NIWA
Taihoro Nukurangi

Freshwater quality monitoring by Environment Southland, Taranaki Regional Council, Horizons Regional Council and Environment Waikato

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Executive Summary

Aim of the study

The Office of the Auditor General (OAG) requested assistance from NIWA on technical matters underpinning OAG's audit of freshwater quality management by regional councils in New Zealand. This report details results of a study performed by NIWA that responds to two specific questions posed by OAG:

1. Do regional councils have effective methods to gather information about and monitor the quality of freshwater?

2. Over the last 10 years, what is the state and trends in water quality as indicated by state of the environment monitoring data collected by regional councils and NIWA?

We have addressed these questions for four regional councils specified by OAG:

- Environment Southland
- Taranaki Regional Council
- Horizons Regional Council
- Environment Waikato

To answer the first question we assessed the methods used to monitor the quality of freshwater in each of the following regions: Southland, Taranaki, Horizons, and Waikato. We first obtained information (metadata) from the regional councils that described their State of Environment (SoE) for physical, chemical, microbiological and biological aspects of water quality monitoring programs for rivers, lakes and groundwater. Specifically, we obtained the locations and the details of monitoring sites, the frequency of monitoring, the variables analysed, the QA/QC and data storage procedures. From this information we assessed the network and monitoring programmes from technical perspectives.

To answer the second question we analysed state and trends in water quality data for rivers and streams (hereafter referred to as "rivers") for the ten year period up to and including 2009. We included sites in the National Water Quality Monitoring Network (NRWQN) that is run by NIWA that are within the four regions.

Findings to question 1: Regional council state of environment monitoring of freshwater

We consider that the four regional councils surveyed have well-planned and operated networks for assessing the current state and long term trends in physical and chemical quality of freshwaters. All four councils have monitoring networks with SoE sites for rivers, lakes and groundwater that are distributed over their regions in a reasonably representative manner (i.e. where the number of sites in different catchments or types of water bodies is commensurate with the overall importance and quantity of water bodies of that type). We also consider that all four councils are monitoring a comprehensive suite of relevant physical, chemical, microbiological and biological variables at a suitable frequency, and that they generally have adequate QA/QC and data storage procedures.

We made a specific evaluation of the adequacy of number of sites included in the river SoE monitoring networks in each regions. Our evaluation was based on whether the networks had sufficient statistical power to detect large scale patterns, defined by River Environment Classification (REC) categories, in water quality state and trends. The REC categories grouped the monitoring sites in four categories on the basis of the dominant topography of their catchments; Low-elevation, Hills, Lakes or Mountains. Such groupings provide insights into the causes of spatial patterns of water quality state and trends in relation to environmental and human factors and can be used to describe how well a network of sites represents the overall environmental variation within a region.

We used river water quality data provided by the councils and from the NRWQN for the 10 year period ending 2009 that had been collected at a quarterly or monthly basis. Trend analysis of water quality data, and to a lesser extent the calculation of the central tendency to evaluate state (i.e. mean or median conditions), is only meaningful if calculated using a continuous time series of observations of sufficient length. Not all the river water quality data sets provided by the regional councils were sufficiently complete to provide robust trend analyses for the 10-year period of our trend analysis. We limited our analysis to data sets for which at least 80% of sample occasions had data. Accepting time series with more missed sample occasions would result in more insignificant results. Thus, for sites that were monitored quarterly, we included sites that had data for 32 quarters of 40 possible quarters and for sites that were monitored monthly we included sites that had data for 96 of 120 possible months. These criteria restricted the number of monitoring sites that we used to estimate state and trends. Environment Southland had approximately 56 sites (depending on variable) that met our criteria for trend analysis. Taranaki and Horizons Regional Councils had 13 and 17 SoE sites (depending on variable) that met our criteria respectively. Environment Waikato had a total of 113 SoE sites which met our criteria for trend analysis.

The river water quality monitoring data for Southland and Waikato were able to detect detailed patterns in both state and trends (i.e. statistically significant differences in state and significant overall trends were found for many REC categories and variables). The data for 12 sites in the Taranaki region was sufficient to detect patterns albeit for fewer REC categories and variables than for Southland and Waikato. The Horizons dataset was barely adequate to describe large scale patterns in water quality state and trends in the region. This is because, in the past, Horizons have employed a system of “rolling SoE sites” whereby some sites have been monitored on a rolling basis, i.e. once every three years 12 months of monthly sampling has been undertaken. This practice is no longer carried out by Horizons Regional Council and the number of SoE sites in the monitoring network has been increased to 63. The large differences between regions in the total number of currently active SoE sites reflect, to a degree, the size of the regions.

We do not consider that any of the regions have too few sites to describe regional patterns in water quality. More sites would provide more detailed information at a larger number of specific locations. A case could be made for further SoE sites added to the current Taranaki regional network of 12 sites (which is comparatively low compared to the 113 sites in Waikato, for example). However, we consider it unlikely that the overall regional picture of water quality state and trends would be greatly different if the number of sites in any of the regions were increased. An important point is that if SoE monitoring is to be of maximum benefit (i.e. be suitable for robust trend analysis) it must be frequent and consistent and this requires an ongoing commitment by the regional councils. However, we acknowledge that trend analysis, while desirable, is not necessarily the most important aspect of SoE monitoring. A trade off between cost, coverage of a region’s water bodies and continuity of the time series has to be made.

We did find that Environment Southland and Horizons need to lower detection limits for some water chemistry variables in order to detect trends in currently high quality water bodies. Ideally councils should measure flows on sampling occasions, so as to assist with interpreting water quality data and to enable both trend analysis and estimation of contaminant loads. Where flows are not measured at water quality sites it is common practice to estimate flows from suitable (close) gauged rivers. We consider that the uncertainties associated with flow estimates should be evaluated so that the robustness of trend analyses based on these flows can be assessed.

The four regional councils surveyed monitor biological characteristics in rivers including periphyton (algae that grows on the bed of rivers) and macro-invertebrates (invertebrate animals that live on the bed of rivers). Biological organisms integrate and express the effect of water quality and habitat over time and provide an index of the ecological health of waters. Because living organisms express (in part) the effect of the historic flux of contaminants, they need not be sampled as frequently as water quality. The biological sampling programs of all councils started in the mid 1990s and there has been a consistent effort to monitor at least annually. Environment Southland, Horizons Regional Council and Environment Waikato sample invertebrates annually, whereas Taranaki Regional Council sample invertebrates twice a year. Annual biological sampling is generally performed during summer in order to assess conditions during the period of low flow, which is generally the period of greatest ecological stress. Annual sampling is subject to occasional bias by atypical conditions such as unseasonal flooding but is generally considered to be suitable (and is the protocol of the NRWQN, for example).

All four regional councils carry out SoE monitoring on lakes. These programs are focussed on the management of individual lakes (e.g., cyanobacteria blooms during summer, long term eutrophication). These programs are targeted to specific “iconic” lakes within each region, which is practical and appropriate. All four regional councils have extensive groundwater monitoring SoE programmes that represent the major aquifers in the regions. Monitoring is predominantly carried out on an annual basis and in accordance with the national protocols.

Findings to question 2: State and trends in water quality

We analysed state and trends in river water quality data because SoE monitoring of freshwaters is most comprehensively and consistently carried out on this type of water body (in terms of the time period for which monitoring has been carried out, sample frequency, variables analysed and intensity of sampling). This study did not analyse state and trends in lake or groundwater quality data. Lake data is collected in a less consistent manner across the regions due to differences in the distribution of lakes (e.g., Taranaki and Horizons have few iconic lakes) and because of differences in the intensity of lake management issues. There are also differences in how groundwater is monitored across the regional councils reflecting differing regional focuses of the groundwater programmes. Most groundwater monitoring programmes indicate stable water chemistry other than for nitrate, which is usually monitored in separate (non-SoE) programmes. There have been recent national studies of the state and trends of lakes[1] across New Zealand for the ten year period up to and including 2009 and groundwater[2] up to and including 2008. In addition, we did not analyse state and trends in biological variables (e.g., macro-invertebrates and periphyton data). Again, this was because of differences in the time period for which biological monitoring has been carried out, sampling frequencies and range of variables analysed by the four regions. These differences reflect differing regional focuses for biological monitoring programmes.

We used data supplied by the councils and from the NRWQN to assess river water quality state in each region. Ten physical and chemical variables were assessed; black disc water clarity, conductivity, dissolved reactive phosphorus, total phosphorus, ammonium, oxidised nitrogen, total nitrogen, *E. coli*, faecal coliform, and in a small number of cases total suspended solids. Nutrient species (oxidised nitrogen, total nitrogen, ammoniacal nitrogen, dissolved reactive phosphorus and total phosphorus) were included because they stimulate the growth of plants, including algae, which can be either suspended in the water column of lakes and rivers or attached to substrates (periphyton). Nutrient contamination results from point and non-point source discharges and is strongly associated with intensive land use. High nutrients can promote excessive ('nuisance') growth of plants that, in turn, can smother habitat, produce adverse fluctuations in dissolved oxygen and pH, and impede flows and block water intakes. Excess plants in water bodies also have and detrimental effects on aesthetics and human uses causing changes to water colour, odour and the general physical nature of the environment. Nitrogen and ammoniacal nitrogen are also toxicants that can adversely affect both ecosystems and human health. Effects of nitrogen on human health mean that it is a key variable that is monitored in ground water. We note that Regional councils routinely measure dissolved oxygen and pH which are water quality variables that are strongly influenced by the growth of plants in water bodies. These variables fluctuate over the course of a day due to the metabolic cycles of plants. This means that one-off samples of dissolved oxygen and pH are not particularly useful as SoE variables because they must be interpreted with reference to the time of day that the sample was taken.

[1] Verburg, P., K. Hamill, M. Unwin and J. Abell. 2010. Lake Water Quality in New Zealand 2010 : Status and Trends. NIWA Client Report: HAM2010-107. Hamilton. 52p.
[2] Daughney, C.; Randall, M. 2009. National Groundwater Quality Indicators Update: State and Trends 1995-2008, GNS Science Consultancy Report 2009/145. 60p. Prepared for Ministry for the Environment, Wellington, New Zealand.

Conductivity is routinely measured by the four councils but conductivity itself does not have adverse effects, at least in New Zealand's 'dilute' waters. However, conductivity is a general indicator of ionic constituents including nutrients. Trends in conductivity can indicate changes in water quality due to human activities. Visual water clarity and suspended solids are monitored because they are associated with the attenuation of light due to contaminants that are suspended in the water column and because settleable solids have the potential for smothering the beds of rivers and downstream water bodies. Visual clarity is generally measured as the sighting range of a black disc (e.g. MfE 1994). Low visual clarity has ecosystem effects, including changes in animal behaviour. Water clarity also has implications for contact recreation due to its effect on human visibility through water. Councils include bacterial variables in monitoring for rivers and lakes. Faecal coliforms and *E. coli* indicate the presence of human or animal faeces and the associated risk of infectious disease from waterborne pathogens for both humans via contact recreation and drinking water and livestock via drinking water.

Overview of state analysis

We used the median value of each of the variables at the sites (or the 95^{th} percentile for *E. coli*) as a measure of the state and compared these to guideline "trigger values" for water quality. The trigger values are not national standards but rather, have been devised to assess the levels of physical and chemical stressors which might have ecological or biological effects. Rather than implying that there will be ecological and biological effects caused by increased levels of physical and chemical stressors, exceedances of trigger levels (referrer to here as "failing" guidelines) indicates cause for further investigation of water quality issues.

Our analysis showed that water quality state between sites within regions was highly variable. The state of individual sites also showed strong variation between variables within sites (i.e. sites can meet guidelines for some variables and not for others). As outlined in Table A, across all regions water quality had strong relationships with REC *Topography* categories with the highest water quality (e.g., highest clarity, lowest conductivity, lowest nutrients and lowest indicator bacteria) generally occurring in the Mountain, Lake and Hill *Topography* categories. Low-elevation sites usually failed water quality guidelines for many variables and Hill *Topography* categories often failed (Table A).

Overview of trend analysis

Trend direction and strength for the ten physical and chemical variables over the ten year period from 2000 to 2009 were quantified using the non-parametric Seasonal Kendall Sen Slope Estimator (SKSE). The SKSE is a commonly used method for estimating trends in data that are subject to appreciable seasonality such as water quality data. Values of the SKSE were normalised by dividing by the median and normalising to 100 to give the *relative* SKSE (RSKSE; %), allowing for direct comparison between sites measured as per cent change per year. A positive RSKSE value indicates an increasing trend, while a negative RSKSE value indicates a decreasing trend. The RSKSE values were also associated with a test of significance. If P is "small" (i.e. $P < 0.05$), it can be concluded that the observed trend is most unlikely to have arisen by chance.

Table A: Water quality state by region and variable for sites grouped by REC Topography category. NA = no sites in the category. Pass = the median of the site median values was acceptable with respect to water quality guidelines3. Fail = the median of the site median values was not acceptable with respect to the water quality guideline. The categories L, H, Lk and M refer to catchments dominated by Low-elevation, Hill, Lake or Mountain topography.

Region	Variable	REC Topography category			
		L	H	Lk	M
Southland	Clarity	Fail	Pass	Pass	Pass
	Dissolved reactive phosphorus	Fail	Pass	Pass	Pass
	Escherichia coli	Fail	Fail	Pass	Pass
	Faecal coliforms	Fail	Pass	Pass	Pass
	Ammoniacal nitrogen	Fail	Pass	Pass	Pass
	Total nitrogen	Fail	Pass	Pass	Pass
	Total phosphorus	Fail	Pass	Pass	Pass
	Oxidised nitrogen	Fail	Pass	Pass	Pass
Taranaki	Clarity	Fail	Pass	NA	NA
	Dissolved reactive phosphorus	Fail	Fail	NA	NA
	Escherichia coli	Fail	Fail	NA	NA
	Faecal coliforms	Pass	Pass	NA	NA
	Ammoniacal nitrogen	Pass	Pass	NA	NA
	Total nitrogen	Fail	Pass	NA	NA
	Total phosphorus	Pass	Pass	NA	NA
	Oxidised nitrogen	Fail	Pass	NA	NA
Horizons	Clarity	Fail	Fail	NA	Fail
	Dissolved reactive phosphorus	Fail	Fail	NA	Pass
	Escherichia coli	Fail	Fail	NA	NA
	Faecal coliforms	NA	NA	NA	NA
	Ammoniacal nitrogen	Pass	Pass	NA	Pass
	Total nitrogen	Fail	Pass	NA	Pass
	Total phosphorus	Fail	Pass	NA	Pass
	Oxidised nitrogen	Fail	Pass	NA	Pass
Waikato	Clarity	Fail	Fail	Fail	Pass
	Dissolved reactive phosphorus	Fail	Fail	Fail	Fail
	Escherichia coli	Fail	Fail	Pass	NA
	Faecal coliforms	Fail	Pass	Pass	NA
	Ammoniacal nitrogen	Pass	Pass	Pass	Pass
	Total nitrogen	Fail	Pass	Pass	Pass
	Total phosphorus	Fail	Fail	Fail	Pass
	Oxidised nitrogen	Fail	Pass	Pass	Pass

[3] The guidelines are provided in Table 2 of this report.

Table B: Ten-year overall trends by region and variable for sites grouped by REC Topography category. NA = less than 3 sites in the category (therefore an overall trend could not be assessed), NS = No significant trend for the category, Deg = a degrading trend for the category, Imp = an improving trend for the category. The categories L, H, Lk and M refer to catchments dominated by Low-elevation, Hill, Lake or Mountain topography.

Region	Variable	REC Topography category			
		L	H	Lk	M
Southland	Clarity	NS	NS	NS	NA
	COND	NS	Deg	NS	NA
	Dissolved reactive phosphorus	NS	Imp	NS	NA
	Escherichia coli	NS	Imp	NA	NA
	Faecal coliforms	NS	Imp	NA	NA
	Ammoniacal nitrogen	Deg	NS	NS	NA
	Oxidised nitrogen	Deg	Deg	NS	NA
	Total nitrogen	Deg	NS	NS	NA
	Total phosphorus	NS	NS	NS	NA
Taranaki	Clarity	Deg	NS	NA	NA
	COND	NS	NS	NA	NA
	Dissolved reactive phosphorus	NS	NS	NA	NA
	Escherichia coli	NS	NS	NA	NA
	Faecal coliforms	NS	NS	NA	NA
	Ammoniacal nitrogen	Deg	NS	NA	NA
	Oxidised nitrogen	NS	NS	NA	NA
	Total nitrogen	NS	NS	NA	NA
	Total phosphorus	NS	NS	NA	NA
Horizons	Clarity	NS	NS	NA	NA
	COND	NS	NS	NA	NA
	Dissolved reactive phosphorus	NS	NS	NA	NA
	Escherichia coli	NS	NS	NA	NA
	Faecal coliforms	NA	NA	NA	NA
	Ammoniacal nitrogen	NS	NS	NA	NA
	Oxidised nitrogen	NS	NS	NA	NA
	Total nitrogen	NS	NA	NA	NA
	Total phosphorus	NS	NA	NA	NA
Waikato	Clarity	Deg	Deg	Deg	NA
	COND	Deg	NS	Deg	NA
	Dissolved reactive phosphorus	Imp	Imp	NS	NA
	Escherichia coli	Deg	NS	NS	NA
	Faecal coliforms	Deg	NS	NS	NA
	Ammoniacal nitrogen	Imp	NS	NS	NA
	Oxidised nitrogen	Deg	Deg	Deg	NA
	Total nitrogen	Deg	Deg	Deg	NA
	Total phosphorus	Imp	Imp	NS	NA

Trend direction and strength at individual sites showed strong variation across variables. An overview of the trends in each region's river water quality is provided by grouping sites by REC Topography categories (Table B). We deemed that there was an overall trend for a REC Topography category if the number of sites that exhibited that trend were greater than could be expected by chance. This was formally evaluated with the Binomial test under the null hypothesis that degrading and improving trends were equally likely. In this manner we found overall degrading trends in clarity in Taranaki and Waikato, degrading trends in conductivity in Waikato, improving trends in Dissolved reactive phosphorus in Southland, Taranaki and Waikato, a degrading trend in *E.coli* in Waikato, improving trends in Ammoniacal nitrogen in Horizons and Waikato and a degrading trend in ammoniacal nitrogen in Taranaki, degrading trends in oxidised nitrogen in Southland, and Waikato, degrading trend in total nitrogen in Southland and Waikato and improving trend in total phosphorus in Horizons and Waikato. When these trends were broken down by REC categories there was a predominance of degrading trends in Low-elevation and Hill *Topography* and the Pasture *Land-cover* categories. These results suggest that water quality degraded over the ten year period in Low-elevation areas and in catchments dominated by pastoral land cover (often in low elevation areas). There were however, generally improving trends in dissolved reactive phosphorus and total phosphorus in all of the regions.

The degrading trends are consistent with increasing intensification of agricultural land use in New Zealand's low elevation and hill country pastoral landscapes. However, there were improving trends in dissolved reactive phosphorus and total phosphorus. The improving trend in phosphorus shown in this study is consistent with a recent national study[4] and may be attributable to two factors. First, there has been increase in phosphorus fertiliser costs over the last decade (an 86% rise in 2008 alone). Second, there has also recently been very active management of soil phosphorus (Olsen-P) levels by the pastoral industry. However, the degrading trend in nitrogen may be attributable to increased farm production. For example, there has been a 20% rise in dairy-farm production. This increase in production is associated with leaching of nitrogen from pasture soils for which there are not currently adequate mitigation methods.

Two points of caution need to be borne in mind in using the state and trends analysis in this report to draw conclusions concerning regional councils' management of freshwater. First, we compared the existing state to non-statutory guideline values. To fully assess whether regional councils are meeting (their own) standards, the standards defined in statutory plans would need to be compared with the state information derived in this study. Second, trends provide information about change in water quality over time but also need to be considered within the broader statutory framework that regional councils have set. That analysis is outside the scope of this report.

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

1. Introduction

The Office of the Auditor General (OAG) requested assistance from NIWA with OAG's audit of freshwater quality management by regional councils. This report details results of a study performed by NIWA for OAG that responds to two specific questions posed by OAG:

- Do regional councils have effective methods to gather information about and monitor the quality of freshwater?
- Over the last 10 years, what is the state and trends in freshwater quality (within selected catchments and regions) as indicated by state of the environment monitoring data collected by regional councils as well as NIWA?

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These questions have been addressed for four regional councils specified by OAG:

- Environment Southland
- Taranaki Regional Council
- Horizons Regional Council
- Environment Waikato

To answer question one we assessed the methods used to monitor the quality of freshwater in each of these regions. We first obtained information (metadata) from the regional councils that described their State of Environment (SoE) for physical, chemical and biological aspects of water quality monitoring programs for rivers, lakes and groundwater. Specifically, we obtained the locations and the details of monitoring sites, the frequency of monitoring, the variables analysed, the QA/QC and data storage procedures. From this information we assessed the network and monitoring programmes from technical perspectives.

To answer question two we analysed state and trends in water quality data for rivers and streams (hereafter referred to as "rivers") for the ten year period up to and including 2009. We included sites in the National Water Quality Monitoring Network (NRWQN) that is run by NIWA that are within the four regions.

The first section of this report describes the methods we used to address these questions. The subsequent two sections provide our response to the two questions for each of the four regions.

2. Methods

2.1 Question 1: Assessment of the methods used by the regions to monitor the quality of freshwater

We obtained information (metadata) from the four regional councils (Waikato, Taranaki, Horizons and Southland) that described their State of Environment (SoE) water quality monitoring programs for rivers, lakes and groundwater including; the locations and the details of sites in their networks, the frequency of monitoring, the variables analysed and the QA/QC and data storage procedures. From this information we reviewed the following aspects of their monitoring programmes:

1 **Network design.** We considered the design of the regional council networks including; the number of sites, where (what types of environments) they cover, sampling interval (frequency) as it relates to future use of the data for trend analysis and load calculations. A key question we addressed was the extent to which the major freshwater resources (rivers, lakes and groundwater) were represented in the SoE programmes. As part of this, for each region, we assessed the extent to which each network of sites represented the environmental variation in freshwater resources. An allied but less easily answered question concerns the overall adequacy of the network. A single definitive test of the adequacy of networks is hard to justify because all the potential uses of SoE data cannot be known. However, a reasonable test is whether the distribution of monitoring sites across a region's water bodies is sufficient to establish general patterns in both state and trends in statistically robust way. We responded to this question for each regions rivers, for which we were analysing state and trends, by grouping both state and trend data by environmentally defined groups. The details of these tests are discussed in section 2.2.5 below.

2 **Water quality variables.** We considered the measured variables and analysis methods. This included review of methods used for sample collection, preservation and stabilisation (for samples analysed in a laboratory at a later date) and analysis. We assessed detection limits (sensitivity of the analytical methods) and significant figures in reported data. Detection limits can be particularly important when monitoring water bodies that have high water quality status and there is an expectation that the time series will be used to perform trend analysis.

3 **Flow data.** When monitoring river water quality, it is important to have flow measurements accompanying each water quality measurement as many water quality variables are subject to either dilution (decreasing concentration with increasing flow, e.g., conductivity) or land runoff (increasing concentration with increasing flow, e.g., total phosphorus). Data can be flow adjusted before trend analysis, to remove the effects of changes in flow on water quality variable

concentrations. Because changes in flow are tied to natural changes in precipitation and evapotranspiration, flow adjustment of water quality variable concentrations allows trends caused by other, largely anthropogenic, changes to be more directly assessed. Without a proper consideration of flow-dependency (of any given variable) it is difficult to decide if concentration increases are a result of more rainfall or increased land loadings. Furthermore, flow data enables accurate calculation of loads and specific yields to characterise land use change in a given catchment.

4 **Microbial variables.** We reviewed the microbial variables that are included in the SoE programmes. Microbial variables provide measures of the risk of infection from waterborne pathogens and may include the faecal indicator bacterium *Escherichia coli* (*E. coli*), or the whole Faecal coliforms (FC) group (that includes *E. coli* , but also other "coliforms" such as those of the genus *Klebsiella*) that are found in the gut of warm-blooded animals.

5 **Biological monitoring**. We reviewed the biological variables (viz. macroinvertebrates, cyanobacteria and periphyton cover) that are included in the SoE programmes. Surveys of biological variables complement water quality monitoring by providing measures of ecosystem health and habitat condition (invertebrates), nuisance growths of plants (periphyton) or potential health risks (cyanobacteria), and by integrating water condition over time.

6 **QA/QC methods.** We considered the quality assurance and control (QA/QC) methods and data storage and QA/QC procedures.

2.2 Question 2: Analysis of state and trends in river water quality

We analysed state and trends in river water quality data because state of environment monitoring of freshwaters is most comprehensively and consistently carried out on this type of water body (in terms of the time period for which monitoring has been carried out, sample frequency, variables analysed and intensity of sampling). This study did not analyse state and trends in lake or groundwater quality data. Lake data is collected in a less consistent manner across the regions due to differences in the distribution of lakes (e.g., Taranaki and Horizons have few iconic lakes) and because of differences in the intensity of lake management issues. There are also differences in how groundwater is monitored across the regional councils reflecting differing regional focuses of the groundwater programmes. Most groundwater monitoring programmes indicate stable water chemistry other than for nitrate, which is usually monitored in separate (non-SoE) programmes. There have been recent national studies of the state and trends of lakes (Verburg et al. 2010) across New Zealand for the ten year period up to and including 2009 and groundwater (Daughney et al. 2009) up to and including 2008. In addition, we did not analyse state and trends in biological variables (e.g., macro-invertebrates and periphyton data). Again, this was because of differences in the time period for which biological monitoring has been carried out, sampling frequencies and range of variables analysed by the four regions. These differences reflect differing regional focuses for their biological monitoring programmes.

2.2.1 Obtaining and formatting river water quality data

All New Zealand regional councils maintain extensive water quality databases, which are frequently used by MfE and other agencies (including NIWA) for specific research projects (e.g., Ballantine et al., 2010). When discussing data requirements for the current project with OAG, it was decided to compile all state-of-environment water quality monitoring data collected by each of the four regional councils for the 10 year period up to the end of 2009. To this we also added the National River Water Quality Network (NRWQN) water quality monitoring data for sites in the four regions. The NRWQN is a national network of river water quality monitoring sites that is operated by NIWA. However, these data are often used by councils to augment their own SoE data and reports.

The data sets used for this study provided records of commonly measured water quality variables (Table 1) at a range of sites over time, but varied widely in reporting formats, reporting conventions, variable names, units of measurement, and sampling frequency. For example, reporting formats ranged from a single Excel sheet with all variables for all sites stored in a single column, to multiple workbooks for individual sites with data for each site distributed over multiple worksheets with each variable stored in a separate column. Electrical conductivity was provided as a field measurement (labelled "Conductivity" or some near equivalent), as a laboratory measurement (typically labelled EC25, i.e., conductivity at 25°C), and sometimes as both within a single region. Units of measurement (most notably for conductivity) varied between regions, and (less commonly) for a single variable within a region. To consolidate these data into a uniform structure and minimise the potential for error associated with manually copying data between worksheets, we used a modified version of a MS-Access database developed for a previous MfE water quality review (Ballantine, et al., 2010). When retrieving data for subsequent analyses, we adopted the following conventions:

1. field conductivity (COND) was used where available, otherwise EC25 (which was highly correlated (r^2 = 0.85) with COND for sites where both variables were reported) was used as a surrogate

2. variables marked as below a specified detection limit were recoded as half the detection limit. For variables marked as above a specified level (e.g., *E. coli* > 20 000), we used the numerical value as given.

3. total nitrogen (TN) for regions which did not specifically report this variable was calculated (where possible) as the sum of Nitrate+Nitrite Nitrogen (NNN) plus Total Kjeldahl Nitrogen (TKN).

4. Sites in estuarine waters were flagged so as to avoid skewing data for variables (such as conductivity) which are likely to be highly elevated in such environments.

Data associated with each site included:

1. site name

2. location and regional council identifier (if available)

3. NZMS260 grid reference (converted from NZTM as appropriate)

4. reach number (NZ Reach) as defined in the River Environment Classification (REC; see Section 2.2.2) scheme (Snelder and Biggs, 2002).

All sites were then assigned a unique identifier based on the corresponding regional council name and site identifier. All analyses were derived from queries of this database, which produced water quality data for the 11 variables described in Table 1 in consistent units.

Table 1: Water quality variables included in this study

Variable type	Variable name	Description	Units
Physical	CLAR	Black disc visibility	m
	COND	Electrical conductivity	μS/cm
	SS	Total suspended solids	mg/L
Nutrients	NH_4-N	Ammoniacal nitrogen	mg/L
	NO_x -N	Oxidised nitrogen	mg/L
	TN	Total nitrogen	mg/L
	DRP	Dissolved reactive phosphorus	mg/L
	TP	Total phosphorus	mg/L
Bacteria indicator	*E. coli*	*Escherichia coli*	n/100 mL
	FC	Faecal coliforms	n/100 mL

Within the regions, over the duration of the sampling, water quality analytical methods have changed. One example of this is field conductivity and lab conductivity at 25°C. Some regional councils previously used one method but, during the sampling period, changed to another method. In such cases, we combined the data that was analysed using different methods to provide a continuous record. In the case of field conductivity and lab conductivity, this was justifiable because the two methods produce data that are strongly correlated ($r^2 = 0.85$).

The resulting data set contained some gaps in temporal coverage corresponding to missed sampling occasions, mixed (quarterly and monthly) sampling by individual councils and the discontinuation or commencement of sites during the period. Trend analysis is only robust if calculated using a data set with few missing values and must be data collected consistently on either a quarterly (i.e. seasonal) or monthly basis. Not all data sets provided by the regional councils were sufficiently complete to provide robust trend analyses for the 10-year period of our trend analysis. For example some sampling occasions (either months or seasons) were missed for many sites (Figure 1). In addition, Horizons historically employed a system of "rolling SoE sites" whereby sites were monitored discontinuously, for example once every three years a years worth of monthly sampling may be undertaken (Figure 1). This strategy increases spatial coverage, but means that data cannot be robustly analysed for trends. To ensure our trend analysis was robust, we limited our analysis to data sets for which at least 80% of sample occasions had data. Thus, for sites that were monitored quarterly, we included sites that had data for 32 quarters of 40 possible quarters. For sites that were monitored monthly we included sites that had data for 96 of 120 possible months.

2.3 Water Quality State

We used the median concentration of all observations and for each water quality variable over the entire time period to describe the water quality state of each site that met our criteria for trend analysis. To place these values in context they have been compared with guidelines and 'trigger values' (Table 2). The median nutrient concentrations have been compared with the New Zealand trigger values for the protection of aquatic ecosystems from the Australian and New Zealand Environment Conservation Council (ANZECC) guidelines (ANZECC, 2000). The trigger values are not national standards but rather, have been devised to assess the levels of physical and chemical stressors which might have ecological or biological effects. Rather than implying that there will be ecological and biological effects caused by increased levels of physical and chemical stressors, exceedances of trigger levels indicate cause for further investigation of water quality issues. Conversely, where trigger levels are *not* exceeded we can have reasonable confidence that water quality is sufficient to support the ecological values. We compared the median clarity measurements to the MFE (1994) water quality guidelines for clarity.

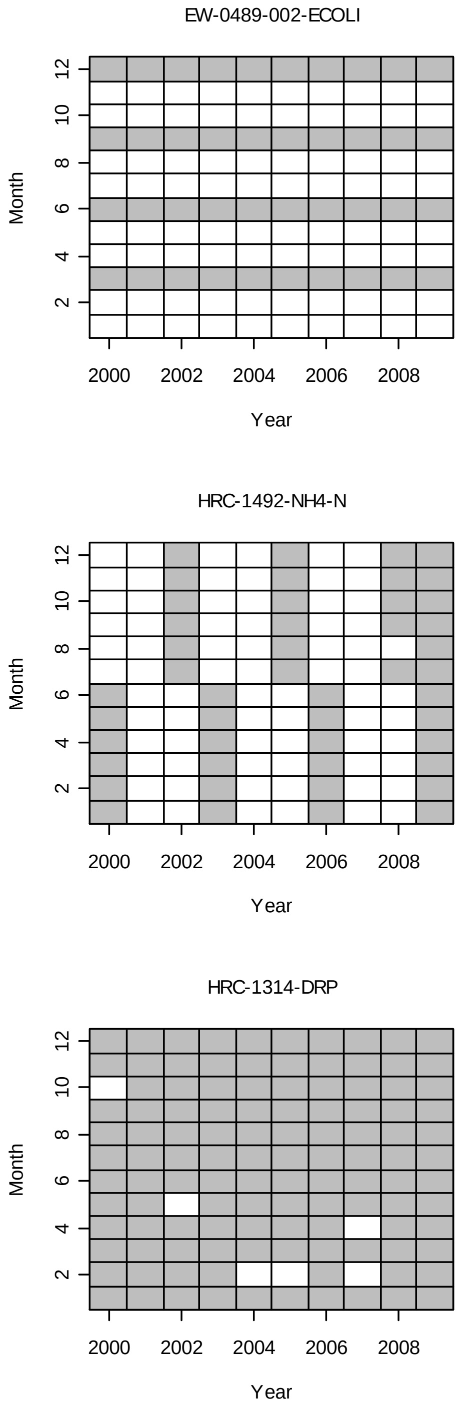

Figure 1: **Typical sample calendars (years on the horizontal axis and months on the vertical axis) showing when data was present for specific variables at three sites. Gaps in temporal coverage are white and sample occasions with data are grey. The upper calendar shows months when *E.coli* data was available for an Environment Waikato site that has been sampled quarterly (seasonally). The middle calendar shows months when NH4-N data is available for a Horizons Regional Council site that has been repeatedly discontinued and re-commenced (a rolling site). The lower calendar shows months when DRP data is available for a Horizons Regional Council site that is sampled monthly but for which some dates have been missed.**

We compared the 95th percentile values for *E. coli* with the microbiological water quality guidelines for recreational use (MfE and MoH, 2003), which are based on the 95th percentile value for *E. coli*. Finally we nominated a guideline of 148/100 mL for Faecal Coliforms (FC) based on the ANZECC (2000) guideline for *E.coli* of 126 /100ml. Because *E. coli* makes up approximately 85% of all faecal coliforms the guideline represents a FC guideline of 148 /100ml.

Table 2: ANZECC trigger values for nutrients (based on median values), MfE guideline for clarity (based on median values) and MfE/MoH guideline value (95th percentile) for *Escherichia coli* and modified ANZECC 2000 guidelines for Faecal Coliforms.

	CLAR (m)	DRP (ppm)	NH_4-N (ppm)	NOx-N (ppm)	TN (ppm)	TP (ppm)	*E. coli* (per 100ml)	FC (per 100ml)
ANZECC (2000) (lowland)		0.010	0.021	0.444	0.614	0.033		
ANZECC (2000) (upland)[5]		0.009	0.010	0.167	0.295	0.026		
MFE (1994) Guideline	1.6							
MfE/MoH (2003)							550[6]	148

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To facilitate comparisons, and to provide an insight into the spatial patterns of water quality and the environmental and human factors that determine these, we compared the median values (95th percentile for *E. coli*) of selected variables for sites for which at least 80% of sample occasions had data, grouped by REC *Topography* and *Land-cover* categories.

2.4 Trend analysis

2.4.1 Statistical analysis

The trend assessment was carried out on data for a ten year time period (2000–2009). Trends in water quality variables can be evident when the data are viewed graphically. For example Figure 2 shows time series for TN, TP and DRP collected over the 10-year period at a site in the Southland region. Trends at all sites and variable

[5] Above 150 metres a.s.l.

[6] The action threshold for *E. coli* is 550 /100 ml. This guideline is for recreational water quality and applies to the "summer season" (1 November to 31 March).

combinations that met our criteria were formally assessed using the non-parametric Seasonal Kendall Sen Slope Estimator (SKSE, Sen 1968). The SKSE is used to quantify the magnitude and direction of trends in data that are subject to appreciable seasonality such as water quality data. Regional councils commonly use the Time Trends software (http://www.niwa.co.nz/our-science/freshwater/tools/analysis) to estimate SKSE values. We used the same method that that is provided by Time Trends within alternative (bespoke) software because of the number of sites considered which would make trend analysis onerous.

It is important to have flow measurements accompanying each water quality measurement because many water quality analytes are subject to either dilution (decreasing concentration with increasing flow, e.g., conductivity) or wash-off (increasing concentration with increasing flow, e.g., total phosphorus). Data can be flow adjusted before trend analysis, to remove the effects of variation in river flow on water quality analyte concentrations. Because changes in river flow are tied to natural changes in precipitation and evapotranspiration, flow adjustment of water quality analyte concentrations allows trends caused by other, largely anthropogenic, changes to be more directly assessed. Trend analysis was carried out on raw data and on flow adjusted data but only flow adjusted trends are discussed in this report since these are usually the most useful basis for inferring change in water quality.

The flow adjustment procedure was performed using LOWESS[7] (LOcally WEighted Scatterplot Smoothing) with a 30 per cent span. Every data point in the record was adjusted depending on the value of flow as outlined by Smith *et al*. (1996): adjusted value = raw value – smoothed value + median value (where the "smoothed value" is that predicted from the flow at time of sampling using LOWESS). For cases where flow data were provided for at least 80% of water quality sampling occasions, we used these flow data to flow adjust each variable. In cases where flow data were provided for less than 80% of water quality sampling occasions we used a flow estimation method (Ballantine et al 2010) to estimate flows and therefore perform flow adjustment.

Values of the SKSE were normalised by dividing by the median to give the *relative* SKSE (RSKSE), allowing for direct comparison between sites measured as per cent change per year. The RSKSE may be thought of as an index of the relative rate of change. A positive RSKSE value indicates an overall increasing trend, while a negative RSKSE value indicates an overall decreasing trend. The SKSE calculations were accompanied by a Seasonal Kendall test (Helsel and Frans, 2006) of the null hypothesis that there is no monotonic trend. If the associated *P*-value is "small" (i.e. *P*

7 LOWESS (locally weighted least squares) is a data analysis technique for producing a "smooth" function that describes a "noisy" relationship between two variables (Cleveland, 1979).

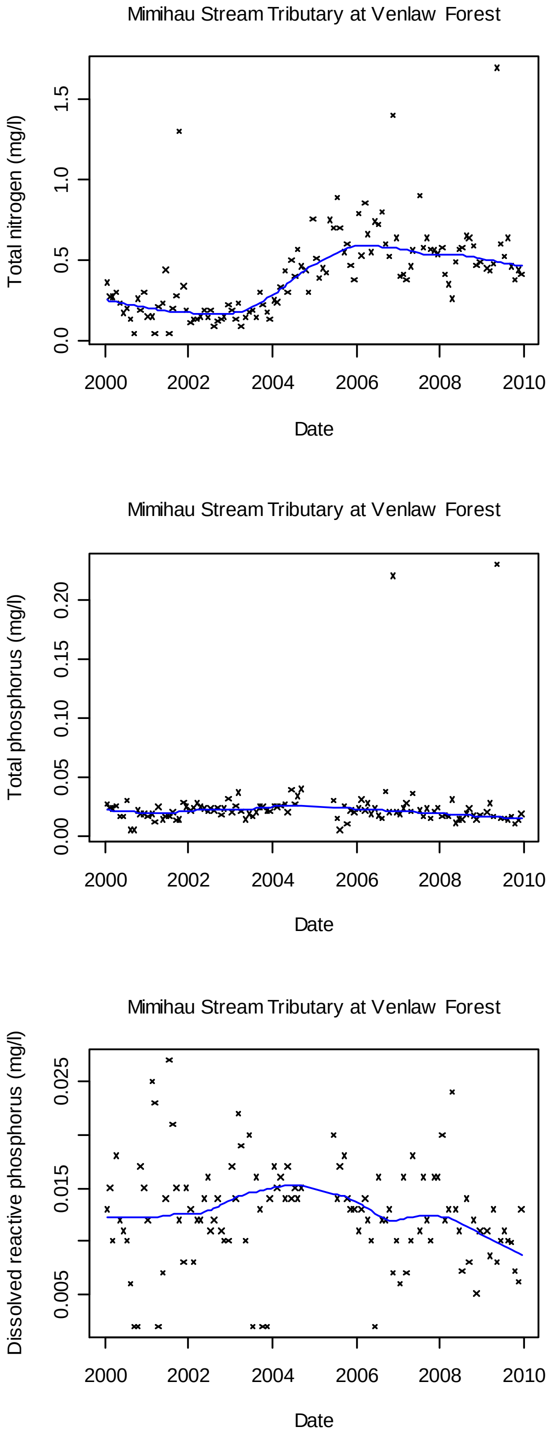

Figure 2. **Scatter-plots of Total Nitrogen, Total Phosphorus and Dissolved Reactive Phosphorus data collected over the 10-year period at a site in the Southland region. A smoothed line has been fitted to the data to illustrate a temporally averaged concentration that indicates the longer term trend. When formal trend analyses were performed on these data the variable in the upper plot (Total Nitrogen) had a significant increasing trend, the variable in the middle plot (Total Phosphorus) had middle plot was stable and variable in the lower plot (Dissolved Reactive Phosphorus) had a significant decreasing trend.**

< 0.05), the null hypothesis can be rejected (i.e. the observed trend or any larger trend, either upwards or downwards, is most unlikely to have arisen by chance).

