Freshwater Quality Monitoring in the Gisborne District

Stock-take, review, and recommendations

Prepared for Gisborne District Council

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Summary

Gisborne District Council (GDC) is in the process of re-evaluating their freshwater state of the environment (SOE) monitoring programme and is developing a regional Freshwater Plan. The council is using the National Policy Statement for Freshwater Management 2011 (NPSFM) and the recently proposed National Objectives Framework (NOF) to establish objectives and freshwater limits for water bodies within their region. As part of this process GDC is investigating whether their current freshwater SOE programme meets the goals of SOE monitoring, such as an ability to report on region-wide trends, and whether they monitor the current and indicated future environmental parameters (attributes) that are identified in the proposed NOF.

GDC secured Envirolink funding to gain advice from NIWA under Medium Advice Grant 1465-GSDC116 to assess the capabilities and limitations of their current SOE freshwater monitoring network. In particular the objectives were 1) to assess how representative the monitoring site locations were of the greater Gisborne region, and 2) to provide advice prioritising a list of environmental parameters to monitor in light of current and likely future attributes identified in the NOF.

GDC currently monitor 28 water quality parameters at 43 sites across the district. Some of these sites are monitored monthly and some bimonthly, with several different subsets of parameters measured at different groups of sites.

Representativeness of the monitoring network

Having a bio-monitoring network that is representative of the wider region is important when a goal of the monitoring is to report on the environmental state or trends at a region-wide or national scale. If this was the sole objective of an SOE monitoring network then areas in the region that vary environmentally should be sampled in proportion to their overall occurrence in the region. We analysed the representativeness of the GDC current biomonitoring network with regard to sites categorised by climate, topography, geology and land cover categories derived from the River Environment Classification (REC) system, a GIS-based hierarchical model of New Zealand's river network. Representativeness was based on length of river in the different categories.

Our analyses strongly suggested that reducing the number of sites in the immediate vicinity of Gisborne City and Poverty Bay, and redistributing these across the wider region, would be a simple and direct way of improving representativeness in environmental space without compromising SOE monitoring goals. Given the lack of road access to many inland parts of the district it may well be impossible (or at least impractical) to attain representativeness across all environmental classes, but there appears to be obvious potential to improve coverage of the main under-represented classes. The sites clustered near Gisborne City mean that the Warm-Dry climate, the Lowland topography, the Alluvial geology and the Pastoral land cover classes are all over represented. Under-represented classes that occur further from Gisborne City are the Cool-Wet and Cool-Extremely Wet climate classes, the Hill topography class, the Hard Sediment geology class and Exotic and Indigenous land cover classes.

While moving or adding sites would improve the representativeness of the monitoring network of the wider Gisborne District, and the analysis presented here could be used to

inform the design of an updated monitoring network for the Gisborne District, it is by no means the only criterion that should be used in final network design. Our analysis is just one way of assessing network representativeness, and takes no account of other criteria such as the overall perceived importance of individual river sections, or identifying and prioritising areas subject to the greatest impact. We make the implicit assumption that river length is an appropriate measure of representativeness, but recognise that other ecologically meaningful weightings (e.g., flow, riverbed area) could equally well be applied. We also acknowledge that regional councils will generally have specific issues that will influence the exact layout of their network, over and above any concerns about representativeness.

Monitoring priorities for environmental parameters

A simple analysis of current monitoring parameters shows that GDC currently measures nine of the 16 attributes included in the proposed NOF and eight of the 12 proposed compulsory attributes. The proposed compulsory attributes that GDC would need to add to their monitoring to align with the proposed NOF are planktonic and benthic cyanobacteria, invertebrates and fish.

The additional proposed NOF attributes that GDC may need to monitor in some sites, depending on the values assigned to those sites, are heavy metals, organic contaminants and pathogens. Total nitrogen (TN), total phosphorus (TP), coloured dissolved organic matter (CDOM) and physical habitat are not included in the proposed NOF, but could be considered for addition to a monitoring programme. A number of national values proposed in the NPSFM do not have attributes assigned currently. Local knowledge and the values identification programme that GDC is undertaking will help identify additional parameters to monitor at all, or a subset of sites.

The parameters that GDC currently monitors but that need relatively significant expansion to include more sites are: nitrates, periphyton and measures of water clarity, such as black disc.

Parameters that we assess as having a relatively low priority for continued monitoring for SOE purposes include alkalinity, magnesium, salinity, sulphate, sodium, chloride, hardness, nitrite, enterococci, potassium, boron and tannins. However, there may be other reasons for continuing to monitor some of these parameters.

The proposed NOF currently provides little information regarding monitoring frequencies required to assess attribute states. These will vary by attribute and may include annual (most likely for invertebrates), monthly (periphyton and most other water quality parameters) or continuous over short time frames (water temperature). The final decision for monitoring frequency may also vary according to other reasons, for example, more frequent *E. coli* monitoring may be required over summer in popular recreation sites or if threshold values are close to being exceeded.

We recommend that consideration is given to overlapping some parameters that are to be discontinued with related new parameters that are to be instigated for a time (say 12 months). This may allow the generation of conversion relationships between the parameters which would help retain the value in any historic long-term data sets.

Consideration of measurements of river flow at monitoring sites is also recommended. This could be a continuous recording gauge at a site, the installation of a stage height staff that

can be read on site visits (and development of stage-discharge relationships), spot discharge readings taken during sites visits and/or the development of models relating flow at nearby gauges to site locations.

We recommend that further investigation is required for several parameters, these include:

- Use of continuous loggers for temperature, dissolved oxygen and pH.
- Monitoring programmes for periphyton (including cyanobacteria), invertebrates and fish. Specific advice relevant to Gisborne District waterways could help improve the cost-effectiveness of monitoring these parameters as there may be key locations that can be prioritised for monitoring or different sampling methodologies may be relevant to individual sites or groups of sites.

Attributes in the proposed NOF are subject to change (although the current planned timeframe will see proposed amendments to the NPSFM including NOF in July) and short-term investigations of some new parameters may be beneficial. Therefore, we recommend that as much flexibility as possible is retained in the GDC biomonitoring programme, at least for the next few years.

We would like to emphasise that our recommendations for parameters to prioritise for monitoring are based on their use in a SOE monitoring programme. The final selection of parameters to include in a monitoring programme should also include consideration of the value of long-term data sets and additional reasons for measurement of a particular parameter, for example to monitor drinking water quality. The addition of selected parameters that are not currently in the proposed NOF will likely be beneficial in some locations. Local knowledge of the system and its stressors and regional policy will help these decisions.

1 Overview and background

In New Zealand, the Resource Management Act (RMA) 1991 Section 35(2)(a) imposes a duty on regional councils to monitor the state of the whole or any part of the environment in their region. Hence councils develop 'State of the Environment' or SOE programmes, the goals of which are to report regional trends or to detect differences in indicators of environmental condition between sites or between sites and guideline values. Historically, regional councils have developed their own monitoring programmes to meet these requirements as there has been a lack of a national framework to identify specific management objectives or a method to ensure comparable information was captured across regions. In 2011 the government released the National Policy Statement for Freshwater Management (NPSFM), which encouraged councils to set freshwater objectives and limits in their regional plans and aimed to improve national consistency in local RMA planning and decision-making.

