenario Set B	6	1		
	Scenario Set C	6	1		
	Scenario Set D	6	1		
	Scenario Set E	6	1		
	Scenario 17	6	1		
	Scenario 18	6	1		
	Scenario 19	7			
	Scenario 20	6	1		
Waimea Basin	Scenario	A	B	C	D
	Baseline 2012	4	8		
	Baseline2037	3	7	2	
	Scenario Set B	3	7	2	
	Scenario Set C	2	10		
	Scenario Set D	4	8		
	Scenario Set E	4	8		
	Scenario 17	4	8		
	Scenario 18	4	8		
	Scenario 19	4	8		
	Scenario 20	3	8	1	

B.2.2: River ecological heath objective based on predicted nitrate concentrations and proposed NOF bands

Five Rivers Basin	Scenario	A	B	C	D
	Baseline 2012	4	1		
	Baseline2037	4	1		
	Scenario Set B	4	1		
	Scenario Set C	4	1		
	Scenario Set D	4	1		
	Scenario Set E	5			
	Scenario 17	4	1		
	Scenario 18	4	1		
	Scenario 19	5			
	Scenario 20	5			

Lowland Zone	Scenario	20	12	5	D
	Baseline 2012	28	10	2	
	Baseline2037	23	15	2	
	Scenario Set B	23	15	2	
	Scenario Set C	31	9		
	Scenario Set D	33	7		
	Scenario Set E	38	2		
	Scenario 17	24	14	2	
	Scenario 18	25	14	1	
	Scenario 19	30	9	1	
	Scenario 20	31	8	1	

Te Anau Basin	Scenario	A	B	C	D
	Baseline 2012	7			
	Baseline2037	7			
	Scenario Set B	7			
	Scenario Set C	7			
	Scenario Set D	7			
	Scenario Set E	7			
	Scenario 17	7			
	Scenario 18	7			
	Scenario 19	7			
	Scenario 20	7			

Waimea Basin	Scenario	A	B	C	D
	Baseline 2012	6	3	3	
	Baseline2037	6	2	4	
	Scenario Set B	6	2	4	
	Scenario Set C	6	2	4	
	Scenario Set D	6	3	3	
	Scenario Set E	7	5		
	Scenario 17	6	3	3	
	Scenario 18	6	3	3	
	Scenario 19	6	4	2	
	Scenario 20	6	4	2	

B.2.3: River Human Heath objective based on predicted E. coli concentrations and proposed NOF bands

Five Rivers Basin	Scenario	A	B	C	D
	Baseline 2012	5			
	Baseline2037	5			
	Scenario Set B	5			
	Scenario Set C	5			
	Scenario Set D	5			
	Scenario Set E	5			
	Scenario 17	5			
	Scenario 18	5			
	Scenario 19	5			
	Scenario 20	5			

Lowland Zone	Scenario	A	B	C	D
	Baseline 2012	10	20	5	5
	Baseline2037	11	19	6	4
	Scenario Set B	20	14	5	1
	Scenario Set C	19	13	6	2
	Scenario Set D	19	13	5	3
	Scenario Set E	18	16	5	1
	Scenario 17	24	11	5	
	Scenario 18	24	11	5	
	Scenario 19	18	16	5	1
	Scenario 20	34	5	1	

Te Anau Basin	Scenario	A	B	C	D
	Baseline 2012	7			
	Baseline2037	7			
	Scenario Set B	7			
	Scenario Set C	7			
	Scenario Set D	7			
	Scenario Set E	7			
	Scenario 17	7			
	Scenario 18	7			
	Scenario 19	7			
	Scenario 20	7			

Waimea Basin	Scenario	A	B	C	D
	Baseline 2012	3	9		
	Baseline2037	6	6		
	Scenario Set B	7	5		
	Scenario Set C	10	2		
	Scenario Set D	10	2		
	Scenario Set E	9	3		
	Scenario 17	9	3		
	Scenario 18	10	2		
	Scenario 19	6	6		
	Scenario 20	11	1		