2.4.2 Flow estimation methods

Many regional council water quality sampling sites either did not have flow recording stations or did not provide flow measurements for the sampling occasions. Therefore, we used a method for estimating flows that interpolates data from gauging stations in the New Zealand Hydrometric Network (Ballantine et al. 2010). Only flow gauges with five or more years of data and that were free from flow modification due to abstractions and dams were used (n = 264). For each water quality site and each date when water quality had been measured we identified the most appropriate flow gauging station. This gauging station was defined as the geographically closest gauging station (Euclidean distance) that shared the same REC Climate and *Topography* category as the monitoring site (see Section 2.5.1) and that also had a record of flow at the time of sampling. The flow recorded at the closest flow gauging station was standardised by dividing by mean flow for the entire flow monitoring period. Standardised flows were then converted to units of $m^3 s^{-1}$ multiplied by the national estimate of mean flow (Woods et al. 2006) associated with each water quality monitoring site.

In a previous study Ballantine et al. (2010) showed that we can have a reasonable level of confidence in the overall findings of water quality trend analyses derived using flows estimated using this method. However, trends for some individual sites have large errors due to uncertainties associated with the flow estimation. Uncertainties associated with these flow estimates reduce the robustness of our trend analysis in comparison to having flow measurements associated with all water quality observations. The implication of this for this study is that the trends for individual sites need to be treated with caution. However, Ballantine et al. (2010) showed that we can be confidant concerning our findings for overall trends (that is trends at the regional scale or by environmentally defined groupings within regions, see Section 2.6).

2.4.3 Categorisation of trends

To provide an interpretation of the trends we categorised them according to their direction and magnitude. Scarsbrook (2006) recognised that statistical significance of a trend does not necessarily imply a 'meaningful' trend, i.e., one that is likely to be relevant in a management context. We followed Scarsbrook (2006) in denoting a 'meaningful' trend as one for which the (statistically significant) RSKSE has an absolute magnitude > 1 per cent $year^{-1}$. Scarsbrook (2006) recognised that the choice of 1 per cent $year^{-1}$ as the 'meaningful' threshold is arbitrary, but this has the advantage that it corresponds to a magnitude that people are likely to detect within a human lifetime. Therefore, trends were categorised as follows:

i. **no significant trend** – the null hypothesis for the Seasonal Kendall test was **not** rejected (i.e., $P > 0.05$)

ii. **significant trend** – the null hypothesis for the Seasonal Kendall test was rejected (i.e., $P < 0.05$) but the magnitude of the trend (SKSE) was less than one per cent per annum of the raw data median (i.e., the RSKSE value was less than 1 per cent year^{-1}). Note that the trend at some sites may be 'significant but not meaningful'

iii. '**meaningful' trend** – the null hypothesis for the Seasonal Kendall test was rejected (i.e., P < 0.05) and the magnitude of the trend (SKSE) was greater than one per cent per annum of the raw data median (i.e., the RSKSE value was greater than 1 per cent year-1 or about 10% per decade)

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2.5 Ranking of sites within regions

To help identify locations or catchments of management concern *within* each region or risk we ranked the sites based on an index derived from the state and trends analysis. The ranking for a site is made by summing scores that are assigned to state and trends for each variable. Variables that fail guidelines were assigned a score of 1 and that pass a score of 0, as follows:.

- meaningful degrading trend was assigned -2,
- significant degrading trend was assigned -1,
- insignificant or stable trend was assigned a score of 0,
- significant and meaningful improving trend was assigned 1,and
- significant and meaningful improving trend was assigned 2.

High values of the index indicate sites that fail several guidelines and for which several trends are degrading and low values represent the reverse. The sites were ordered in tables from highest risk (i.e. those with the largest index) to lowest concern. We stress that this is a subjectively defined ranking and the actual level of management concern must also include consideration of the values that are affected and their significance, which we have not considered. We also urge caution in using state and trends at specific sites as a basis for making conclusions about management because water quality conditions can be affected by very localized activities and be associated with legacies. We therefore consider that an overview of the region's water quality is more robustly made by grouping sites by River Environment Classification (REC) categories (see section 2.6.3).

2.6 Determination of overall state, trends and assessment of the monitoring network

We assessed overall state, trends in each region and each council's river monitoring network by grouping sites according to River Environment Classification categories (REC; see Section 2.5.4 below). The REC groups rivers that share similar environmental characteristics and which therefore tend to have similar physical and biological characteristics (Snelder and Biggs, 2002). REC *Topography* and *Land-cover* categories classify rivers according to the dominant topography and land cover of their catchments. Such groupings are commonly used to provide insights into the causes of spatial patterns of water quality state 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).

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2.6.1 Representativeness of council's river monitoring network

We performed an analysis to assess how well each council's river monitoring network represented the environmental variability of the region's rivers by first evaluating the number of SoE sites in all combinations of REC *Topography* and *Land-cover* categories. We then compared the number of sites in each combination of REC *Topography* and *Land-cover* categories with the total length of rivers belonging to this category. The implicit assumption here was that river length is an appropriate weighting of 'representativeness'. This assessment, therefore, provides an indication of how representative the regional councils monitoring networks are in relation to river length in various categories. We acknowledge there are other physically and ecologically meaningful weightings that could be applied also (e.g., flow or riverbed area). We also acknowledge that regional councils have specific issues that influence the exact layout of their networks. The assessment provided here is just one way of assessing the 'representativeness' of the monitoring. Other criteria against which a monitoring network might be assessed could consider the overall perceived importance of water bodies or focus on areas subject to the greatest impact.

We made two sets of representativeness analyses. First, we counted the sites that that met our criteria for trend analysis (see Section 2.4). This provides an assessment of the representativeness of the historic network (i.e., how representative the council's network *was* – over the 10-year period 1999-2009). Second, we counted sites in the SoE network as of 2009 to analyse how representative the council's network *is now*. Ongoing changes in the number and location of network sites will mean that, in future, the existing network may be more or less representative than it was over the 10-year period.

2.6.2 Determination of overall state, trends and assessment of the statistical power monitoring network

Previous studies have shown that water quality state and trends vary strongly between sites within regions. In addition, studies have shown that within sites, there can be strong variation in water quality state and trends between variables. Sites can meet guidelines for some variables and not for others (e.g., Ballantine et al. 2009). There can also be conflicting trends at sites for different variables. For example, Figure 2 shows three quite different trends at the same site; a significant increasing trend for TN, a stable trend for TP and decreasing trend for DRP.

To provide regional summaries of water quality state and trends we grouped water quality sites into REC *Topography* and *Land-cover* categories and provided an overview of the category. For state we use boxplots to show the central tendency (i.e. the median) and dispersion (5th, 25th, 75th and 95th percentile values) of the median values of the individual sites in each group for each variable. We compared the median of the grouped values to the guidelines to show whether the categories "overall" tended to be within or exceed guideline values. We also tested whether there were statistically significant differences in the median of site median values when grouped by REC *Topography* and *Land-cover* categories using the Kruskal–Wallis one-way analysis of variance. A significant Kruskal–Wallis statistic indicates that there are differences in the group medians. We consider that the Kruskal–Wallis is one of many possible measures of the adequacy of the number of sites in each region's monitoring network. A significant test indicates sufficient statistical power (numbers of sites relative to the variability of the site medians) to detect large scale patterns (as defined by REC categories) in water quality state. Insignificant Kruskal–Wallis statistics would suggest that more sites are needed.

We used the binomial test[8] to determine "overall trends" for sites grouped by REC *Topography* and *Land-cover* categories in each region and for each variable. We deemed that there was an overall trend in a certain direction for a grouping if the number of sites that exhibited that trend were greater than could be expected if increasing and decreasing trends were equally likely. The binomial test determined whether there are more trends in a group of sites than could be expected by chance. To perform a binomial test we first counted the number of positive RSKSE values (increasing trends). Note that all RSKSE values were included regardless of their *p* values. We then performed a "two-tailed" binomial test based on expectation that sites have a 50 per cent probability of having an increasing trend. If the resulting *p*-value was less then 0.05 we rejected the null hypothesis, i.e. we concluded that there were more trends in a group than could be expected by chance and that the group exhibited an "overall" trend. We then determined the overall trend direction as positive if the

8 The binomial test is used for discrete dichotomous data, where each sampling event can result in one of only two outcomes.

proportion of positive trends was greater than 50 per cent and negative if the reverse were true. A complication arises because RSKSE values can take the value zero for several reasons, some of which are related to data quality. In particular, RSKSE can be zero if there are many non-detect values in the time-series or if there are many identical values (ties), which occurs if the precision of the test or recorded concentrations are low. We added half of the number of sites with RSKSE values equal to zero to the number of increasing trends and performed the test based on this number. Note that the reported values are the number of sites with RSKSE values equal to zero regardless of their *p*-values and should not be confused with stable trends (i.e. RSKSE values equal to zero and $p < 0.05$).

We used the binomial tests as another measure of the adequacy of the monitoring network. A significant test indicates sufficient statistical power (numbers of sites relative to the variability of the trends among sites) to detect large scale patterns (as defined by REC categories) in water quality trends. We consider that insignificant binomial tests suggest large scale patterns in a region's water quality trends cannot be inferred and that more sites would be needed to detect such large scale patterns in trends.

2.6.3 River Environment Classification

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 catchment of each segment is described by various environmental variables (i.e. catchment characteristics) and these are categorised to define REC categories. REC *Topography* and *Land-cover* categories have previously been shown to distinguish significant differences in many river characteristics including water quality and hydrology (e.g., Snelder *et al.*, 2005). We used the geographic coordinates and site names to locate all sites in the database on a single NZ Reach[9] in the REC river network. Once linked with the river network, all sites were able to be associated with their REC categories and other data (e.g., site elevation) that were subsequently used in our analyses.

[9] The NZ reach is a unique valley segment, defined by the upstream and downstream tributaries, which is represented by the digital river network on which the REC is based.

Table 3: REC categories for the *Topography* and *Land-cover* groups of categories and the category criteria (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	

3. Regional council methods for monitoring freshwater quality

3.1 Environment Southland

3.1.1 Rivers physical-chemical and microbiological

Baseline river water quality monitoring commenced in Southland in 1989 as part of the National River Water Quality Monitoring Network run by NIWA. There are five sites in the NRWQN within the region, located on four main river systems (Waiau, Aparima, Oreti and Mataura). To supplement this network, Environment Southland established a comprehensive monitoring programme in 1994 and 1995. Regular monthly monitoring of faecal indicator bacteria commenced in July 1994 at 15 sites. In July 1995, a network of 26 sites (not including, the NIWA sites) was established to monitor physico-chemical variables. This network was modified between July 1999 and July 2000 to incorporate tests for *faecal* indicator bacteria at all water quality sites (Meijer 2010).

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Currently, Environment Southland conducts monthly monitoring of 70 sites on 43 rivers (Table 4). The majority have records of 10-15 years of data, providing a good basis for trend analysis. There are 17 geographical zones, but some do not have surface water monitoring sites (viz. Fiordland, Coastal Longwoods, Stewart Island may be included in future following a review by Aquanet), with the reason being that the sites are very difficult to access, or have few pressures on the resources that warrant inclusion in the SoE monitoring programme.

Table 4. Total number of current river SoE monitoring sites in each region by variables analysed. The number of sites for which the ten water quality variables are analysed for each region is provided in Section 4 for Southland (Table 9), Taranaki (Table 15), Horizons (Table 21) and Waikato (Table 25).

Variables	Environment Southland	Taranaki Regional Council	Horizons Regional Council	Environment Waikato
Physical-Chemical and microbiological	70	13	63	113
Periphyton	70	21	42	46
Macro-invertebrates	70	51	42	46
Microbes including blue-green algae for bathing water	11	14	14	12

There were 56 SoE water quality monitoring sites in the Southland region that met our criteria for trend analysis. The majority of these sites were located in Low-elevation *Topography* and Pastoral *Land-cover* categories. These categories are also the most commonly occurring REC category by river length (Table 5). The Hill *Topography* category was well represented by 16 sites that were distributed over Exotic and Indigenous Forest, Tussock and Pasture *Land-cover* categories. The network included only one site in the Mountain *Topography* category and 4 in the Lake *Topography* category. Thus, the monitoring network gave good representation of the environmental variability of the region's rivers, but, as expected under-represented unimpacted regions – because of difficulty of access and lack of obvious pressures. Environment Southland staff have recently reviewed their SoE monitoring programme and recommended an increase to 94 water quality monitoring sites. This provides the opportunity to refine the representativeness of the network by including more unimpacted (reference) and urban sites, and modifying the spatial coverage of water quality sites to improve representation of management zones defined by the Regional Water Plan.

Table 5. Numbers of river SoE water quality monitoring sites in the Southland region that met our criteria for trend analysis and (in brackets) the number of apparent SoE sites in 2009 (i.e. having at least one sample in each season during 2009). The sites have been classified by REC *Topography* and *Land-cover* categories (see Table 3) and the colour scale indicates the total proportion of river length in the Region that is classified by each of the categories.

Topography \ Landcover	B	EF	IF	M	P	S	T	U	W
M	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
Lk	0 (0)	0 (0)	3 (4)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)
L	0 (0)	0 (0)	4 (5)	0 (0)	28 (36)	0 (0)	0 (0)	1 (1)	2 (2)
H	0 (0)	1 (1)	3 (3)	0 (0)	9 (10)	0 (0)	3 (4)	0 (0)	0 (0)
GM	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Proportion of River Length
- 0-0.05
- 0.05-0.1
- 0.1-0.15
- 0.15-0.2
- 0.2-0.25
- 0.25-0.3
- 0.3-0.35
- 0.35-0.4
- 0.4-0.45
- 0.45-0.5
- 0.5-0.55
- 0.55-0.6
- 0.6-0.65
- 0.65-0.7

Flow data are available for most occasions when water quality data is obtained; either from permanent flow monitoring sites, actual gaugings, or estimates based on nearby flow monitoring sites. Thirteen sites are at Environment Southland flow gauging stations site; six sites have NIWA gauging stations; two sites have rated Environment Southland gauging stations and 15 have a gauging station within 15 km (total of 36). The remaining 36 sites have flow measurements estimated from known relationships to nearby flow sites. While this means that sites are generally associated with flow data for each monitoring occasion more detailed analysis would be needed to assess whether the estimated flows are adequate or should be improved.

Samples were routinely analysed for 14 water quality variables: black disc water clarity, conductivity, dissolved oxygen, dissolved reactive P, total P, *E. coli*, faecal coliform, ammonium N, nitrate plus nitrite N, total N, pH, total suspended solids, temperature and turbidity. Samples from seven sites were also monitored for BOD. The range of variables is very similar to that of the NRWQN except that ES do not measure CDOM, but do include SS and FC (as well as *E. coli*).

Statistically significant differences in water quality state for sites grouped by REC *Topography* and *Land-cover* categories were observed for most variables (see Section 4.1.1). In addition, overall trends (in specific REC *Topography* and *Land-cover* categories) were observed for several variables (see Section 4.1.2). These analyses indicate that the river water physical-chemical and microbiological quality monitoring program is adequate, at least from the perspective that it has sufficient statistical power (numbers of sites relative to their variability) to detect large scale patterns (as defined by REC categories) in water quality state and trends in the Southland region.

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3.1.2 Rivers biological

Invertebrate and periphyton surveys have been conducted at approximately 70 sites per year since 2007. This monitoring was started in 1996, with more sites added over time such that about 70 sites (on average) have been surveyed annually since 2007. Invertebrate data are expressed as MCI and SQMCI scores to detect changes over time for river ecosystem health. Periphyton samples (collected following Stark 2010) are analysed for chlorophyll *a* and Ash Free Dry Weight (AFDW) and assessed according to standard procedures. Periphyton are sampled once annually during summer, when pressures of temperature and algae growth and are likely to be highest, and river flows are low and stable. Annual biological sampling during summer is a useful way of capturing habitat stress at low flows and high temperatures, but may miss seasonal land use impacts such as the peak production from dairy farming that occurs during spring and is subject to bias from atypical conditions (e.g. higher than usual rainfall and river flow). However, annual sampling is generally considered to be suitable (and is the protocol of the NRWQN, for example) (Stark and Phillips 2009).

3.1.3 Contact recreation and drinking water

Water samples are analysed for *E. coli* (a faecal indicator organism) from 11 popular freshwater bathing sites over summer. Seven sites are tested weekly between December and March each summer, and four sites are tested monthly over the whole year with the aim being to warn the public of potential health risk. In addition, faecal coliforms have been monitored at monthly intervals at 71 representative river sites throughout the region, since 1994. This second data set provides a picture of trends in faecal contamination within the region; especially relevant given the large number of dairy conversions in Southland. These programmes are augmented by case-study investigations such as a study of faecal pollution in Waituna Lagoon. Bacterial concentrations are evaluated according to the National bathing guideline thresholds (MfE and MoH, 2003).

Drinking water monitoring is predominantly of groundwaters and is evaluated according the the Drinking Water Standard for New Zealand (Ministry of Health). The Standard specifies maximum acceptable values (MAV) for *E. coli*, nitrate-N, manganese, pH, chloride, total hardness, sulphate, sodium and iron.

3.1.4 Lakes

Environment Southland began regular lake water quality monitoring in July 2000 on Lake Te Anau, and on Lake Manapouri in July 2002. Three small lakes on Southland's southern coast (Lake George, Lake Vincent and The Reservoir) were sampled in early 2002. Prior to this, data on the water quality of Southland's lakes was limited to one-off investigations and spot samples. Regular water quality monitoring on the Waituna Lagoon commenced in October 2001 (Meijer 2010). These lakes are either potentially threatened by runoff from land use intensification, or are actually undergoing change. There are several lakes in the region that are not presently monitored, including Lake Monowai, Lake Hauroko, Lake Poteriteri and Lake Hakapoua – which are all difficult to access but likely to be in pristine condition. However, the inclusion of these large, nationally valuable, lakes in the SoE programme may be worth consideration in future. Environment Southland staff have recently reviewed their SoE monitoring programme and recommended water quality monitoring of more coastal lakes.

Lake waters are sampled at monthly intervals at two sites on Lake Te Anau and three sites on Lake Manapouri, at two depths on occasions when the lake is isothermal (i.e. top and bottom waters are within 3ºC), and from the epilimnion and hypolimnion when the lake is stratified. Waituna lagoon is sampled monthly at four sites. Regular monitoring commenced at one site (East) in October 2001 and three additional sites were included (West, Centre, South) in August 2003. Sites are located in the deepest areas of the lagoon near freshwater and saline inputs. Surface water samples (only) are collected and analysed for the same suite as for the lakes, but with the addition of *E. coli* (a faecal indicator organism).

Lake waters are analysed in the field for: Secchi depth, dissolved oxygen, temperature and conductivity. Samples are analysed in the laboratory for pH, nitrate+nitrite N, ammoniacal N, total N, dissolved reactive P, total P, chlorophyll *a*, turbidity, total and volatile suspended solids, by RJ Hill Laboratories Ltd using standard methods and procedures for sampling and sample stabilisation. Environment Southland should give consideration to lower detection levels for some variables, particularly when looking at pristine lake water chemistry. The absence of *E. coli* in the suite of lake water variables is notable but may be included elsewhere in bathing water programmes. Given the changes in land use within Southland it may be appropriate to include *E. coli* as a water quality variable in the lakes monitoring programme.

3.1.5 Groundwater

Groundwaters are classified into 29 zones that cover the major aquifers of the region and fall into four broad categories: riparian aquifers, terrace aquifers, lowland aquifers and fractured rock aquifers. Groundwater is extensively used for domestic, stock and municipal water supplies throughout the Southland Region. Groundwater is also extensively used for industrial and farm (particularly dairy shed) supply which also require water of potable quality.

The main monitoring network comprises approximately 45 sites distributed across the major aquifer systems that are sampled quarterly for a wide range of variables: conductivity, chloride, sodium, bicarbonate, calcium, magnesium, total hardness, manganese, iron, nitrate, dissolved reactive phosphorus and *E. coli* (in 200 wells within the main network). In addition, about 250 sites are monitored for resource consent compliance and there are several other ad hoc investigations of groundwater quantity and quality (e.g. nitrate "hotspots", pesticides). Water quality is assessed principally against the Drinking Water Standards for New Zealand (2008) for potable supply, or the ANZECC (2000) guideline for stock water supply or other uses.

3.1.6 QA/QC and data storage

Water chemistry samples are now analysed by RJ Hill Laboratories, Christchurch (IANZ accredited laboratory) with appropriate methods for natural waters (Meijer 2010). It is worth noting that detection levels (DLs) for some variables reported by Hill Laboratories are higher than for other environmental "water" laboratories. For example, DLs cited by Hills for total N and ammoniacal N are 0.1 and 0.01 g m^{-3}, respectively, compared with 0.01 and 0.001 g m^{-3} for the NIWA water laboratory in Hamilton. This will reduce the future ability of the program to detect trends in water bodies that are currently in good condition. Some 'split' samples are sent to Hill Laboratories and to two other laboratories (Environment Canterbury and MLS Envirolab, Invercargill) for interlaboratory comparison. Results showed some variation between laboratories but were generally satisfactory.

Invertebrate samples are analysed by Ryder Consulting, Dunedin with QA/QC check analyses provided by Stephen Moore, Landcare Research, Auckland. The check analyses indicate that most invertebrates were correctly identified by Ryder Consulting and that the numbers of individuals missed by Ryder (but found by Landcare) in the sorted residue were generally low. Environment Southland have recently reviewed their SoE monitoring programme and recommended an increase in the number of annual river biomonitoring sites.

Environment Southland supplied us with multiple spreadsheets and do not appear to have a database for their water quality data. This makes it difficult to restructure data or to efficiently interrogate the data sets.

3.2 Taranaki Regional Council

3.2.1 Rivers physical-chemical and microbiological

Samples from TRC's river SoE monitoring sites are routinely analysed for 19 water quality variables Temp, flow, DO, BOD5, pH, conductivity, black disc visibility, turbidity, absorbance (3 wavelengths), ammonia-N, nitrate-N, total-N, DRP, total P, alkalinity, SS, and faecal coliforms *E. coli*, and enterococci bacteria. This suite of microbial and physico-chemical variables provides a good description of the land use impacts and the suitability of the monitored water resources for protection of ecosystem health, human contact and recreation and stock health, and provides a sound data base for evaluating river water quality status, trends and loads.

Monitoring sites are distributed across the region and distinguish differences between predominantly forest catchments (near the National Park boundary) and predominantly pasture catchments (often near the coast). However, there are no sites that represent unimpacted (reference) conditions. This seems to be a limitation caused by the inaccessibility of upland reference sites and the extensive nature of intensive agriculture in the region.

There were 12 SoE water quality monitoring sites in the Taranaki region that met our criteria for trend analysis. The majority of monitoring sites were predominantly located in Low-elevation *Topography* and Pastoral *Land-cover* categories, which was also the most commonly occurring REC category by river length (Table 6). The indigenous Forest (IF) category of *land-cover*, particularly in lowlands, appears under-represented. However, the representativeness is a little difficult to assess with only 12 SoE sites.

Table 6. Numbers of river SoE water quality monitoring sites in the Taranaki region that met our criteria for trend analysis and (in brackets) the number of apparent SoE sites in 2009 (i.e. having at least one sample in each season during 2009). The sites have been classified by REC *Topography* and *Land-cover* categories (see Table 3) and the colour scale indicates the total proportion of river length in the Region that is classified by each of the categories.

Topography \ Landcover	B	EF	IF	M	P	S	T	U	W
M	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lk	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
L	0 (0)	0 (0)	0 (0)	0 (0)	7 (7)	0 (0)	0 (0)	0 (0)	0 (0)
H	0 (0)	0 (0)	3 (3)	0 (0)	1 (2)	1 (1)	0 (0)	0 (0)	0 (0)
GM	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Proportion of River Length
0-0.05
0.05-0.1
0.1-0.15
0.15-0.2
0.2-0.25
0.25-0.3
0.3-0.35
0.35-0.4
0.4-0.45
0.45-0.5
0.5-0.55
0.55-0.6
0.6-0.65
0.65-0.7

River flows are estimated in all TRC river water quality monitoring. Flow gaugings are carried out each month at four sites for ratings purposes. Flows are recorded from all other sites but only added to the data base after the site has been validated by TRC or (depending on the site) NIWA hydrological staff and ratings have been verified for the sampling periods. The combination of instantaneous flow-concentration data pairs enables flow-adjustment for trend analysis and for loads to be calculated and compared temporally and spatially.

Despite the small number of SoE sites in the Taranaki region compared to the other regions, statistically significant differences in water quality state for sites grouped by REC *Topography* and *Land-cover* categories were observed for some variables (see Section 4.2.1). In addition, a small number of overall trends (in specific REC *Topography* and *Land-cover* categories) were observed for several variables (see Section 4.2.2). These analyses indicate that the river water physical-chemical and microbiological quality monitoring program is adequate, at least from the perspective that it has sufficient statistical power (numbers of sites relative to their variability) to detect large scale patterns (as defined by REC categories) in water quality state and trends in the Taranaki region.

3.2.2 Rivers biological

TRC conduct freshwater macroinvertebrate and nuisance periphyton monitoring. Invertebrates are sampled twice per year (summer and spring) at 51 sites on 22 rivers. These sites range from near pristine to those located in intensively farmed catchments, allowing numerous upstream-downstream comparisons; and impacted *versus* unimpacted comparisons and the major geological and ecoregions are included. Sites monitored for consents are included with SoE sites. The data provide a good picture of the ecological status of Taranaki rivers and is analysed for long term trends in river health based on the MCI score. Trends in MCI scores have been used by TRC to indicate where riparian management has been effective in improving river habitat condition (TRC 2009a).

Periphyton is sampled year per year (summer and spring) at 21 sites on 10 rivers. This regional coverage includes upper, middle and lower catchment sites and enables analysis of river slimes and trend analysis. Benthic cyanobacteria are sampled at 11 sites fortnightly during the period November-March.

3.2.3 Contact recreation and drinking water

Water samples are analysed for: faecal coliforms, *E. coli* and enterococci, 13 times a year during the period November to March at 14 popular freshwater bathing sites over summer. The annual medians of these data are used for trend analysis. A freshwater cyanobacteria monitoring programme sample five sites at popular freshwater bathing spots includes four lake beaches and one river site.

3.2.4 Groundwater

TRC participate in two national monitoring programmes that give resource information about their region. Five wells in the Taranki region are included in the IGNS national groundwater quality monitoring programme (NGMP). The NGMP analyses groundwater to 15 chemical constituents on a quarterly basis. The National Survey of Pesticides in Groundwater (NSPG) is conducted by ESR on a four yearly basis. The NSPG analyses for major pesticide groups include organonitrogen herbicide, acid herbicide and organochlorine pesticides. In addition, TRC monitor nitrogen in shallow groundwater at between 65 and 80 wells on a five-yearly basis. The groundwater programmes (Appendix 1) cover the major geological formations where aquifers occur and address the key points of resource use and availability, and quality in relation to land uses.

3.2.5 Lakes

Lake Rotorangi is only lake of significance in the Taranaki region. In our opinion the TRC monitoring programme adequately describes the chemical and nuisance plant status of the lake. Two sites on the lake are sampled four times annually for DRP, TN, conductivity, NO_x-N, NH_4-N, BOD, TP, clarity, temperature, plankton, benthic invertebrates. TRC carries out depth profiles of temperature and dissolved oxygen

(DO) at three sites (the additional site is at the head of the lake) four times (seasonally) each year. Turbidity, black disc water clarity, suspended solids, conductivity, chlorophyll-*a* and pH are measured at all sites at the surface, and in the epilimnetic and hypolimnetic layers. Whole lake surveys of macrophytes are conducted every three years, and additional measurements are carried out to check for benthic nutrient release (occurring under temporarily deoxygenated conditions) during surveys in mid- to late summer.

3.2.6 QA/QC and data storage

All analyses are performed by the Taranki Regional Council IANZ registered chemistry laboratory using Standard Methods. The lab is not externally accredited for bacterial analysis, but performs QC/QA checks. Internal and external QC exercises for the SoE monitoring programme include an annual interlaboratory comparison where split samples are analysed by NIWA (Hamilton) and the results compared with the TRC laboratory. Recent results show good agreement (mostly +/-10%) between the two laboratories for a wide range of variables (TRC 2009b). In general, the TRC analytical laboratory performed well in interlaboratory QC tests.

All data from Taranaki Regional Council's field measurements and laboratory analyses are stored in a water quality archiving database which ensures the data can be efficiently extracted for analysis.

3.3 Horizons Regional Council

3.3.1 Rivers physical-chemical and microbiological

In common with some other regional councils, Horizons do not distinguish between SoE monitoring sites and other sites in their long-term monitoring programmes. For example, the current rivers SoE programme comprises 63 sites that are visited and sampled at monthly intervals (Table 4). Another 93 'reference' sites upstream of consented discharges and 13 contact recreation sites are monitored at regular intervals and are included in the overall monitoring programme to give a total of 169 sites that are used to describe the state of water quality in the region. Water quality data from monthly monitoring upstream of discharge sites is often amalgamated with SoE data because of the added information that is gained about water resource condition, although such sites are not called "SoE" sites. This has in the past led to some confusion. For example, a report by the Parliamentary Commissioner for the Environment (PCE, 2004) identified that many regional councils did not monitor BOD, although Horizons do monitor BOD at over 50 sites in the Manawatu catchment alone.

In the past, Horizons have employed a system of "rolling SoE sites" whereby some sites have been monitored on a rolling basis, i.e. once every three years 12 months of monthly sampling has been undertaken. This practice is no longer carried out by Horizons regional Council because of the need to have at least five years of continuous (monthly) monitoring data for trend analysis.

The 63 Horizons Regional Council SoE river sampling sites are located on 35 different rivers. The region has four major river systems: Whanganui, Rangatikei, Manawatu and Whangaehu that collectively have 17 sites as well as several tributaries with sampling sites. The current monitoring programme, therefore, covers a broad range of environmental conditions in the region. However, there were only 17 SoE water quality monitoring sites in the Horizons region that met our criteria for trend analysis. All but one of these sites was located in Low-elevation and Hill *Topography* and Pastoral *Land-cover* categories. These combinations of categories were also the most commonly occurring by river length (Table 7).

Table 7. Numbers of river SoE water quality monitoring sites in the Horizons region that met our criteria for trend analysis and (in brackets) the number of apparent SoE sites in 2009 (i.e. having at least one sample in each season during 2009). The sites have been classified by REC *Topography* and *Land-cover* categories (see Table 3) and the colour scale indicates the total proportion of river length in the Region that is classified by each of the categories.

Topography	B	EF	IF	M	P	S	T	U	W
M	0 (0)	0 (0)	0 (1)	0 (0)	1 (2)	0 (0)	0 (0)	0 (0)	0 (0)
Lk	0 (0)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0 (0)	0 (0)	0 (0)
L	0 (0)	0 (0)	0 (0)	0 (0)	4 (25)	0 (0)	0 (0)	0 (0)	0 (0)
H	0 (0)	0 (0)	0 (4)	0 (0)	2 (18)	0 (3)	0 (0)	0 (0)	0 (0)
GM	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Landcover

Proportion of River Length: 0-0.05, 0.05-0.1, 0.1-0.15, 0.15-0.2, 0.2-0.25, 0.25-0.3, 0.3-0.35, 0.35-0.4, 0.4-0.45, 0.45-0.5, 0.5-0.55, 0.55-0.6, 0.6-0.65, 0.65-0.7

Horizons SoE monitoring samples are analysed for a suite of water quality variables but some detection levels appear high for the analysis of natural freshwaters. For example, the DRP detection limit was identified as too high for trend analysis by Ballantine & Davies-Colley (2009). Ammonium N is cited to 0.01 g m^{-3}, whereas the ANZECC (2000) default trigger value for ammonium N in moderately disturbed lowland rivers is 0.021 g m^{-3} and some waters may have very low concentrations of c.

0.005 g m^{-3}. This will reduce the future ability of the program to detect trends in water bodies that are currently in good condition. Field measurements are made using established methods (e.g. calibrated field meters for dissolved oxygen (DO) and temperature). Some SoE sites have continuous monitoring of temperature (32), conductivity (3) and dissolved oxygen (5). Flow data (either measured or derived) are available for 54 sites but only 41 of these are SoE sites.

The small number of SoE sites in the Horizons region resulted in few statistically significant differences in water quality state for sites grouped by REC *Topography* and *Land-cover* categories (see Section 4.3.1). In addition, there were few detectable overall trends (in specific REC *Topography* and *Land-cover* categories) (see Section 4.3.2). These analyses indicate that the river water physical-chemical and microbiological quality monitoring program had insufficient statistical power (numbers of sites relative to their variability) to detect large scale patterns (as defined by REC categories) in water quality state and trends in the Horizons region. We note, however, that the statistical power of Horizon's SoE network will substantially increase in future now that the system of "rolling SoE sites" has been abandoned and the number of SoE sites in the monitoring network has been increased.

3.3.2 Rivers biological

Approximately 42 of the SoE sites are also surveyed annually for benthic invertebrates and monthly for periphyton. Results are expressed as macroinvertebrate community index (MCI) scores for state and trend analysis. Periphyton cover is estimated visually, but samples are also taken for chlorophyll *a* assessment of biomass.

3.3.3 Lakes

State-of-the-Environment lake monitoring is only conducted on Lake Horowhenua, but 3-4 lakes are sampled at weekly intervals during the bathing season for contact recreation. These samples are analysed for *E. coli* and cyanobacteria (which can sometimes be neurotoxic to humans and domestic animals on contact). Lake Horowhenua is sampled at monthly intervals at three sites along the axis of the lake. Samples are bulked and analysed as for river samples as wellas cyanobacteria during summer. We consider this monitoring programme is adequate for a shallow, dune lake such as Horowhenua.

3.3.4 Contact recreation and drinking water

Horizons Regional Council routinely tests water quality at fourteen popular swimming spots in the Region between 1 December and 30 April each summer season. Sites include coastal and river mouth beaches, rivers, Lake Wiritoa, Duddings Lake and

Lake Horowhenua. Samples are analysed for cyanobacteria (blue-green algae) and faecal indicator organisms (Enterococci, faecal and total coliforms).

3.3.5 Groundwater

Seven groundwater management zones have been identified by HRC. Currently 32 groundwater sites are monitored of which 28 are SoE sites but since early 2008 this has been reduced to 25. All 25 sites are sampled once every seven months. This sampling frequency was considered the most cost-effective monitoring frequency in order to guarantee sampling of wells in all seasons in all months, with a return period of 12 years. On-site field measurements made at the time of sampling include temperature, electrical conductivity (EC), pH and redox potential. Laboratory analyses include major cations (Ca, Mg, Na, K) and anions (HCO_3, SO_4, Cl), important minor constituents (Fe, Mn), nutrients (NO_x-N, NH_4-NDRP), and other indicative parameters (SiO_2, F, B, Br). Occasionally, samples are collected and analysed for microbial indicators, viz. *E. Coli*.

Horizons groundwater quality data is described in detail recent reviews by Daughney et al. (2009) and Zarour (2009). The main conclusions being that human activities have little detectable influence on groundwater quality and groundwater quality across the Region is similar to the average expectation for aquifers around the world. Trend tests for the sites that have sufficient data indicate that most parameters at most sites have remained constant with time. While it appears that groundwater quality in the Region has not been changing, there is a need to commit to long-term, regular groundwater quality monitoring at a core set of sites to confirm this assessment.

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3.3.6 QA/QC and data storage

Samples were originally analysed by the Horizons Regional Council laboratory, which merged with the Palmerston City Council laboratory to form Central Environmental Laboratories (CEL) four years ago. Since 2009, samples have been analysed by Watercare Services Ltd., Auckland. Thus, the council has had analytical results from three different organisations with the prospect of incompatibility between the different analysts. The council have checked this by splitting samples and conducting inter-laboratory comparisons (the latest being a 3-laboratory comparison between CEL, Watercare and RJ Hills in 2010.

Benthic invertebrates are identified and enumerated by Stark Laboratories; with QA checks provided on 10% of samples by Biosorted Ltd. Five periphyton chlorophyll *a* samples a month being sent to NIWA, Christchurch, for QA comparison.

All data from field measurements and laboratory analyses are stored in Horizons' water quality archiving database. This ensures the data can be efficiently extracted for analysis.

3.4 Environment Waikato

3.4.1 Rivers physical-chemical and microbiological

A total of 113 river sites in the Waikato region, including 10 Waikato River sites are currently being monitored and are reported on annually (Table 4). Data sets for many of the rivers began in 1990 although not all water quality variables have been monitored for the same length of time, e.g. records of visual clarity did not begin until 1995, while records of *Escherichia coli* did not begin until 1998.

Ten locations along the Waikato River are visited monthly (Taupo, Ohaaki, Ohakuri, Whakamaru, Waipapa, Hamilton-Narrows, Hamilton-Horotiu, Huntly, Mercer and Tuakau), and an additional four locations are included for the summer intensive microbiological survey. The major tributaries that enter the Waikato River are also monitored monthly as part of the Regional River Monitoring Programme (RERIMP) initiated in 1993. Three locations (Taupo at Reids Farm, Hamilton at Wellington Street, and Rangiriri) are sampled by NIWA as part of the NRWQN (EW 2008). The 13 Waikato River sites provide a comprehensive description of the Waikato River water quality along its length and, together with tributary river data and other monitoring information (e.g. from Consents to discharge wastewater), identify major inputs to the River.

The current level of monitoring and annual reporting of Waikato River water quality data seems comensurate with the importance of the Waikato River. However, the bottom waters of the Waikato River hydro-lakes are not monitored. The current EW main-stem sampling (10 sites) focuses only on the outflows from three of the lakes (i.e. the surface waters), effectively treating them as river sites. As a result little is known about any long-term changes in the bottom waters; particularly DO depletion and sediment release of As, N and P. We recognise though, that deepwater sampling would involve significant extra resources (boats, minimum of two staff per trip, specialised field instruments and samplers).

The monitoring of other Waikato rivers is based on the following major rivers and key tributaries: Upper Waikato River tributaries; Lower Waikato Tributaries; Waipa River; West Coast rivers, Coromandel Peninsula streams; Lake Taupo inflows; Hauraki Rivers (vis. Piako and Waihou River systems). These waters range in size and include approximately 20 sites where mean flows are <1 m^3/s and catchment areas < 30 km^2. The monitoring programme covers all major water resources within the region, giving a good description of the state of the Waikato regional rivers and enabling trend analysis to be conducted (e.g., Vant 2008).

There were 115 SoE water quality monitoring sites in the Waikato region that met our criteria for trend analysis. The majority of these sites were located in Low-elevation and Hill *Topography* and Pastoral *Land-cover* categories, which were also the most commonly occurring by river length (Table 8). However, the Exotic Forest, Indigenous Forest, Urban and Scrub *Land-cover* categories were also represented with reasonably balanced numbers of sites.

Table 8. Numbers of river SoE water quality monitoring sites in the Waikato region that met our criteria for trend analysis and (in brackets) the number of apparent SoE sites in 2009 (i.e. having at least one sample in each season during 2009). The sites have been classified by REC *Topography* and *Land-cover* categories (see Table 3) and the colour scale indicates the total proportion of river length in the Region that is classified by each of the categories.

Topography \ Landcover	B	EF	IF	M	P	S	T	U	W
M	0 (0)	0 (0)	1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lk	0 (0)	1 (1)	2 (2)	0 (0)	11 (12)	0 (0)	0 (0)	0 (0)	0 (0)
L	0 (0)	2 (2)	8 (8)	0 (0)	58 (58)	0 (0)	0 (0)	3 (3)	0 (0)
H	0 (0)	3 (3)	6 (6)	0 (0)	19 (20)	1 (1)	0 (0)	0 (0)	0 (0)
GM	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Proportion of River Length
0-0.05
0.05-0.1
0.1-0.15
0.15-0.2
0.2-0.25
0.25-0.3
0.3-0.35
0.35-0.4
0.4-0.45
0.45-0.5
0.5-0.55
0.55-0.6
0.6-0.65
0.65-0.7

Water quality samples are analysed for up to 40 variables (27 routinely) for the purposes of ecological health, human uses including recreation, water supply and drinking water. The Waikato River Independent Scoping Study (WRISS) report has identified some issues relating to future iwi co-management of the Waikato River. WRISS identified the need for a cultural health index, to be developed by iwi that captures "health and wellbeing". The WRISS identified the need for fish and other kai abundance to be monitored. The WRISS report points out the difficulties in measuring the direct indicators (e.g. whitebait catch) and suggests some surrogates (e.g., habitat area). WRISS also identified the need for food safety assessment and possibly monitoring (e.g., mercury and arsenic in fish, faecal microbes on watercress, boron in drinking water, pesticides).

For 41 sites flow data is either available at or close to each site (primary) or is available from "secondary" sites (within about 20 km) enabling flow-adjustment of data for trend analysis (Vant 2008). For the remaining 72 sites a "flow index" is calculated, based on the flow at the time of sampling at a location elsewhere on the relevant river, or on a similar river nearby. This approach involves uncertainty in the flow estimates, with implications for trend analysis and for load calculations.

Statistically significant differences in water quality state for sites grouped by REC *Topography* and *Land-cover* categories were observed for most variables (see Section 4.4.1). In addition, overall trends (in specific REC *Topography* and *Land-cover* categories) were observed for several variables (see Section 4.4.2). These analyses indicate that the river water physical-chemical and microbiological quality monitoring program is adequate, at least from the perspective that it has sufficient statistical power (numbers of sites relative to their variability) to detect large scale patterns (as defined by REC categories) in water quality state and trends in the Waikato region.