The original NPSFM was followed up in 2013 by the 'draft proposed amendments to the National Policy Statement for Freshwater Management – a discussion document' which provides a draft National Objectives Framework (NOF) that defines the process for setting values, objectives and limits for freshwater bodies (see the Glossary for definition of these terms). The proposed NOF aims to identify a list of potential values for freshwater bodies and to associate them with measurable attributes that can be used to indicate whether such values are being met. The NOF provides a list of possible nationally consistent values that a particular freshwater body could be managed for, such as contact recreation, ecosystem health or irrigation. Each value has a set of measurable attributes that can be used to indicate the level at which such values are being bet, and that can also provide management targets. The attributes are divided into three levels of different quality, excellent (A), good (B) and fair (C), which represent the range of states at which the value may be provided for. There is also a fourth level, a national bottom line, which indicates the state below which the value will not be provided for. Target attribute states are chosen regionally to ensure that water bodies meet or move towards the identified important values.

The current NOF is a discussion document, and neither attributes nor attribute states for each value have been fully confirmed or populated. The identification of attributes and setting the numerical bands that define them is an ongoing process as information becomes available. So far two compulsory values have been set, 'ecosystem health' and 'human health- secondary contact', with a range of other values that must also be considered. Attributes have been identified for some values, and numerical attribute bands identified for a subset of these.

Gisborne District Council (GDC) is in the process of re-evaluating their freshwater SOE monitoring programme and are developing a regional Freshwater Plan. The council is using the NPSFM and the proposed NOF to establish objectives and freshwater limits for water bodies within their region. As part of this process the council is investigating whether their current freshwater SOE programme meets the goals for SOE monitoring, such as an ability to report on region-wide trends, and whether their current monitoring programme includes the current and indicated future attributes that are identified in the proposed NOF.

2 Purpose of the report

GDC secured Envirolink funding to gain advice from NIWA under Medium Advice Grant C01X1329 to assess the capabilities and limitations of their current SOE freshwater monitoring network. In particular the objectives were 1) to assess how representative the monitoring site locations were of the greater Gisborne region, and 2) to provide advice prioritising a list of environmental parameters to monitor in light of current and likely future attributes identified in the NOF.

Specifically, we undertook a desktop analysis using information provided by GDC regarding site locations, measured environmental parameters and the geospatial extent of the Gisborne region.

This involved two tasks:

1. Representativeness analyses to determine whether the current distribution of monitoring sites reflects the larger Gisborne region in terms of climate, geology and landuse categories derived from the River Environment Classification (REC).
2. An assessment of the parameters measured currently by GDC with regard to current and indicated future attributes identified in NOF and recommendations of parameters to prioritise for measurement

The representativeness analysis can be found in Section 3 and the assessment of parameters to monitor in Section 4. Section 5 includes recommended processes and next steps. Note that this report deals with the 43 freshwater riverine sites identified by GDC. Two estuarine locations were removed from the data set as they couldn't be matched to the REC.

3 Task 1: Representativeness analysis

3.1 Introduction

Having a bio-monitoring network that is representative of the wider region is important when a goal of the monitoring is to report on the environmental state or trends at a region-wide or national scale. If this was the only objective or driver for monitoring then areas of the region that vary environmentally should be sampled in proportion to their overall occurrence in the region. An assessment of how representative the biomonitoring network is of the larger region can be undertaken by creating groups of sites based on similar environmental conditions. Such groups tend to share ecological values and be affected by similar stressors and can also form the basis of management units for which similar objectives and limits can be set.

The proposed amendments to the NPSFM uses the term 'freshwater management unit' to refer to areas over which freshwater objective and limits will apply. Such units can then be managed with different objectives, policies and rules in a regional plan (Rouse and Norton 2009). The size of units is set by the regional council and can be at the scale of sub-catchments, individual catchments or multiple catchments. Currently, GDC groups results from water quality monitoring by sub-catchment. This is a valid approach as sub-catchments generally have similar environmental conditions and stressors. However, other ways of grouping sites may also be valid. The River Environment Classification (REC) (Snelder and Biggs 2002) is a useful tool to help define management units as it is GIS based and can be used to map every section of river in New Zealand. The REC categorises rivers that share similar environmental characteristics, such as climate, topography, geology and land cover, and which therefore tend to have similar physical and biological characteristics (Snelder and Biggs 2002). The REC categories will group sites that are environmentally similar but may be geographically independent. This provides a different way of grouping sites as compared to setting spatially delimited groups such as those defined by catchment or sub-catchments. Final freshwater management units may be set using a combination of environmentally- and spatially-delimited groups.

REC categories are commonly used to provide insights into the causes of spatial patterns of water quality state and trends in relation to human and environmental factors and to describe how well a network of sites represents the overall environmental variation within a region (e.g., Larned et al. 2013; Kelly et al. 2014). We use the REC to categorise sites based on climate, topography, geology and land cover and assess how representative the current GDC water quality monitoring network is of the wider region.

Representative estimates of river water-quality state or trend across areas like the Gisborne region require two conditions to be met. First, data from rivers representing the majority of environmental or geographic areas in the region should be included. If some types of classes are excluded, the estimated state or trend will be over-influenced by classes that are included. For example, a regional water quality analysis that included agricultural or urban land cover classes, but that excluded less human-modified areas, such as native forest land cover classes, may erroneously indicate that water quality is worse than the true region-wide state.

The second condition is that the number of monitoring sites from each environmental or geographic class, and the abundance of each class in the assessment area, should have the same proportions. This condition can be applied before compiling data (by selecting sites in proportion to the size of their environmental class) or after compiling data (by assigning a weighting factor to the data from each environmental class). For example, if lake-fed rivers comprise 20% of the total number of rivers (or 20% of the total river length) in an assessment area, lake-fed rivers should comprise 20% of the monitoring sites used for assessment. If these conditions are not met, rare environmental classes may have too much influence on estimated water quality and common classes may have too little influence. Proportionality or weighting factors available for use include a) the number of rivers in each environmental class as a proportion of total river number, b) the length of river channel in each class as a proportion of total river length, c) the relative amount of river flow, d) or the catchment area of a river as a proportion of total area.

GDC uses 43 river sites to monitor riverine water quality. We classified these sites based on the REC climate, topography, geology and land cover categories and assessed how representative the locations of 43 monitoring sites were of the wider region in terms of the length of river in each of the REC classes.

While the representativeness analysis below provides one way of assess the distribution of sites within a monitoring network it should be remembered that there are many other reasons for sites to be located in particular place, such as monitoring the condition of sites that have a particular value or that are likely to be more impacted than other locations.