B.3: Catchment Aggregated Results

B.3.1: River ecological health objective based on predicted Chlorophyll-a concentrations and nominated bands

	Scenario	A	B	C	D
Aparima	Baseline 2012	5	4		
	Baseline2037	5	4		
	Scenario Set B	5	4		
	Scenario Set C	5	4		
	Scenario Set D	5	4		
	Scenario Set E	6	3		
	Scenario 17	5	4		
	Scenario 18	5	4		
	Scenario 19	4	4	1	
	Scenario 20	3	6		
Mataura	Scenario	A	B	C	D
	Baseline 2012	8	18		
	Baseline2037	7	17	2	
	Scenario Set B	7	17	2	
	Scenario Set C	6	20		
	Scenario Set D	8	18		
	Scenario Set E	9	17		
	Scenario 17	8	18		
	Scenario 18	8	18		
	Scenario 19	8	18		
	Scenario 20	6	19	1	
Oreti	Scenario	A	B	C	D
	Baseline 2012	5	9	1	
	Baseline2037	6	8	1	
	Scenario Set B	7	7	1	
	Scenario Set C	7	8		
	Scenario Set D	7	8		
	Scenario Set E	7	8		
	Scenario 17	7	7	1	
	Scenario 18	7	7	1	
	Scenario 19	5	9	1	
	Scenario 20	6	9		
Waiau	Scenario	A	B	C	D
	Baseline 2012	8	2		
	Baseline2037	6	4		
	Scenario Set B	8	2		
	Scenario Set C	8	2		
	Scenario Set D	8	2		
	Scenario Set E	8	2		
	Scenario 17	8	2		
	Scenario 18	8	2		
	Scenario 19	9	1		
	Scenario 20	8	2		

B.3.2: River ecological heath objective based on predicted nitrate concentrations and proposed NOF bands

	Scenario	A	B	C	D
Aparima	Baseline 2012	8	1		
	Baseline2037	8	1		
	Scenario Set B	8	1		
	Scenario Set C	8	1		
	Scenario Set D	8	1		
	Scenario Set E	9			
	Scenario 17	8	1		
	Scenario 18	8	1		
	Scenario 19	8	1		
	Scenario 20	8	1		
Mataura	Scenario	20	12	5	D
	Baseline 2012	18	5	3	
	Baseline2037	15	7	4	
	Scenario Set B	15	7	4	
	Scenario Set C	19	3	4	
	Scenario Set D	20	3	3	
	Scenario Set E	21	5		
	Scenario 17	16	7	3	
	Scenario 18	16	7	3	
	Scenario 19	18	6	2	
	Scenario 20	19	5	2	
Oreti	Scenario	A	B	C	D
	Baseline 2012	11	3	1	
	Baseline2037	10	4	1	
	Scenario Set B	10	4	1	
	Scenario Set C	12	3		
	Scenario Set D	12	3		
	Scenario Set E	14	1		
	Scenario 17	10	4	1	
	Scenario 18	11	4		
	Scenario 19	12	3		
	Scenario 20	12	3		
Waiau	Scenario	A	B	C	D
	Baseline 2012	10			
	Baseline2037	10			
	Scenario Set B	10			
	Scenario Set C	10			
	Scenario Set D	10			
	Scenario Set E	10			
	Scenario 17	10			
	Scenario 18	10			
	Scenario 19	10			
	Scenario 20	10			

B.3.3: River Human Heath objective based on predicted E. coli concentrations and proposed NOF bands

	Scenario	A	B	C	D
Aparima	Baseline 2012	4	2	2	1
	Baseline2037	4	2	2	1
	Scenario Set B	6	1	1	1
	Scenario Set C	6	1	1	1
	Scenario Set D	6	1	1	1
	Scenario Set E	6	2		1
	Scenario 17	6	2	1	
	Scenario 18	6	2	1	
	Scenario 19	6	1	1	1
	Scenario 20	7	1	1	