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3.4.2 Rivers biological

Environment Waikato has been carrying out annual assessments of invertebrate community composition in rivers since 1994 as part of the Regional Ecological Monitoring of Streams (REMS) programme. These sites include wadeable high-gradient rivers with stony beds, low-gradient wadeable streams dominated by soft sediments, and some larger non-wadeable streams with long term records that have been retained while sampling protocols are developed. From 2005, sampling has included a network of 23 wadeable 'reference sites' in undeveloped catchments to provide a baseline against which to measure change, and a range of sites representing low, moderate and high levels of pastoral land-cover ('land-cover sites'). Sampling at 46 'long-term sites', including three reference sites, has been conducted for more than 10 years using consistent protocols that have enabled assessment of temporal trends in ecological condition at these sites (Collier and Kelly 2005). Condition is assessed using four macroinvertebrate-based measures derived from 200+ counts of individuals: number of different types of mayflies, stoneflies and caddisflies (excluding algal-piercing Hydroptilidae)—EPT* richness; the percent abundance of these sensitive insects—%EPT; a measure of tolerance to organic pollution—the Macroinvertebrate Community Index or MCI; and an integrative score of all three metrics—Average Score Per Metric or ASPM. Metrics were also calculated reflecting (i) habitat quality based on qualitative assessments of nine riparian, bank and channel attributes, and (ii) instream plant cover and proliferation. Assessments of periphyton and macrophyte metrics were also made at most sites sampled since 2005, following the methods described in Collier et al. (2006).

The SoE monitoring of rivers by Environment Waikato is comprehensive and enables an overall understanding of the state of the region's rivers. The program has been in existence for a sufficiently long period for trends to be detected in relation to land-use. Some deficiencies in the program have been identified by EW staff, for example, ideally, the bottom-waters of the Waikato River hydro lakes would be routinely monitored and more sites would have well-rated flow gauges.

3.4.3 Rivers biological

3.4.4 Groundwater

A total of 11 groundwater level sites are monitored by Environment Waikato using permanent recorders. In 2008 a total of 550 samples were taken from 346 groundwater water quality sites as part of the following monitoring programmes: Regional Groundwater (110 wells annually), the National Groundwater Monitoring Programme (10 wells quarterly), Taupo (37 six-monthly) and Coromandel Groundwater Projects, Nitrates (30 quarterly), Pesticides (4 quarterly and 80 four-yearly) and Microbial (80 wells four-yearly). Community supplies are also monitored involving 88 schools biannually. The 110 regional wells are considered SoE sites and other nitrate, pesticide and microbial sites are subsets used for environmental indicators.

Regional (SoE) groundwater quality monitoring is undertaken annually with 23 variables determined for 110 sites. This network represents generally vulnerable aquifers with relatively young groundwater in aerobic conditions. Wells with significant iron concentrations are excluded from this network. Thirty sites are monitored quarterly and ten sites monitored quarterly as part of the National Groundwater Monitoring Programme. Routine water variables were determined on a quarterly basis at 37 sites as part of the Lake Taupo Project. In 2008, pesticides and microbial indicators were monitored at 80 sites across the region.

Comprehensive aquifer representation was a primary factor in site selection for the groundwater SoE programme. Aquifers likely to show temporal change were given preference over likely old waters and anaerobic conditions. Factors for individual well selection included good log information, ease of access and sampling.

Quarterly sampling is considered sufficiently frequent for changes in groundwater. Annual sampling reflects cost constraints. Lower frequency sampling e.g. four yearly for some indicators is used as a periodic check for any change rather than to detect linear trends.

Environment Waikato have an extensive groundwater monitoring SoE programme that represents all major aquifers in the region describes the groundwater resources, within the constraints of cost for this work. Monitoring is predominantly done annually and again reflects the cost limitations. Sampling protocols are in accordance with the National Protocol for SoE Groundwater Sampling (Daughney et al. 2006), and address issues of concern in the Waikato Region, notably nitrate.

3.4.5 Lakes

A long term programme monitoring the lake Taupo's water quality began in 1994. This program is conducted by NIWA with field assistance from the Department of Internal Affairs, Taupo Harbourmaster's Office. The programme initially focused on oxygen depletion rates, but now targets phytoplankton biomass, water clarity, and nutrient (particularly nitrate) accumulation in the lake. The long-term monitoring programme uses the historical mid-lake site, Site A. Monitoring of additional sites in the Kuratau Basin (Site B) and the Western Bays (Site C) between January 2002 and December 2004 suggested that spatial variability of water quality across Lake Taupo is minimal such that the mid-lake site may be regarded as representative of the open water quality of the lake. Further validation of the use of a single mid-lake monitoring site was obtained from a comparison of upper water column nutrient and chlorophyll *a* concentrations and algal enumeration between Site A and near-shore sites in Whangamata Bay (Kinloch) and Whakaipo Bay, over a two-year period from February 2007 up to June 2009. The study determined that "the near-shore water quality was very similar to the mid-lake water quality" and that "within this similarity in the measured data was much variability which may be due to short period time lags between the near-shore and mid-lake sites with respect to nutrient sources, and the zones of algal growth".

Water sampling is carried out at 2-4 week intervals and samples are analysed for Secchi disc, chlorophyll *a*, nitrate+nitrite-nitrogen, ammoniacal-N, dissolved organic N, particulate-N, total nitrogen, dissolved reactive phosphorus, dissolved organic phosphorus, particulate phosphorus, total phosphorus, and algal species dominance in integrated-tube water samples from the top 10 m. Zooplankton net hauls from 100 m (63 μm mesh) are preserved in 4% formalin and stored pending analysis. In addition, 12 bathing beaches around the lake are monitored weekly (up to 12 times) during summer (December-February), on alternate years, for water clarity and *E. coli* (a faecal indicator bacteria).

The other lakes in the Waikato region have been categorised by Environment Waikato into the following groups: Taupo volcanic zone lakes (viz. Lake Taupo); Waikato River hydro lakes (included in the Waikato River monitoring programme); peat lakes; riverine lakes; and west coast sand dune lakes. Environment Waikato currently monitors five shallow riverine lakes (Rotomanuka North, Rotoroa, Waahi, Waikare and Whangape). Monitoring of water quality follows the method established by the

New Zealand Lakes Water Quality Monitoring Programme, which was subsequently adopted as a Ministry for the Environment protocol (Burns et al., 2000). Each site is monitored monthly, except for lakes Waahi, Waikare and Whangape, which are monitored every two months. Trophic level indicators are calculated for chlorophyll *a*, Secchi depth, total nitrogen and total phosphorus and results displayed on the EW website. Another four lakes (Mangahia, Ngaroto, Rotokauri and Rotomanuka South) had monitoring programmes that have now ceased because available information is deemed sufficient (Barnes 2002).

The importance of Lake Taupo and the current level of interest in preserving its near pristine state have provided the impetus for an intensive monitoring programme that meets both SoE needs and research on abating or mitigating adverse effects from land use activities. Most of the 100 or so lakes in the region are small (less than 10 ha) and monitoring is focused on those with ecological values or under land use pressures (e.g., eutrophication from pastoral runoff). West coast dune lakes are not included in the regular lake monitoring programme, but three of them (Harihari, Otamatearoa and Taharoa) are part of a group of lakes that have been studied as part of a "special investigation" to assess lake ecological health, including water quality, involving visits to each of lakes three times each year for the past four years (W. Vant, Environment Waikato. pers. comm.).

3.4.6 QA/QC and data storage

Chemical and microbial analyses of water samples are carried out with comprehensive QA/QC procedures. Some variables are measured in the field, but the majority are analysed by (IANZ-registered) Hill Laboratories using standard analytical methods with detection levels that are sufficiently low for environmental monitoring (EW 2008). Sample collection, stabilisation and transport are in accordance with ISO9001:2000 protocols for quality management. Back-up samples are held for two months until results have been verified by routine quality assurance procedures.

All data from field measurements and laboratory analyses are stored in Environment Waikato’s water quality archiving database (TimeStudio). This ensures that data can be efficiently extracted for analysis.

4. State and trends in freshwater quality

4.1 Environment Southland

A maximum of 56 SoE sites in the Southland region met our criteria for trend analysis varied by water quality variable (Table 9), but only 1 site for SS data. The location of these sites, the variables they include and their water quality state and trend are summarised in the maps shown in Figure 3 to Figure 11. In general these maps show that sites on the eastern Southland plains have tended to exceed guidelines more frequently than the more inland sites regardless of variable being considered. The spatial patterns of trends is less clear with increasing and decreasing trends occurring in both upland and low elevation sites. The state of individual sites showed strong variation across variables (Appended Table 31). Sites can meet guidelines for some variables and not for others. Trend direction and strength at individual sites also showed strong variation across variables. This variability in state and trends within sites according to the variables that are being considered makes it difficult to single out particular sites or catchments as problematic. The sites have been ordered in Appended **Table 31** according to a ranking from worst to best water quality. This is a subjective ranking that does not take into account potentially important factors such as the extent to which sites fail guidelines. It is also important to note that the network of sampling sites shown in Figure 3 to Figure 11 is sparse relative to the region's river network. We therefore consider that an overview of the region's water quality is more robustly made by considering the grouping and assessment of state and trends data in the following two sections.

Table 9. Number of river sites in Southland by variable and REC categories that meet criteria for trend analysis. See Table 3 for an explanation of the REC categories.

	Landcover							Topography					Total
	EF	IF	P	S	T	U	W	GM	H	L	Lk	M	
CLAR	1	8	37	0	5	1	2	0	15	34	4	1	54
COND	1	10	37	0	5	1	2	0	16	35	4	1	56
DRP	1	10	36	0	5	1	2	0	16	34	4	1	55
ECOLI	1	8	34	0	5	1	2	0	14	34	2	1	51
FC	1	8	33	0	5	1	2	0	14	33	2	1	50
NH_4-N	1	10	37	0	5	1	2	0	16	35	4	1	56
NO_x-N	1	10	37	0	5	1	2	0	16	35	4	1	56
SS	0	0	1	0	0	0	0	0	0	1	0	0	1
TN	1	10	37	0	5	1	2	0	16	35	4	1	56
TP	1	10	36	0	5	1	2	0	16	34	4	1	55

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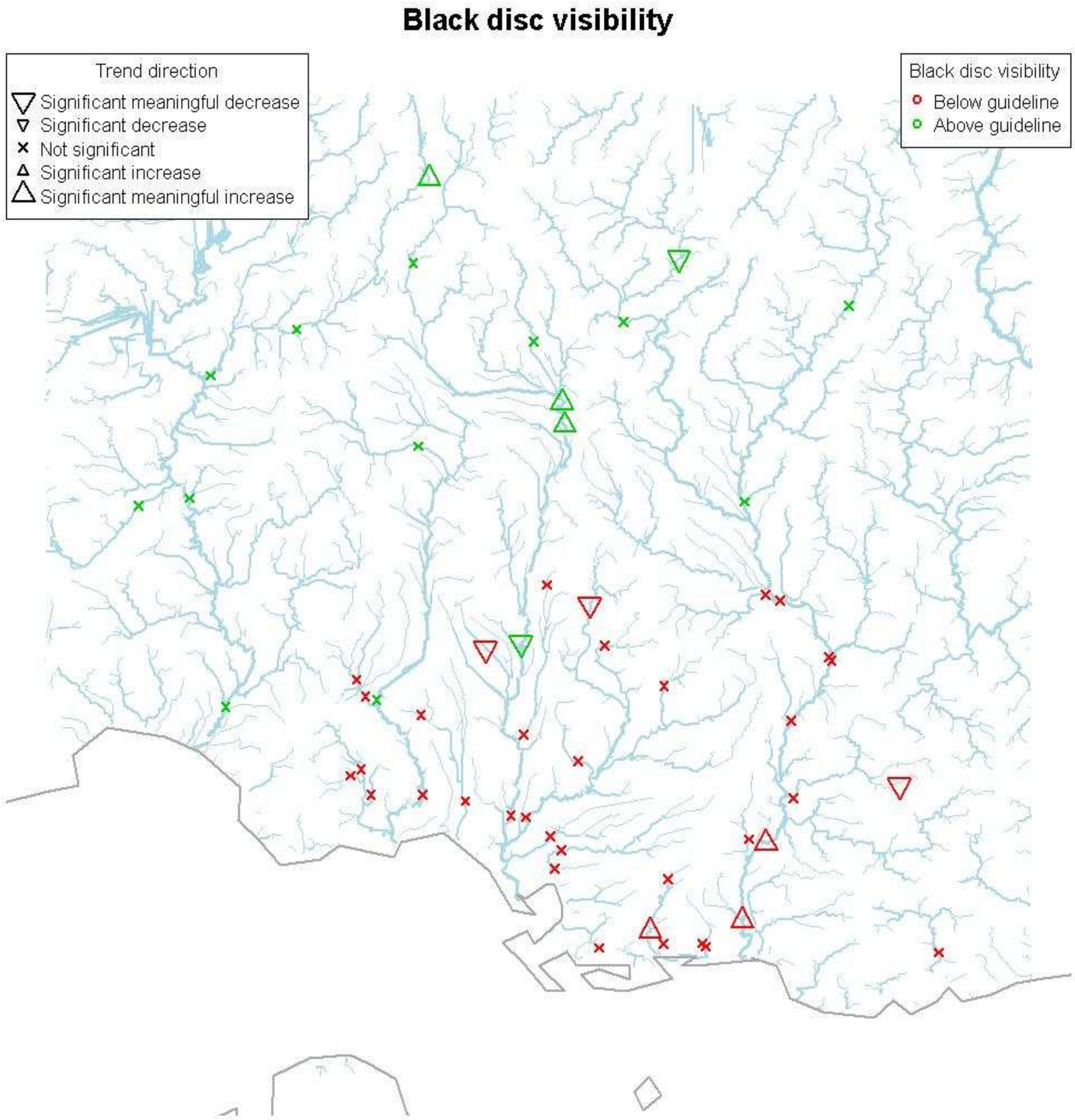

Figure 3. Location of the Southland region SoE sites for which visual clarity data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

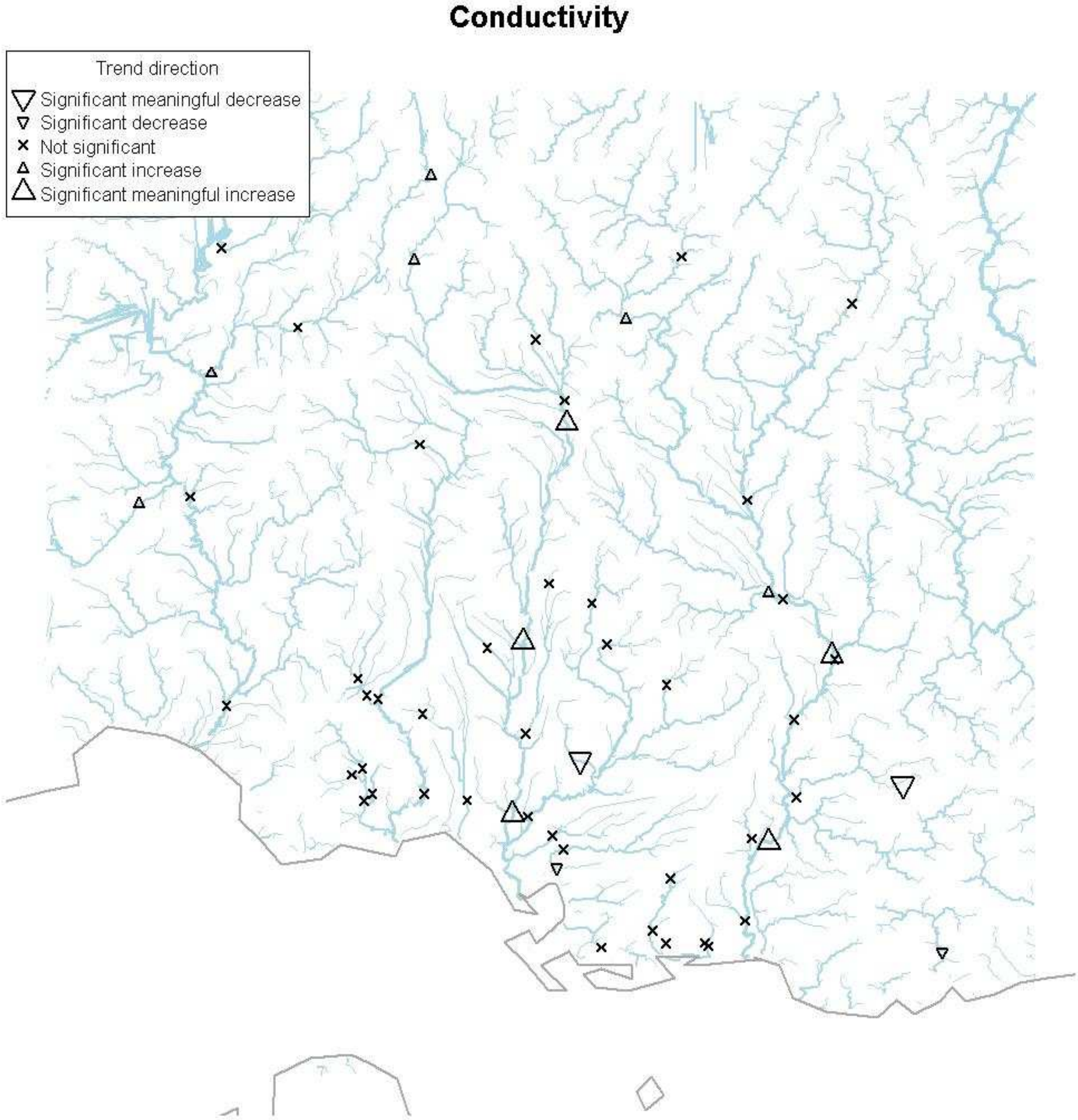

Figure 4: Location of the Southland region SoE sites for which conductivity data met our criteria for trend analysis showing the size of the trend. Note that conductivity is an indicator of ion content, but that there is no guideline value.

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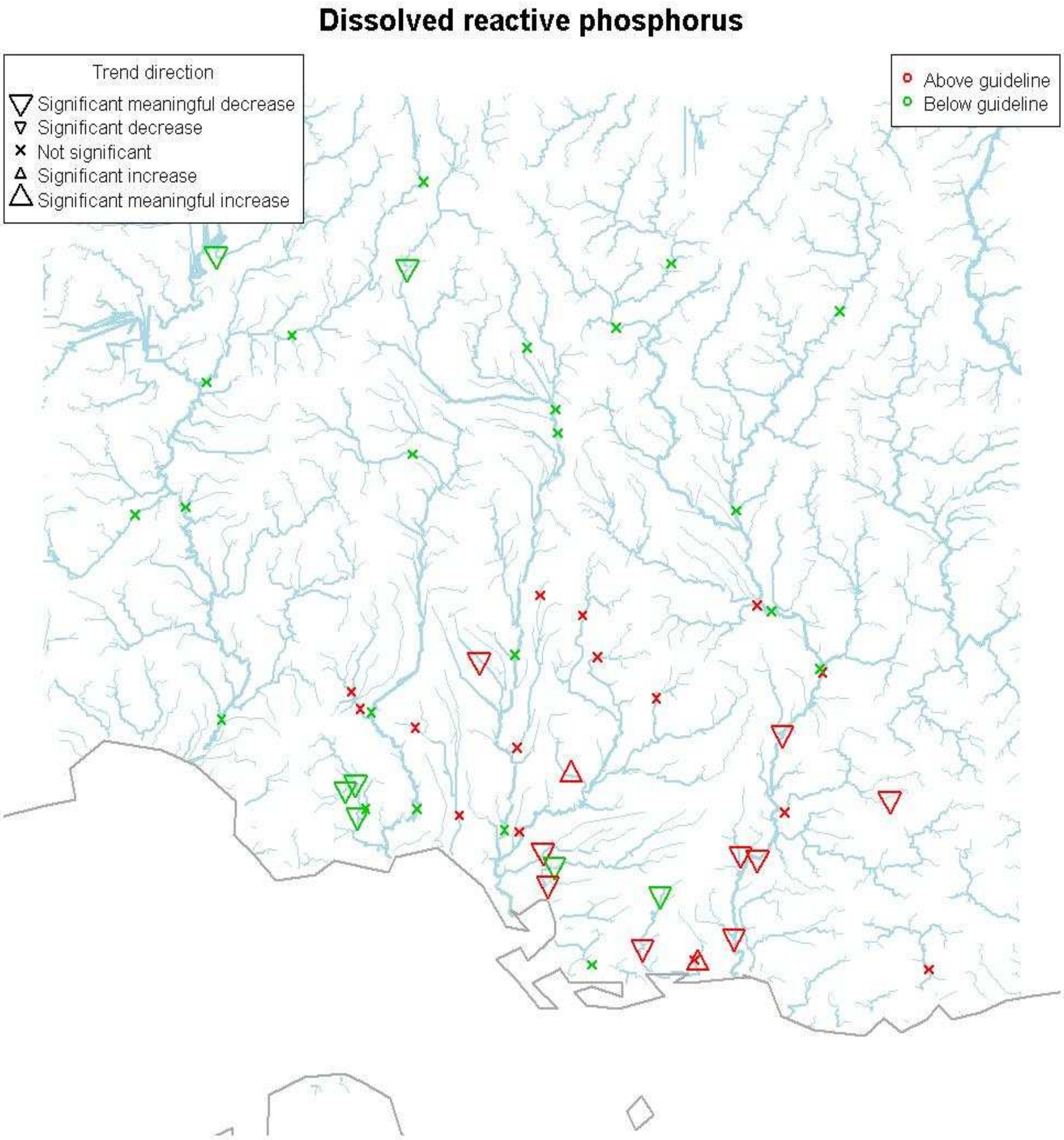

Figure 5. Location of the Southland region SoE sites for which DRP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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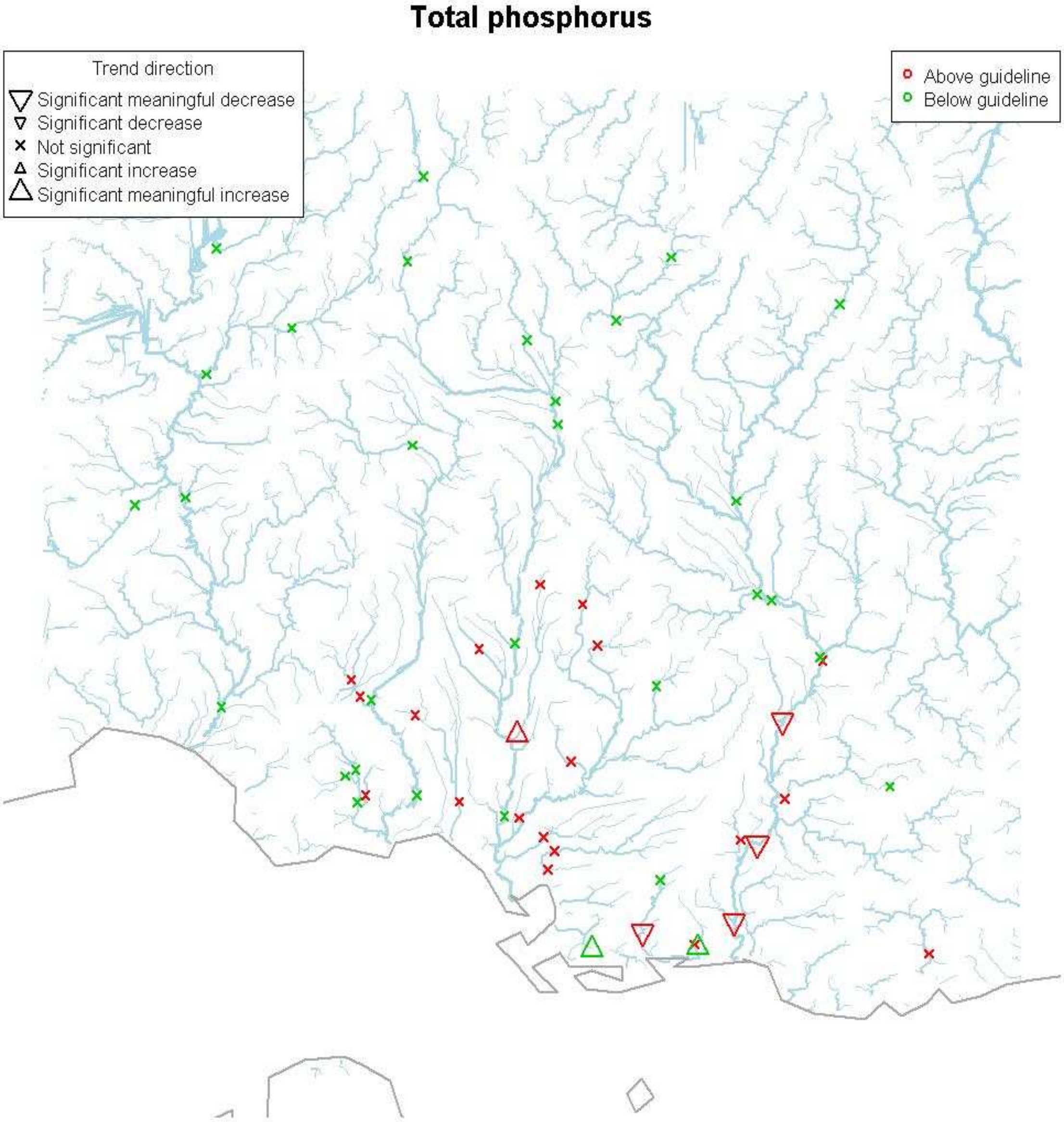

Figure 6: Location of the Southland region SoE sites for which TP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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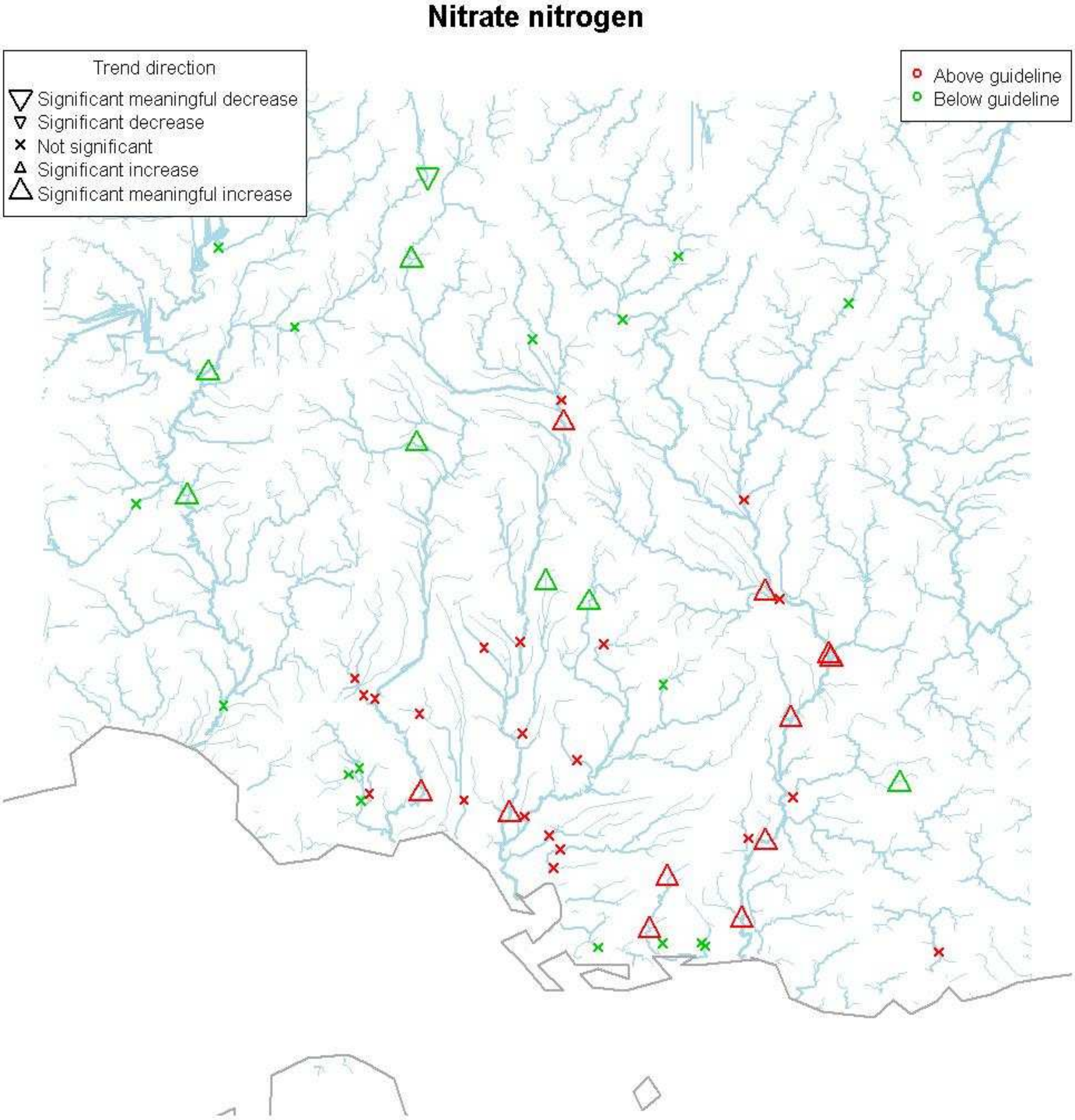

Figure 7: Location of the Southland region SoE sites for which NOx-N data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

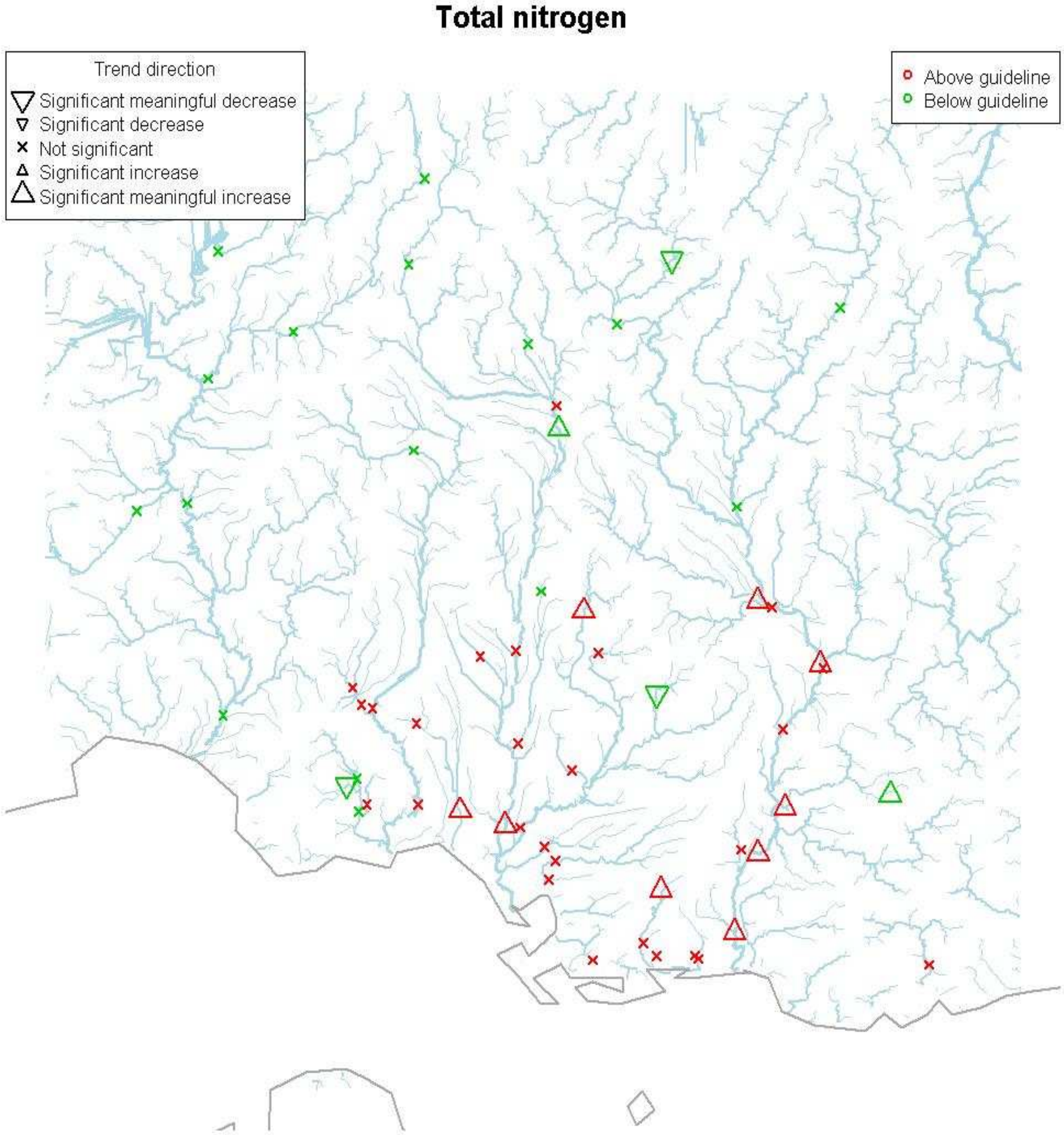

Figure 8: **Location of the Southland region SoE sites for which TN data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.**

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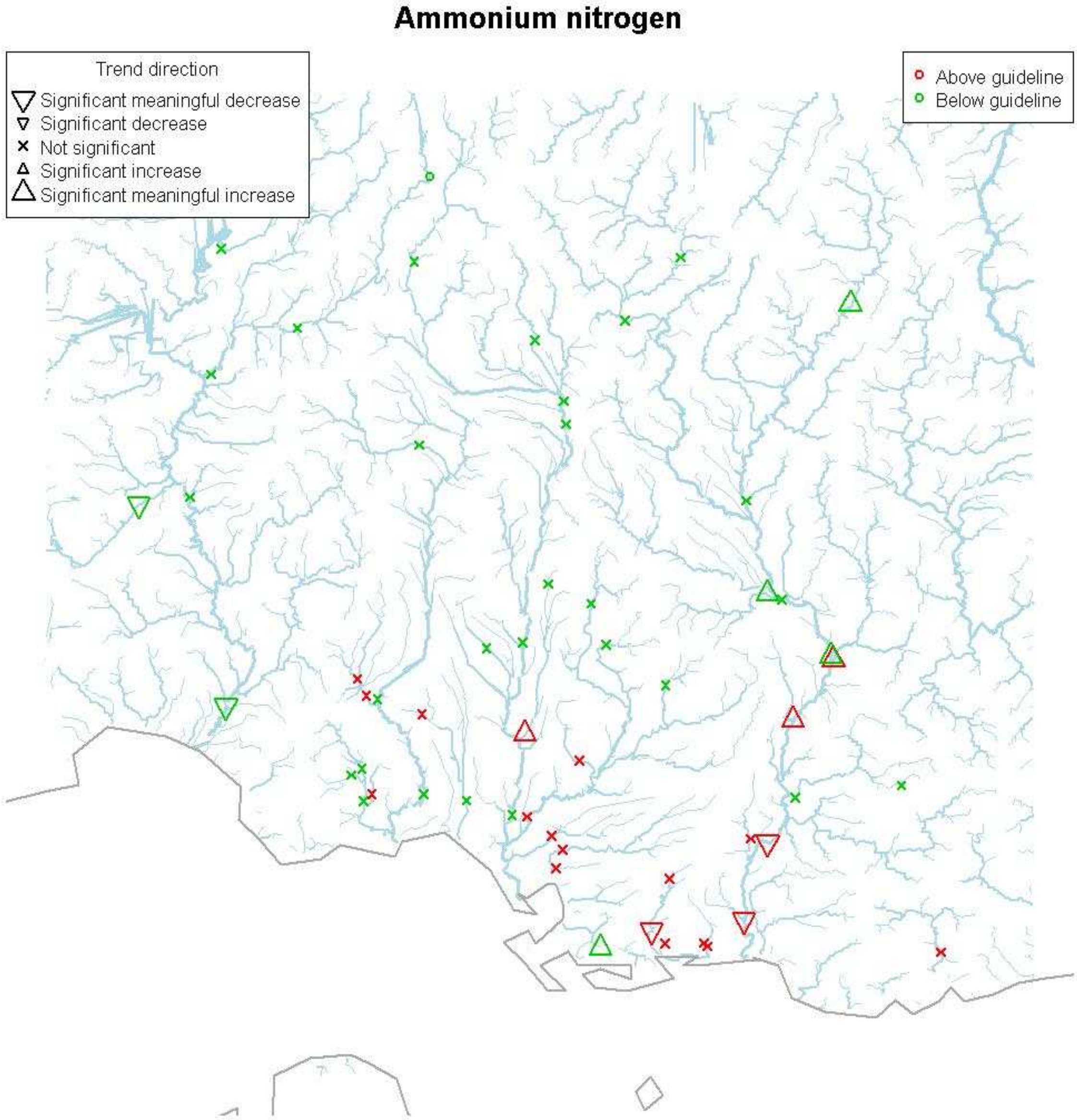

Figure 9: Location of the Southland region SoE sites for which NH4-N data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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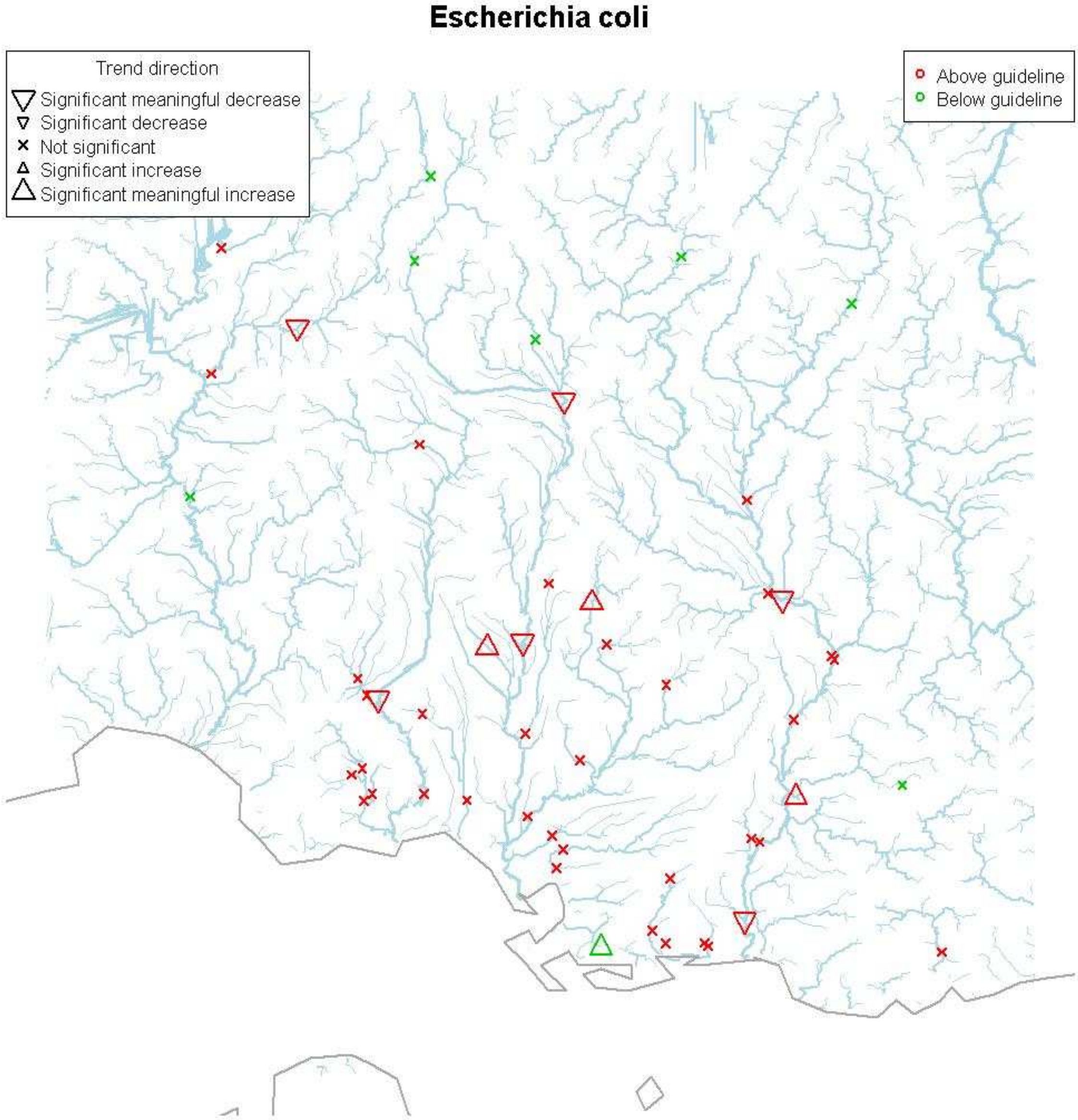

Figure 10: **Location of the Southland region SoE sites for which *E.coli* data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.**

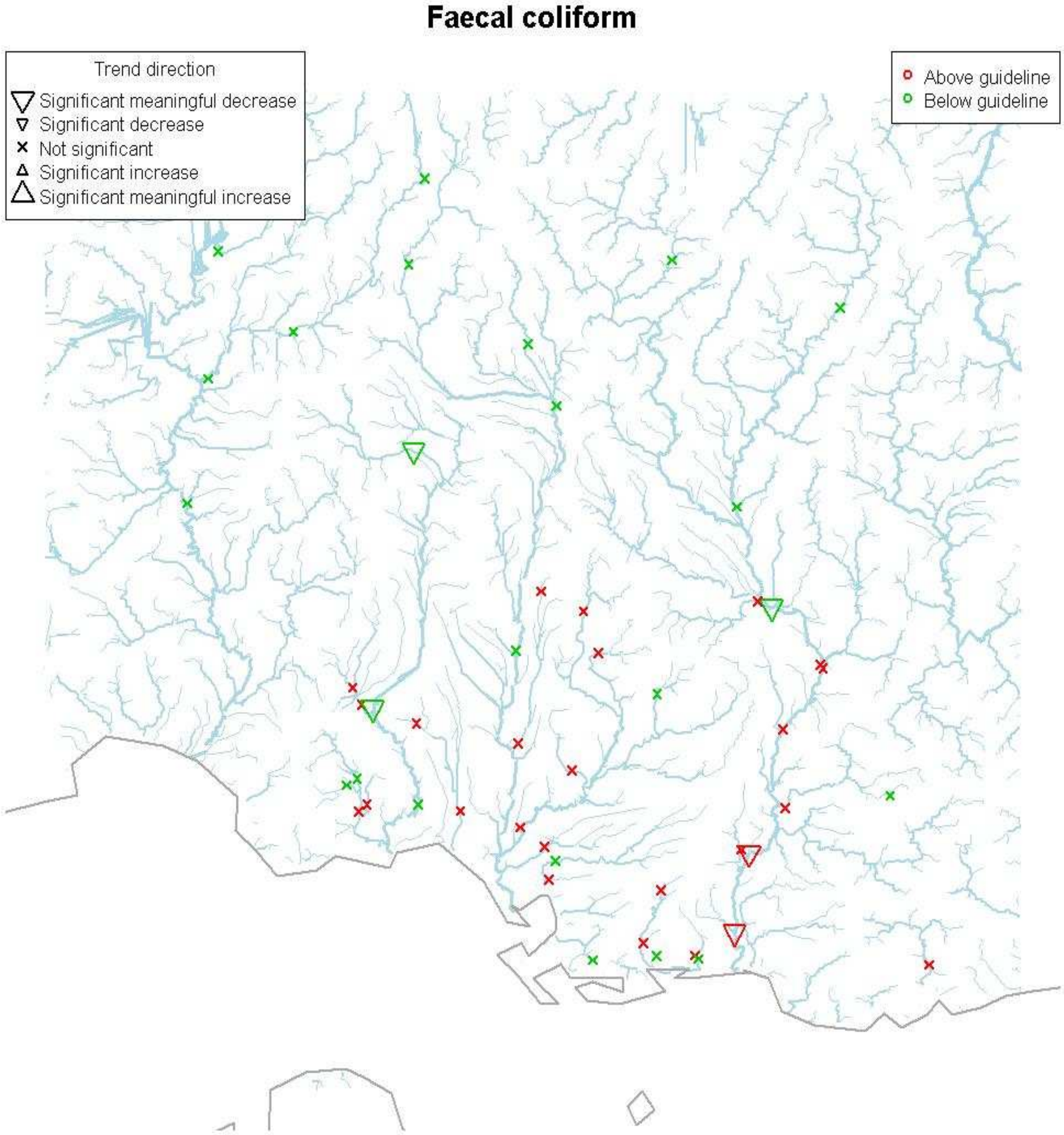

Figure 11: Location of the Southland region SoE sites for which Faecal Coliform (FC) data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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4.1.1 Water Quality State

Water quality patterns in Southland had strong relationships with REC *Topography* categories, with the highest water quality (e.g., highest Clarity, lowest conductivity, lowest nutrients and lowest indicator bacteria) in Mountain and Lake *Topography* categories and poorer water quality in Hill followed by Low Elevation *Topography* categories (Figure 12). Patterns in water quality were also strongly related to REC *Land-cover* categories (Figure 13 and Table 10). The Urban *Land-cover* category had the poorest water quality and sites in this category exceeded water quality guidelines for all variables considered. Sites in the Pasture *Land-cover* category also had generally poor water quality with more than 50% of sites exceeding guidelines for all variables except *E.coli*. The majority of sites in the other REC *Land-cover* categories were within the guideline values.