3.2 Methods

3.2.1 The River Environment Classification (REC)

To assess the extent to which the current GDC site network is representative of river environments throughout the district, we used the River Environment Classification (REC; Snelder and Biggs 2002) to classify all GDC rivers in environmental space. The REC is a hierarchical model of New Zealand's river network, derived from a Digital Elevation Model (DEM) with a spatial resolution of 50 m. We used Version 2 of the REC, comprising ~570 000 unique river segments defined by upstream and downstream confluences with tributaries, with a mean segment length of 740 m. Each segment is associated with its upstream catchment, also derived from the DEM, and with a suite of additional catchment descriptors derived from a Geographic Information System (GIS) database. For the purposes of this study we limited our attention to the first four levels of the REC hierarchy, describing the climate, topography, geology, and land cover of New Zealand (Table 3-1). Collectively these variables characterise environmental gradients in the Gisborne District over spatial scales from 1-100 km, representing variation in climate (e.g., cold wet, warm dry, warm wet); source of flow (e.g., mountain, hill, lowland); geology (e.g., soft sediment, volcanic acidic); and landcover (e.g., indigenous forest, pasture).

Table 3-1: REC classes used in this study to characterise river environments in the Gisborne District. Classes absent from the district (e.g., source of flow = glacial mountain) are not shown. See Snelder and Biggs (2002) for a more detailed description of the Geology and Landcover classes.

Variable	Class name	Class	Class definition
Climate	Cool wet	CW	mean temp. < 12 °C; 500 mm ≤ rainfall < 1500 mm
	Cool extremely wet	CX	mean temp. < 12 °C; rainfall ≥ 1500 mm
	Warm dry	WD	mean temp. ≥ 12 °C; rainfall < 500 mm
	Warm wet	WW	mean temp. ≥ 12 °C; 500 mm ≤ rainfall < 1500 mm
	Warm extremely wet	WX	mean temp. ≥ 12 °C; rainfall ≥ 1500 mm
Hydrological source of flow	Mountain	M	50% of annual rainfall above 1000 m
	Hill	H	50% of annual rainfall between 400 m and 1000 m
	Low elevation	L	50% of annual rainfall below 400 m
Geology	Alluvium	Al	spatially dominant geology category
	Hard sedimentary rocks	HS	spatially dominant geology category
	Miscellaneous	M	spatially dominant geology category
	Soft sediment	SS	spatially dominant geology category
	Volcanic acidic	VA	spatially dominant geology category
Landcover	Bare	B	spatially dominant landcover category
	Exotic Forest	EF	spatially dominant landcover category
	Indigenous Forest	IF	spatially dominant landcover category
	Miscellaneous	M	spatially dominant landcover category
	Pastoral	P	spatially dominant landcover category
	Scrub	S	spatially dominant landcover category
	Tussock	T	spatially dominant landcover category
	Urban	U	spatially dominant landcover category

3.2.2 Site matching

We used a GIS shape file provided by GDC to locate all REC segments located within the district boundary. We then used the coordinates for each site, also provided by GDC, to co-locate each site with the corresponding REC segment, cross-checking as necessary to ensure that sites near tributary confluences were associated with the correct segment. We were able to match 43 of the 45 current sites in this way, the two exceptions being sites on the lower 1 km of the Turanganui River (Turanganui @ Gladstone Road bridge, NZTM 2037630, 5707961; Turanganui @ The Cut, NZTM 2036929, 5707560). These are highly estuarine (Gladstone Road bridge) and essentially coastal (The Cut), and are thus not represented in the REC which is generally limited to waters above the upstream tidal limit.

The 43 matched sites included three instances where two sites in close proximity to each other were matched to the same REC segment. This means that the two sites within each pair are indistinguishable from a hydrological perspective, at spatial scales at or above the characteristic scale (i.e., ~700 m) of the REC. Allowing for these duplicates, the total number of distinct river segments represented in the current GDC network reduces to 40.

A total of 19,444 REC segments lie within the Gisborne District (Figure 3-1), representing a total river length of 12 348 km. This representation is accurate at the characteristic REC spatial scale of ~700 m within the body of the district, but potentially inaccurate (at the same spatial scale) along the inland boundary of the district which does not necessarily coincide with catchment boundaries. For example, the mainstem of the Motu River is well represented above the Mangaotane Stream confluence (NZTM 2011490, 5771670), but becomes fragmented below that point as successive REC segments begin to straddle the regional boundary. For the purposes of this study we ignore these discrepancies.

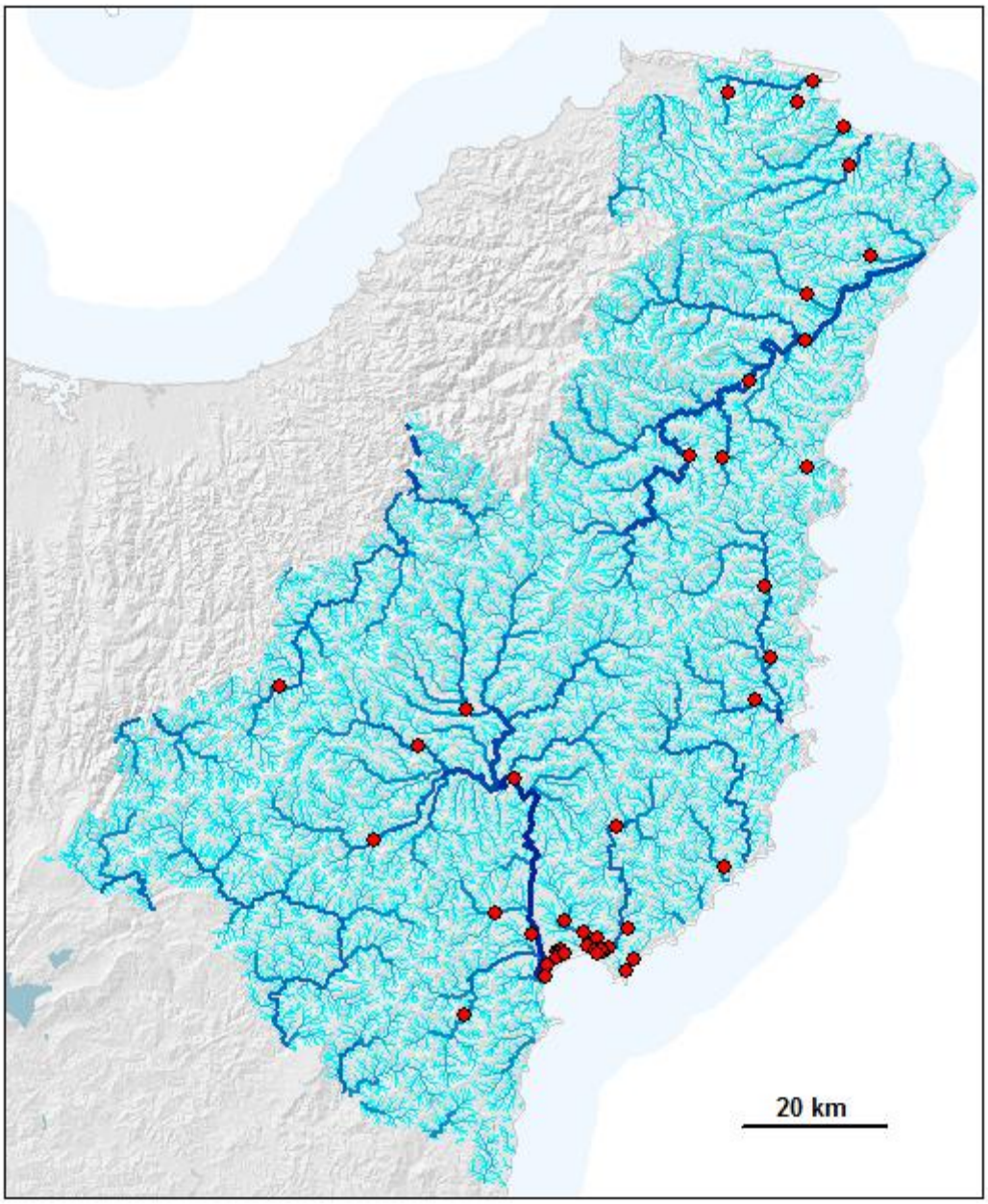

Figure 3-1: REC representation of river drainage in the Gisborne District. Current monitoring sites are marked by red symbols.