	Scenario	A	B	C	D
Mataura	Baseline 2012	7	18		1
	Baseline2037	10	15	1	
	Scenario Set B	14	11	1	
	Scenario Set C	17	8	1	
	Scenario Set D	18	7	1	
	Scenario Set E	14	11	1	
	Scenario 17	17	8	1	
	Scenario 18	19	6	1	
	Scenario 19	12	13	1	
	Scenario 20	24	2		

	Scenario	A	B	C	D
Oreti	Baseline 2012	7	4	2	2
	Baseline2037	7	4	2	2
	Scenario Set B	7	6	2	
	Scenario Set C	7	5	2	1
	Scenario Set D	7	5	1	2
	Scenario Set E	7	5	3	
	Scenario 17	8	5	2	
	Scenario 18	8	5	2	
	Scenario 19	7	6	2	
	Scenario 20	13	2		

	Scenario	A	B	C	D
Waiau	Baseline 2012	9	1		
	Baseline2037	9	1		
	Scenario Set B	10			
	Scenario Set C	10			
	Scenario Set D	9	1		
	Scenario Set E	9	1		
	Scenario 17	10			
	Scenario 18	9	1		
	Scenario 19	9	1		
	Scenario 20	10			

Appendix C: Tabulated Data and Results: Estuaries

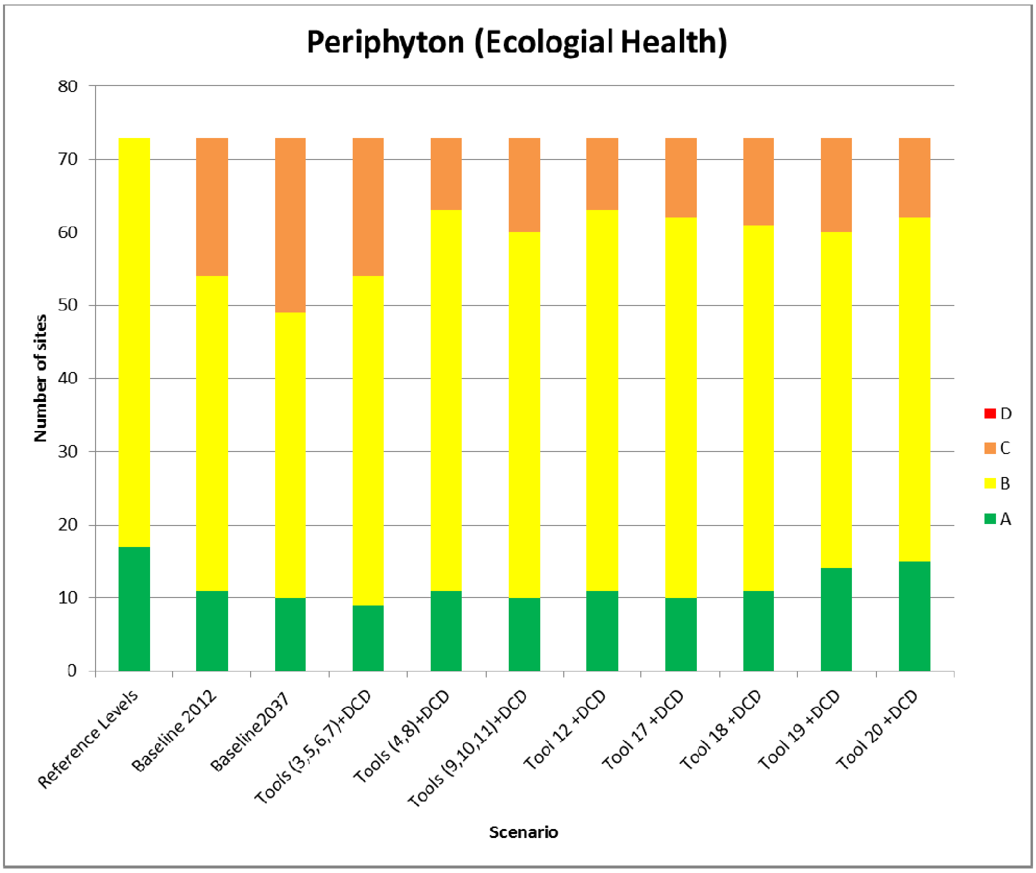
			Baseline20 12 loads (t/y)		Baseline20 37 loads (t/y)		Scenario B loads (t/y)		Scenario C loads (t/y)		Scenario D loads (t/y)		Scenario E loads (t/y)		Scenario 17 loads (t/y)		Scenario 18 loads (t/y)		Scenario 19 loads (t/y)		Scenario 20 loads (t/y)		Reference Levels	
EST_NAME	Area	NewClass	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP
Bluff Harbour	54,580,551	Shallow tidal lagoon	29	3	25	3	31	3	29	3	24	3	22	3	30	3	25	3	27	3	22	3	18	0
Haldane Estuary	1,886,750	Shallow tidal lagoon	36	4	36	4	39	4	38	4	38	4	34	4	38	4	41	4	35	4	30	4	10	1
Jacobs River Estuary	6,697,056	Shallow tidal lagoon	1677	95	2011	107	1788	91	1445	79	1304	80	873	69	1716	85	1653	82	1392	77	1481	82	386	6
Lake Brunton	258,532	Shallow ICOLL	15	0	14	0	17	0	16	0	13	0	10	0	21	0	17	0	14	0	11	0	1	0
New River Estuary	39,823,925	Shallow tidal lagoon	5159	360	5793	390	5461	343	4458	312	4160	310	3023	292	5526	328	5164	330	4447	313	4480	322	928	15
Toetoes Harbour	4,745,903	Shallow tidal river estuary	4721	338	5591	381	5457	356	4732	329	4447	330	3118	310	5200	335	5028	338	4216	312	4061	312	1248	21
Waiau River	758,127	Shallow tidal river estuary	2130	233	2526	255	2424	247	2270	238	2080	239	1647	237	2444	244	2353	240	2017	229	2039	240		
Waikawa Harbour	6,422,282	Shallow tidal lagoon	136	13	175	16	151	14	139	13	146	14	127	13	149	14	140	13	133	13	128	13	34	2
Waituna Lagoon	13,590,093	Shallow ICOLL	251	15	231	15	258	13	194	10	165	10	95	8	240	11	217	11	193	10	169	11	53	1
CALCULATE loads (mg/m2/d)																								
EST_NAME		NewClass	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (	TN/m2 (	TP/m2 (mg/m2/d)		