Table 10: Kruskall Wallis tests performed by variable for Southland river SoE sites grouped by REC *Topography* and *Land-cover* categories. See Table 3 for an explanation of the REC categories. Statistically significant tests are shown with blue text.

Variable	Topography			Land-cover		
	Statistic	*p*-value	*n*	Statistic	*p*-value	*n*
CLAR	*30.53*	*0.000*	*54*	*24.97*	*0.000*	*54*
COND	*38.59*	*0.000*	*56*	*21.40*	*0.001*	*56*
SS	NA	NA	1	NA	NA	1
NH_4-N	*27.60*	*0.000*	*56*	*24.37*	*0.000*	*56*
NO_x-N	*15.70*	*0.001*	*56*	*36.71*	*0.000*	*56*
TN	*24.14*	*0.000*	*56*	*35.29*	*0.000*	*56*
DRP	*23.88*	*0.000*	*55*	*22.17*	*0.000*	*55*
TP	*28.28*	*0.000*	*55*	*23.10*	*0.000*	*55*
E.coli	*17.03*	*0.001*	*51*	*30.88*	*0.000*	*51*
FC	*16.84*	*0.001*	*50*	*30.87*	*0.000*	*50*

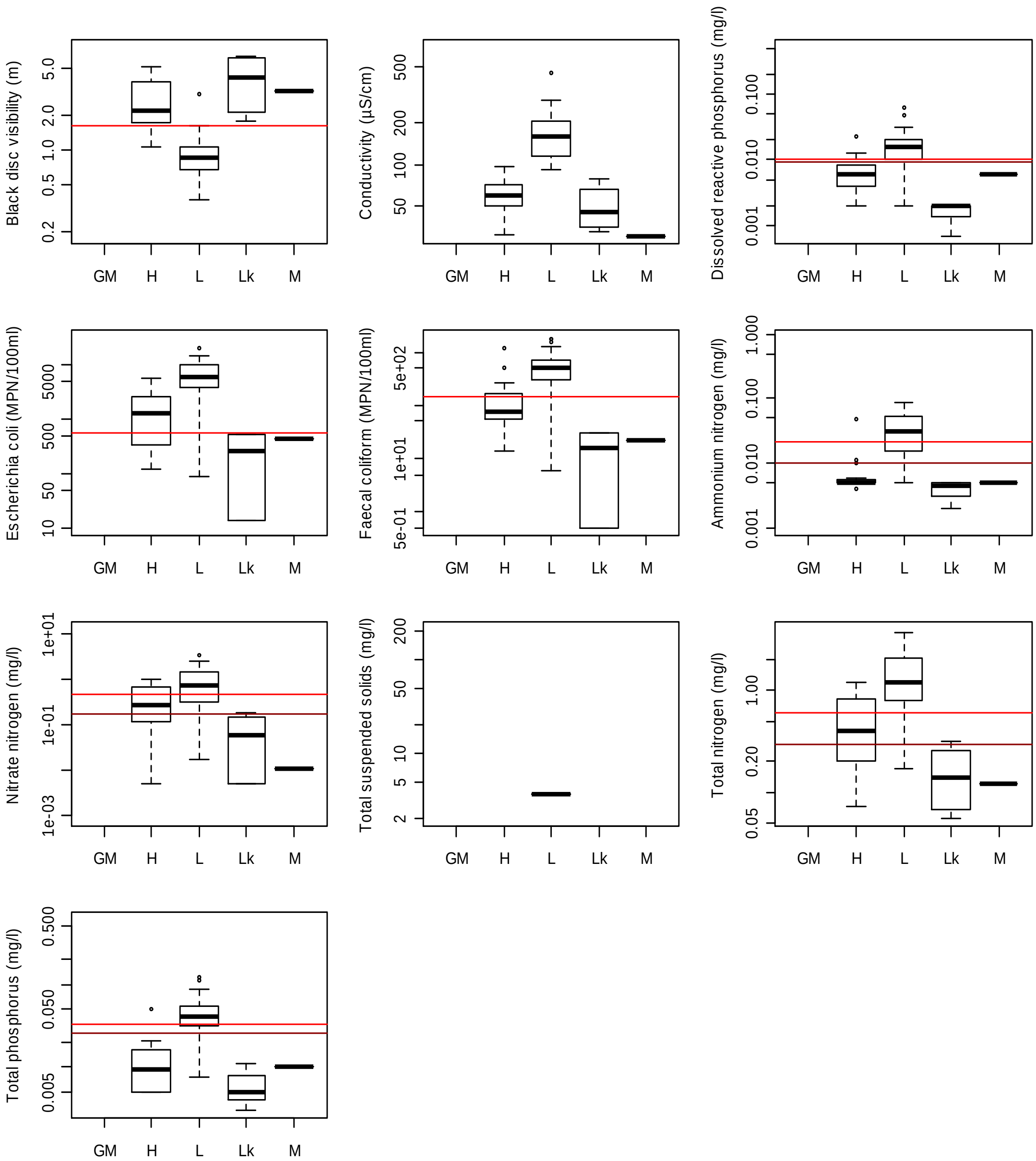

Figure 12: Median values for Southland sites of the ten water quality variables grouped by REC *Topography* categories. See Table 3 for an explanation of the REC categories. The guideline values the water quality variables shown in Table 2 are shown as horizontal lines. Where there are two horizontal lines these refer to the upland and lowland site guidelines. Note that low values of Clarity indicate poor water quality, whereas for other variables high values indicate poor water quality.

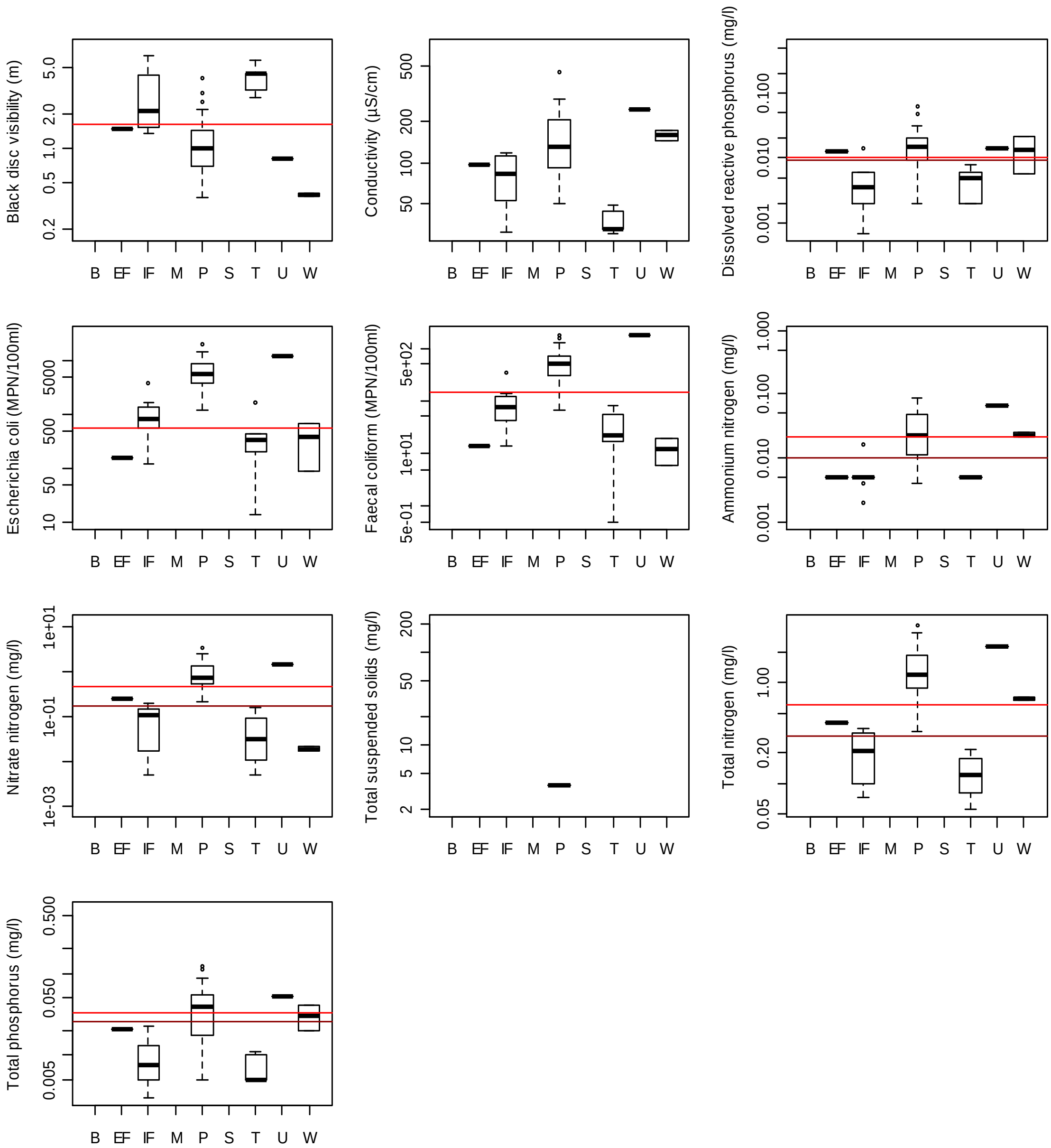

Figure 13: Median values for Southland sites of the ten water quality variables grouped by REC *Land-cover* categories. See Table 3 for an explanation of the REC categories. The guideline values the water quality variables shown in Table 2 are shown as horizontal lines. Where there are two horizontal lines these refer to the upland and lowland site guidelines. Note that low values of Clarity indicate poor water quality, whereas for other variables high values indicate poor water quality.

4.1.2 Water Quality Trends

Trends in water quality for the Southland Region are presented in Table 11 and Table 12. There was generally a mixture of both increasing and decreasing trends for all variables. There were increasing overall regional trends (i.e. based on all sites in the region) for COND, NH_4-N, NO_x-N and TN and decreasing overall regional trends for FC and DRP (Table 12). The overall regional trends were not significant for the other variables.

Table 11: Number of sites with significant and meaningful trends for all sites in the Southland Region by water quality variable.

Variable	Total number of sites	Meaningful decreases	Significant decreases	Not significant	Significant increases	Meaningful increases
Clarity	54	5	0	43	0	6
Conductivity	56	2	2	41	6	5
DRP	55	16	0	37	0	2
ECOLI	51	3	0	48	0	0
FC	50	5	0	45	0	0
NH_4-N	56	5	0	44	0	7
NO_x-N	56	1	0	37	0	18
SS	1	0	0	1	0	0
TN	56	3	0	42	0	11
TP	55	4	0	48	0	3

Table 12: Overall trends for the Southland region by water quality variable determined by grouping trends for all sites and using a binomial test (Significance level = 0.05).

Variable	Total number of sites	p	Overall trend direction
Clarity	54	1	Not Significant
Conductivity	56	0.005	Increasing
DRP	55	0	Decreasing
ECOLI	51	0.092	Not Significant
FC	50	0.003	Decreasing
NH_4-N	56	0.022	Increasing
NO_x-N	56	0	Increasing
SS	NA	NA	NA
TN	56	0.001	Increasing
TP	55	0.788	Not Significant

There were eight overall trends in the *Topography* category groupings (Table 13). There was a significant overall decreasing trend (improving water quality) in DRP, ECOLI and FC for sites in the Hill *Topography* category (Binomial test; Table 13). There was a significant overall increasing trend for COND and NO_x-N (deteriorating water quality) for the Hill sites (Binomial test; Table 13). In sites in the Low-elevation *Topography* category there were overall increasing trends in NH_4-N NO_x-N and TN.

Table 13: REC *Topography* categories for which there were significant overall trends in the Southland Region by water quality variable. See Table 3 for an explanation of the REC categories.

Variable	REC *Topography* category	Total number of Sites	*p*-value (binomial test of overall trend)	Overall trend
COND	**H**	**16**	**0.001**	**Increasing**
DRP	**H**	**16**	**0**	**Decreasing**
ECOLI	**H**	**14**	**0.013**	**Decreasing**
FC	**H**	**14**	**0.013**	**Decreasing**
NO_x-N	**H**	**16**	**0.004**	**Increasing**
NH_4-N	**L**	**35**	**0.041**	**Increasing**
NO_x-N	**L**	**35**	**0**	**Increasing**
TN	**L**	**35**	**0.001**	**Increasing**

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There were five overall trends in the Pasture *Land-cover* category groupings (Table 14). No other *Land-cover* category groupings had significant overall trends. There was a significant overall decreasing trend (improving water quality) in DRP and FC for sites (Binomial test; Table 14). There were significant overall increasing trends (deteriorating water quality) for COND, NOx-N and TN (Binomial test; Table 14).

Table 14: REC *Land-cover* categories for which there were significant overall trends in the Southland Region by water quality variable. See Table 3 for an explanation of the REC categories.

Variable	REC *Land-cover* category	Total number of Sites	*p*-value (binomial test of overall trend)	Overall trend
COND	Pasture	37	0.008	Increasing
DRP	Pasture	36	0.011	Decreasing
FC	Pasture	33	0.005	Decreasing
NO_x-N	Pasture	37	0	Increasing
TN	Pasture	37	0	Increasing

4.2 Taranaki Regional Council

A maximum of 12 SoE sites in the Taranaki region met our criteria for trend analysis by water quality variable (Table 15). The location of these sites, the variables they include and their water quality state and trend are summarised on Figure 14 to Figure 24. In general the maps show that the more coastal or lower sites on the Taranaki Ring Plains have tended to exceed guidelines more frequently than those higher on the slopes of Mount Taranaki and the other headwater locations regardless of variable being considered. The spatial patterns of trends is less clear with increasing and decreasing trends occurring in both upland and low elevation sites. The state of individual sites showed strong variation across variables (Appended Table 32). Sites can meet guidelines for some variables and not for others. Trend direction and strength at individual sites also showed strong variation across variables. This variability in state and trends within sites according to the variables that are being considered makes it difficult to single out particular sites or catchments as problematic. The sites have been ordered in Appended Table 32 according to a ranking from worst to best water quality. This is a subjective ranking that does not take into account potentially important factors such as the extent to which sites fail guidelines. IWe note that the network of sampling sites shown in Figure 14 to Figure 24 is sparse relative to the region's river monitoring network.

Table 15.: Number of river sites in Taranaki by variable and REC categories that meet criteria for trend analysis. See Table 3 for an explanation of the REC categories.

Variable	Landcover							Topography					Total
	EF	IF	P	S	T	U	W	GM	H	L	Lk	M	
CLAR	0	3	8	1	0	0	0	0	5	7	0	0	12
COND	0	3	8	1	0	0	0	0	5	7	0	0	12
DRP	0	3	8	1	0	0	0	0	5	7	0	0	12
ECOLI	0	2	6	1	0	0	0	0	4	5	0	0	9
FC	0	2	6	1	0	0	0	0	4	5	0	0	9
NH_4-N	0	3	8	1	0	0	0	0	5	7	0	0	12
NO_x-N	0	3	8	1	0	0	0	0	5	7	0	0	12
SS	0	0	0	0	0	0	0	0	0	0	0	0	0
TN	0	3	8	1	0	0	0	0	5	7	0	0	12
TP	0	3	8	1	0	0	0	0	5	7	0	0	12

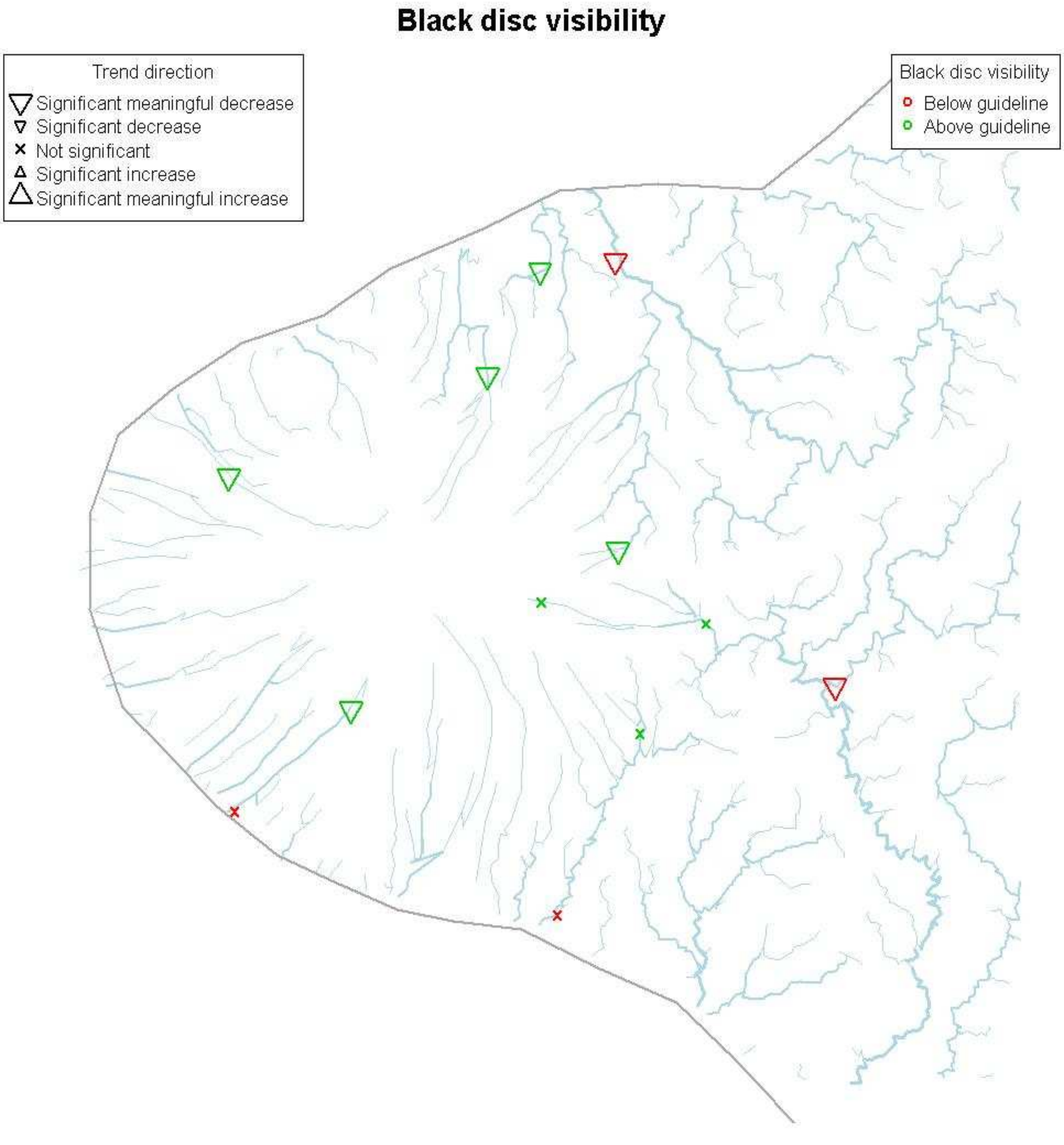

Figure 14:. Location of the Taranaki region SoE sites for which Clarity data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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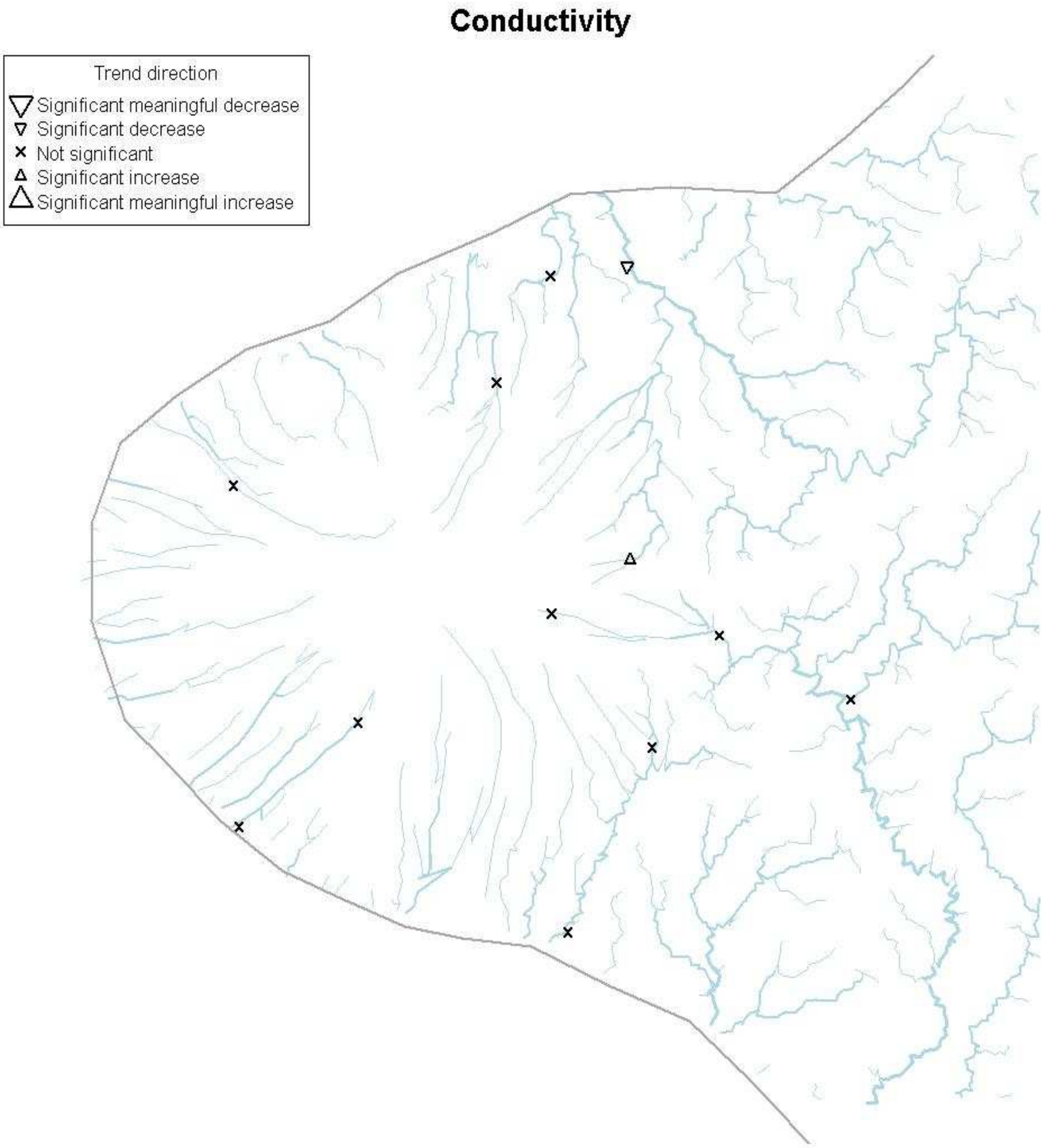

Figure 15. Location of the Taranaki region SoE sites for which conductivity data met our criteria for trend analysis showing the size of the trend. Note that conductivity is an indicator of ion concentration but that there is no guideline value.

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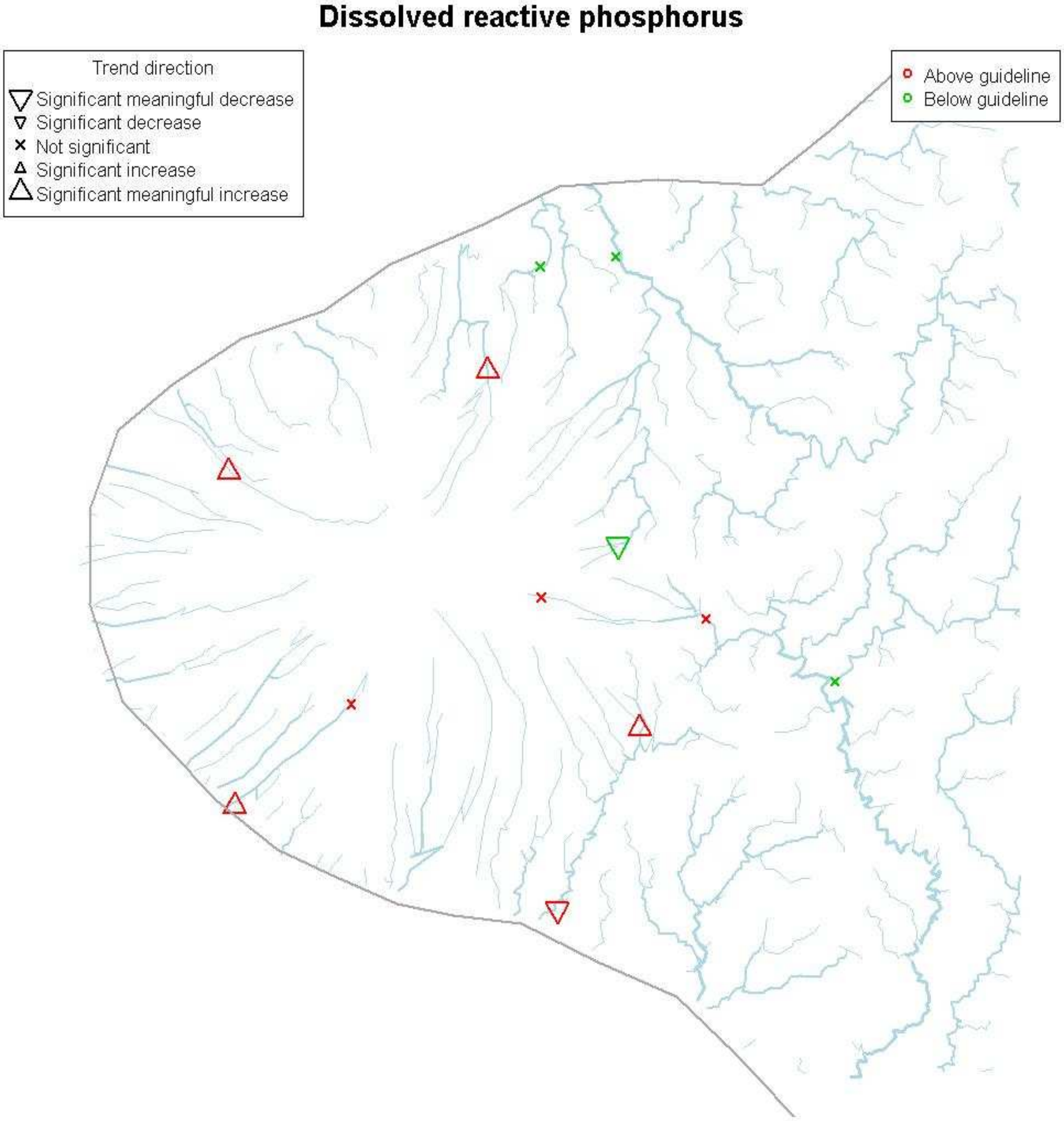

Figure 16: Location of the Taranaki region SoE sites for which DRP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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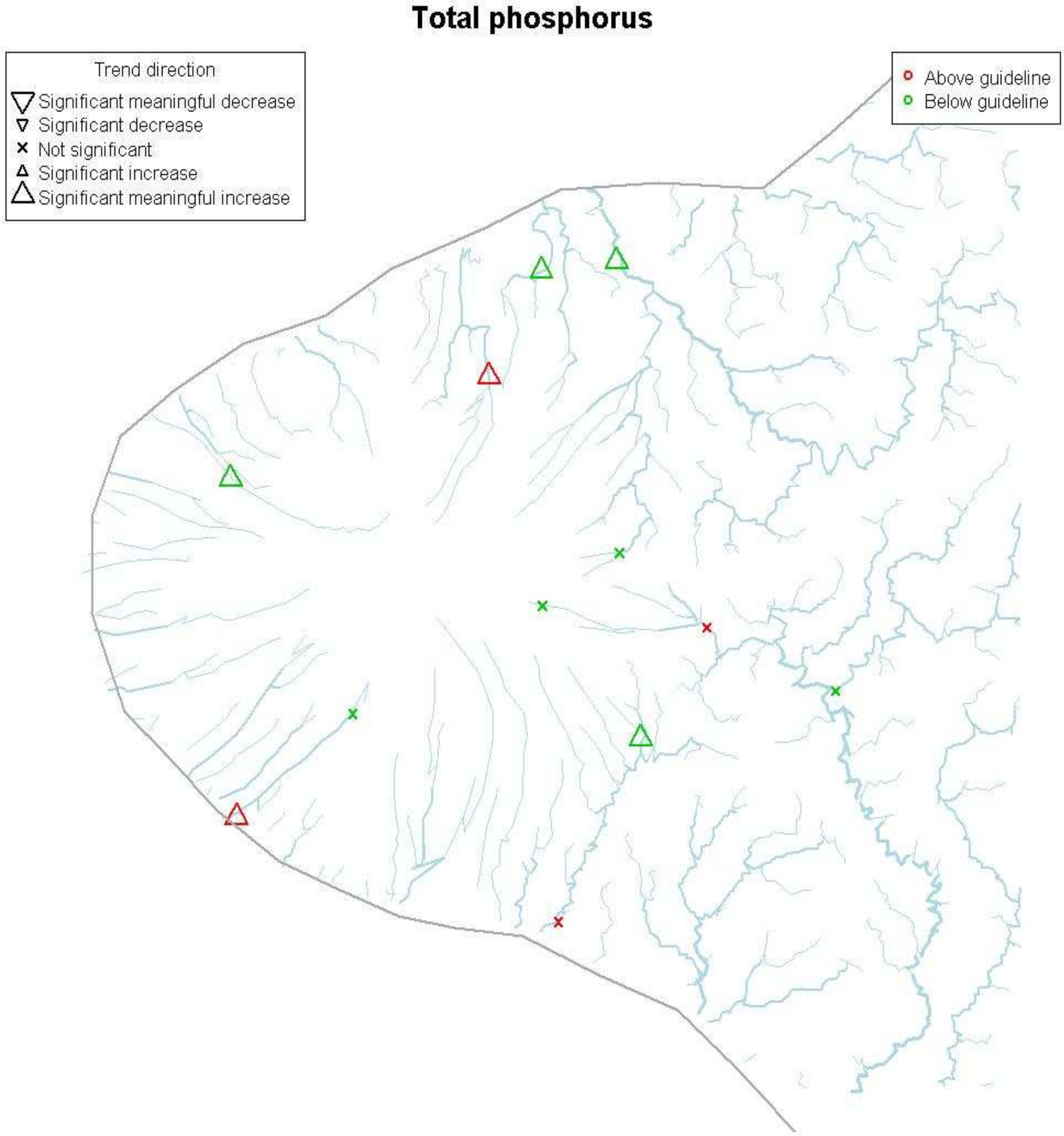

Figure 17: Location of the Taranaki region SoE sites for which TP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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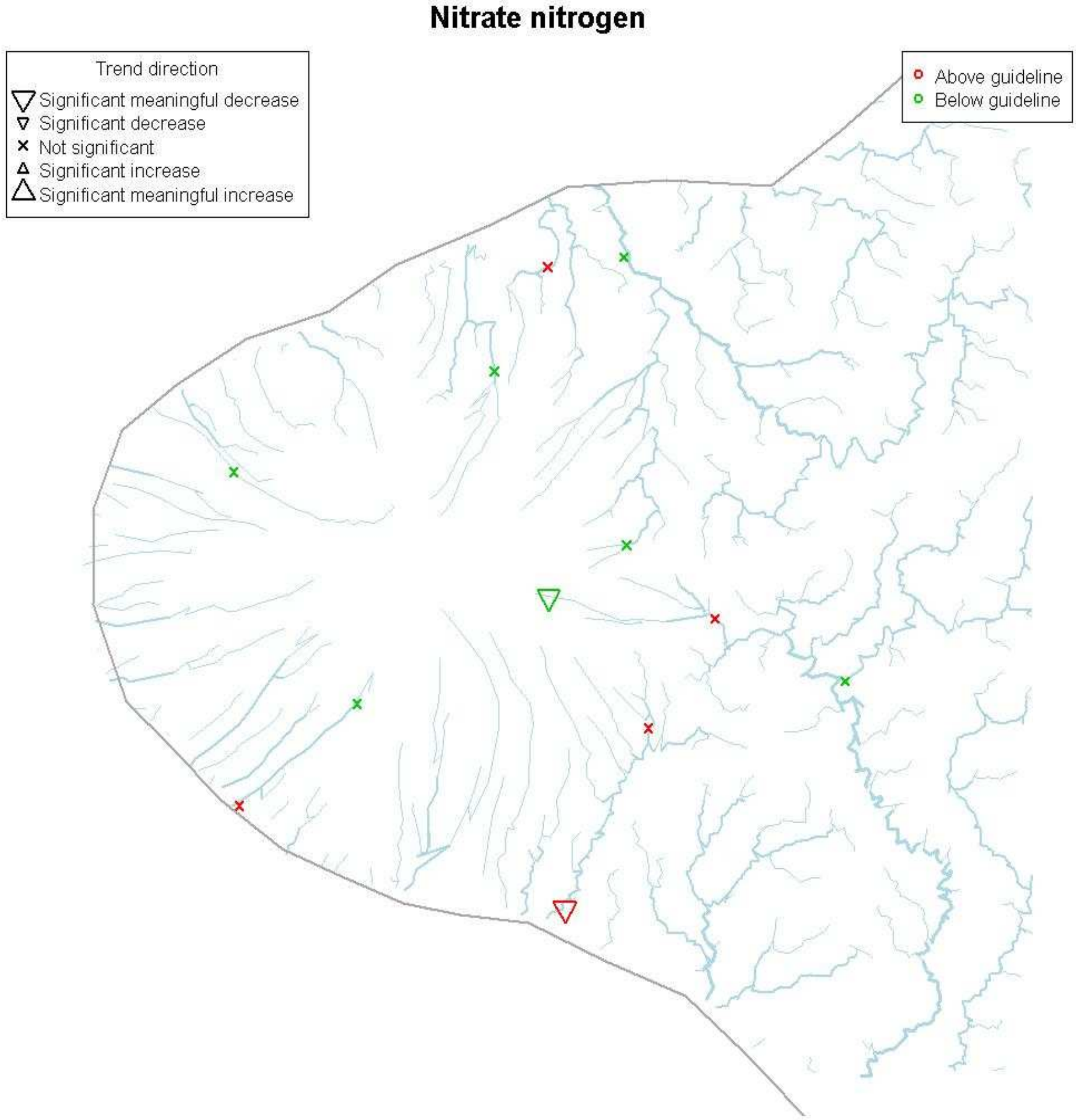

Figure 18: Location of the Taranaki region SoE sites for which NOx-N data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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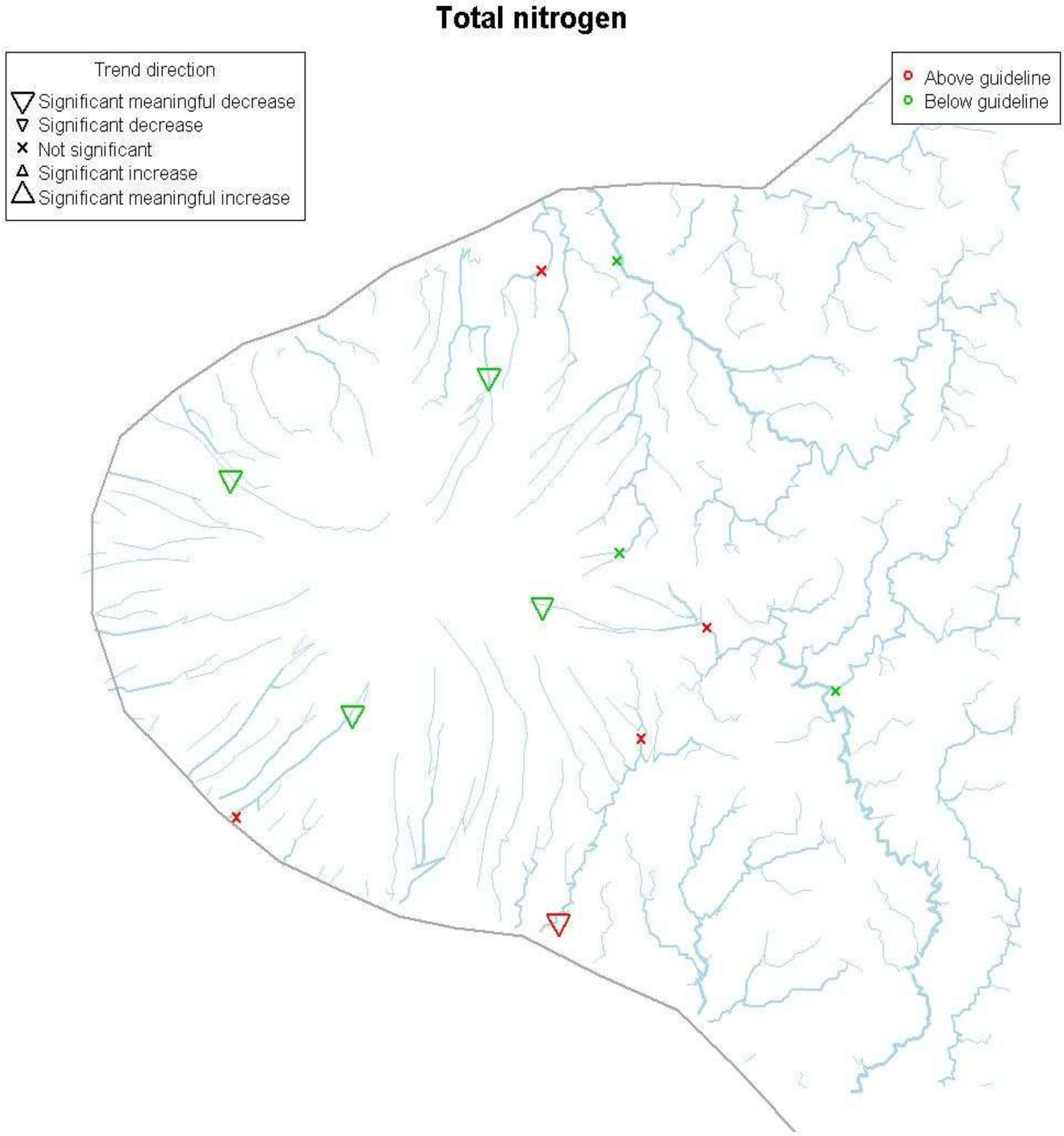