3.2.3 Site classification

We classified GDC rivers and sites at five levels, representing the four REC classes as listed in Table 3-1, and a composite climate/source-of-flow class (e.g., CW/H = climate class CW + source-of-flow class H). For each class we determined: the total river length in km; the number of monitoring sites within the class; total river length and site numbers as a percentage of the total (based on the 43 sites which can be matched to the REC); the number of sites per 1,000 km of river length within the class; the number of sites required in each REC category for a representative distribution of the 43 sites; and the change in current sites numbers required for each REC category to achieve representativeness. The number of sites per 1,000 km of river length within the class provides a consistent way to characterise site distribution among classes, noting that the mean figure for the Gisborne District is 3.48 sites per 1,000 km (43 sites per 12,348 km).

3.3 Results

3.3.1 General remarks

A simple visual assessment of the current distribution of sites in Figure 3-1 identifies that the current monitoring network is not uniformly distributed over the Gisborne District. Environmental gradients aside, sites are strongly clustered around Gisborne city and the lower Waipaoa River, with 21 sites within a 10 km radius of Gisborne (see Figure 3-1). These represent 47% of the 45 monitoring sites within the full data set, and 44% of the 43 sites matched to the REC. However, it must be remembered that monitoring networks are designed for multiple purposes, with representativeness of the wider region being only one. There are likely to be clear historic reasons that the network may have developed this locational bias.

A fundamental REC descriptor is stream order, an objective index of catchment scale and complexity (Strahler 1964). Within the Gisborne District, stream order ranges from 1 (for fingertip headwater tributaries) to 7 (for the Waipaoa River below the Waikohu confluence). The current site network is well distributed across this range, with all orders represented by at least one site, and 29 of 40 matched segments of 3rd to 5th order (Table 3-2). Other criteria aside, this suggests that the network is broadly representative in terms of stream order, bearing in mind that 1st and 2nd order streams are generally too small and/or inaccessible to be viable for water quality monitoring.

Table 3-2: Distribution of GDC monitoring sites by stream order.

Stream order	1	2	3	4	5	6	7
Number of sites	1	6	8	10	13	3	2

3.3.2 REC climate class

Over 85% of GDC rivers fall within one of three REC climate classes, representing classes WW (39%), CW (28%), and CX (18%; see definitions of abbreviations in Table 3-3, Figure 3-2). These are broadly aligned with local topography, with CX corresponding to the crest of the Raukumara Range, CW marking their eastern slopes, and WW dominant in the east. Class WD is limited to the lower portion of the Waipaoa catchment, and class WX to the ranges north of Mt Hikurangi.

Table 3-3: Distribution of GDC river environments and monitoring sites by REC climate class. The first five columns for each class show the river length within the Gisborne District, as total km and percentage of all GDC rivers; the number of sites, as total sites and percentage of all GDC sites; and the number of sites per 1000 km of river. The final two columns show the number of sites required to establish representativeness across all classes (N_{sites} (rep)), and the difference between this value and the current number of sites (Delta N_{sites}). Blue shaded squares indicate classes that require more sites to achieve representativeness and orange shaded squares indicate classes that currently have more sites than required for representativeness (assuming the total number of sites remains the same).

Climate class	Length (km)	% of total km	Number of sites	% of sites	Sites / 1000 km	N_{sites} (rep)	Delta N_{sites}
WW (warm wet)	4 844	39.25	14	32.56	2.89	17	3
CW (cold wet)	3 437	27.85	6	13.95	1.75	12	6
CX (cold extremely wet	2 233	18.10	1	2.33	0.45	8	7
WD (warm dry)	986	8.00	16	37.21	16.21	3	-13
WX (warm extremely wet)	840	6.81	6	13.95	7.14	3	-3
Total	**12 343**	**100**	**43**	**100**	**3.48**	**43**	**0**

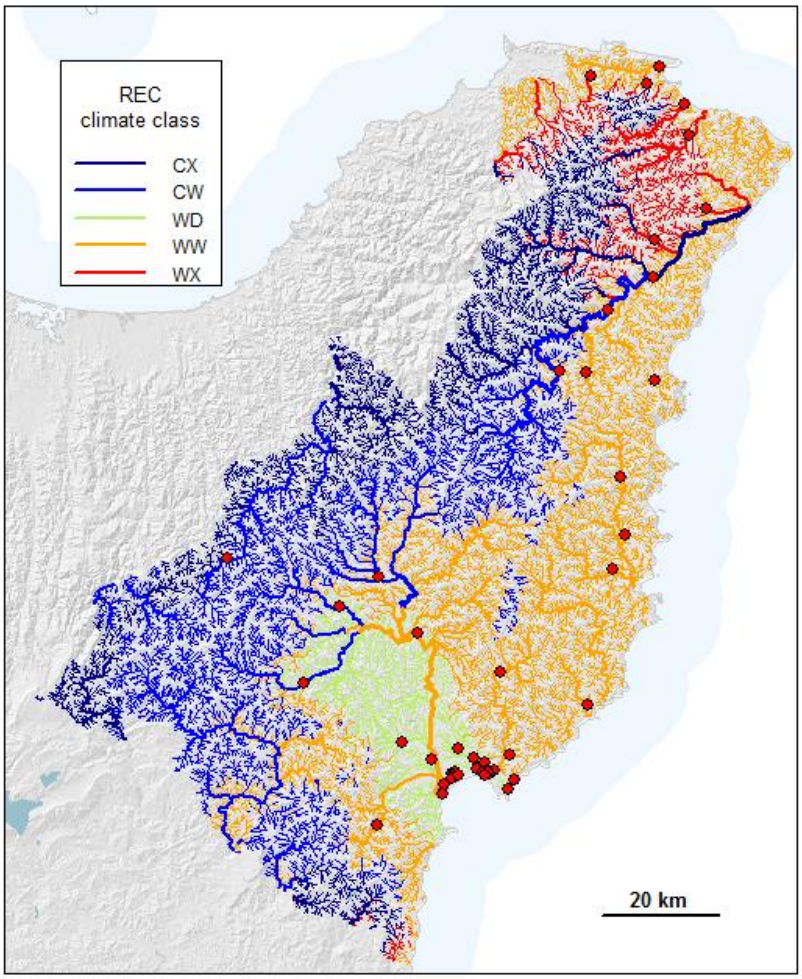

Figure 3-2: GDC water quality monitoring sites in relation to REC climate class.