Bluff Harbour		Shallow tidal lagoon	1	0	1	0	2	0	1	0	1	0	1	0	2	0	1	0	1	0	1	0	1	0
Haldane Estuary		Shallow tidal lagoon	52	6	52	6	56	7	55	6	55	6	49	6	55	6	59	6	51	6	44	6	15	1
Jacobs River Estuary		Shallow tidal lagoon	686	39	823	44	732	37	591	32	533	33	357	28	702	35	676	34	570	32	606	34	158	3
Lake Brunton		Shallow ICOLL	162	3	154	4	180	4	173	4	134	3	102	3	224	4	182	3	149	3	118	3	13	1
New River Estuary		Shallow tidal lagoon	355	25	399	27	376	24	307	21	286	21	208	20	380	23	355	23	306	22	308	22	64	1
Toetoes Harbour		Shallow tidal river estuary	2726	195	3227	220	3150	206	2732	190	2567	191	1800	179	3002	194	2903	195	2434	180	2344	180	721	12
Waiau River		Shallow tidal river estuary	7697	843	9127	922	8760	893	8203	859	7517	863	5951	855	8831	881	8505	866	7288	828	7367	866		
Waikawa Harbour		Shallow tidal lagoon	58	6	75	7	65	6	59	6	62	6	54	5	64	6	60	6	57	5	55	6	14	1
Waituna Lagoon		Shallow ICOLL	51	3	47	3	52	3	39	2	33	2	19	2	48	2	44	2	39	2	34	2	11	0
Convert loads into rating based on Est Summary C17:G20																								
Bluff Harbour			A		A		A		A		A		A		A		A		A		A		A	
Haldane Estuary			B		B		B		B		B		B		B		B		B		B		A	
Jacobs River Estuary			D		D		D		D		D		D		D		D		D		D		C	
Lake Brunton			D		D		D		D		D		D		D		D		D		D		B	
New River Estuary			D		D		D		D		D		D		D		D		D		D		B	
Toetoes Harbour			D		D		D		D		D		D		D		D		D		D		C	
Waiau River			D		D		D		D		D		D		D		D		D		D			
Waikawa Harbour			B		B		B		B		B		B		B		B		B		B		A	
Waituna Lagoon			D		D		D		D		C		C		D		D		D		C		B	
Convert loads into "GOOD" or "POOR" based on rules in Y2:AA5 - WRIGGLE CLASS																								
Bluff Harbour			GOOD	na	GOOD	na	GOOD	na	GOOD	na	GOOD	na	GOOD	na	GOOD	na	GOOD	na	GOOD	na	GOOD	na	GOOD	na
Haldane Estuary			POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	GOOD	na	POOR	na	POOR	na	POOR	na	GOOD	na	GOOD	na
Jacobs River Estuary			POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na
Lake Brunton			POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	GOOD	GOOD
New River Estuary			POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na
Toetoes Harbour			POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	GOOD	na
Waiau River			POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na		na
Waikawa Harbour			POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	POOR	na	GOOD	na
Waituna Lagoon			POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	GOOD	GOOD