Figure 19: Location of the Taranaki region SoE sites for which TN data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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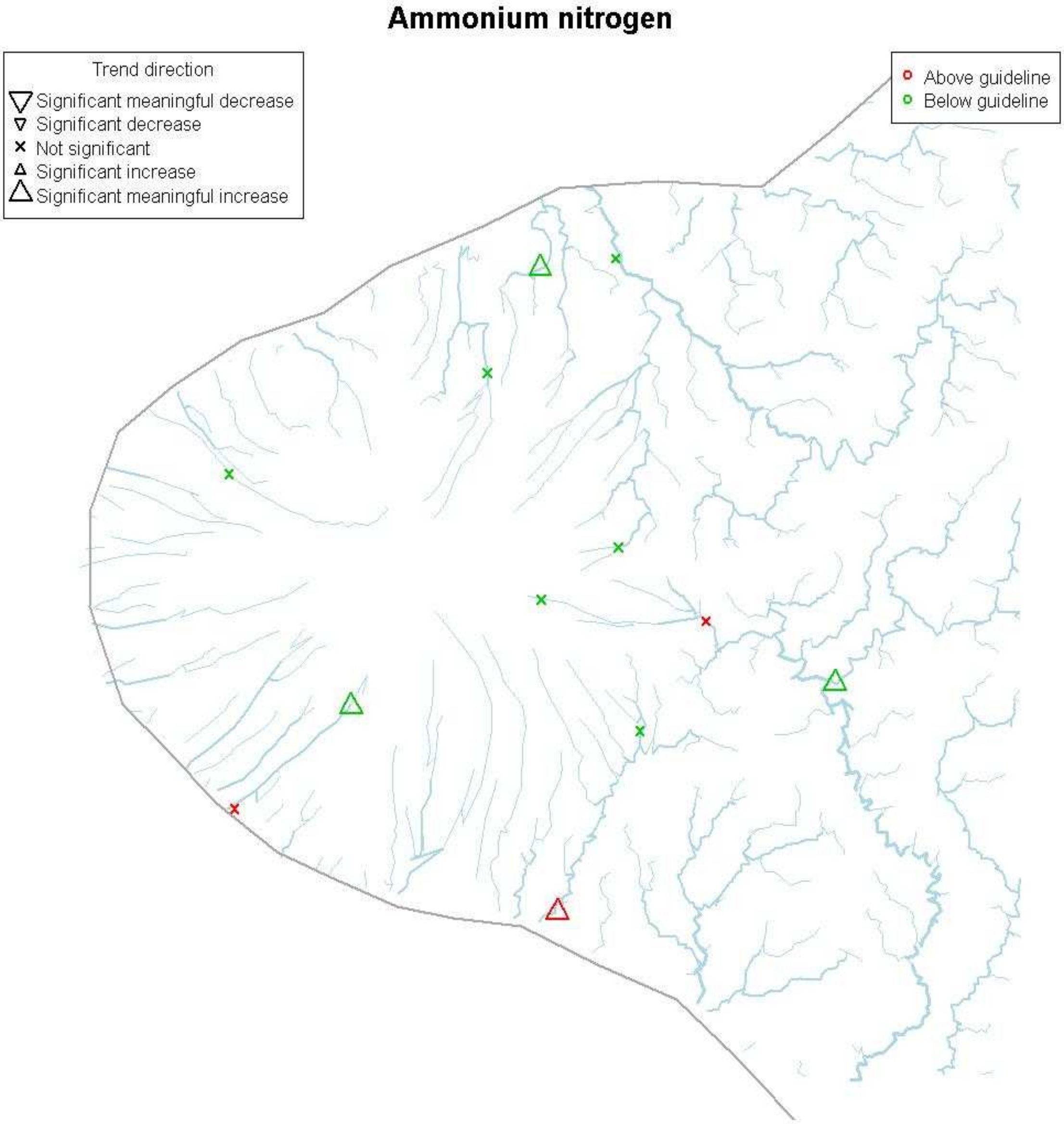

Figure 20: Location of the Taranaki region SoE sites for which NH4-N data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

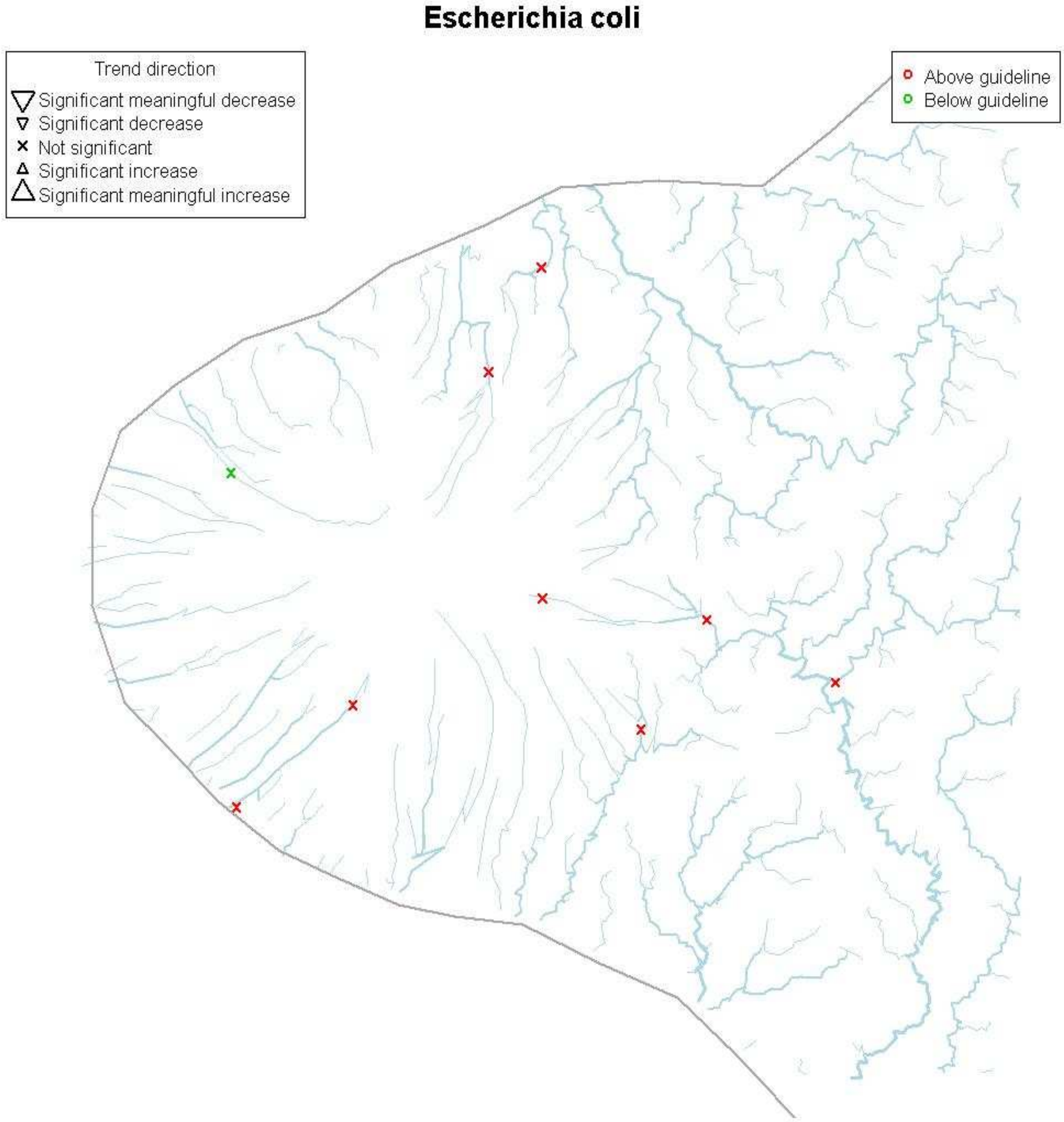

Figure 21: Location of the Taranaki region SoE sites for which *E.coli* data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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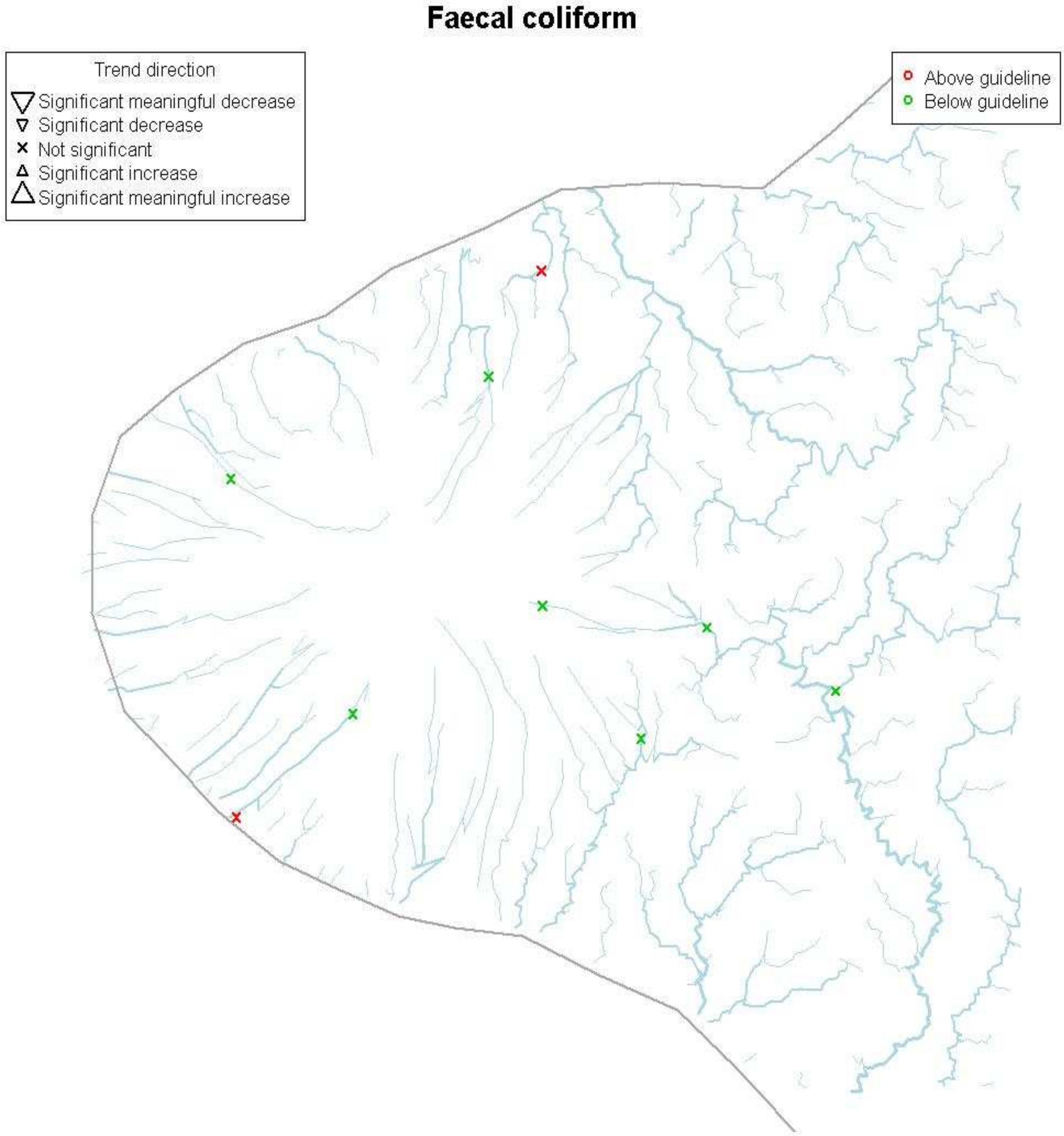

Figure 22: Location of the Taranaki region SoE sites for which Faecal Coliform (FC) data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

4.2.1 Water Quality State

As shown on maps (Figure 14 to Figure 21) and Table 16 water quality patterns in the Taranaki region had strong relationships with Topography of the upstream catchments. These topographic differences are illustrated by REC *Topography* categories with the higher water quality (e.g., highest Clarity, lowest conductivity, lowest nutrients and lowest indicator bacteria) in the Hill *Topography* category than in the Low-elevation *Topography* category (Figure 23). Patterns in water quality were also strongly related to REC *Land-cover* categories (Figure 24 and Table 16). The Pasture *Land-cover* category had the poorest water quality with the majority of sites in this category exceeding water quality guidelines for all variables. The majority of sites in the other REC *Land-cover* categories were within the guideline values. The majority of sites in the Taranki region exceed the DRP guidelines probably because the volcanic soils of the region that are naturally high in phosphorus (for example, DRP is fairly high in IF as well as P (Figure 24).

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Table 16. Kruskall Wallis tests performed by variable for Taranaki river SoE sites grouped by REC *Topography* and *Land-cover* categories. See Table 3 for an explanation of the REC categories. Statistically significant tests are shown with blue text.

Variable	Topography			Land-cover		
	Statistic	*p*-value	*n*	Statistic	*p*-value	*n*
CLAR	*6.34*	*0.012*	*12*	4.88	0.087	12
COND	*4.81*	*0.028*	*12*	*7.62*	*0.022*	*12*
NH_4-N	*8.13*	*0.004*	*12*	*7.54*	*0.023*	*12*
NO_x-N	*7.28*	*0.007*	*12*	*7.52*	*0.023*	*12*
TN	*8.08*	*0.004*	*12*	*7.62*	*0.022*	*12*
DRP	0.01	0.935	12	0.12	0.943	12
TP	1.49	0.222	12	2.36	0.307	12
E.coli	*4.86*	*0.027*	*9*	5.60	0.061	9
FC	*4.90*	*0.027*	*9*	5.65	0.059	9

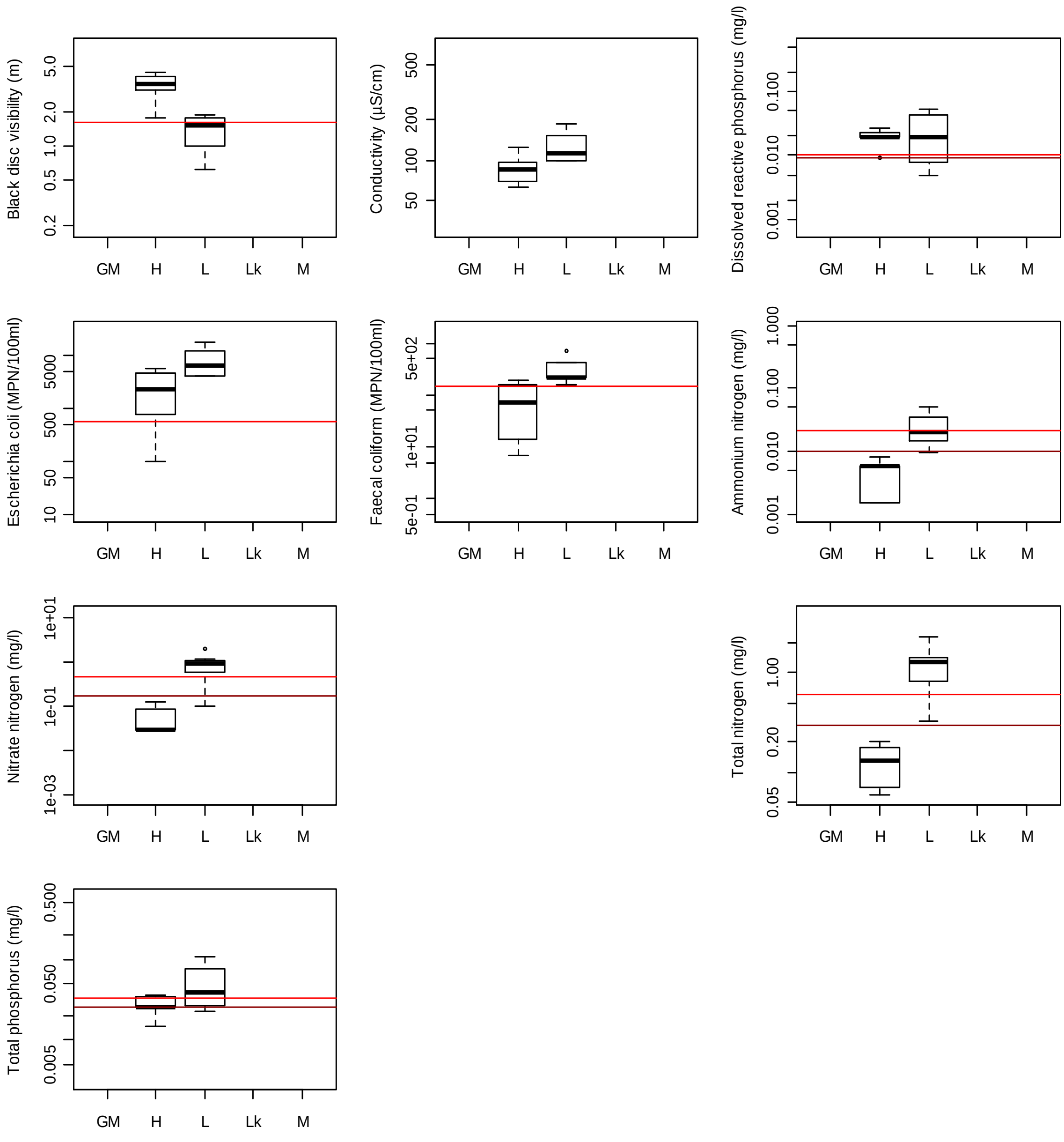

Figure 23. Median values for Taranaki region sites of the nine water quality variables grouped by REC *Topography* categories. See Table 3 for an explanation of the REC categories. The guideline values the water quality variables shown in Table 2 are shown as horizontal lines. Where there are two horizontal lines these refer to the upland and lowland site guidelines. Note that low values of Clarity indicate poor water quality, whereas for other variables high values indicate poor water quality.

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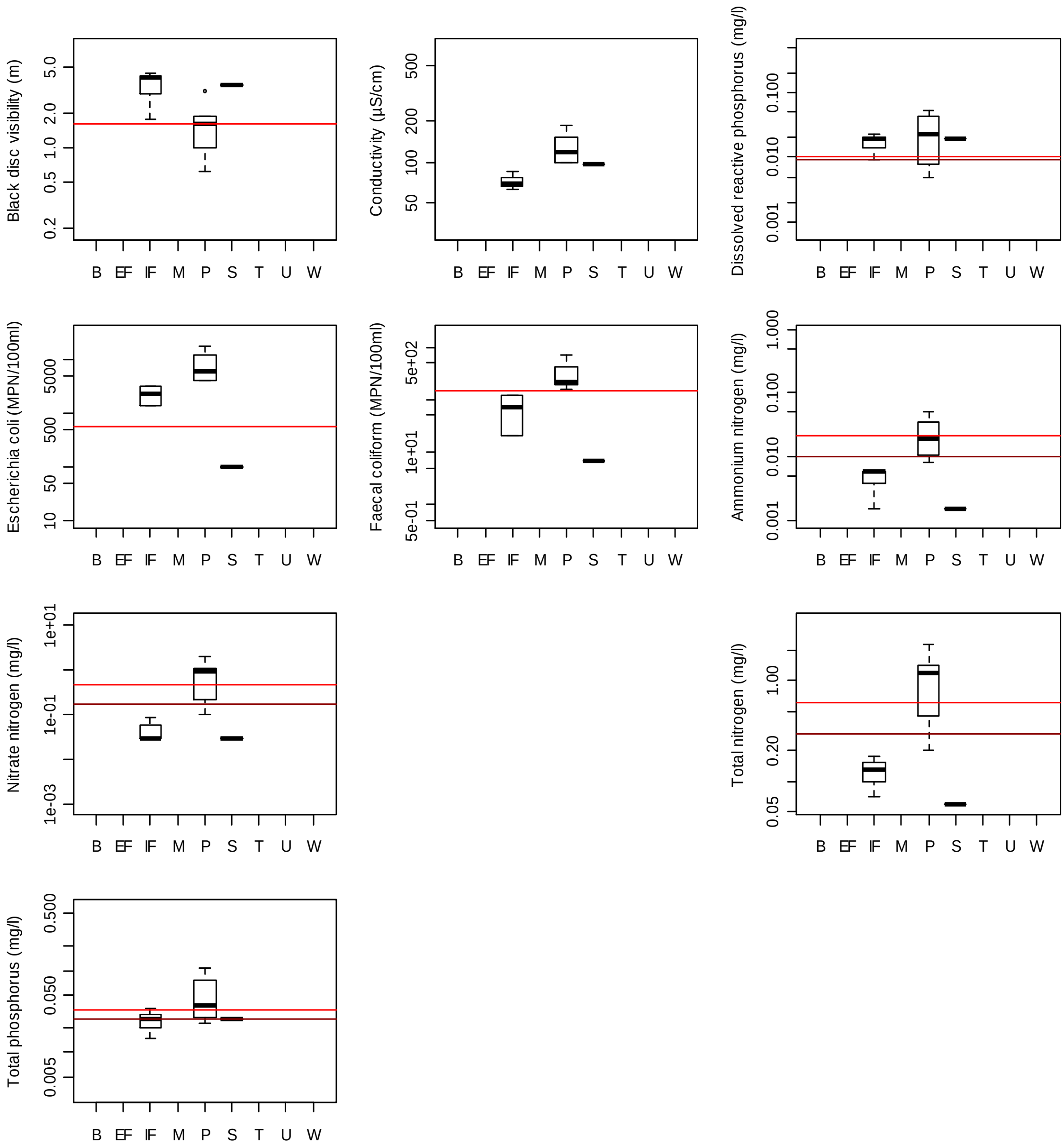

Figure 24: **Median values for Taranaki region sites of nine water quality variables grouped by REC *Land-cover* categories. See Table 3 for an explanation of the REC categories. The guideline values the water quality variables shown in Table 2 are shown as horizontal lines. Where there are two horizontal lines these refer to the upland and lowland site guidelines. Note that low values of Clarity indicate poor water quality, whereas for other variables high values indicate poor water quality.**

4.2.2 Water Quality Trends

Trends in water quality for the Taranaki region are presented in Table 17 and Table 18. There was generally a mixture of both increasing and decreasing trends for all variables considered (Table 17). The majority of overall regional trends (i.e. based on all sites in the region) indicate degrading water quality. There were increasing overall regional trends for NOx-N and TN (deteriorating water quality) and decreasing overall regional trends for Clarity (improving water quality) (Table 17). There was an overall decreasing trend for DRP indicating improving conditions for this variable (Table 17). The overall regional trends were not significant for the other variables.

Table 17: Number of sites with significant and meaningful trends for all sites in the Taranaki region by water quality variable.

Variable	Total number of sites	Meaningful decreases	Significant decreases	Not significant	Significant increases	Meaningful increases
CLAR	12	3	0	9	0	0
COND	12	0	0	11	1	0
DRP	12	1	0	8	0	3
ECOLI	9	0	0	9	0	0
FC	9	0	0	9	0	0
NH_4-N	12	0	0	10	0	2
NO_x-N	12	2	0	10	0	0
TN	12	2	0	10	0	0
TP	12	0	0	8	0	4

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Table 18: Overall trends for the Taranaki region by water quality variable determined by grouping trends for all sites and using a binomial test (Significance level = 0.05).

Variable	Total number of sites	p	Overall trend direction
Clarity	**12**	**0**	**Decreasing**
Conductivity	**12**	**0.388**	**Not Significant**
DRP	**12**	**0.039**	**Decreasing**
ECOLI	**9**	**0.18**	**Not Significant**
FC	**9**	**0.039**	**Increasing**
NH_4-N	**12**	**0.006**	**Increasing**
NO_x-N	**12**	**0.774**	**Not Significant**
TN	**12**	**0.146**	**Not Significant**
TP	**12**	**0.388**	**Not Significant**

There were two overall trends in the *Topography* category groupings (Table 19). There was a significant overall decreasing trend in clarity for sites in the Low-elevation *Topography* category (Binomial test; Table 19). There was also a significant overall increasing trend for conductivity and NH_4-N for sites in the Low-elevation *Topography* category (Binomial test; Table 19).

Table 19: REC *Topography* categories for which there were significant overall trends in the Taranaki Region by water quality variable. See Table 3 for an explanation of the REC categories.

Variable	REC *Topography* category	Total number of Sites	*p*-value (binomial test of overall trend)	Overall trend
CLAR	L	7	0.016	Decreasing
NH4-N	L	7	0.016	Increasing

There were four overall trends in the Pasture *Land-cover* category groupings (Table 20). No other *Land-cover* category groupings had significant overall trends. All four overall trends in the Pasture *Land-cover* categories indicated degrading water quality in these rivers over the period of analysis. There was a significant overall decreasing trend in Clarity and significant overall increasing trends for FC, E.coli and NH_4-N (Binomial test; Table 20).

In general the overall trends (i.e. based on the groupings of sites) indicate degrading water quality. However, there was an improving overall regional trend in DRP. This was not significant however in the REC *Topography* and *Land-cover* category groupings.

Table 20: REC *Land-cover* categories for which there were significant overall trends in the Taranaki Region by water quality variable. See Table 3 for an explanation of the REC categories.

Variable	REC *Land-cover* category	Total number of Sites	*p*-value (binomial test of overall trend)	Overall trend
CLAR	P	8	0.008	Decreasing
ECOLI	P	6	0.031	Increasing
FC	P	6	0.031	Increasing
NH_4-N	P	8	0.008	Increasing

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4.3 Horizons Regional Council

A maximum of 17 SoE sites in the Horizons Regional Council region met our criteria for trend analysis (Table 21). The location of these sites, the variables they include and their water quality state and trend are summarised on Figure 25 to Figure 32. The maps highlight that sites in the catchment of the Manawatu River have tended to exceed guidelines for a range of variables including clarity, DRP, TP, NO_x-N, TN and *E.coli*. The spatial patterns of trends are less clear with increasing and decreasing trends occurring throughout the region. The state of individual sites showed strong variation across variables (Appended Table 29). Sites can meet guidelines for some variables and not for others. Trend direction and strength at individual sites also showed strong variation across variables. This variability in state and trends within sites according to the variables that are being considered makes it difficult to single out particular sites or catchments as problematic. The sites have been ordered in Appended Table 29 according to a ranking from worst to best water quality. This is a subjective ranking that does not take into account potentially important factors such as the extent to which sites fail guidelines. The network of sampling sites shown in Figure 25 to Figure 32 is sparse relative to the region's river network.

Table 21: Number of sites in Horizons by variable and REC categories that meet criteria for trend analysis. See Table 3 for an explanation of the REC categories.

Variable	Landcover							Topography					Total
	EF	IF	P	S	T	U	W	GM	H	L	Lk	M	
CLAR	0	1	15	0	0	0	0	0	7	8	0	1	16
COND	0	1	16	0	0	0	0	0	7	9	0	1	17
DRP	0	1	16	0	0	0	0	0	7	9	0	1	17
ECOLI	0	0	8	0	0	0	0	0	4	4	0	0	8
FC	0	0	0	0	0	0	0	0	0	0	0	0	0
NH_4-N	0	1	14	0	0	0	0	0	6	8	0	1	15
NO_x-N	0	1	16	0	0	0	0	0	7	9	0	1	17
SS	0	1	9	0	0	0	0	0	5	5	0	0	10
TN	0	0	7	0	0	0	0	0	2	4	0	1	7
TP	0	0	8	0	0	0	0	0	2	5	0	1	8

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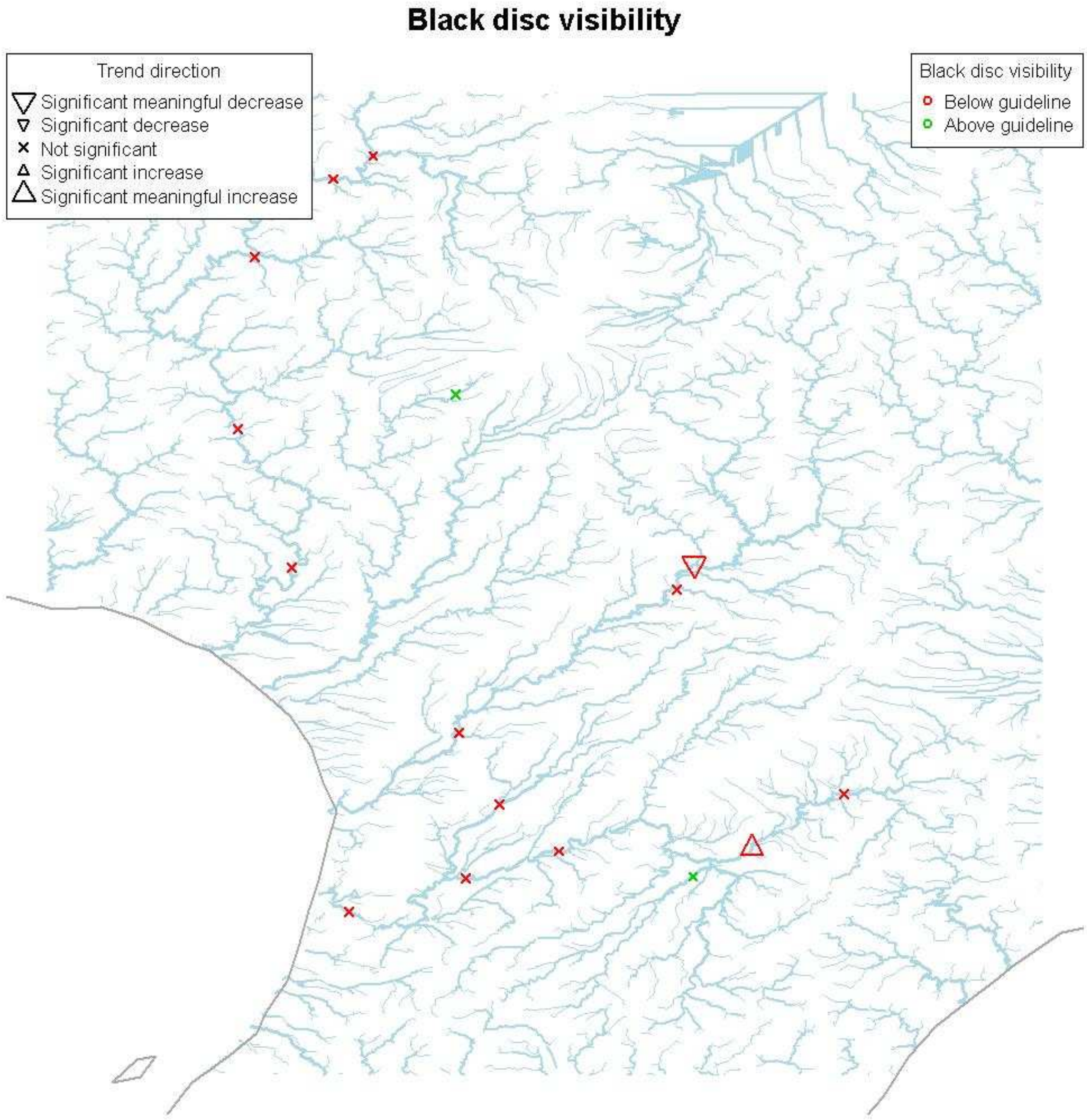

Figure 25: Location of the Horizons region SoE sites for which Clarity data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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Conductivity

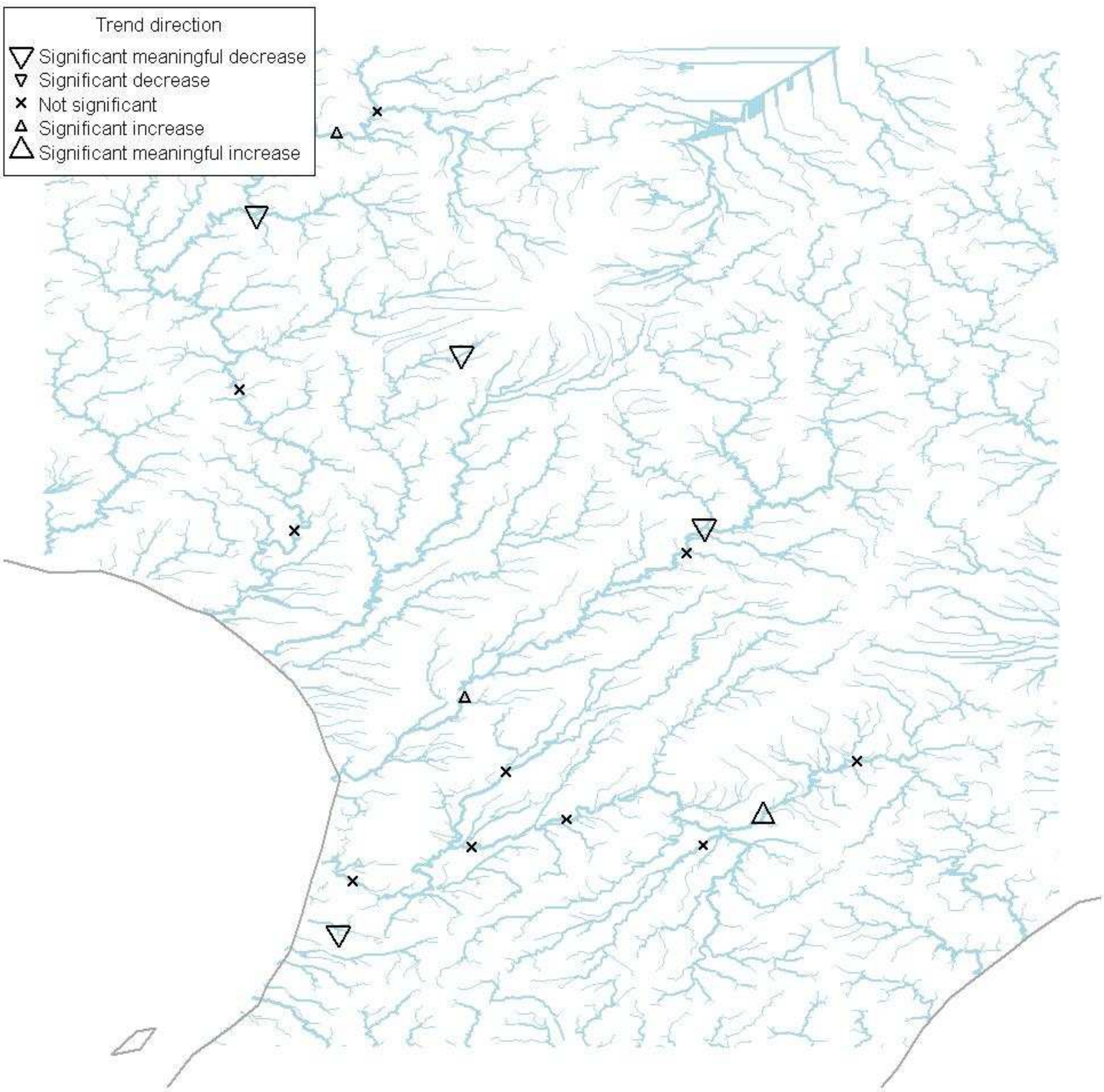

Figure 26: Location of the Horizons region SoE sites for which conductivity data met our criteria for trend analysis showing the size of the trend. Note that conductivity is an indicator of contamination but that there is no guideline value.

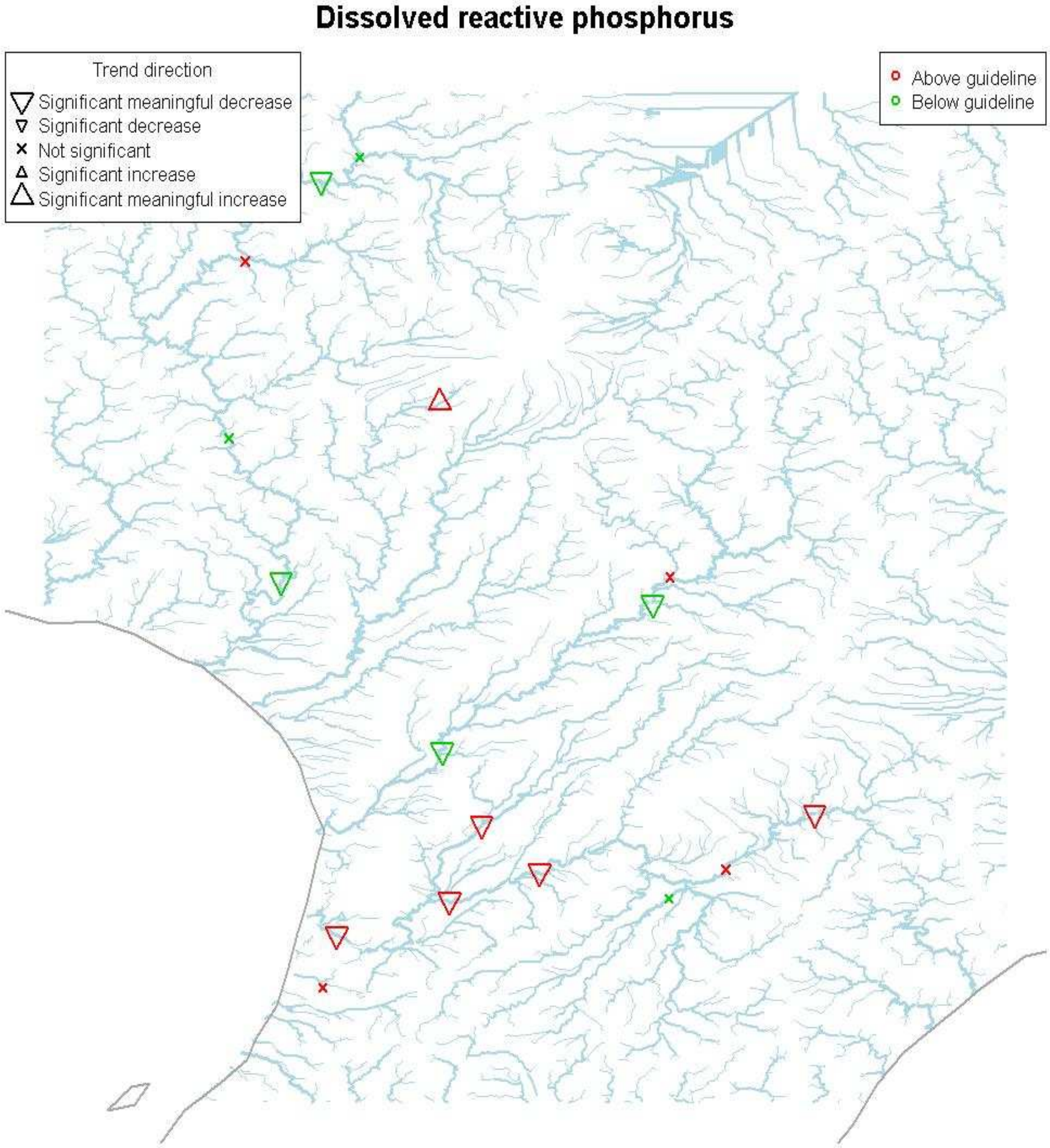

Figure 27: Location of the Horizons region SoE sites for which DRP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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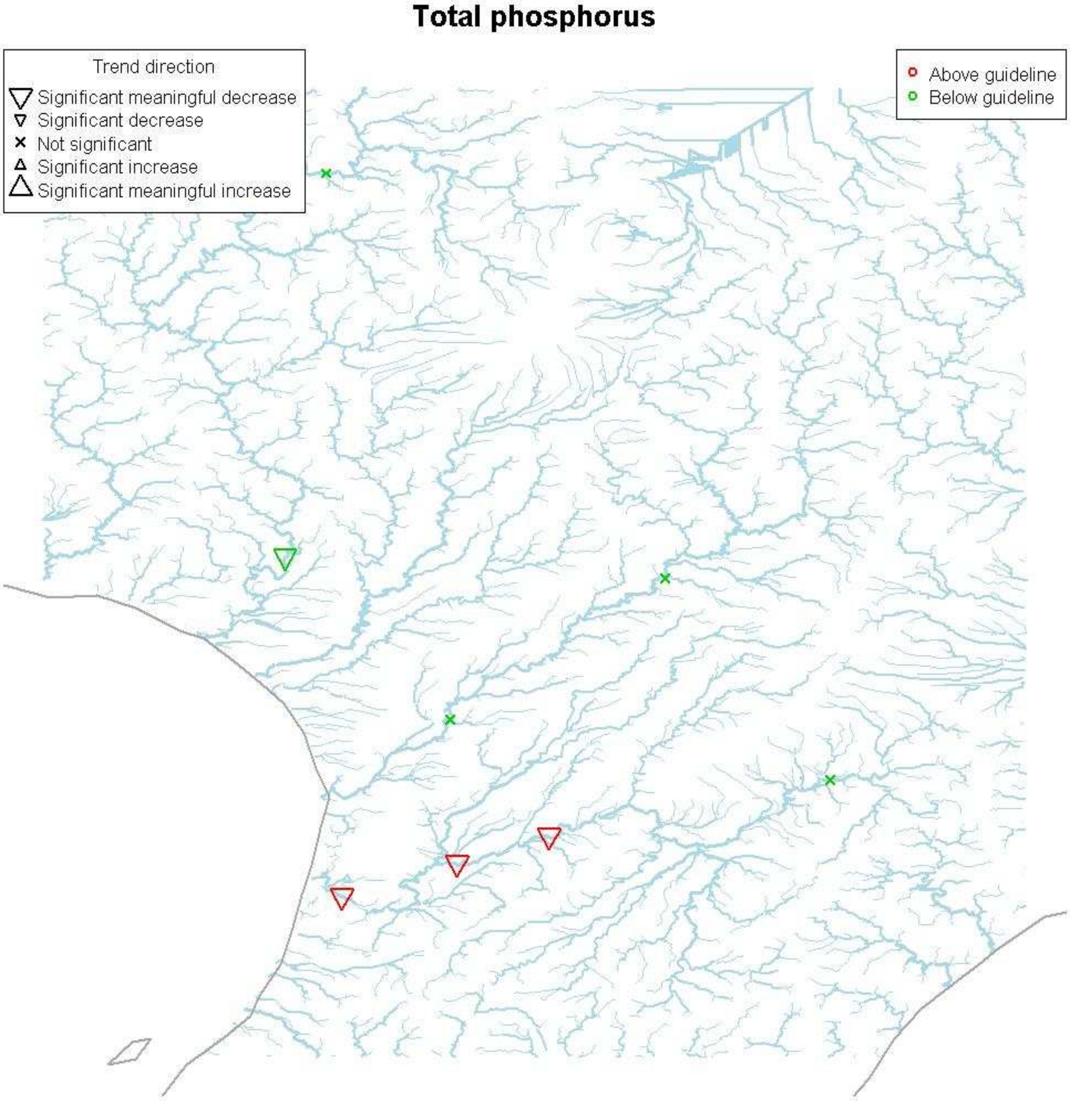