The current monitoring network is generally not well aligned with climate class. Of the five classes represented within the district only Class WW is evenly represented, with the present number of sites (14) only three short of the 17 required to achieve representativeness (Table 3-3). By contrast, classes CW and CX are under-represented, by six and seven sites respectively, while classes WD and WX are over-represented. By far the most striking discrepancy is for class WD, which represents 8% of total river length but accounts for 37% of GDC sites, and is represented by 13 more sites than required from a representativeness perspective (Table 3-3).

3.3.3 REC source-of-flow class

Virtually all (97.7%) of GDC rivers fall into source-of-flow classes L (low elevation) and H (hill) (respectively 50.7% and 47.0%; Table 3-4), with only 2.3% of rivers classified as M (mountain). Even more than for climate class, source-of-flow class corresponds directly to local topography (Figure 3-3), generally grading evenly from northwest to southeast across the district.

Table 3-4: Distribution of GDC river environments and monitoring sites by REC source-of-flow class. The first five columns for each class show the river length within the Gisborne District, as total km and percentage of all GDC rivers; the number of sites, as total sites and percentage of all GDC sites; and the number of sites per 1000 km of river. The final two columns show the number of sites required to establish representativeness across all classes (N_{sites} (rep)), and the difference between this value and the current number of sites (Delta N_{sites}). Blue shaded squares indicate classes that require more sites to achieve representativeness and orange shaded squares indicate classes that currently have more sites than required for representativeness (assuming the total number of sites remains the same).

Source of flow class	Length (km)	% of total km	Number of sites	% of sites	Sites / 1000 km	N_{sites} (rep)	Delta N_{sites}
L (low elevation)	6256	50.69	33	76.74	5.27	22	-11
H (hill)	5800	46.99	10	23.26	1.72	20	10
M (mountain)	286	2.32	0	0	0	1	1
Total	**12 343**	**100**	**43**	**100**	**3.48**	**43**	**0**

The current monitoring network is strongly skewed towards lowland sites, with 33 and 10 sites in classes L and H, respectively (Table 3-4). Achieving representativeness would require an essentially even distribution across these two classes, and would involve shifting 10-11 sites from class L to class H. Class M requires at most one site, although this is likely to be difficult (if not impossible) to achieve given the lack of road access across this class.

3.3.4 REC climate/source-of-flow class

Combining the REC climate and source-of-flow classes into a composite class provides a finer level of spatial resolution than either class does individually, with ten classes represented by at least one river segment (Table 3-5, Figure 3-4). In general, however, the extra level of resolution does not add greatly to the environmental gradients apparent from REC climate class alone (c.f. Figure 3-2), most notably for climate/source-of-flow class CD/L which is essentially identical to climate class CD.

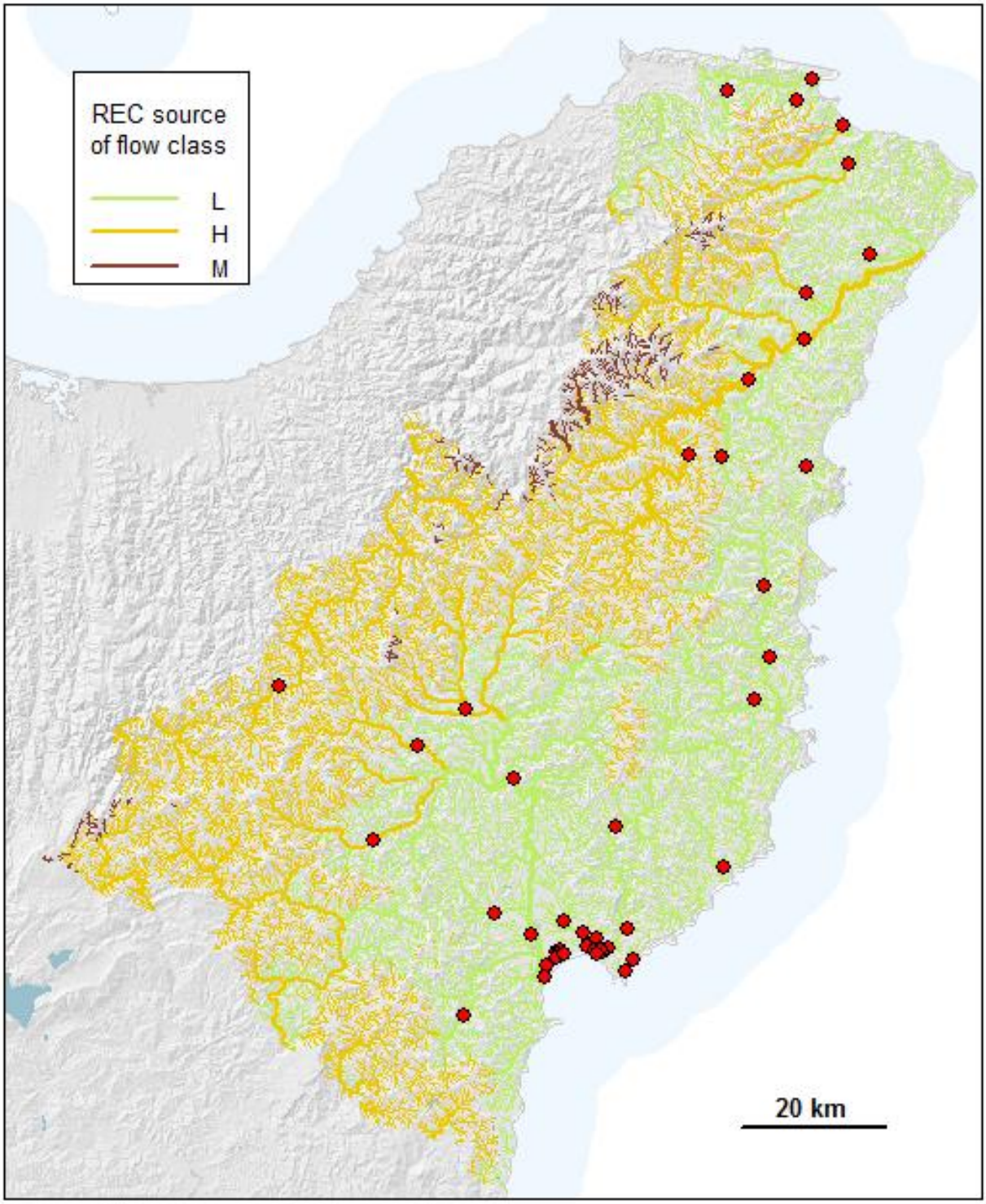

Figure 3-3: GDC water quality monitoring sites in relation to REC source-of-flow class.

Table 3-5: Distribution of GDC river environments and monitoring sites by REC climate / source-of-flow class. The first five columns for each class show the river length within the Gisborne District, as total km and percentage of all GDC rivers; the number of sites, as total sites and percentage of all GDC sites; and the number of sites per 1000 km of river. The final two columns show the number of sites required to establish representativeness across all classes (N_{sites} (rep)), and the difference between this value and the current number of sites (Delta N_{sites}). Blue shaded squares indicate classes that require more sites to achieve representativeness and orange shaded squares indicate classes that currently have more sites than required for representativeness (assuming the total number of sites remains the same).