Appendix D: Results for DCD Scenarios

D.1: Regionally aggregated results for DCD scenarios

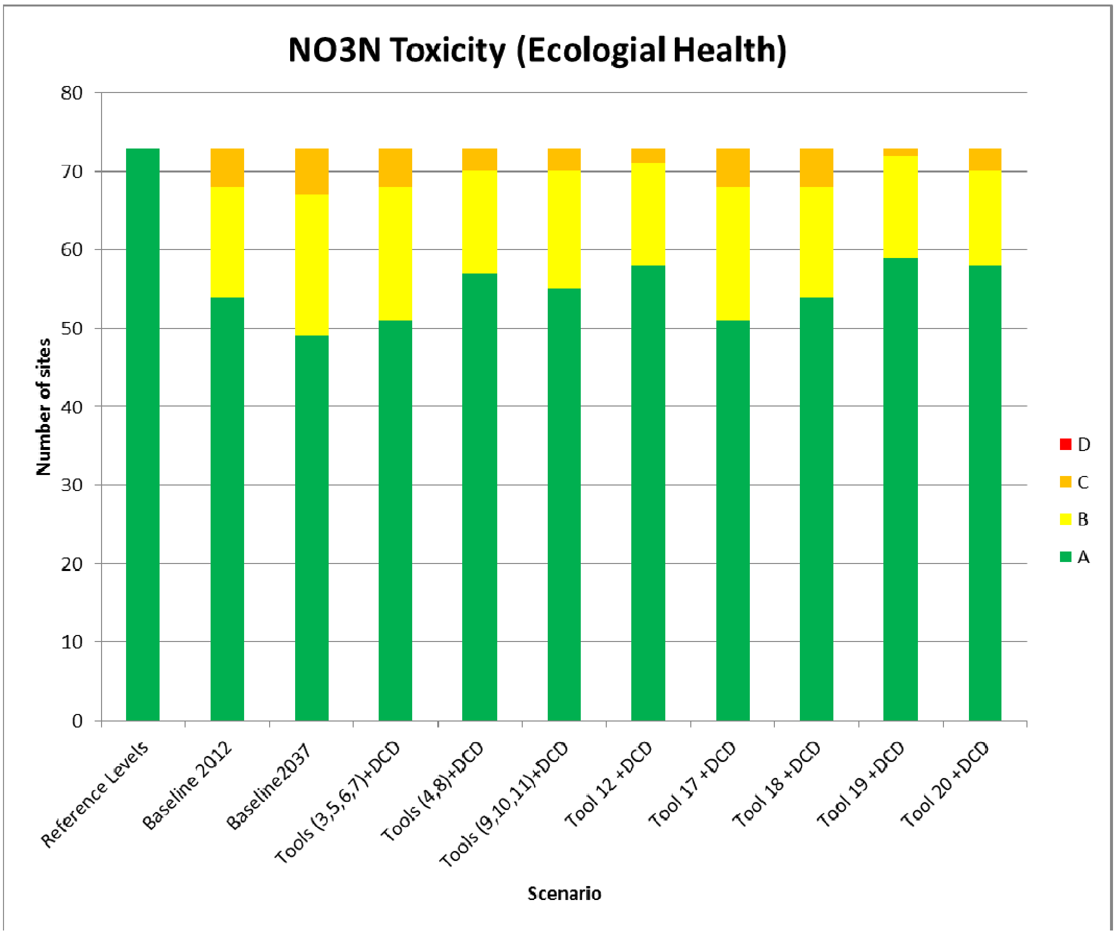
D.1.1: River ecological health objective based on predicted Chlorophyll-a concentrations and nominated bands for scenarios with DCD