Figure 28: Location of the Horizons region SoE sites for which TP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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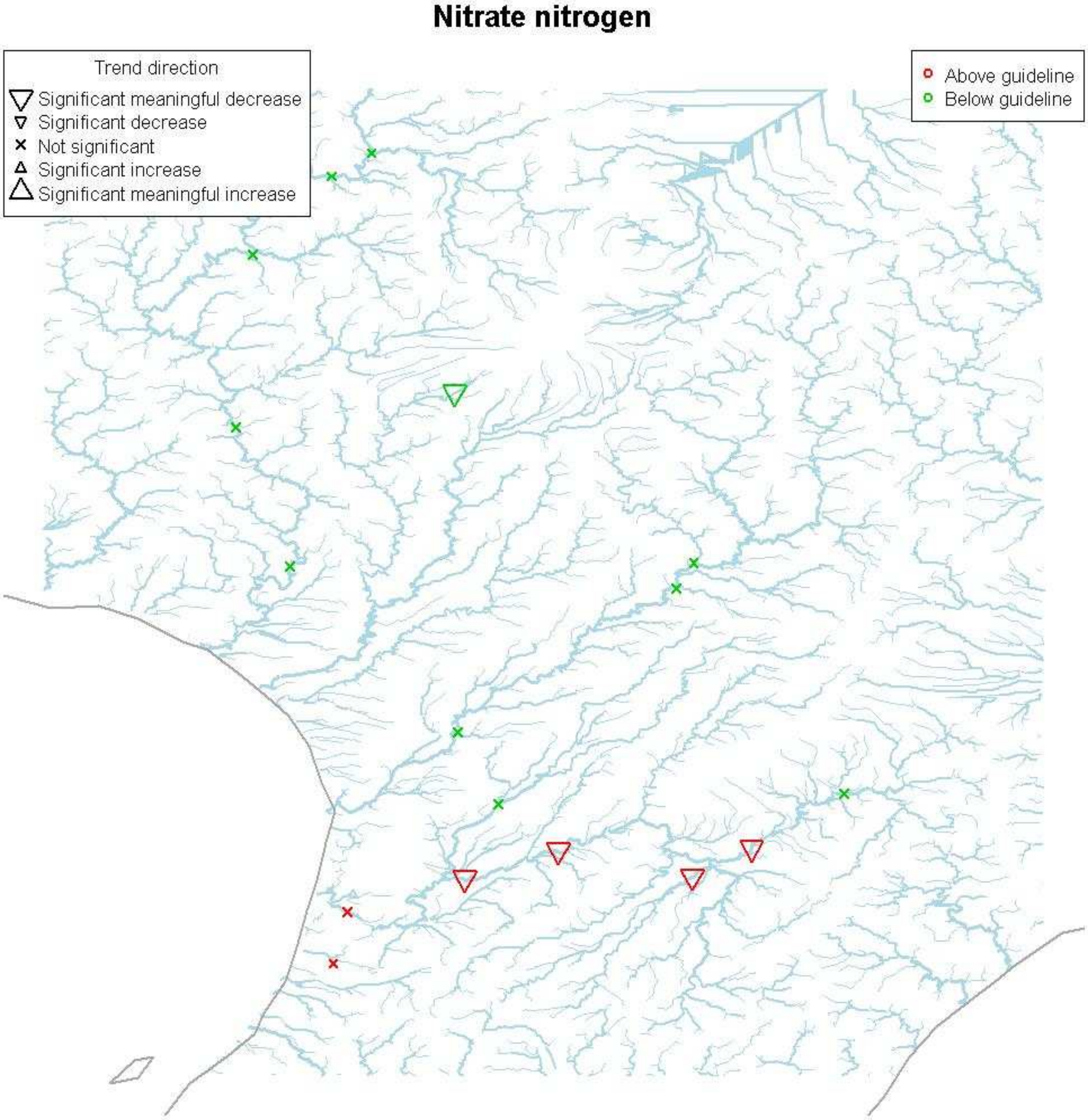

Figure 29: Location of the Horizons region SoE sites for which NOx-N data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

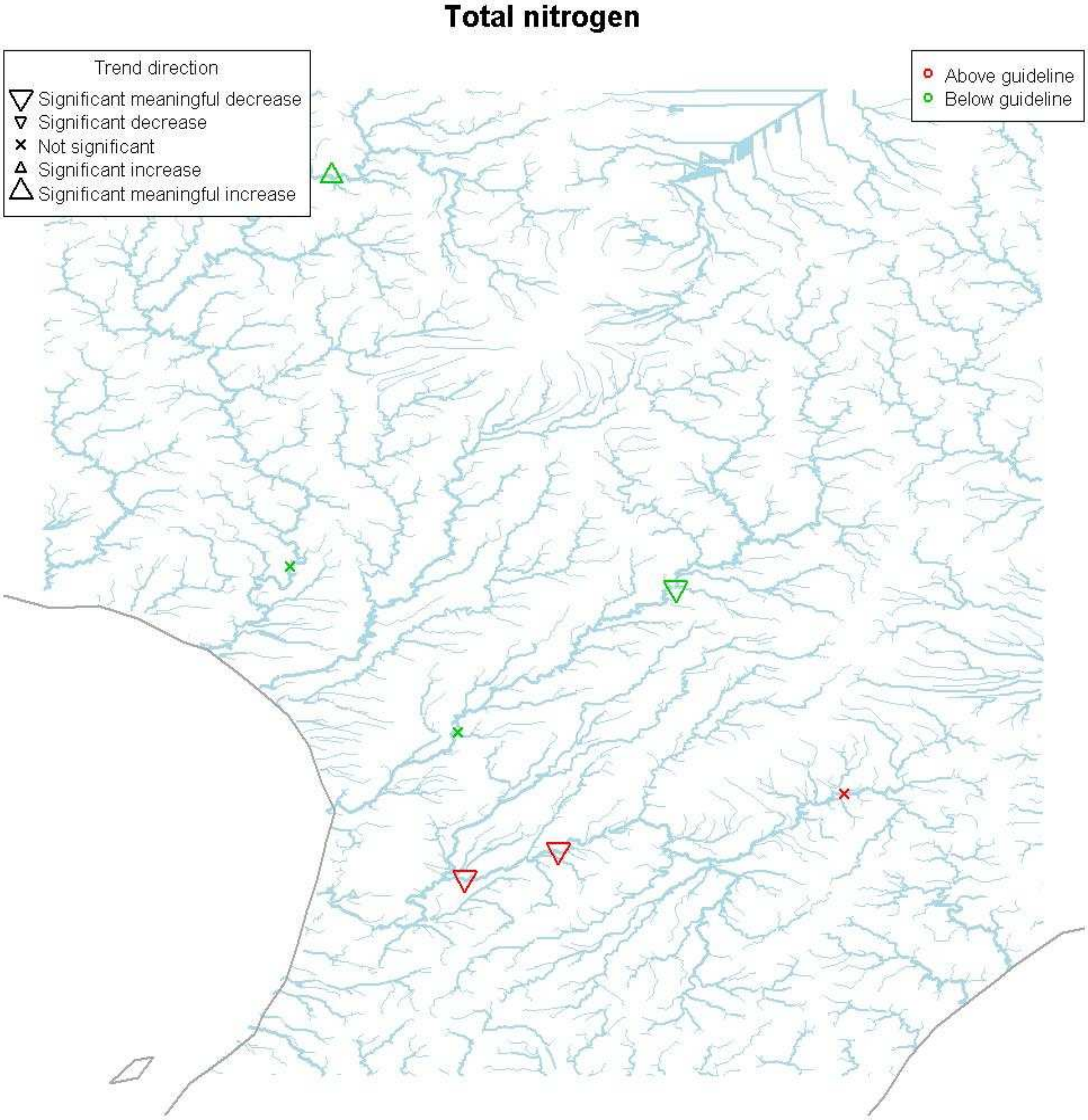

Figure 30: Location of the Horizons region SoE sites for which TN data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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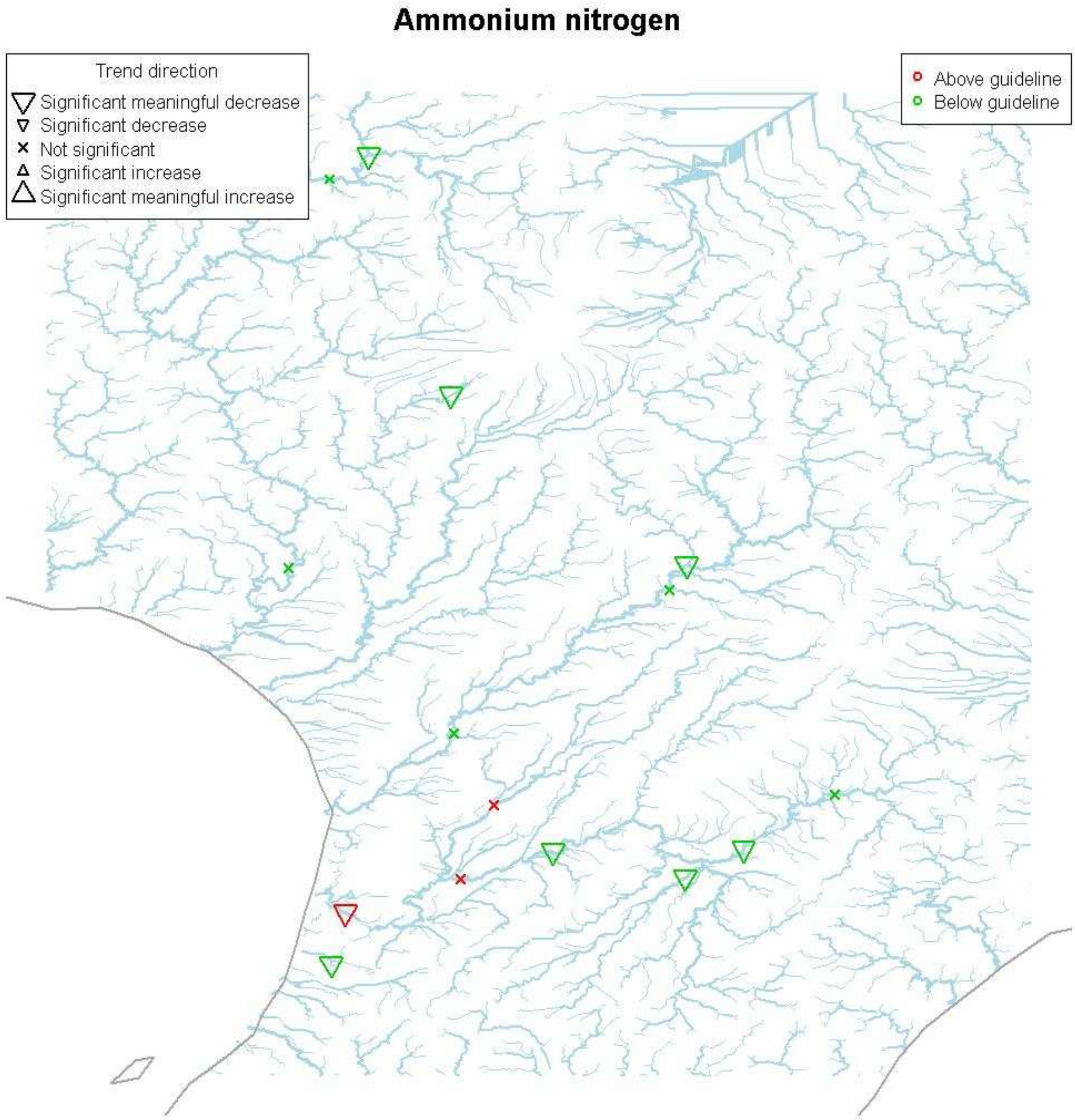

Figure 31: Location of the Horizons region SoE sites for which NH4-N data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

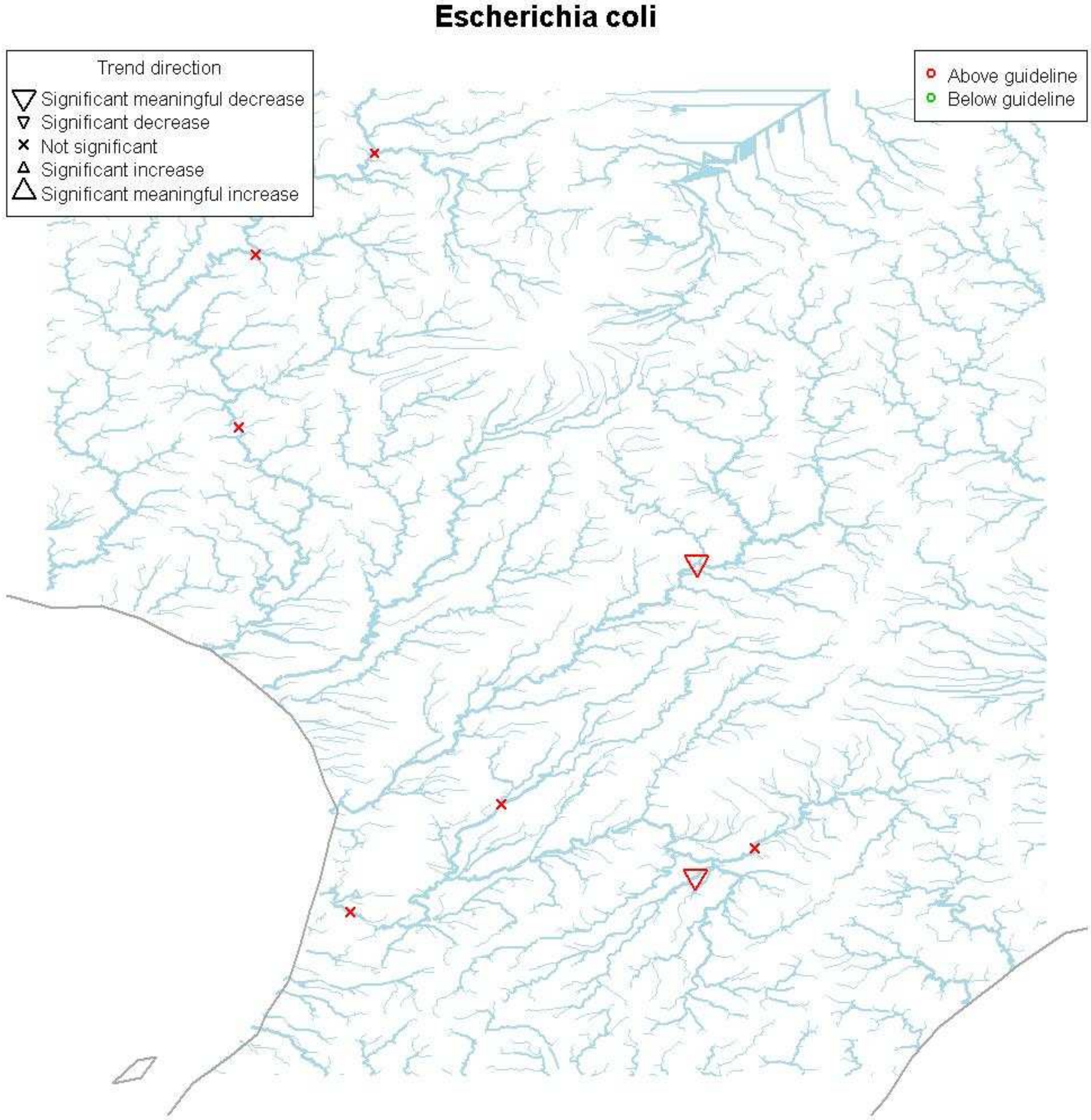

Figure 32: Location of the Horizons region SoE sites for which *E.coli* data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

4.3.1 Water Quality State

The low number of sites that met our criteria for analysis meant that we detected few significant patterns in water quality in the Horizons region (Table 22). The highest water quality (e.g., highest Clarity, lowest conductivity, lowest nutrients and lowest indicator bacteria) occurred in the Hill *Topography* category and poorer water quality occurred in Low Elevation *Topography* categories (Figure 33). Water clarity in the region was remarkable in that nearly all sites were below the guideline value (i.e., the water clarity is regionally poor and often unsuitable for contact recreation). This may be partly attributable to the soils of the region that are vulnerable to erosion. Patterns in water quality were also strongly related to REC *Land-cover* categories (Figure 34). The Pasture *Land-cover* category had poor water quality with the majority of sites in this category exceeding water quality guidelines for all variables considered. Very few of the analysed sites belonged to other REC *Land-cover* categories (Figure 33), so no significant patterns in water quality state associated with *Land-cover* categories could be detected (Table 22).

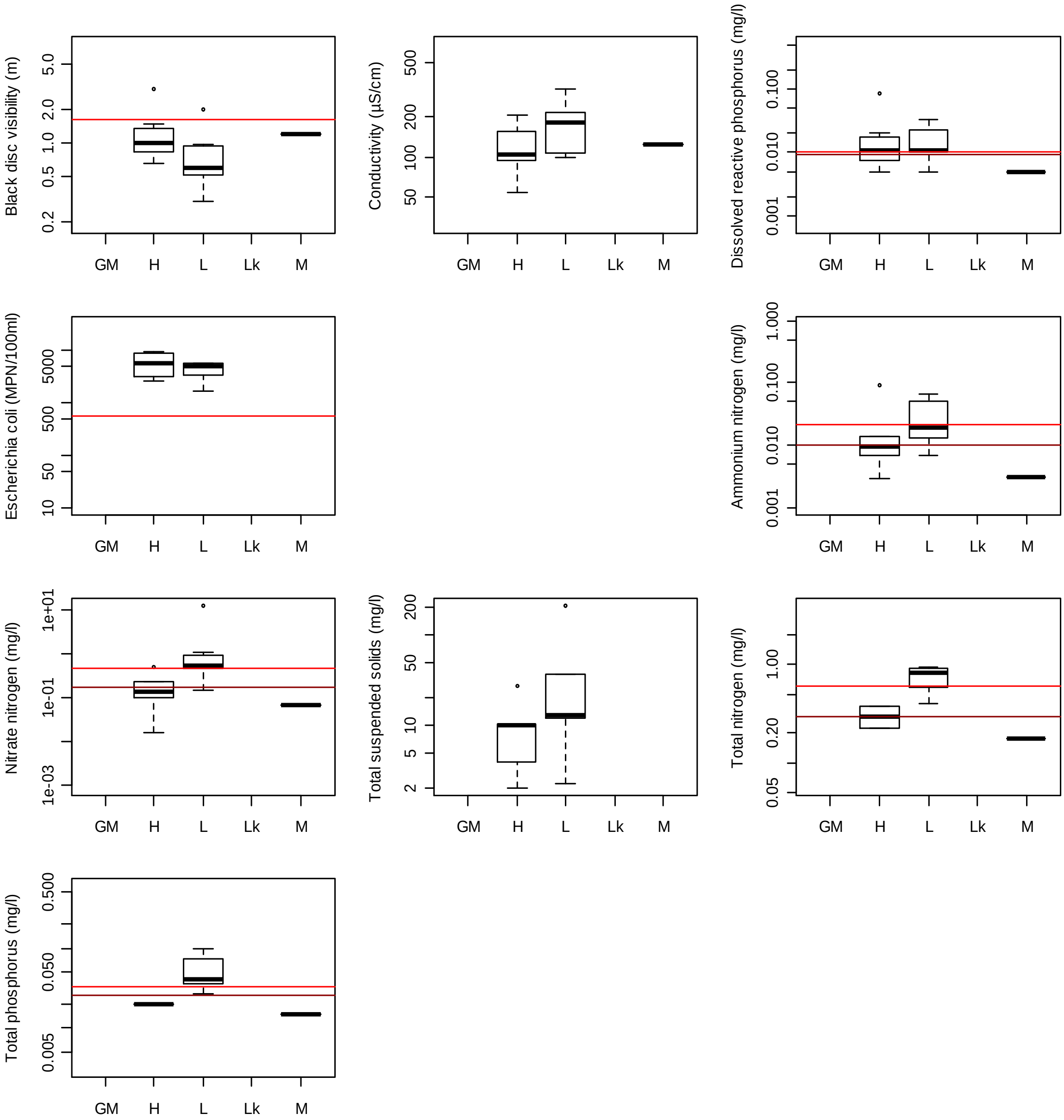

Figure 33: Median values for Horizons Regional Council sites of the nine water quality variables grouped by REC *Topography* categories. See Table 3 for an explanation of the REC categories. The guideline values the water quality variables shown in Table 2 are shown as horizontal lines. Where there are two horizontal lines these refer to the upland and lowland site guidelines. Note that low values of Clarity indicate poor water quality, whereas for other variables high values indicate poor water quality.

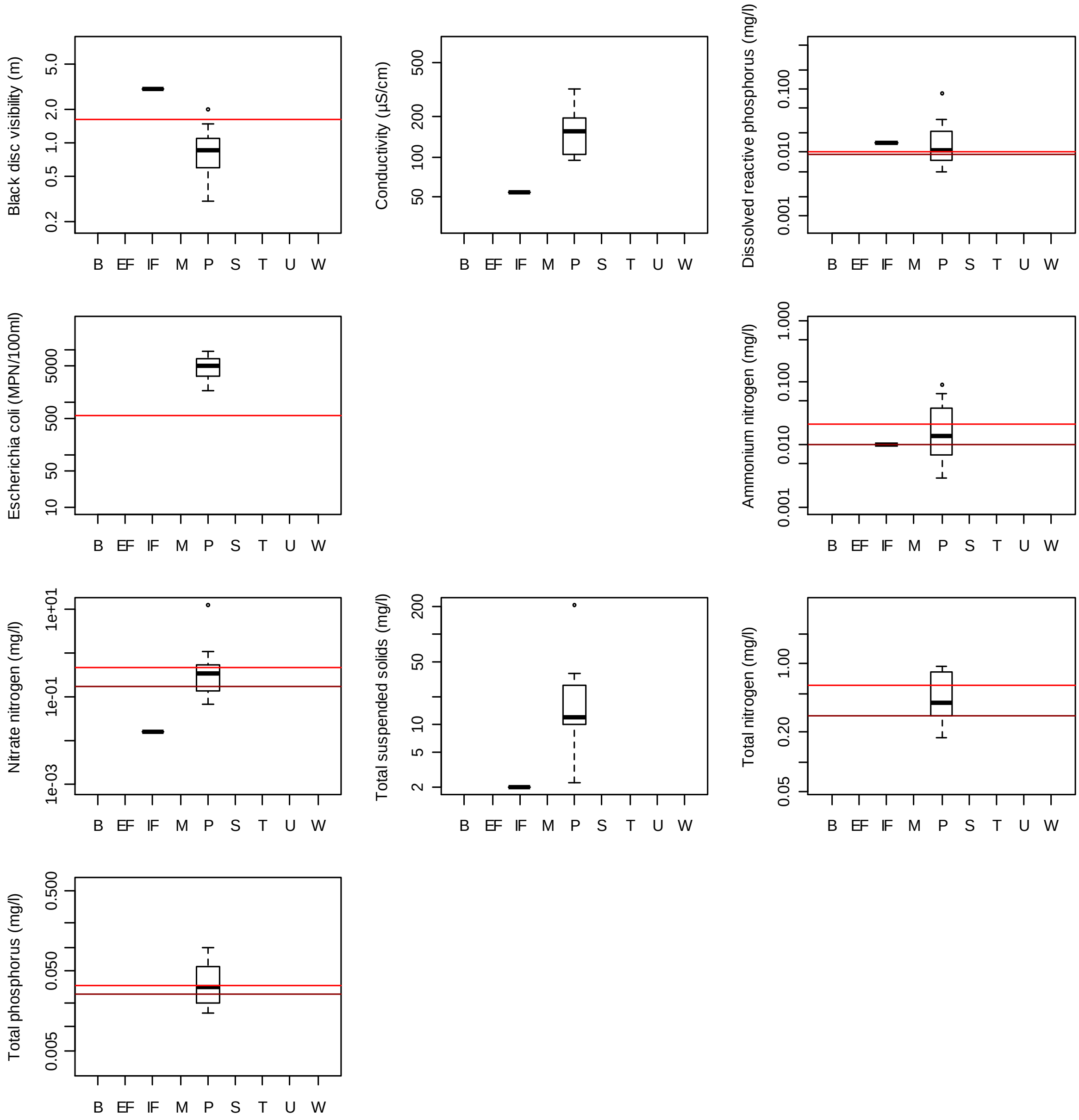

Figure 34: Median values for Horizons Regional Council sites of nine water quality variables grouped by REC *Land-cover* categories. See Table 3 for an explanation of the REC categories. The guideline values the water quality variables shown in Table 2 are shown as horizontal lines. Where there are two horizontal lines these refer to the upland and lowland site guidelines. Note that low values of Clarity indicate poor water quality, whereas for other variables high values indicate poor water quality.

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Table 22: Kruskall Wallis tests performed by variable for Horizons river SoE sites grouped by REC *Topography* and *Land-cover* categories. See Table 3 for an explanation of the REC categories. Statistically significant tests are shown with blue text.

Variable	Source of Flow			Land-cover		
	Statistic	*p*-value	*n*	Statistic	*p*-value	*n*
CLAR	4.05	0.132	16	2.65	0.104	16
COND	3.43	0.180	17	2.67	0.102	17
SS	1.84	0.175	10	2.45	0.117	10
NH_4-N	3.88	0.144	15	0.21	0.643	15
NO_x-N	*8.30*	*0.016*	*17*	2.67	0.102	17
TN	4.82	0.090	7	NA	NA	7
DRP	2.93	0.231	17	0.17	0.683	17
TP	5.25	0.072	8	NA	NA	8
E.coli	0.33	0.564	8	NA	NA	8

4.3.2 Water Quality Trends

Trends in water quality for the Horizons Regional Council region are presented in Table 23 and Table 24. There was generally a mixture of both increasing and decreasing trends for all variables, however the majority of significant trends were meaningful decreases (Table 17). The small number of sites that met our criteria for analysis meant that there were few overall trends that were significant and limited the extent to which we can comment on these. There were decreasing overall regional trends (i.e. based on all sites in the region) for NH_4-N and TP (Table 24). There was only one overall trend when sites were grouped by REC categories. This was for NH_4-N in the Pasture *Land-cover* category.

Table 23:: Number of sites with significant and meaningful trends for all sites in the Horizons Regional Council region by water quality variable.

Variable	Total number of sites	Meaningful decreases	Significant decreases	Not significant	Significant increases	Meaningful increases
CLAR	**16**	**1**	**0**	**14**	**0**	**1**
COND	**17**	**4**	**0**	**10**	**2**	**1**
DRP	**17**	**9**	**0**	**7**	**0**	**1**
ECOLI	**8**	**0**	**0**	**8**	**0**	**0**
NH_4-N	**15**	**8**	**0**	**7**	**0**	**0**
NO_x-N	**17**	**5**	**0**	**12**	**0**	**0**
SS	**10**	**1**	**0**	**7**	**0**	**2**
TN	**7**	**3**	**0**	**3**	**0**	**1**
TP	**8**	**4**	**0**	**4**	**0**	**0**

Table 24. Overall trends for the Horizons Regional Council region by water quality variable determined by grouping trends for all sites and using a binomial test (Significance level = 0.05).

Variable	Total number of sites	p	Overall trend direction
NH_4-N	15	0.007	Decreasing
TP	8	0.008	Decreasing

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4.4 Environment Waikato

A maximum of 115 SoE sites in the Waikato region met our criteria for trend analysis by water quality (Table 25). The location of these sites, the variables they include and their water quality state and trend are summarised on Figure 35 to Figure 44. The maps highlight that sites in the headwaters of the Waipa River, the lake Taupo catchments and the Coromandel Peninsular have good water quality (mostly within guidelines for a range of variables). Sites located in the lower elevation plains of the central and coastal Waikato including the valleys of the Waikato, Waipa, Waihou and Piako rivers had poorer water quality (Figure 35 to Figure 44). The spatial patterns of trends are less clear with increasing and decreasing trends occurring throughout the region. A strong downward trend in visual water clarity is evident at a majority of sites and strong upwards trends in nitrate and TN. The state of individual sites showed strong variation across variables (Appended Table 34). Sites can meet guidelines for some variables and not for others. Trend direction and strength at individual sites also showed strong variation across variables. This variability in state and trends within sites according to the variables that are being considered makes it difficult to single out particular sites or catchments as problematic. The sites have been ordered in Appended Table 34 according to a ranking from worst to best water quality. This is a subjective ranking that does not take into account potentially important factors such as the extent to which sites fail guidelines. It is also important to note that the network of sampling sites shown in Figure 35 to Figure 44 is sparse relative to the region's river network. We therefore consider that an overview of the region's water quality is more robustly made by considering the grouping and assessment of state and trends data in the following two sections.

Table 25. Number of sites in the Waikato region by variable and REC categories that meet criteria for trend analysis. See Table 3 for an explanation of the REC categories.

Variable	Landcover							Topography					Total
	EF	IF	P	S	T	U	W	GM	H	L	Lk	M	
CLAR	6	16	80	0	0	3	0	0	22	70	12	1	105
COND	6	17	88	1	0	3	0	0	29	71	14	1	115
DRP	6	17	88	1	0	3	0	0	29	71	14	1	115
ECOLI	6	13	59	0	0	3	0	0	20	52	9	0	81
FC	6	13	59	0	0	3	0	0	20	52	9	0	81
NH_4-N	6	17	88	1	0	3	0	0	29	71	14	1	115
NO_x-N	6	17	88	1	0	3	0	0	29	71	14	1	115
SS	0	0	0	0	0	0	0	0	0	0	0	0	0
TN	6	17	88	1	0	3	0	0	29	71	14	1	115
TP	6	17	88	1	0	3	0	0	29	71	14	1	115

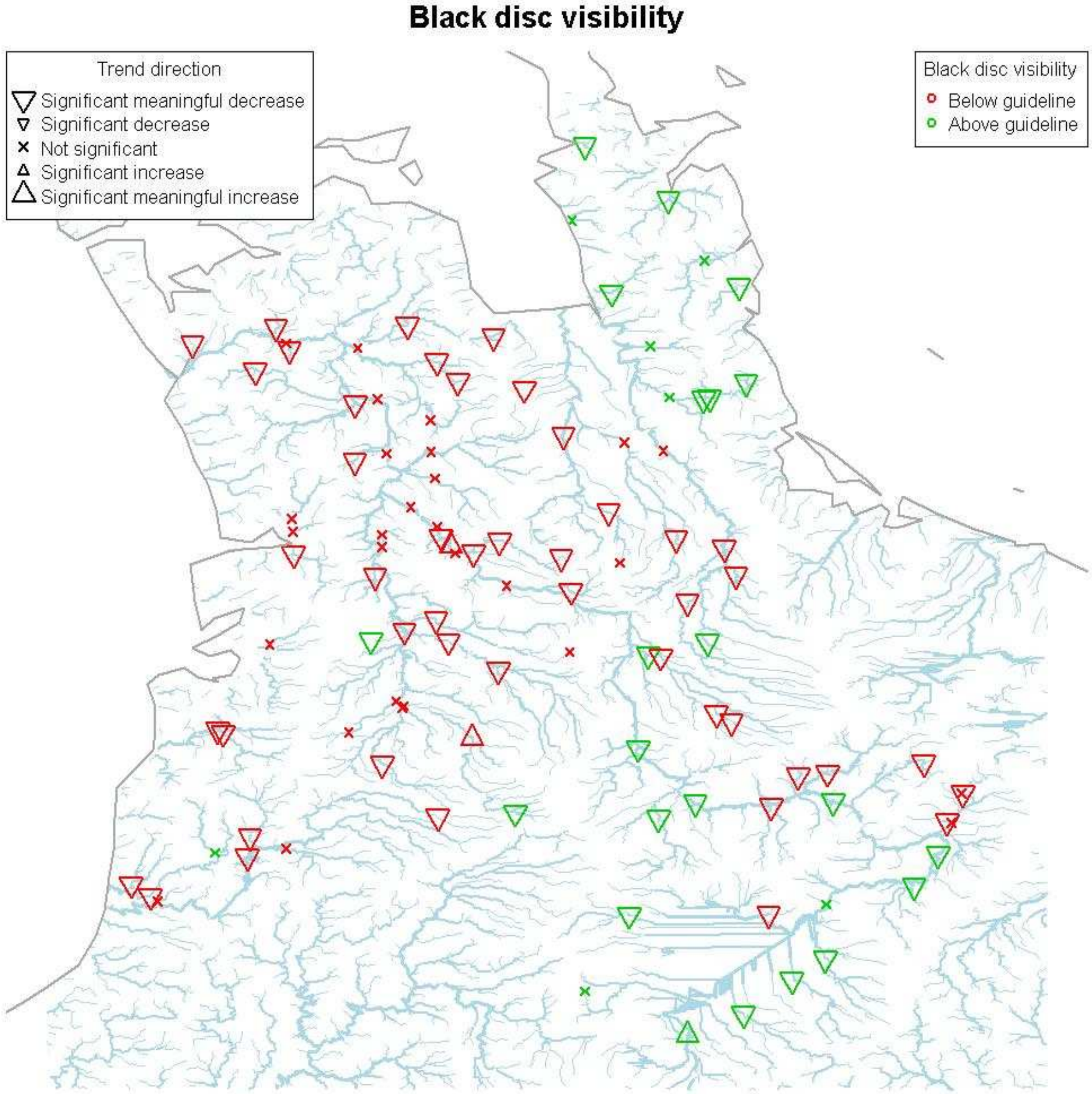

Figure 35. Location of the Waikato region SoE sites for which Clarity data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

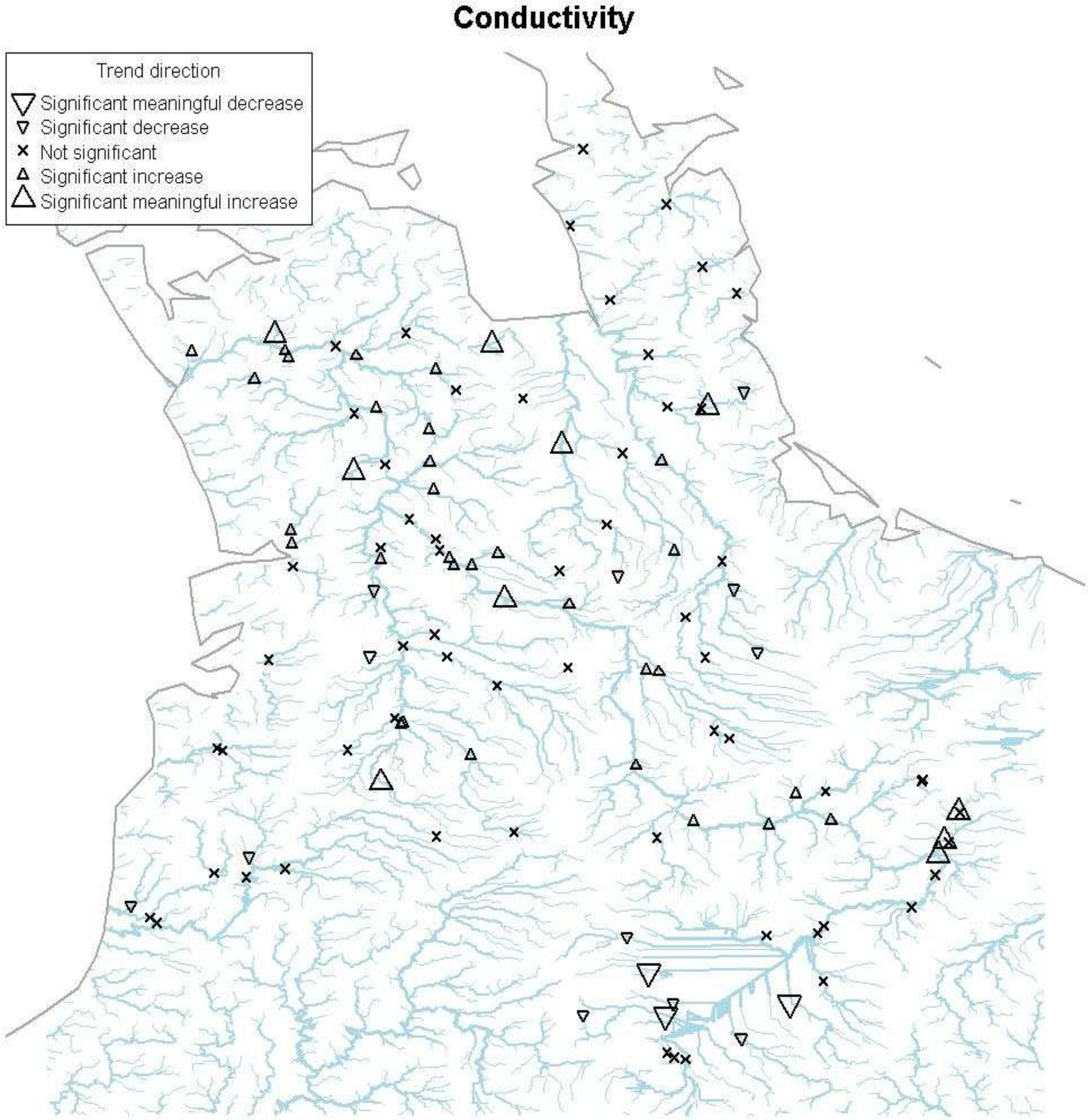

Figure 36: Location of the Waikato region SoE sites for which Conductivity data met our criteria for trend analysis showing the size of the trend. Note that conductivity is an indicator of ion concentration and contamination but that there is no guideline value.