Climate class	Length (km)	% of total km	Number of sites	% of sites	Sites / 1000 km	N_{sites} (rep)	Delta N_{sites}
WW/L	4592	37.20	14	32.56	3.05	16	2
CW/H	3366	27.28	6	13.95	1.78	12	6
CX/H	1948	15.79	1	2.33	0.51	7	6
WD/L	986	8.00	16	37.21	16.21	3	-13
WX/L	608	4.93	3	6.98	4.93	2	-1
CX/M	284	2.31	0	0	0	1	1
WW/H	251	2.04	0	0	0	1	1
WX/H	232	1.88	3	6.98	12.90	1	-2
CW/L	69	0.57	0	0	0	0	0
CW/M	1	0.01	0	0	0	0	0
Total	**12 343**	**100**	**43**	**100**	**3.48**	**43**	**0**

Consistent with this interpretation, anomalies in the current site distribution in climate/source-of-flow space are similar to those already identified for climate class. Class WD/L is highly over-represented; classes CW/H and CX/H are highly under-represented, and class WW/L is slightly under-represented (Table 3-5). Four other classes (WX/L, CX/M, WW/H, WX/H) which collectively account for 11.1% of total river length require 1-2 sites per class to achieve representativeness. Two of these (WX/L, WX/H) are currently over-represented by one and two sites, respectively, while the other two (CX/M, WW/H) are currently unrepresented and require one site in each class. The remaining two classes (CW/L, CW/M) jointly account for less than 0.6% of river length and to not justify representation at the current level of site density.

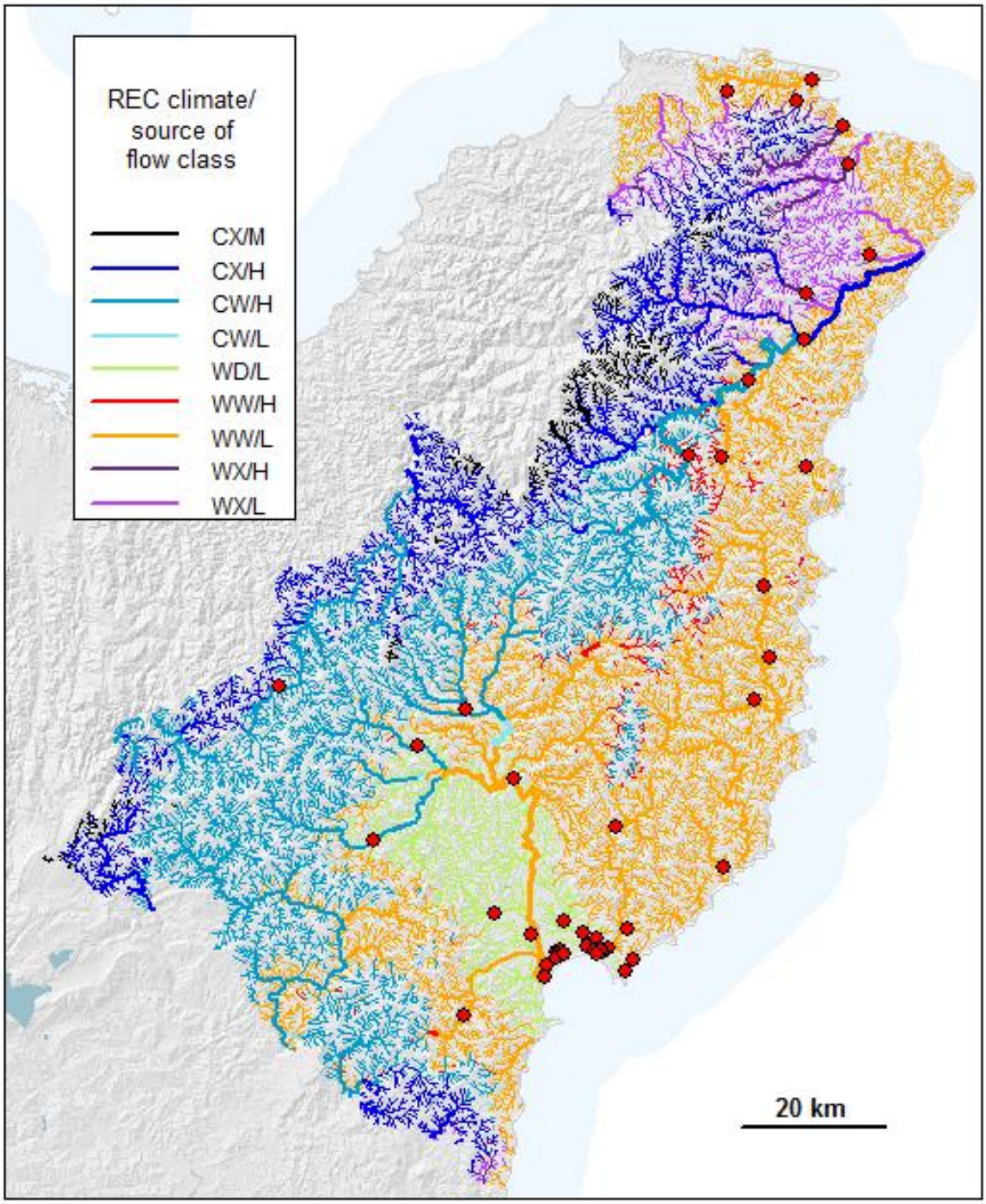

Figure 3-4: GDC water quality monitoring sites in relation to REC climate and source-of-flow class. For plotting purposes a single REC segment in class CW/M has been pooled with class CX/M.

3.3.5 REC geology class

The GDC region is relatively homogenous with respect to catchment geology, with nearly 60% of rivers classed as soft sediment (SS), and a further 25% classed as hard sediment (HS). Class VA (volcanic acidic) accounts for 11.6% of rivers, with the remaining 3.8% classed as either alluvium (Al; 2.2%) or miscellaneous (M; 1.6%; Table 3-6). The two dominant geology classes are approximately aligned with catchment boundaries: most of the Waipaoa catchment, and the smaller coastal catchments south of Tolaga Bay are in class SS, whereas the northern part of the region (including most of the Waipu catchment) is in class HS. Class VA is mainly limited to the Huiarau Range northeast of Lake Waikaremoana, a less well-defined band extending from near Tolaga Bay northwest to the Raukumara Range, and the southwest of Hicks Bay. Class Al essentially coincides with the lower Waipaoa floodplain below Ormond (Figure 3-5).

The current GDC site network is well aligned within geology class SS, with the number of existing sites (26) exactly equal to the number required to achieve representativeness (Table 3-6). By contrast, classes HS and VA are under-represented, with 6 additional sites required in class HS, and two in class VA. By far the most striking discrepancy, however, is for class Al, which accounts for 21% of the existing sites, but represents only 2.2% of river length. The nine current sites in this class include seven on the coastal plain between Awapuni Road and the tidal reaches of the Waipaoa River, together with two on the northwest outskirts of Gisborne city within 5 km of the coast.