Scenario	A	B	C	D
Baseline2037	10	39	24	0
Tools (3,5,6,7)+DCD	9	45	19	0
Tools (4,8)+DCD	11	52	10	0
Tools (9,10,11)+DCD	10	50	13	0
Tool 12 +DCD	11	52	10	0
Tool 17 +DCD	10	52	11	0
Tool 18 +DCD	11	50	12	0
Tool 19 +DCD	14	46	13	0
Tool 20 +DCD	15	47	11	0
Baseline 2012	11	43	19	0
Reference Levels	17	56	0	0



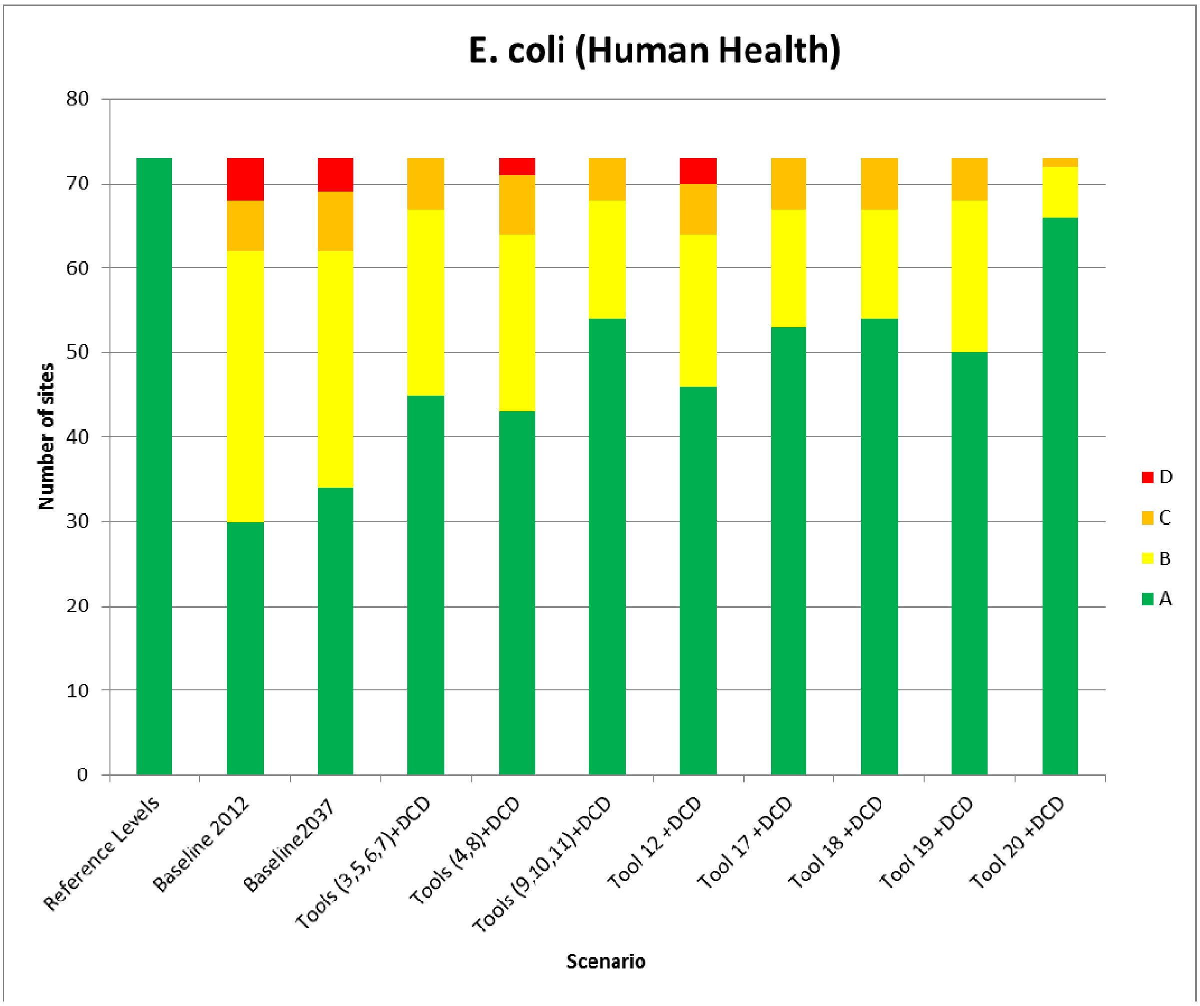
D.1.2: River ecological heath objective based on predicted nitrate concentrations and proposed NOF bands for scenarios with DCD

Scenario	A	B	C	D
Baseline2037	49	18	6	0
Tools (3,5,6,7)+DCD	51	17	5	0
Tools (4,8)+DCD	57	13	3	0
Tools (9,10,11)+DCD	55	15	3	0
Tool 12 +DCD	58	13	2	0
Tool 17 +DCD	51	17	5	0
Tool 18 +DCD	54	14	5	0
Tool 19 +DCD	59	13	1	0
Tool 20 +DCD	58	12	3	0
Baseline 2012	54	14	5	0
Reference Levels	73	0	0	0



D.1.3: River Human Heath objective based on predicted E. coli concentrations and proposed NOF bands for scenarios with DCD

Scenario	A	B	C	D
Baseline2037	34	28	7	4
Tools (3,5,6,7)+DCD	45	22	6	0
Tools (4,8)+DCD	43	21	7	2
Tools (9,10,11)+DCD	54	14	5	0
Tool 12 +DCD	46	18	6	3
Tool 17 +DCD	53	14	6	0
Tool 18 +DCD	54	13	6	0
Tool 19 +DCD	50	18	5	0
Tool 20 +DCD	66	6	1	0
Baseline 2012	30	32	6	5
Reference Levels	73	0	0	0