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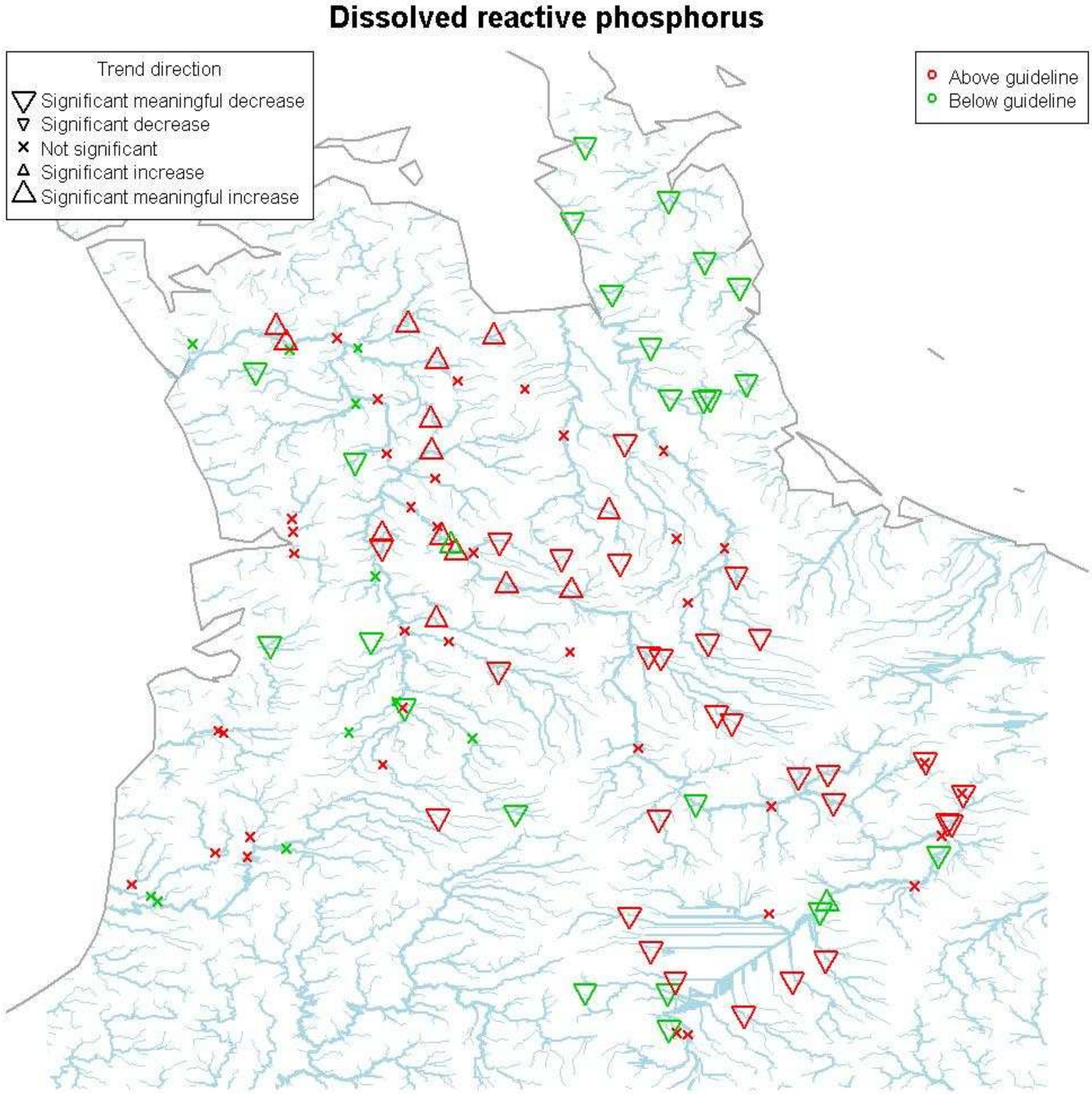

Figure 37: Location of the Waikato region SoE sites for which DRP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

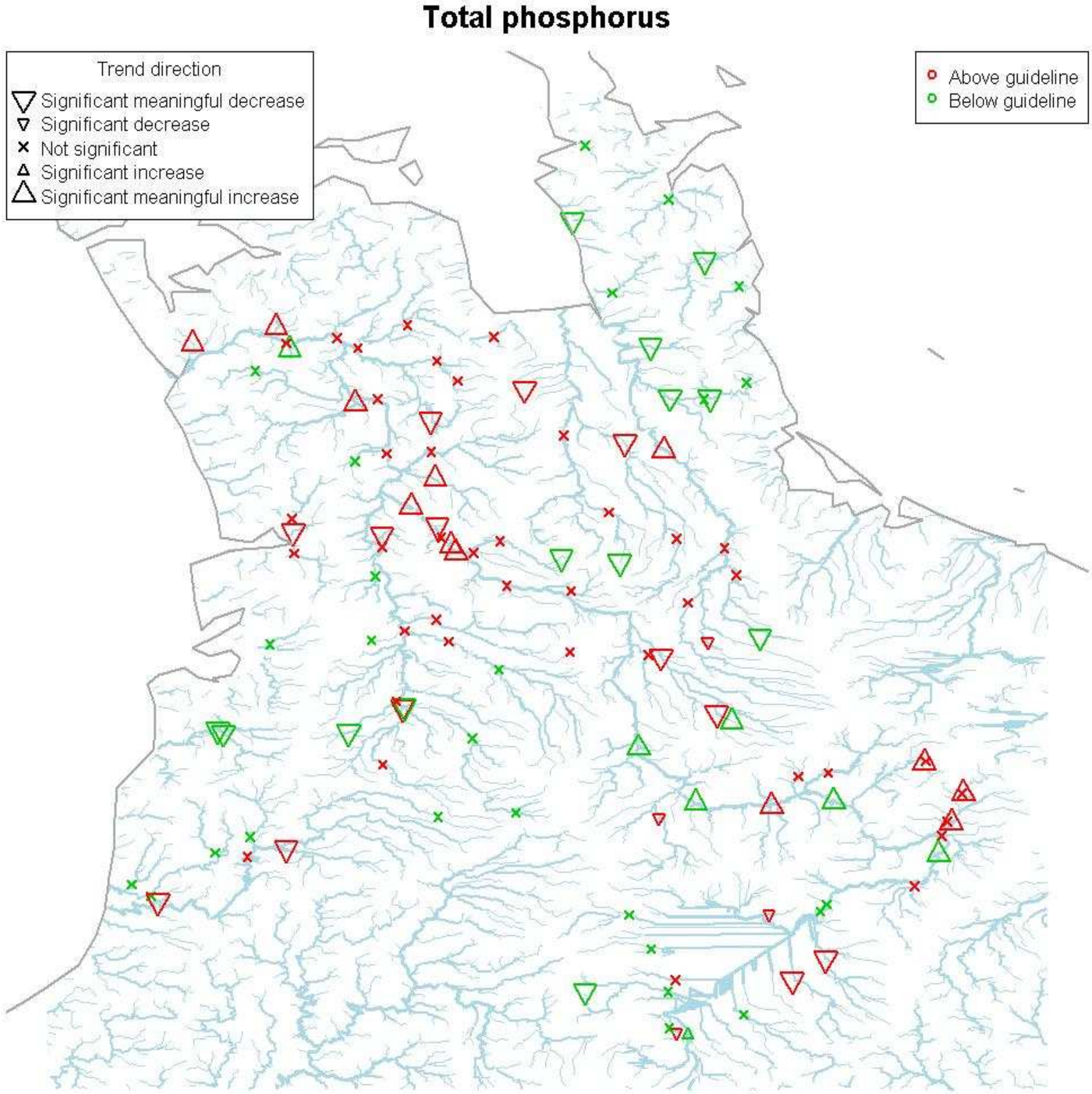

Figure 38: Location of the Waikato region SoE sites for which DRP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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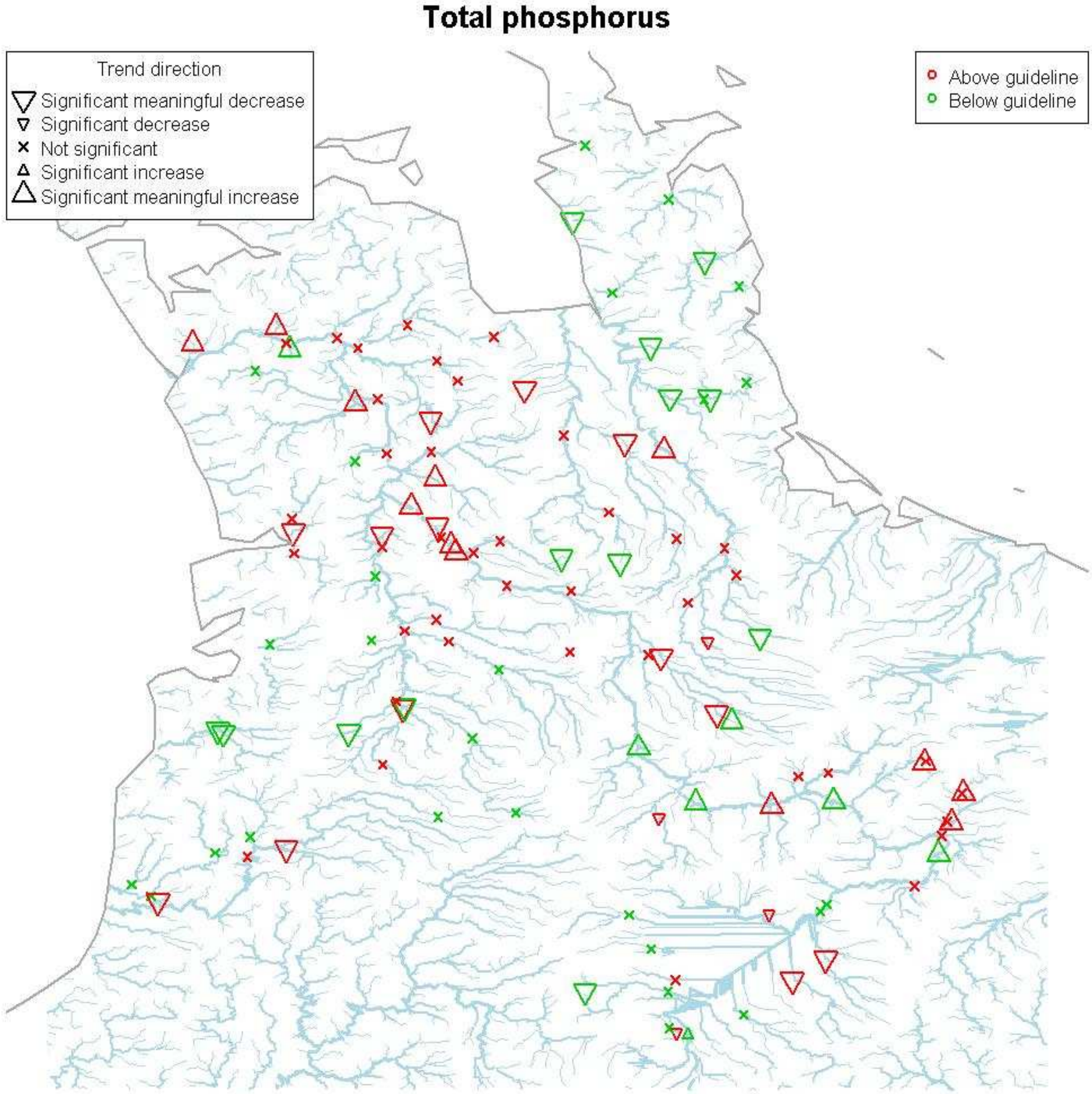

Figure 39: Location of the Waikato region SoE sites for which TP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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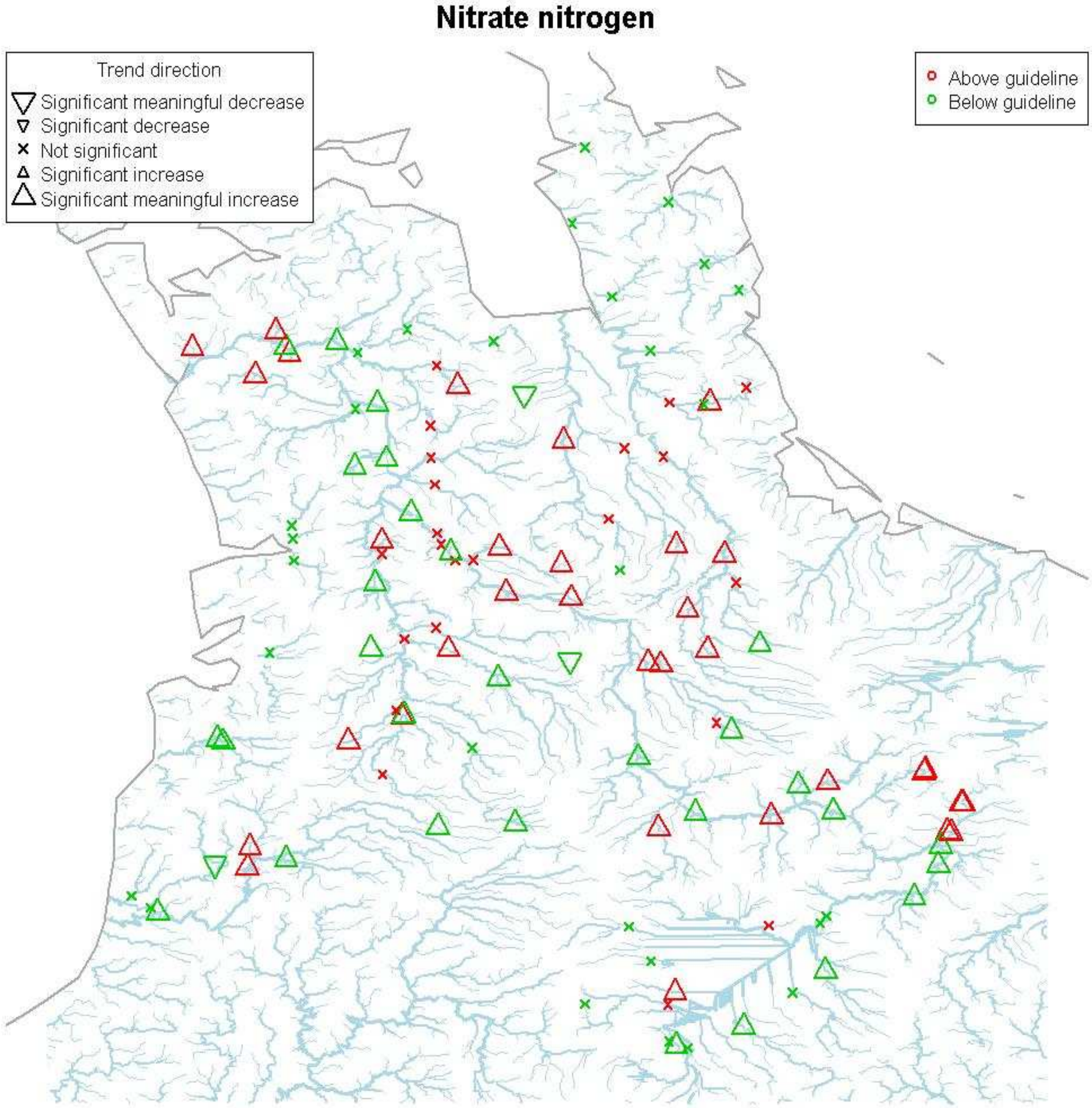

Figure 40: Location of the Waikato region SoE sites for which NOx-N data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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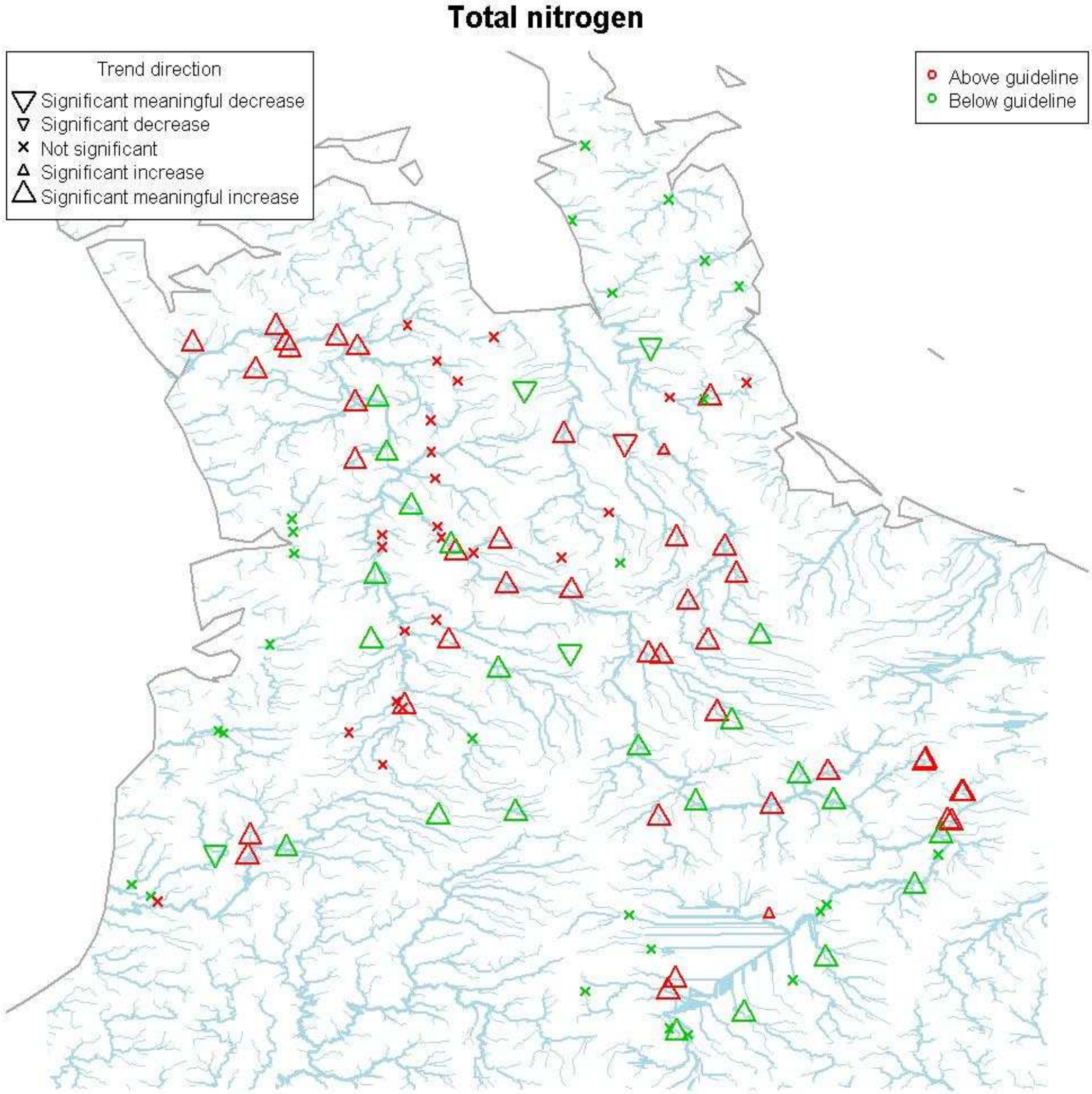

Figure 41: Location of the Waikato region SoE sites for which TN data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

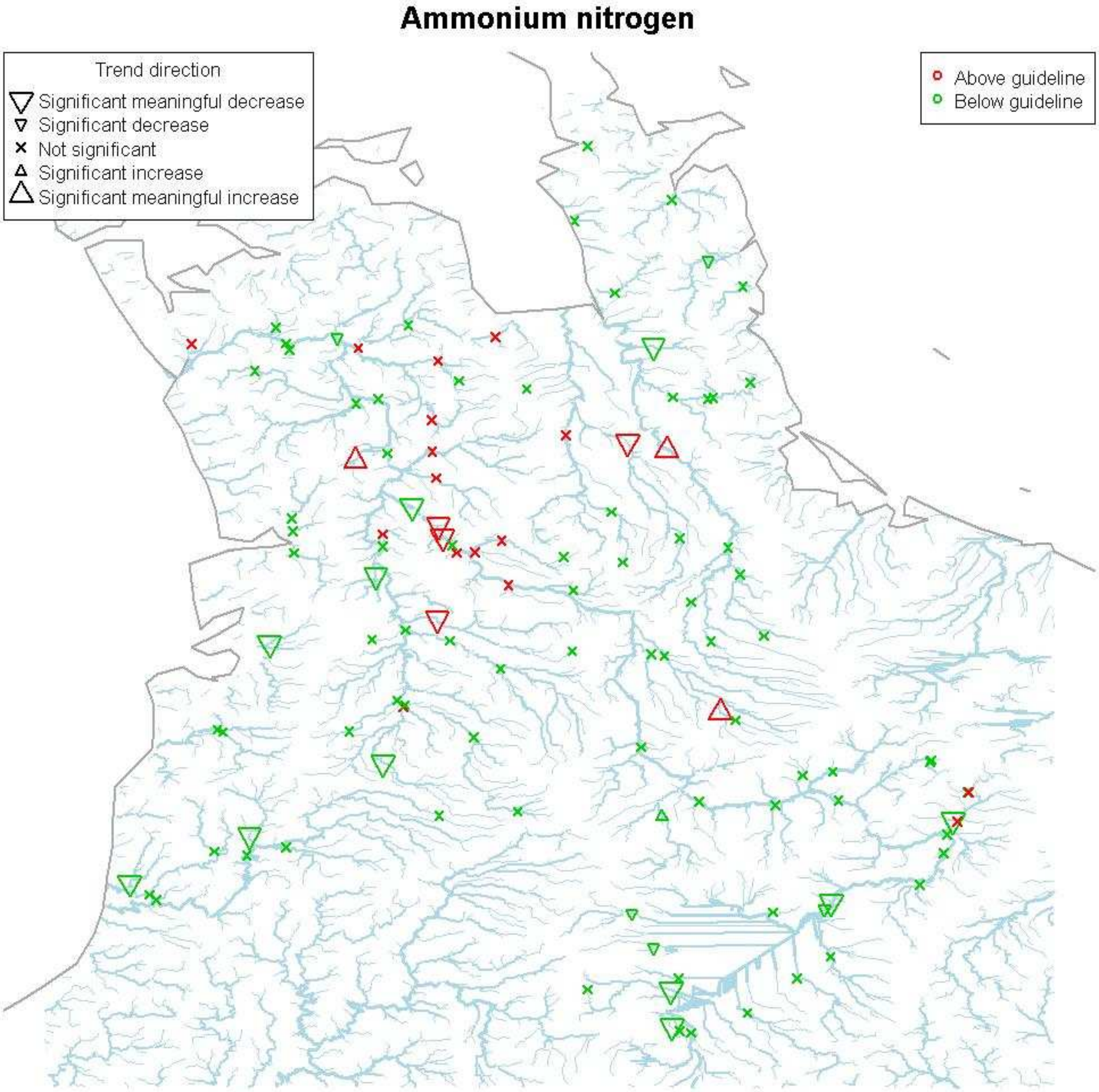

Figure 42: Location of the Waikato region SoE sites for which DRP data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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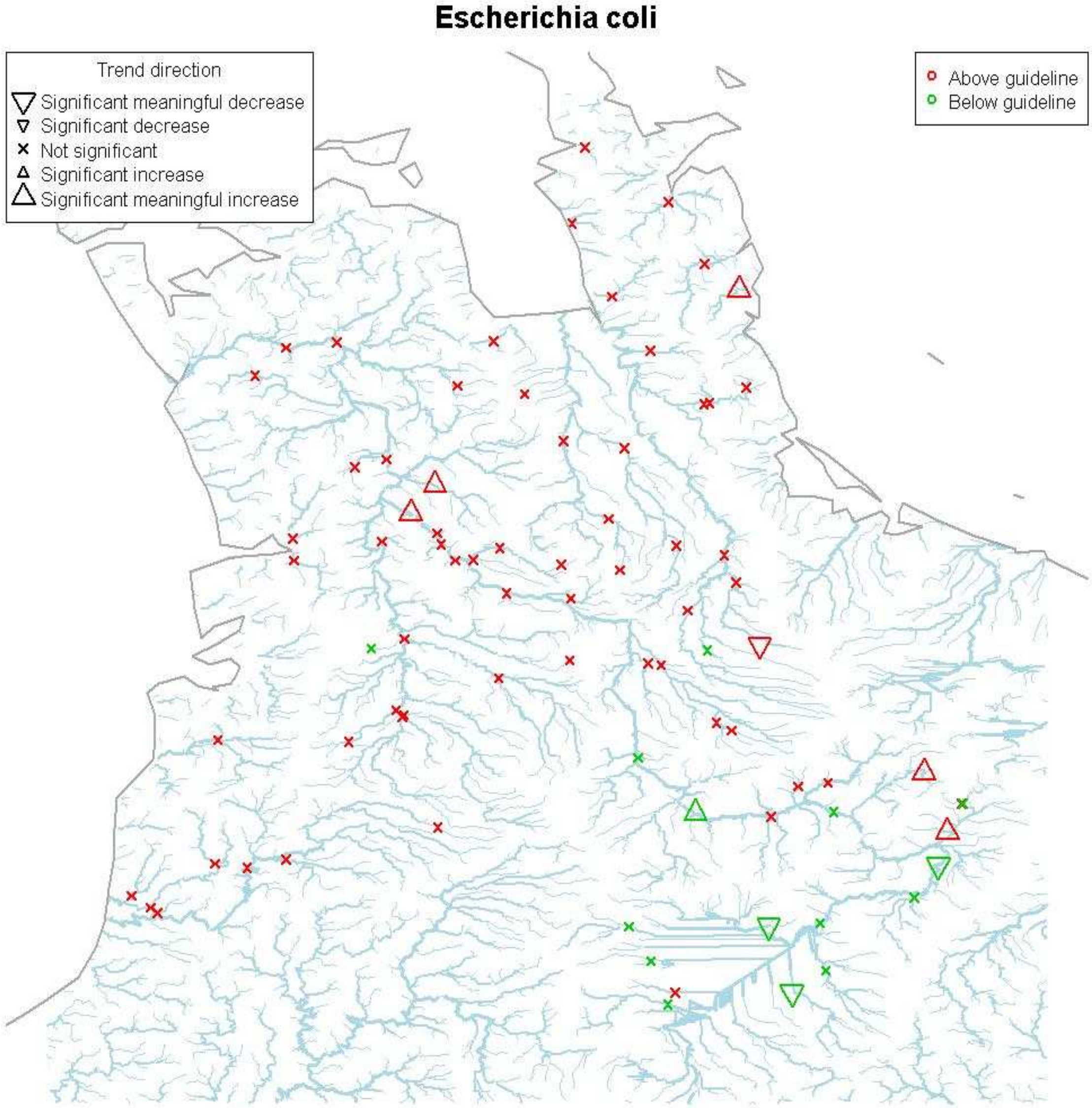

Figure 43: Location of the Waikato region SoE sites for which *E.coli* data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

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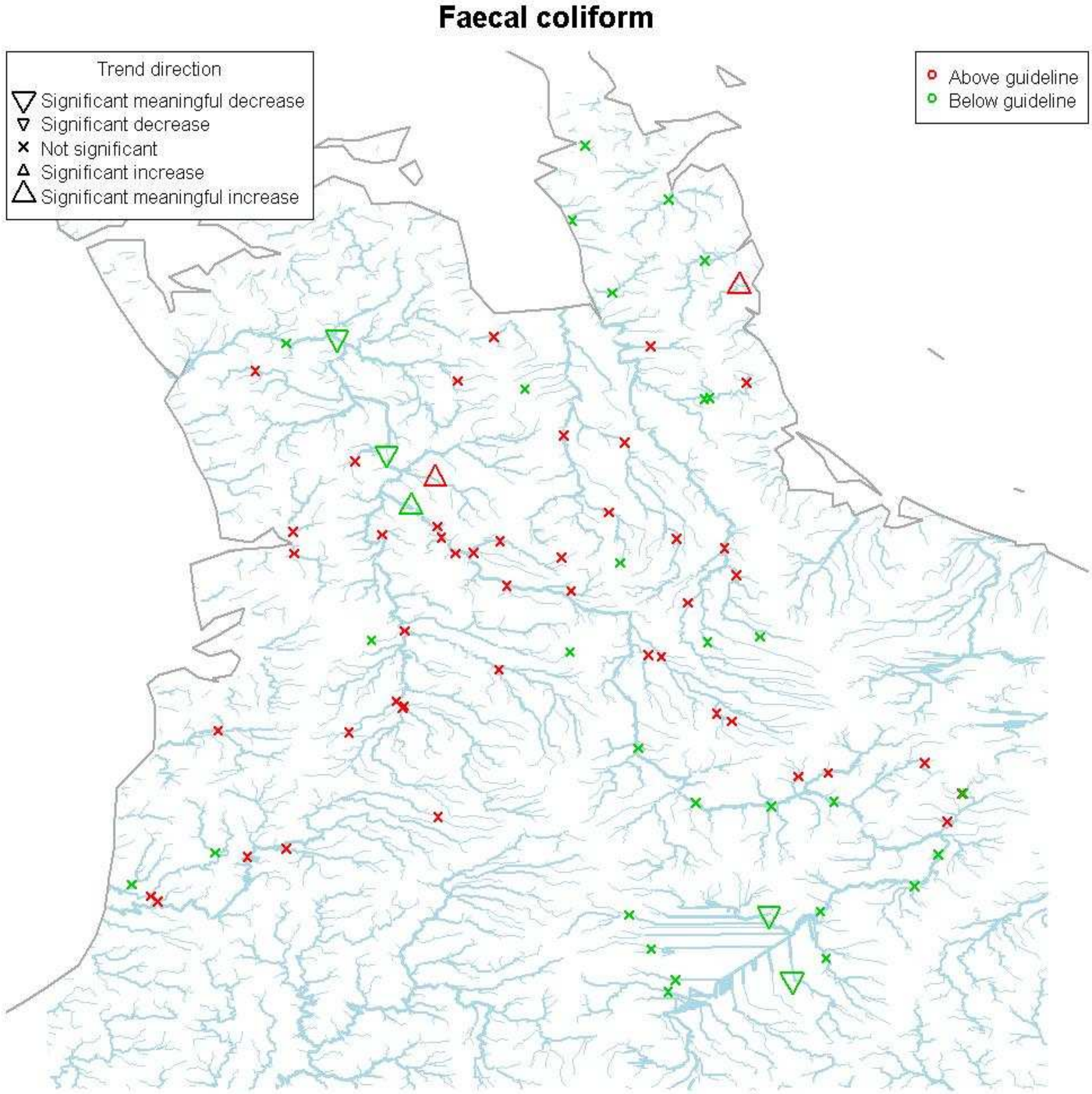

Figure 44: Location of the Waikato region SoE sites for which Faecal Coliform (FC) data met our criteria for trend analysis showing the size of the trend and whether the site median values are above or below the guideline values shown in Table 2.

4.4.1 Water Quality State

Water quality patterns in the Waikato region had strong relationships with REC *Topography* categories with the highest water quality (e.g., highest Clarity, lowest conductivity, lowest nutrients and lowest indicator bacteria) generally occurring in the Lake and Hill *Topography* categories and poorer water quality in Low-elevation *Topography* categories (Figure 45 and Table 26). The majority of sites in the Lake, Hill and Low-elevation *Topography* categories were below the water clarity guideline value (i.e. had poor water clarity). The majority of sites in the Lake, Hill and Low-elevation *Topography* categories were above the guidelines for the other water quality variables. This is mainly attributable to the dominance of Pastoral land use in the region Table 8. Patterns in water quality were strongly related to REC *Land-cover* categories Figure 46 and Table 26). Urban sites had very poor water quality (Figure 46), followed by the Pasture *Land-cover* category. The majority of pasture sites exceeded water quality guidelines for all variables considered. Sites in the other REC *Land-cover* categories had generally better water quality **(**Figure 46)**.**

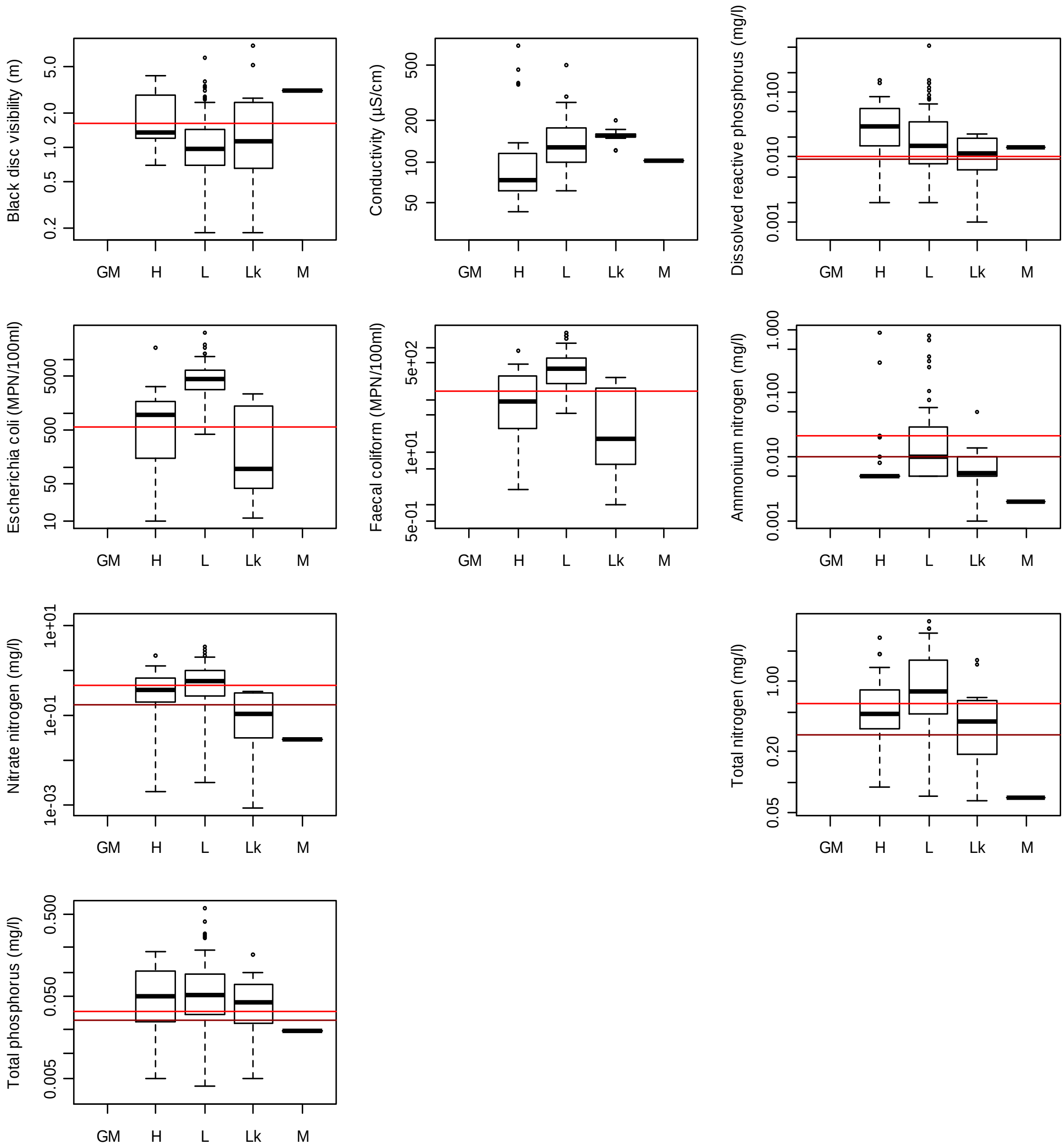

Figure 45: Median values for Environment Waikato SoE sites of the nine water quality variables grouped by REC *Topography* categories. See Table 3 for an explanation of the REC categories.The guideline values for the water quality variables shown in Table 2 are shown as horizontal lines. Where there are two horizontal lines these refer to the upland and lowland site guidelines. Note that low values of Clarity indicate poor water quality, whereas for other variables high values indicate poor water quality.

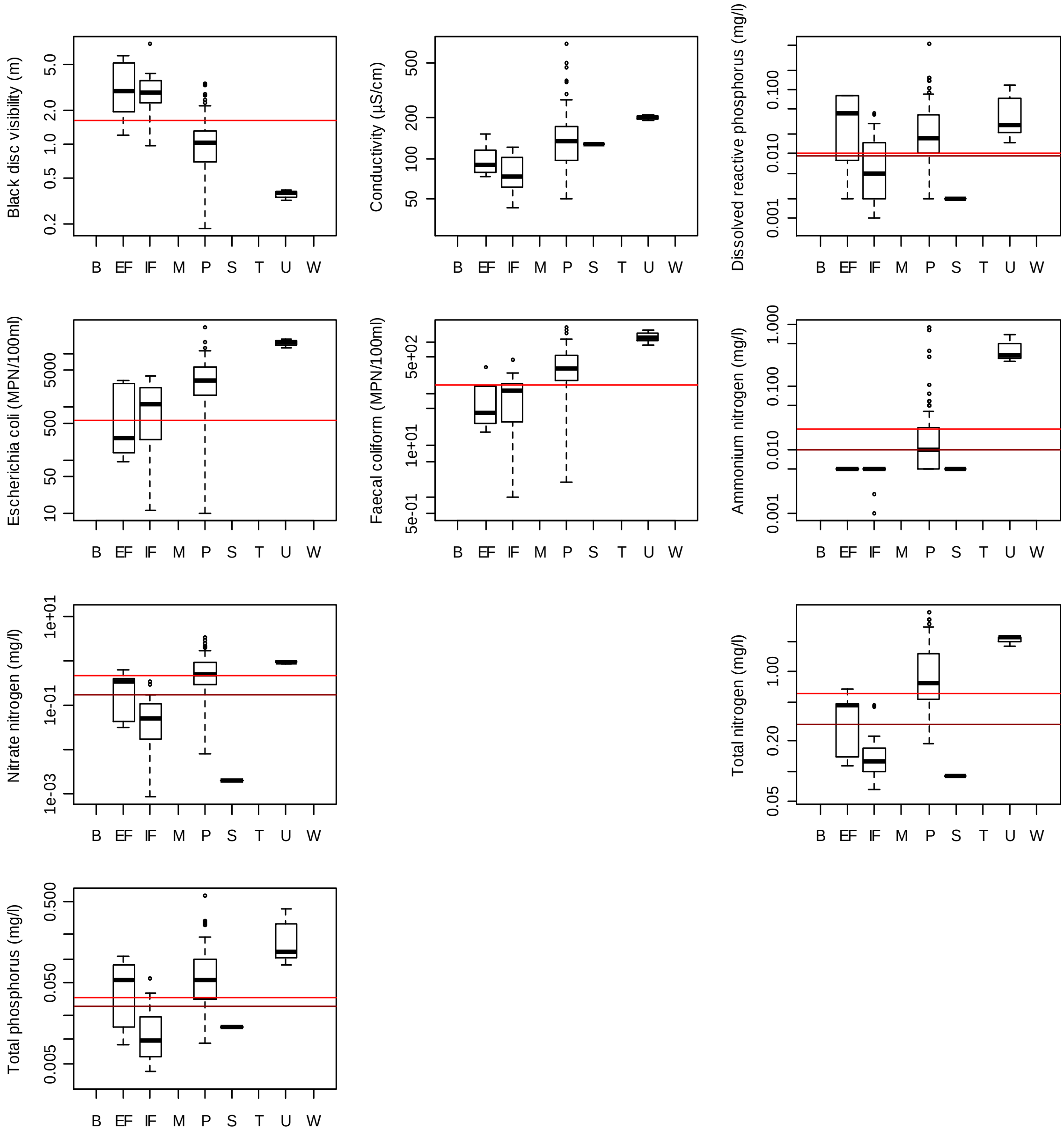

Figure 46: Median values for Environment Waikato SoE sites of nine water quality variables grouped by REC *Land-cover* categories. See Table 3 for an explanation of the REC categories. The guideline values for the water quality variables shown in Table 2 are shown as horizontal lines. Where there are two horizontal lines these refer to the upland and lowland site guidelines. Note that low values of Clarity indicate poor water quality, whereas for other variables high values indicate poor water quality.

Table 26. Kruskall Wallis tests performed by variable for Waikato river SoE sites grouped by REC *Topography* and *Land-cover* categories. Statistically significant tests are shown with blue text.

Variable	Source of Flow			Land-cover		
	Statistic	*p*-value	*n*	Statistic	*p*-value	*n*
CLAR	*13.16*	*0.004*	*105*	*40.95*	*0.000*	*105*
COND	*22.75*	*0.000*	*115*	*26.07*	*0.000*	*115*
NH_4-N	*18.69*	*0.000*	*115*	*35.35*	*0.000*	*115*
NO_x-N	*21.23*	*0.000*	*115*	*40.38*	*0.000*	*115*
TN	*14.99*	*0.002*	*115*	*49.21*	*0.000*	*115*
DRP	*8.15*	*0.043*	*115*	*15.03*	*0.005*	*115*
TP	2.06	0.560	115	*31.93*	*0.000*	*115*
E.coli	*31.68*	*0.000*	*81*	*21.02*	*0.000*	*81*
FC	*27.80*	*0.000*	*81*	*22.27*	*0.000*	*81*

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4.4.2 Water Quality Trends

Trends in water quality for the Waikato region are presented in Table 27 and Table 28. There was generally a mixture of both increasing and decreasing trends for all variables. There were overall regional trends (i.e. based on all sites in the region) for all variables except FC (Table 28). There were increasing overall regional trends for conductivity, *E.coli*, NO_x-N and TN indicating water quality degradation for these variables. There was a consistent decreasing overall regional trend for clarity, again indicating water quality degradation. There were decreasing overall regional trends for DRP, NH4-N and TP (Table 28), which indicate water quality improvement.

Table 27: Number of sites with significant and meaningful trends for all sites in the Waikato region by water quality variable.

Variable	Total number of sites	Meaningful decreases	Significant decreases	Not significant	Significant increases	Meaningful increases
CLAR	**105**	**67**	**0**	**35**	**0**	**3**
COND	**115**	**3**	**12**	**60**	**30**	**10**
DRP	**115**	**51**	**0**	**48**	**0**	**16**
ECOLI	**81**	**2**	**0**	**77**	**0**	**2**
FC	**81**	**4**	**0**	**74**	**0**	**3**
NH_4-N	**115**	**15**	**5**	**91**	**1**	**3**
NO_x-N	**115**	**3**	**0**	**50**	**0**	**62**
TN	**115**	**5**	**0**	**49**	**2**	**59**
TP	**115**	**26**	**4**	**66**	**1**	**18**

Table 28: Overall trends for the Waikato region by water quality variable determined by grouping trends for all sites and using a binomial test (Significance level = 0.05).

Variable	Total number of sites	p	Overall trend direction
CLAR	105	0	Decreasing
COND	115	0.005	Increasing
DRP	115	0	Decreasing
ECOLI	81	0.045	Increasing
NH_4-N	115	0	Decreasing
NOx-N	115	0	Increasing
TN	115	0	Increasing
TP	115	0	Decreasing

There were many overall trends in the REC *Topography* category groupings (Table 29). In general these trends indicate decreasing water quality in Hill and Low-elevation categories. For example, there were decreasing trends in Clarity and increasing trends in NO_x-N, TN, COND, *E.coli* and FC. However, there were also decreasing trends (i.e. improving water quality trends) in TP and DRP (Binomial test; Table 29).

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Table 29: REC *Topography* categories for which there were significant overall trends in the Waikato Region by water quality variable. See Table 3 for an explanation of the REC categories.

Variable	REC *Topography* category	Total number of Sites	*p*-value (binomial test of overall trend)	Overall trend
CLAR	Hill	22	0	Decreasing
DRP	Hill	29	0	Decreasing
NO_x-N	Hill	29	0.001	Increasing
TN	Hill	29	0	Increasing
TP	Hill	29	0.024	Decreasing
CLAR	Low-elevation	70	0	Decreasing
COND	Low-elevation	71	0	Increasing
DRP	Low-elevation	71	0.009	Decreasing
ECOLI	Low-elevation	52	0.003	Increasing
FC	Low-elevation	52	0.036	Increasing
NH_4-N	Low-elevation	71	0	Decreasing
NO_x-N	Low-elevation	71	0	Increasing
TN	Low-elevation	71	0	Increasing
TP	Low-elevation	71	0	Decreasing
CLAR	Lake	12	0.039	Decreasing
COND	Lake	14	0.002	Increasing
NO_x-N	Lake	14	0.002	Increasing
TN	Lake	14	0.002	Increasing

There were many overall trends in the REC *Land-cover* category groupings (Table 30). In general these trends indicate decreasing water quality. For example, there were decreasing trends in Clarity (i.e. decreasing water quality) in Exotic Forest, Indigenous Forest and Pasture categories. There were also increasing trends in COND, ECOLI, NOx-N, and TN (i.e. decreasing water quality). However, there were also decreasing trends (i.e. improving water quality trends) in FC in the Exotic Forest category, COND, DRP, NH4-N and TP in the Indigenous Forest category and DRP, NH4-N and TP in the Pasture category (Binomial test; Table 30).