Table 3-6: Distribution of GDC river environments and monitoring sites by REC geology class. The first five columns for each class show the river length within the Gisborne District, as total km and percentage of all GDC rivers; the number of sites, as total sites and percentage of all GDC sites; and the number of sites per 1000 km of river. The final two columns show the number of sites required to establish representativeness across all classes (N_{sites} (rep)), and the difference between this value and the current number of sites (Delta N_{sites}). Blue shaded squares indicate classes that require more sites to achieve representativeness and orange shaded squares indicate classes that currently have more sites than required for representativeness (assuming the total number of sites remains the same).

Climate class	Length (km)	% of total km	Number of sites	% of sites	Sites / 1000 km	N_{sites} (rep)	Delta N_{sites}
SS (soft sediment)	7390	59.87	26	60.47	3.52	26	0
HS (hard sediment)	3057	24.77	5	11.63	1.64	11	6
VA (volcanic acidic)	1425	11.55	3	6.98	2.10	5	2
Al (alluvium)	270	2.19	9	20.93	33.30	1	-8
M (miscellaneous)	199	1.61	0	0	0	1	1
Total	**12 343**	**100**	**43**	**100**	**3.48**	**43**	**0**

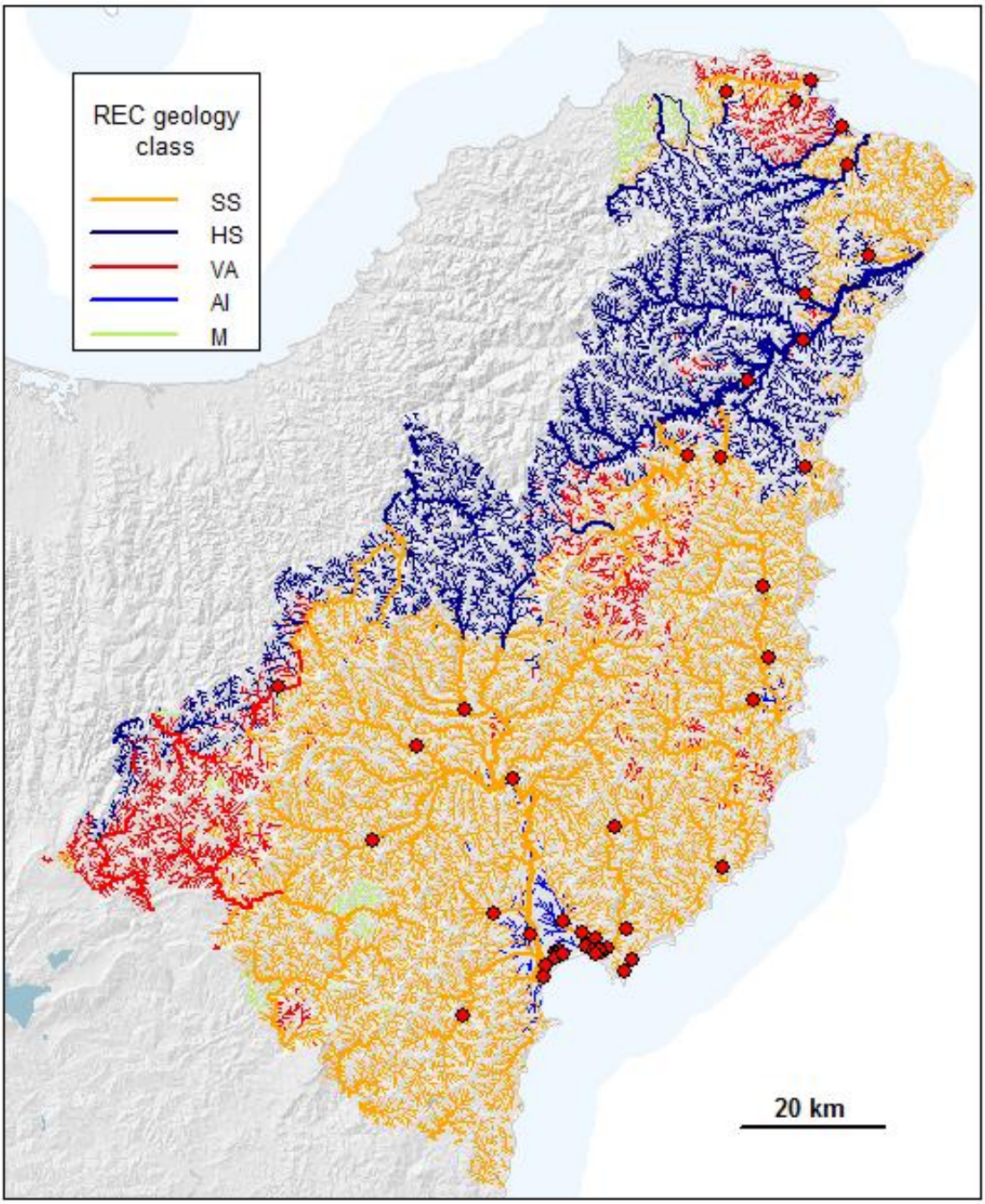

Figure 3-5: GDC water quality monitoring sites in relation to REC geology class.

3.3.6 REC landcover class

The distribution of GDC rivers by REC landcover class parallels their distribution over geology classes, with one class (pastoral; P) accounting for nearly two thirds (63%) or total river length, and two more classes (exotic forest (EF); indigenous forest (IF); each 16%) accounting for most of the remainder. Pockets of scrub (class S) in coastal regions from Tokomaru Bay to Hicks Bay account for 5% of the total (Table 3-7, Figure 3-6). Other landcover classes, primarily urban (U), account for 0.4% of the total.

Table 3-7: Distribution of GDC river environments and monitoring sites by REC landcover class. The first five columns for each class show the river length within the Gisborne District, as total km and percentage of all GDC rivers; the number of sites, as total sites and percentage of all GDC sites; and the number of sites per 1000 km of river. The final two columns show the number of sites required to establish representativeness across all classes (N_{sites} (rep)), and the difference between this value and the current number of sites (Delta N_{sites}). Blue shaded squares indicate classes that require more sites to achieve representativeness and orange shaded squares indicate classes that currently have more sites than required for representativeness (assuming the total number of sites remains the same).