D.2: Estuary results for scenarios with DCD

D.2.1 Estuary performance against NOF bands for scenarios with DCD

Estuary Name	Class	Reference Levels	Baseline 2012	Baseline2037	Tools (3,5,6,7)+DCD	Tools (4,8)+DCD	Tools (9,10,11)+DCD	Tool 12 +DCD	Tool 17 +DCD	Tool 18 +DCD	Tool 19 +DCD	Tool 20 +DCD
Bluff Harbour	Shallow tidal lagoon	A	A	A	A	A	A	A	A	A	A	A
Haldane Estuary	Shallow tidal lagoon	A	B	B	B	B	B	B	B	B	B	B
Jacobs River Estuary	Shallow tidal lagoon	C	D	D	D	D	D	D	D	D	D	D
Lake Brunton	Shallow ICOLL	B	D	D	D	D	D	D	D	D	D	D
New River Estuary	Shallow tidal lagoon	B	D	D	D	D	D	D	D	D	D	D
Toetoes Harbour	Shallow tidal river estuary	C	D	D	D	D	D	D	D	D	D	D
Waiau River	Shallow tidal river estuary		D	D	D	D	D	D	D	D	D	D
Waikawa Harbour	Shallow tidal lagoon	A	B	B	B	B	B	B	B	B	B	B
Waituna Lagoon	Shallow ICOLL	B	D	D	D	D	D	C	D	D	C	C

D.2.2 Estuary performance based on Wriggle thresholds for scenarios with DCD

Estuary Name	Class	Reference Levels	Baseline 2012	Baseline2037	Tools (3,5,6,7)+DCD	Tools (4,8)+DCD	Tools (9,10,11)+DCD	Tool 12 +DCD	Tool 17 +DCD	Tool 18 +DCD	Tool 19 +DCD	Tool 20 +DCD
Bluff Harbour	Shallow tidal lagoon	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD	GOOD
Haldane Estuary	Shallow tidal lagoon	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	GOOD
Jacobs River Estuary	Shallow tidal lagoon	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Lake Brunton	Shallow ICOLL	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
New River Estuary	Shallow tidal lagoon	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Toetoes Harbour	Shallow tidal river estuary	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Waiau River	Shallow tidal river estuary		POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Waikawa Harbour	Shallow tidal lagoon	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR
Waituna Lagoon	Shallow ICOLL	GOOD	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR	POOR

D.2.3 Modelled total nitrogen loads to the estuaries compared to the load required to achieve at least a C band for scenarios with DCD

Estuary Name	Class	Reference Levels	Baseline 2012	Baseline2037	Tools (3,5,6,7)+DCD	Tools (4,8)+DCD	Tools (9,10,11)+DCD	Tool 12 +DCD	Tool 17 +DCD	Tool 18 +DCD	Tool 19 +DCD	Tool 20 +DCD
Bluff Harbour	Shallow tidal lagoon	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Haldane Estuary	Shallow tidal lagoon	0.07	0.26	0.26	0.31	0.31	0.27	0.27	0.31	0.29	0.25	0.22
Jacobs River Estuary	Shallow tidal lagoon	0.79	3.43	4.11	3.36	2.74	3.01	2.73	3.41	3.28	2.69	3.03
Lake Brunton	Shallow ICOLL	0.34	4.25	4.04	4.95	4.40	4.89	3.91	4.54	4.97	3.74	3.09
New River Estuary	Shallow tidal lagoon	0.32	1.77	1.99	1.81	1.46	1.62	1.44	1.75	1.75	1.46	1.54
Toetoes Harbour	Shallow tidal river estuary	0.72	2.73	3.23	2.97	2.63	2.68	2.56	2.83	2.80	2.34	2.34
Waiau River	Shallow tidal river estuary		7.70	9.13	8.57	7.67	8.18	7.61	8.18	8.44	7.20	7.37
Waikawa Harbour	Shallow tidal lagoon	0.07	0.29	0.37	0.35	0.32	0.29	0.30	0.29	0.30	0.28	0.27
Waituna Lagoon	Shallow ICOLL	0.28	1.33	1.23	1.23	1.07	1.06	0.97	1.22	1.08	0.95	0.90