In general the overall trends (i.e. based on the groupings of sites) indicate degrading water quality. However, there was an improving overall regional trend in DRP and TP.

Table 30: REC *Land-cover* categories for which there were significant overall trends in the Waikato Region by water quality variable. See Table 3 for an explanation of the REC categories.

Variable	REC *Land-cover* category	Total number of Sites	*p*-value (binomial test of overall trend)	Overall trend
CLAR	EF	6	0.031	Decreasing
FC	EF	6	0.031	Decreasing
CLAR	IF	16	0.004	Decreasing
COND	IF	17	0.049	Decreasing
DRP	IF	17	0.013	Decreasing
NH_4-N	IF	17	0.049	Decreasing
TP	IF	17	0	Decreasing
CLAR	P	80	0	Decreasing
COND	P	88	0	Increasing
DRP	P	88	0.002	Decreasing
ECOLI	P	59	0.036	Increasing
NH_4-N	P	88	0.001	Decreasing
NO_x-N	P	88	0	Increasing
TN	P	88	0	Increasing
TP	P	88	0.042	Decreasing

5. Discussion and Conclusions

5.1 Do regional councils have effective methods to gather information about and monitor the quality of freshwater?

In our opinion, the four regional council monitoring networks provide a good basis for assessing the quality of freshwater. All four councils now have networks that have reasonable numbers of SoE sites for rivers, lakes and groundwater that are distributed over their regions in a fairly representative manner (i.e. where the number of sites in different catchments or types of water bodies is in proportion to the overall importance and quantity of water bodies of that type). We also found that all four councils were monitoring a common suite of water quality variables.

We made a specific test of the adequacy of the river SoE monitoring networks in the regions. Our test of adequacy was based on asking whether the networks had sufficient statistical power (numbers of sites relative to the variability of the site medians) to detect statistically significant large scale patterns, defined by River Environment Classification (REC) categories, in water quality state and trends. We used the river water quality data for the 10 year period ending 2009 that met our criteria for trend analysis to conduct this test (i.e. that had been collected at quarterly or monthly on at least 80% of sampling occasions). The river water quality monitoring data for Southland and Waikato comprised sufficient sites that met these criteria that we were able to detect detailed patterns in both state and trends (i.e. statistically significant differences in state and significant overall trends were found for many REC categories and variables). The data for Taranaki comprised only 12 sites but this was sufficient to detect patterns albeit for fewer REC categories and variables than for Southland and Waikato. The dataset for Horizons comprised 17 sites and was barely adequate to describe large scale patterns in water quality state and trends in the region. This is because, in the past, Horizons have employed a system of "rolling SoE sites" whereby some sites have been monitored on a rolling basis, i.e. once every three years 12 months of monthly sampling has been undertaken. This practice is no longer carried out by Horizons Regional Council and the number of SoE sites in the monitoring network has been increased.

We found that councils have given due consideration to QA/QC and data storage issues. Environment Southland and Horizons need to consider lowering detection for some variables, notably DRP and Ammoniacal-N, because high detection limits will mask trends in currently high quality water bodies. Councils could consider tightening up on hydrometric infrastructure under-pinning water quality monitoring, for example, by establishing quantified relationships between flow at sampling sites and flow gauging stations. An indication of the uncertainties associated with flow estimates will be valuable for future load calculations, even if not strictly needed for flow-adjustment in trend analysis. We also consider that storage of water quality data in a database is highly desirable because this allows easy interrogation of the data and datasets to be restructured efficiently.

There were large differences between regions in the numbers of SoE sites that met our criteria for inclusion in the trend and state analysis. In all four cases council staff indicated that they are currently monitoring a larger number of sites than we assessed in this report, and the approximate sizes of their existing networks has been reported. The difference between analysed sites and the size of existing networks reflects an ongoing effort by regional councils to increase monitoring coverage. The relatively small number of SoE sites from TRC and Horizons that were included in our analysis reflects disruptions and changes to monitoring programs over the previous ten years. We have provided supplementary material that shows whether there was data provided by the councils for each site, in each month over the ten year period by water quality variable. These graphs indicate when sites were opened, analysed variables were changed and whether there were disruptions to the program. The important point is that if monitoring is to be of maximum benefit it must be consistent and this requires an ongoing commitment by the regional councils.

There were inconsistencies between regions in terms of certain detailed aspects of SoE monitoring. These inconsistencies include sampling protocols (such as frequency), laboratory analysis methods, QA/QC procedures and storage of water quality data. Inconsistencies between regions is not an issue for individual regions, however it is a national issue in that it leads to difficulties in collating data and also prevents robust comparison or amalgamation of data or statistics (e.g., trends). The Ministry for Environment (Tanya Gray pers. comm.) is currently leading efforts (supported by the Regional Council SWIM group Graham Sevicke-Jones, Hawkes Bay Regional Council pers. comm.) to improve monitoring consistency across all of the regions and territorial local authorities.

5.2 What is the state and trends in water quality as indicated by state of the environment monitoring data?

5.2.1 Water quality state

The assessment of water quality state shows that water quality was highly variable throughout the individual regions. Median nutrient concentrations at sites frequently exceeded the ANZECC (2000) trigger values and median clarity at sites was frequently lower than guidelines. Faecal bacterial levels were also high, with *E. coli* numbers exceeding the MfE/MoH (2003) action value at many sites (based on the 95th percentiles).

Land-use impacts on water quality state were clear, with poor water quality (high nutrients and faecal pollution, and low visual clarity) being associated with pastoral land cover and even poorer water quality in urban streams. These patterns with land cover are consistent with reports by other authors in previous studies, (e.g., Ballantine and Davies-Colley, 2009; Hamill and McBride, 2003; Larned *et al.*, 2003; Larned *et al.*, 2004; Snelder and Scarsbrook, 2002).

5.2.2 Water quality trends

The trend analyses indicate that trend strength and direction is highly variable across sites in the four study regions. We used the binomial test to indicate whether there were "overall trends" in sites grouped in several ways. We found overall degrading trends in clarity in Taranaki and Waikato, degrading trends in conductivity in Waikato, improving trends in DRP in Southland, Taranaki and Waikato, a degrading trend in *E.coli* in Waikato, improving trends in NH_4-N in Horizons and Waikato and a degrading trend in NH_4-N in Taranki, degrading trends in NO_x-N in Southland and Waikato, a degrading trend in TN in Southland and Waikato and improving trend in TP in Horizons and Waikato. When these trends were broken down by REC categories there was a predominance of degrading trends in Low-elevation and Hill *Topography* and Pasture *Land-cover* categories. These results suggest that water quality decreased over the ten year period in Low-elevation areas and in catchments dominated by pastoral land cover. There were however, generally improving trends in DRP and TP in all of the regions.. The improving trend in phosphorus shown in this study (consistent with a recent national study by Ballantine et al. 2010) may be attributable to two factors. First, there has been increase in phosphorus fertiliser costs over the last decade (an 86% rise in 2008 alone). Second, there has also recently been very active management of soil phosphorus (Olsen-P) levels by the pastoral industry. However, nitrogen has increased due to increased farm production. For example, there has been a 20% rise in dairy-farm production. This increase in production is associated with leaching of nitrogen from pasture soils for which there are not currently adequate mitigation methods

A point of caution need to be borne in mind in using the state and trends analysis in this report to draw conclusions concerning regional councils' management of freshwater. We compared the existing state to guideline values. To fully assess whether regional councils are meeting (their own) standards, the standards defined in statutory plans would need to be compared with the state information derived in this study. Second, trends provide information about change in water quality over time and also need to be considered within the broader statutory framework that regional councils have set. The analysis is outside the scope of this report.

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Appendix

Table 31. State and trends for individual sites in the Southland Region. For state, F indicates the median site value fails the most lenient guideline and P indicates a pass. For trends -2 indicates a meaningful degrading trend, -1 a significant degrading trend, 0 is either a stable or insignificant trend, 1 is a significant improving trend and 2 is a meaningful improving trend. The sites are ordered in the table from poorest quality (i.e. those with the largest numbers of variables failing guidelines and with degrading trends) to highest quality. NA indicates that data were not available for the variable.

		State								Trends									
Code	Site Name	CLAR	DRP	ECOLI	FC	NH4.N	NOx.N	TN	TP	CLAR	COND	DRP	ECOLI	FC	NH4.N	NOx.N	SS	TN	TP
ES-058	Otamita Stream at Mandeville	F	F	F	F	P	F	F	P	0	1	0	0	0	2	2	NA	2	0
ES-085	Mataura River at Gore	F	P	F	F	P	F	F	P	0	2	0	0	0	2	2	NA	2	0
ES-031	Winton Stream at Lochiel	F	F	F	F	F	F	F	F	0	0	0	0	0	2	0	NA	0	2
ES-053	Waikaka Stream at Gore	F	F	F	F	F	F	F	F	0	0	0	0	0	2	2	NA	0	0
ES-120	Otapiri Stream at Otapiri Gorge	F	F	F	F	P	P	F	F	2	0	0	0	0	0	2	NA	2	0
ES-153	Currens Creek Triburary at Waituna lagoon	F	F	F	P	F	P	F	F	0	0	2	0	0	0	0	NA	0	2
ES-067	Waimatuku Stream at Lornville Riverton H	F	F	F	F	P	F	F	F	0	0	0	0	0	0	0	NA	2	0
ES-117	Mimihau Stream at Wyndham	F	F	F	F	P	F	F	F	0	0	0	0	0	0	0	NA	2	0
ES-150	Waituna Creek at Mokotua	F	P	F	F	F	F	F	F	0	0	-2	0	0	0	2	NA	2	0
ES-022	Otautau Stream at Otautau-Tuatapere Road	F	F	F	F	F	F	F	F	0	0	0	0	0	0	0	NA	0	0
ES-032	Makarewa River at Wallacetown	F	F	F	F	F	F	F	F	0	0	0	0	0	0	0	NA	0	0
ES-045	Mataura River 200m d/s Mataura Bridge	F	F	F	F	F	F	F	F	0	0	-2	0	0	2	2	NA	0	-2
ES-135	Tussock Creek at Cooper Road	F	F	F	F	F	F	F	F	0	-2	2	0	0	0	0	NA	0	0
ES-137	Waimatuku Stream d/s Bayswater Bog	F	F	F	F	F	F	F	F	0	0	0	0	0	0	0	NA	0	0
ES-139	Opouriki Stream at Tweedie Road	F	F	F	F	F	F	F	F	0	0	0	0	0	0	0	NA	0	0
ES-143	Otautau Stream at Waikouro	F	F	F	F	F	F	F	F	0	0	0	0	0	0	0	NA	0	0
NAT-DN08	Oreti @ Riverton Hy Br	P	P	NA	NA	P	F	F	P	0	2	0	NA	NA	0	2	NA	2	0
ES-014	Aparima River at Thornbury	F	P	F	F	P	F	F	P	0	0	0	0	0	0	2	NA	0	0
ES-065	Waikawa River at Progress Valley	F	F	F	F	F	F	F	F	0	-1	0	0	0	0	0	NA	0	0
ES-094	Oreti River at Centre Bush	P	P	F	P	P	F	F	P	2	2	0	0	0	0	0	NA	0	0

ES-122	Makarewa River at Lora Gorge Road	F	F	F	F	P	F	F	F	0	0	0	0	0	0	0	NA	0	0
ES-130	Bog Burn d/s Hundred Line Road	F	F	F	NA	F	F	F	F	2	0	-2	0	NA	0	0	0	0	0
ES-152	Currens Creek at Waituna Lagoon Road	F	F	F	F	F	P	F	F	0	0	0	0	0	0	0	NA	0	0
ES-155	Winton Stream d/s Winton Dam	F	F	F	F	P	P	P	F	0	0	0	0	0	0	2	NA	0	0
ES-040	Waikiwi Stream at North Road	F	F	F	F	F	F	F	F	0	0	-2	0	0	0	0	NA	0	0
ES-041	Waihopai Stream u/s Queens Drive	F	F	F	F	F	F	F	F	0	0	-2	0	0	0	0	NA	0	0
ES-084	Oteramika Stream at Seaward Downs	F	F	F	F	F	F	F	F	0	0	-2	0	0	0	0	NA	0	0
NAT-DN07	Oreti @ Lumsden	P	P	NA	NA	P	F	F	P	-2	2	0	NA	NA	0	2	NA	2	0
ES-042	Otepuni Creek at Nith Street	F	F	F	F	F	F	F	F	0	-1	-2	0	0	0	0	NA	0	0
ES-148	Mokotua Stream at Awarua	F	P	P	P	F	P	F	P	0	0	0	-2	0	2	0	NA	0	2
ES-154	Moffat Creek at Moffat Road	F	NA	F	F	F	P	F	NA	0	0	NA	0	0	0	0	NA	0	NA
ES-007	Mararoa River at Weir Road	P	P	F	P	P	P	P	P	0	1	0	0	0	0	2	NA	0	0
ES-051	Waikaia River at Waipounamu Bridge Road	P	P	F	F	P	F	F	P	0	0	0	0	0	0	0	NA	0	0
ES-057	Mimihau Stream Tributary at Venlaw Forest	F	F	P	P	P	P	P	P	2	-2	-2	0	0	0	2	NA	2	0
NAT-DN05	Mataura @ Seaward Downs	F	F	NA	NA	F	F	F	F	-2	2	-2	NA	NA	-2	2	NA	2	-2
ES-029	Irthing Stream at Ellis Road	P	P	F	F	P	F	F	P	-2	0	0	0	0	0	0	NA	0	0
ES-043	Mataura River at Gorge Road	F	F	F	F	F	F	F	F	-2	0	-2	0	-2	-2	2	NA	2	-2
ES-052	Waikaia River u/s Piano Flat	P	P	P	P	P	P	P	P	0	0	0	0	0	2	0	NA	0	0
ES-063	Waituna Creek at Marshall Road	F	F	F	F	F	F	F	F	-2	0	-2	0	0	-2	2	NA	0	-2
ES-096	Waiau River at Sunnyside	P	P	P	P	P	P	P	P	0	0	0	0	0	0	2	NA	0	0
ES-011	Aparima River at Dunrobin	P	P	F	P	P	P	P	P	0	0	0	0	-2	0	2	NA	0	0
ES-023	Oreti River at Three Kings	P	P	P	P	P	P	P	P	0	1	-2	0	0	0	2	NA	0	0
ES-038	Dunsdale Stream at Dunsdale Reserve	F	F	F	P	P	P	P	P	0	0	0	0	0	0	0	NA	-2	0
ES-046	Mataura River at Otamita Bridge	F	P	F	F	P	F	F	P	0	0	0	-2	-2	0	0	NA	0	0
ES-118	Mararoa River at The Key	P	P	F	P	P	P	P	P	0	0	0	0	0	0	0	NA	0	0
NAT-DN06	Mataura @ Parawa	P	P	NA	NA	P	P	P	P	0	1	0	NA	NA	0	0	NA	0	0
ES-018	Pourakino River at Ermedale Road	F	P	F	P	P	P	P	P	0	0	-2	0	0	0	0	NA	0	0
ES-028	Cromel Stream at Selby Road	P	P	P	P	P	P	P	P	0	0	0	0	0	0	0	NA	0	0
ES-044	Mataura River at Mataura Island Bridge	NA	NA	F	F	NA	NA	NA	NA	NA	NA	NA	0	-2	NA	NA	NA	NA	NA
ES-091	Mataura River at Garston	P	P	P	P	P	P	P	P	2	0	0	0	0	0	0	NA	-2	0

ES-095	Aparima River at Otautau	P	P	F	F	P	F	F	P	0	0	0	-2	-2	0	0	NA	0	0
ES-098	Waikaia River at Waikaia	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
ES-138	Pourakino River at Traill Road	NA	P	F	F	P	P	P	P	NA	0	-2	0	0	0	0	NA	0	0
ES-099	Upukeroa River at Milford/Te Anau Road Bridge	NA	P	F	P	P	P	P	P	NA	0	-2	0	0	0	0	NA	0	0
ES-016	Cascade Creek at Pourakino Valley Road	F	P	F	P	P	P	P	P	0	0	-2	0	0	0	0	NA	-2	0
NAT-DN09	Waiau @ Tuatapere	P	P	NA	NA	P	P	P	P	0	0	0	NA	NA	-2	0	NA	0	0
ES-008	Mararoa River at South Mavora Lake	P	P	P	P	P	P	P	P	-2	1	0	0	0	0	-2	NA	0	0

Table 32: State and trends for individual sites in the Taranaki Region. For state, F indicates the median site value fails the most lenient guideline and P indicates a pass. For trends -2 indicates a meaningful degrading trend, -1 a significant degrading trend, 0 is either a stable or insignificant trend, 1 is a significant improving trend and 2 is a meaningful improving trend. The sites are ordered in the table from poorest quality (i.e. those with the largest numbers of variables failing guidelines and with degrading trends) to highest quality. NA indicates that data were not available for the variable.

		State								Trends								
Code	Site Name	CLAR	DRP	ECOLI	FC	NH4.N	NOx.N	TN	TP	CLAR	COND	DRP	ECOLI	FC	NH4.N	NOx.N	TN	TP
TRC-PNH000900	Punehu Stream @ S.H. 45	F	F	F	F	F	F	F	F	0	0	2	0	0	0	0	0	2
TRC-MRK000420	Mangaoraka Stream @ Corbett Rd. (Recorder site).	P	P	F	F	P	F	F	P	2	0	0	0	0	2	0	0	2
TRC-WGG000500	Waingongoro River @ Eltham Rd Bridge	P	F	F	F	P	F	F	F	0	0	2	0	0	0	0	0	2
TRC-WKH000500	Waiwhakaiho River @ S.H.3	P	F	F	F	P	P	P	F	2	0	2	0	0	0	0	-2	2
TRC-MGH000950	Mangaehu River @ Raupuha Rd Bridge	F	P	F	F	P	P	P	P	2	0	0	0	0	2	0	0	0
TRC-PAT000360	Patea River @ Skinner Road Bridge	P	F	F	F	F	F	F	F	0	0	0	0	0	0	0	0	0
TRC-PNH000200	Punehu Stream @ Wiremu Rd.	P	F	F	P	P	P	P	F	2	0	0	0	0	2	0	-2	0
TRC-STY000300	Stony River @ Mangatete Road	P	F	P	P	P	P	P	P	2	0	2	0	0	0	0	-2	2
NAT-WA01	Waitara @ Bertrand Rd	F	P	NA	NA	P	P	P	P	2	-1	0	NA	NA	0	0	0	2
NAT-WA03	Waingongoro @ SH45	F	F	NA	NA	F	F	F	F	0	0	-2	NA	NA	2	-2	-2	0
NAT-WA02	Manganui @ SH3	P	P	NA	NA	P	P	P	P	2	1	-2	NA	NA	0	0	0	0
TRC-MKW000300	Maketawa Stream @ Tarata Rd.	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TRC-PAT000200	Patea River @ Barclay Road Bridge	P	F	F	P	P	P	P	P	0	0	0	0	0	0	-2	-2	0

Table 33: State and trends for individual sites in the Horizons Region. For state, F indicates the median site value fails the most lenient guideline and P indicates a pass. For trends -2 indicates a meaningful degrading trend, -1 a significant degrading trend, 0 is either a stable or insignificant trend, 1 is a significant improving trend and 2 is a meaningful improving trend. The sites are ordered in the table from poorest quality (i.e. those with the largest numbers of variables failing guidelines and with degrading trends) to highest quality. NA indicates that data were not available for the variable.

		State								Trends									
Code	Site Name	CLAR	DRP	ECOLI	FC	NH4.N	NOx.N	TN	TP	CLAR	COND	DRP	ECOLI	FC	NH4.N	NOx.N	SS	TN	TP
HRC-1077	Oroua at Awahuri Bridge	F	F	F	NA	F	F	NA	NA	0	0	-2	0	NA	0	0	0	NA	NA
NAT-WA07	Manawatu @ Weber Rd	F	F	NA	NA	P	F	F	F	0	0	-2	NA	NA	0	0	NA	0	0
HRC-1314	Whanganui at Pipiriki	F	P	F	NA	NA	P	NA	NA	0	0	0	0	NA	NA	0	0	NA	NA
HRC-1507	Pohangina River @ Mais Reach	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	NA	NA
NAT-TU01	Whanganui @ Te Maire	F	P	NA	NA	P	P	P	P	0	1	-2	NA	NA	0	0	NA	2	0
HRC-0168	Hautapu U/s Rangitikei	F	F	F	NA	P	P	NA	NA	2	-2	0	0	NA	-2	0	0	NA	NA
HRC-1307	Whanganui River D/S Retaruke confl.(Wades Ldg)	F	F	F	NA	NA	P	NA	NA	0	-2	0	0	NA	NA	0	NA	NA	NA
HRC-0151	Hokio Stream @ Lake outlet @ weir	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
HRC-1008	Manawatu at Hopelands	F	F	F	NA	P	F	NA	NA	-2	2	0	0	NA	-2	-2	0	NA	NA
HRC-1032	Manawatu @ WHIROKINO BOAT RAMP	F	F	F	NA	F	F	NA	F	0	0	-2	0	NA	-2	0	0	NA	-2
HRC-1301	Whanganui at Cherry Grove	F	P	F	NA	P	P	NA	NA	0	0	0	0	NA	-2	0	0	NA	NA
NAT-WA06	Rangitikei @ Kakariki	F	P	NA	NA	P	P	P	P	0	1	-2	NA	NA	0	0	NA	0	0
HRC-0004	Mangawhero at DoC Headquarters	P	F	NA	NA	P	P	NA	NA	0	-2	2	NA	NA	-2	-2	2	NA	NA

Table 34. State and trends for individual sites in the Waikato Region. For state, F indicates the median site value fails the most lenient guideline and P indicates a pass. For trends -2 indicates a meaningful degrading trend, -1 a significant degrading trend, 0 is either a stable or insignificant trend, 1 is a significant improving trend and 2 is a meaningful improving trend. The sites are ordered in the table from poorest quality (i.e. those with the largest numbers of variables failing guidelines and with degrading trends) to highest quality. NA indicates that data were not available for the variable.

		State								Trends								
Code	Site Name	CLAR	DRP	ECOLI	FC	NH4.N	NOx.N	TN	TP	CLAR	COND	DRP	ECOLI	FC	NH4.N	NOx.N	TN	TP
EW-0683-004	Otamakokore Stm @ Hossack Rd	F	F	F	F	P	F	F	F	2	0	0	2	0	0	2	2	2
EW-1282-008	Whakapipi Stm @ SH22 Br	F	F	NA	NA	P	F	F	F	2	2	2	NA	NA	0	2	2	2
EW-0230-005	Karapiro Stm @ Hickey Rd Bridge	F	F	F	F	P	F	F	F	2	1	2	0	0	0	2	2	0
EW-0488-001	Mangawhero Stm @ Cambridge-Ohaupo Rd	F	F	F	F	F	F	F	F	0	2	2	0	0	0	2	2	0
EW-0749-015	Piako River @ Paeroa-Tahuna Rd Br	F	F	F	F	F	F	F	F	2	2	0	0	0	0	2	2	0
EW-0258-004	Komakorau Stm @ Henry Rd	F	F	F	F	F	F	F	F	0	1	0	2	2	0	0	0	2
EW-0398-001	Mangakotukutuku Stm (Rukuhia) @ Peacockes Rd	F	F	F	F	F	F	F	F	0	1	2	0	0	0	0	2	2
EW-1202-007	Waipapa Stm (Mokai) @ Tirohanga Rd Br	F	F	F	P	P	F	F	F	2	1	0	0	0	0	2	2	2
EW-0041-009	Awaroa River (Waiuku) @ Otaua Rd Br opp Moseley Rd	F	P	NA	NA	F	F	F	F	2	1	0	NA	NA	0	2	2	2
EW-0669-006	Oraka Stm @ Lake Rd	F	F	F	F	F	F	F	F	2	0	0	0	0	0	2	2	0
EW-1249-015	Waitoa River @ Landsdowne Rd Br	F	F	F	F	P	F	F	F	2	1	0	0	0	0	2	2	0
EW-0039-011	Awaroa Stm (Rotowaro) @ Sansons Br	F	P	F	F	F	P	F	P	2	2	-2	0	0	2	2	2	0
EW-0240-005	Kawaunui Stm @ SH5 Br	F	F	F	F	P	F	F	F	0	2	0	0	0	0	2	2	0
EW-0421-010	Mangaonua Stm @ Hoeka Rd	F	F	F	F	F	F	F	F	2	1	-2	0	0	0	2	2	0
EW-0556-009	Mokau River @ Totoro Rd Recorder	F	F	F	F	P	F	F	F	2	0	0	0	0	0	2	2	0

EW-0612-009	Ohaeroa Stm @ SH22 Br	F	P	NA	NA	P	F	F	F	2	1	0	NA	NA	0	2	2	2
EW-1122-018	Waihou River @ Okauia	F	F	F	F	P	F	F	F	2	0	0	0	0	0	2	2	0
EW-1230-001	Waitakaruru River (Hauraki Plains) @ Coxhead Rd Br	F	F	F	F	F	P	F	F	2	2	2	0	0	0	0	0	0
EW-0749-010	Piako River @ Kiwitahi	F	F	F	F	F	F	F	F	2	0	2	0	0	0	0	0	0
EW-1131-133	Waikato River @ Tuakau Br	F	F	F	P	P	P	F	F	0	1	2	0	0	0	2	2	0
EW-1186-002	Waiotapu Stm @ Campbell Rd Br	F	F	P	P	F	F	F	F	2	0	-2	0	0	0	2	2	2
NAT-HM05	Waihou @ Te Aroha Br	F	F	NA	NA	F	F	F	F	0	1	0	NA	NA	2	0	1	2
EW-0335-001	Little Waipa Stm @ Arapuni - Putaruru Rd	P	F	F	F	P	F	F	F	2	1	-2	0	0	0	2	2	0
EW-0380-002	Mangakara Stm (Reporoa) @ SH5	F	F	F	F	P	F	F	F	2	2	-2	0	0	-2	2	2	0
EW-0417-007	Mangaone Stm @ Annebrooke Rd Br	F	F	F	F	F	F	F	F	2	1	0	0	0	0	0	0	0
EW-0665-005	Opuatia Stm @ Ponganui Rd	F	P	F	F	P	F	F	F	2	1	-2	0	0	0	2	2	0
EW-0818-002	Puniu River @ Bartons Corner Rd Br	F	F	NA	NA	P	F	F	F	2	0	0	NA	NA	0	2	2	0
EW-0934-001	Tahunaatara Stm @ Ohakuri Rd	F	F	F	F	P	F	F	F	2	0	-2	0	0	0	2	2	0
EW-1098-001	Waerenga Stm @ Taniwha Rd	F	F	F	F	P	F	F	F	2	0	0	0	0	0	2	0	0
EW-1131-069	Waikato River @ Horotiu Br	F	F	F	F	P	P	P	F	0	0	0	0	2	-2	2	2	2
EW-1287-007	Whakauru Stm @ U/S SH1 Br	F	F	F	F	P	P	P	F	2	0	-2	0	0	0	2	2	2
EW-1293-009	Whangamarino River @ Jefferies Rd Br	F	F	NA	NA	F	F	F	F	2	1	2	NA	NA	0	0	0	0
EW-0359-001	Mangaharakeke Stm (Atiamuri) @ SH30 (Off Jct SH1)	F	F	F	F	P	P	P	F	2	1	-2	0	0	0	2	2	0
EW-0407-001	Mangamingi Stm (Tokoroa) @ Paraonui Rd Br	F	F	F	F	F	F	F	F	2	0	-2	0	0	2	0	2	-2
EW-0624-005	Ohote Stm @ Whatawhata/Horotiu Rd	F	F	F	F	F	F	F	F	0	0	2	0	0	0	2	0	-2
EW-0786-002	Pokaiwhenua Stm @ Arapuni - Putaruru Rd	F	F	F	F	P	F	F	F	2	1	-2	0	0	0	2	2	-2
EW-1131-143	Waikato River @ Waipapa Tailrace	P	F	P	P	P	P	P	P	2	1	0	0	0	0	2	2	2

EW-1186-004	Waiotapu Stm @ Homestead Rd Br	F	F	NA	NA	F	F	F	F	0	0	-2	NA	NA	0	2	2	2
EW-1236-002	Waitawhiriwhiri Stm @ Edgecumbe Street	F	F	F	F	F	F	F	F	2	0	2	0	0	-2	0	0	0
NAT-HM03	Waikato @ Hamilton Traffic Br	F	F	NA	NA	P	P	P	F	-2	1	2	NA	NA	0	2	2	2
EW-0443-003	Mangapu River @ Otorohanga	F	F	F	F	F	F	F	F	0	1	0	0	0	0	2	0	-2
EW-0481-007	Mangawara Stm @ Rutherford Rd Br	F	F	NA	NA	F	F	F	F	0	1	2	NA	NA	0	0	0	0
EW-0556-005	Mokau River @ Mangaokewa Rd (Off SH30)	F	F	F	F	P	P	P	F	2	0	-2	0	0	0	2	2	0
EW-0619-019	Ohinemuri River @ Queens Head	P	F	F	F	P	F	F	P	2	2	-2	0	0	0	2	2	-2
EW-1191-010	Waipa River @ Pirongia-Ngutunui Rd Br	F	F	F	F	P	F	F	F	2	0	0	0	0	0	0	0	0
EW-1302-001	Whangape Stm @ Rangiriri-Glen Murray Rd	F	P	NA	NA	P	P	F	F	2	0	0	NA	NA	0	0	2	2
EW-0388-001	Mangakino Stm (Whakamaru) @ Sandel Rd	P	F	NA	NA	P	F	F	F	2	0	-2	NA	NA	1	2	2	-1
EW-0428-003	Mangaotaki River @ SH3 Br	F	F	NA	NA	P	F	F	F	2	-1	0	NA	NA	-2	2	2	0
EW-0438-003	Mangapiko Stm (Pirongia/Te Awamutu) @ Bowman Rd	F	F	NA	NA	F	F	F	F	2	0	2	NA	NA	-2	0	0	0
EW-0453-006	Mangatangi River @ SH2 Maramarua	F	F	NA	NA	P	P	F	F	2	0	2	NA	NA	0	0	0	0
EW-0476-007	Mangatutu Stm (Waikeria) @ Walker Rd Br	F	F	F	F	P	P	P	P	2	0	-2	0	0	0	2	2	0
EW-0802-001	Pueto Stm @ Broadlands Rd Br	P	F	P	P	P	P	P	F	2	0	0	0	0	0	2	2	0
EW-1057-006	Torepatutahi Stm @ Vaile Rd Br	NA	F	NA	NA	P	P	P	F	NA	2	0	NA	NA	0	2	2	0
EW-1131-107	Waikato River @ Ohakuri Tailrace Br	P	F	P	P	P	P	P	P	2	1	-2	0	0	0	2	2	2
EW-1131-147	Waikato River @ Whakamaru Tailrace	P	F	P	P	P	P	P	P	2	1	-2	0	0	0	2	2	2
EW-1174-004	Waiomou Stm @ Matamata-Tauranga Rd	F	F	F	F	P	F	F	F	2	-1	-2	0	0	0	0	2	0
NAT-HM04	Waikato @ Rangiriri	F	F	NA	NA	P	P	P	F	0	1	0	NA	NA	0	2	2	0
EW-0414-012	Mangaokewa Stm @ Te Kuiti Borough W/S Intake	F	F	NA	NA	P	F	F	F	2	2	0	NA	NA	-2	0	0	0
EW-0421-016	Mangaonua Stm @ Te Miro Rd	F	F	F	F	P	F	F	F	2	0	-2	0	0	0	2	0	-2

EW-0516-005	Matahuru Stm @ Waiterimu Road Below Confluence	F	F	NA	NA	F	F	F	F	0	1	2	NA	NA	0	0	0	-2
EW-1122-041	Waihou River @ Whites Rd	P	F	P	P	P	F	F	F	2	0	-2	0	0	0	2	2	-1
EW-1131-077	Waikato River @ Huntly-Tainui Br	F	F	F	F	P	P	P	F	0	0	0	0	-2	0	2	2	0
EW-1247-002	Waitetuna River @ Te Uku-Waingaro Rd	F	F	F	F	P	P	P	F	2	0	0	0	0	0	0	0	0
EW-1293-007	Whangamarino River @ Island Block Rd	F	P	NA	NA	F	P	F	F	0	1	0	NA	NA	0	0	2	0
EW-0513-003	Marokopa River @ Speedies Rd (Off Te Anga Rd)	F	F	F	F	P	P	P	P	2	0	0	0	0	0	2	0	-2
EW-0557-005	Mokauiti Stm @ Three Way Point - Aria	F	P	F	F	P	P	P	F	0	0	0	0	0	0	2	2	-2
EW-1131-091	Waikato River @ Mercer Br	NA	F	F	F	P	P	F	F	NA	0	0	0	-2	-1	2	2	0
EW-1253-005	Waitomo Stm @ SH31 Otorohanga	F	P	F	F	P	F	F	F	0	0	0	0	0	0	0	0	0
EW-1318-004	Whareroa Stm (Taupo District) @ Lakeside Lake Taupo	NA	F	F	P	P	F	F	F	NA	-1	-2	0	0	0	2	2	0
EW-1323-001	Whirinaki Stm @ Corbett Rd	NA	F	NA	NA	P	F	F	F	NA	0	-2	NA	NA	0	2	2	0
EW-0033-009	Awakino River @ SH3 Awakau Rd Junction	F	P	F	F	P	P	P	P	2	0	0	0	0	0	0	0	0
EW-0504-002	Mapara Stm (Lake Taupo) @ Off Mapara Rd	F	F	P	P	P	F	F	F	2	0	0	0	-2	0	0	1	-1
EW-0556-002	Mokau River @ Awakau Rd	F	P	F	F	P	P	F	F	0	0	0	0	0	0	2	0	-2
EW-1045-003	Tokaanu Stm @ Off SH41 Turangi	NA	F	NA	NA	P	P	P	F	NA	0	0	NA	NA	0	2	2	-1
EW-1167-004	Waingaro River (Pukemiro) @ Ruakiwi Rd Off SH22	F	F	NA	NA	P	P	F	F	0	1	0	NA	NA	0	0	0	0
EW-1191-012	Waipa River @ SH3 Otorohanga	F	P	F	F	P	P	F	P	0	1	-2	0	0	0	2	2	-2
EW-1253-007	Waitomo Stm @ Tumutumu Rd	F	P	F	F	P	F	F	P	0	0	0	0	0	0	2	0	-2
EW-0222-016	Kaniwhaniwha Stm @ Wright Rd	F	P	NA	NA	P	P	P	P	2	-1	0	NA	NA	-2	2	2	0
EW-0253-004	Kirikiriroa Stm @ Tauhara Dr	F	F	F	F	F	F	F	F	0	0	0	0	0	-2	0	0	-2
EW-0616-001	Ohautira Stm @ Waingaro Te Uku Rd	F	F	F	F	P	P	P	F	0	1	0	0	0	0	0	0	-2
EW-0971-	Tauranga-Taupo River @ Te Kono Slackline	P	F	NA	NA	P	P	P	P	2	-1	-2	NA	NA	0	2	2	0

004																		
EW-0976-001	Tawarau River @ Off Speedies Rd	F	F	NA	NA	P	P	P	P	2	0	0	NA	NA	0	2	0	-2
EW-1131-105	Waikato River @ Ohaaki Br	P	P	P	P	P	P	P	P	2	0	-2	0	0	0	2	0	2
EW-1191-005	Waipa River @ Mangaokewa Rd	P	P	NA	NA	P	P	P	P	2	0	-2	NA	NA	0	2	2	0
EW-1226-001	Waitahanui River @ Blake Rd	P	F	P	P	P	P	P	F	2	0	-2	0	0	0	2	2	-2
EW-1312-003	Wharekawa River @ SH25	P	P	F	F	P	P	P	P	2	0	-2	0	2	0	0	0	0
NAT-HM02	Waipa @ SH23 Br Whatawhata	F	F	NA	NA	P	F	F	F	0	1	-2	NA	NA	0	0	0	0
EW-0410-004	Manganui River @ Off Manganui Rd	F	F	F	F	P	P	P	P	2	-1	0	0	0	-2	0	0	0
EW-0477-010	Mangauika Stm @ Te Awamutu Borough W/S Intake	P	P	P	P	P	P	P	P	2	-1	-2	0	0	0	2	2	0
EW-0619-020	Ohinemuri River @ SH25 Br	P	P	F	F	P	F	F	P	2	-1	-2	0	0	0	0	0	0
EW-1257-003	Waiwawa River @ SH25 Coroglen	P	P	F	F	P	P	P	P	2	0	-2	0	0	0	0	0	0
EW-0234-011	Kauaeranga River @ Smiths Cableway/Recorder	P	P	F	P	P	P	P	P	2	0	-2	0	0	0	0	0	0
EW-1105-003	Waiau River @ E309 Rd Ford	P	P	F	P	P	P	P	P	2	0	-2	0	0	0	0	0	0
EW-1239-032	Waitekauri River @ U/S Ohinemuri Conflu	P	P	F	P	P	P	P	P	2	0	-2	0	0	0	0	0	0
NAT-HM01	Waipa @ Otewa	F	F	NA	NA	P	P	P	P	-2	1	0	NA	NA	0	0	0	0
EW-0398-026	Mangakotukutuku Stm (Rukuhia) @ Waterford Road	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EW-0411-009	Mangaohoi Stm @ South Branch Maru Rd	F	F	F	P	P	P	P	F	0	0	0	0	0	0	-2	-2	0
EW-0421-050	Mangaonua Stm @ Harbutt Road Bridge	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EW-0489-002	Mangawhero Stm (Kaihere) @ Mangawara Rd	F	F	F	P	P	P	P	F	2	0	0	0	0	0	-2	-2	-2
EW-0504-001	Mapara Stm (Lake Taupo) @ Mapara Rd Culvert Taupo	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EW-1131-101	Waikato River @ Narrows Br	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EW-1131-328	Waikato River @ Narrows Boat Ramp	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

EW-1249-018	Waitoa River @ Mellon Rd Recorder	F	F	F	F	F	F	F	F	0	0	-2	0	0	-2	0	-2	-2
EW-1300-001	Whangamata Stm (Kinloch) @ Whangamata Rd	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EW-1318-003	Whareroa Stm @ Whareroa Station Bridge	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NAT-RO06	Waikato @ Reids Farm	P	P	NA	NA	P	P	P	P	0	0	2	NA	NA	-2	0	0	0
NAT-TU02	Tongariro @ Turangi	P	F	NA	NA	P	P	P	P	-2	0	0	NA	NA	0	0	0	1
EW-0033-006	Awakino River @ Gribbon Rd	P	F	F	F	P	P	P	P	0	0	0	0	0	0	-2	-2	0
EW-1106-004	Waihaha River @ SH32	P	F	P	P	P	P	P	P	2	-1	-2	0	0	-1	0	0	0
EW-1173-002	Waiohotu Stm @ Waiohotu Rd (Off SH5)	NA	F	F	P	P	P	P	P	NA	-1	-2	-2	0	0	2	2	-2
EW-0282-005	Kuratau River @ Te Rae Street	NA	P	P	P	P	F	F	P	NA	-2	-2	0	0	-2	0	2	0
EW-0753-004	Piakonui Stm @ Piakonui Rd	F	F	F	P	P	P	P	P	0	-1	-2	0	0	0	0	0	-2
NAT-HM06	Ohinemuri @ Karangahake	P	P	NA	NA	P	F	F	P	0	0	-2	NA	NA	0	0	0	-2
EW-0658-001	Oparau River @ Langdon Rd (Off Okupata Rd)	F	P	NA	NA	P	P	P	P	0	0	-2	NA	NA	-2	0	0	0
EW-0940-010	Tairua River @ Morrisons Br Hikuai	P	P	F	F	P	P	P	P	0	0	-2	0	0	-1	0	0	-2
EW-0954-005	Tapu River @ Tapu-Coroglen Rd	P	P	F	P	P	P	P	P	0	0	-2	0	0	0	0	0	-2
EW-1131-127	Waikato River @ Taupo Control Gates	NA	P	P	P	P	P	P	P	NA	0	-2	0	0	-1	0	0	0
EW-1301-001	Whanganui Stm @ Lakeside Lake Taupo	NA	F	P	P	P	P	P	P	NA	-2	-2	0	0	-1	0	0	0
EW-1491-001	Tokaanu Power Station Tailrace Canal @ SH41 Bridge	NA	P	NA	NA	P	P	P	P	NA	0	-2	NA	NA	-2	0	0	0
EW-0282-004	Kuratau River @ SH41 Moerangi	P	P	NA	NA	P	P	P	P	0	-1	-2	NA	NA	0	0	0	-2
EW-0169-002	Hikutaia River @ Old Maratoto Rd	P	P	F	F	P	P	P	P	0	0	-2	0	0	-2	0	-2	-2
EW-0171-005	Hinemaiaia River @ SH1	P	F	P	P	P	P	P	F	2	-2	-2	-2	-2	0	0	0	-2