Climate class	Length (km)	% of total km	Number of sites	% of sites	Sites / 1000 km	N_{sites} (rep)	Delta N_{sites}
P (pasture)	7741	62.72	34	79.07	4.39	27	-7
EF (exotic forest)	1954	15.83	1	2.33	0.51	7	6
IF (indigenous forest)	1939	15.71	2	4.65	1.03	7	5
S (scrub)	662	5.36	0	0	0	2	2
U (urban)	34	0.28	6	13.95	176.26	0	-6
B (bare ground)	6	0.06	0	0	0	0	0
T (tussock)	3	0.03	0	0	0	0	0
M (miscellaneous)	1	0.01	0	0	0	0	0
Total	**12 343**	**100**	**43**	**100**	**3.48**	**43**	**0**

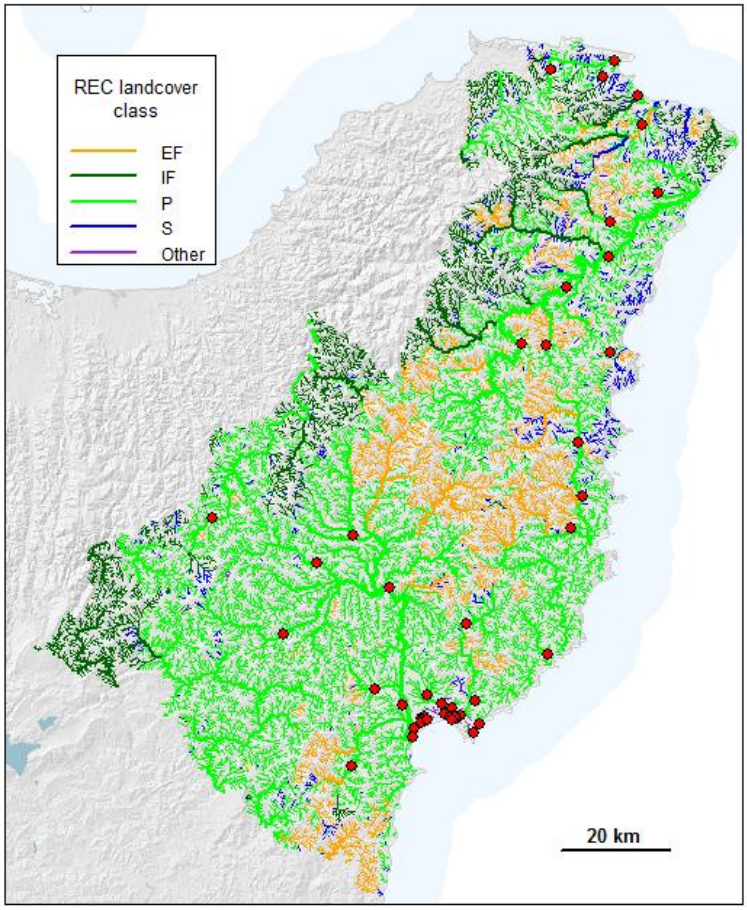

Figure 3-6: GDC water quality monitoring sites in relation to REC landcover class. For plotting purposes, classes U, B, T, and M (collectively 0.4% of total river length) have been pooled as "Other".

The current GDC monitoring network is skewed in favour of landcover classes P and U (over-represented by seven and six sites, respectively), and against classes EF and IF (under-represented by six and five sites, respectively). The over-representation of class P is modest in relative terms (34 current vs. 27 required), but is far more striking for class U where the 0.3% of river length under urban landcover accounts for 14% (6 of 43) of total sites. Likewise, the two forested classes are markedly under-represented, with three current sites totalled across both classes vs. 14 required to achieve representativeness. No current sites occur in class S.

3.4 Representativeness analysis: summary

Most SOE river monitoring programmes operated by New Zealand regional councils have two basic objectives: to make accurate statements about biological and water-quality conditions at regional scales, and to compare biological and water-quality conditions in agricultural, urban and unmodified landcover classes. In some cases, these objectives are mutually exclusive: the first requires a highly representative monitoring network with sites in all classes, and the second requires sufficient within-class replication of sites to detect between-class differences (Larned and Unwin 2012).

We believe that the analysis presented here should be used to inform the design of an updated monitoring network for the Gisborne District, but not to dictate it. Our analysis is just one way of assessing network representativeness, and takes no account of other criteria such as the overall perceived importance of individual river sections, or identifying and prioritising areas subject to the greatest impact. We acknowledge that regional councils will generally have specific issues that will influence the exact layout of their network, over and above any concerns about representativeness. There are historical reasons for monitoring water quality at specific locations including SOE monitoring, resource consent compliance and monitoring impacts of stressors within individual sub-catchments. Consequently, specific locations may be monitored for reasons other than representativeness.

We assume that river length is an appropriate measure of representativeness, but other ecologically meaningful weightings (e.g., flow, riverbed area) could equally well be applied.

Subject to these caveats, our analyses strongly suggest that reducing the number of sites in the immediate vicinity of Gisborne City and Poverty Bay, and redistributing these across the wider region, would be a simple and direct way of improving representativeness in environmental space without compromising SOE monitoring goals. Given the lack of road access to many inland parts of the district, it may well be impossible (or at least impractical) to attain representativeness across all environmental classes, but there appears to be obvious potential to improve coverage of the main under-represented classes. For example, such a transfer could potentially address all of the main imbalances implicit in Tables 3.3 – 3.7, in terms of climate class (exchanging class WD for classes CW and CX); source-of flow class (exchanging class L for class H); climate/source-of-flow class (exchanging class WD/L for classes CW/H and CX/H); geology class (exchanging class Al for class HS); and landcover class (exchanging class P for classes EF and IF).

Section 5 of this report provides further information and recommendations regarding how this information could be used during assessment or re-design of the sampling network.

4 Task 2: Monitoring priorities for environmental parameters

4.1 Introduction

GDC currently undertakes water quality monitoring at 43 riverine sites (Figure 4-1). There are historical reasons for monitoring water quality at these locations including SOE monitoring, resource consent compliance and monitoring impacts of stressors within individual sub-catchments. Consequently, different water quality parameters are measured at different groups of sites and at different frequencies.

The purpose of this task was to compare the current parameters monitored by the GDC with attributes currently identified and indicated as likely future attributes in the proposed NOF. The goal is to provide information that will assist GDC in aligning their current monitoring with that required to meet the proposed NOF. Please note that the proposed NOF is a work in progress and will be expanded over time. We provide recommendations based on the information in the Proposed Amendments to the National Policy Statement for Freshwater Management – a Discussion Document that was released in 2013 (Ministry for the Environment 2013). We also use information from reports created as part of the National Environmental Monitoring and Reporting (NEMaR) project which aimed to achieve more consistent and dependable regional SOE monitoring and reporting on freshwaters in New Zealand (see the Glossary for definition of terms used in the NPSFM and NOF).

Please note that the recommendations for priorities for monitoring individual parameters that follow below are based on attributes listed in the proposed NOF and their relevance to SOE monitoring. However, it should be noted that parameters are monitored for reasons other than SOE monitoring, which will affect their final priority for measurement.

4.2 Current GDC riverine water quality monitoring network

GDC's current water quality monitoring network is divided into two regions; the Waipaoa-Gisborne and East Coast region (Figure 4-1). Within these regions there are several sets of environmental parameters that are measured. The Waipaoa-Gisborne sites are divided into three groups, each of which have different, but overlapping, combinations of water quality parameters that are measured. Within these three groups, *E. coli* concentrations are monitored at some sites and not at others. In general the same water quality parameters are measured at the 19 riverine East Coast sites, although *E.coli* is also only measured at some sites. Most of the Waipaoa-Gisborne sites are monitored monthly, apart from 7 sites on drains that are monitored bimonthly. All East Coast sites are monitored bimonthly. In total, seventeen sites are visited monthly, while 25 are visited bimonthly to collect water quality samples (Figure 4-1 and Figure 4-2).

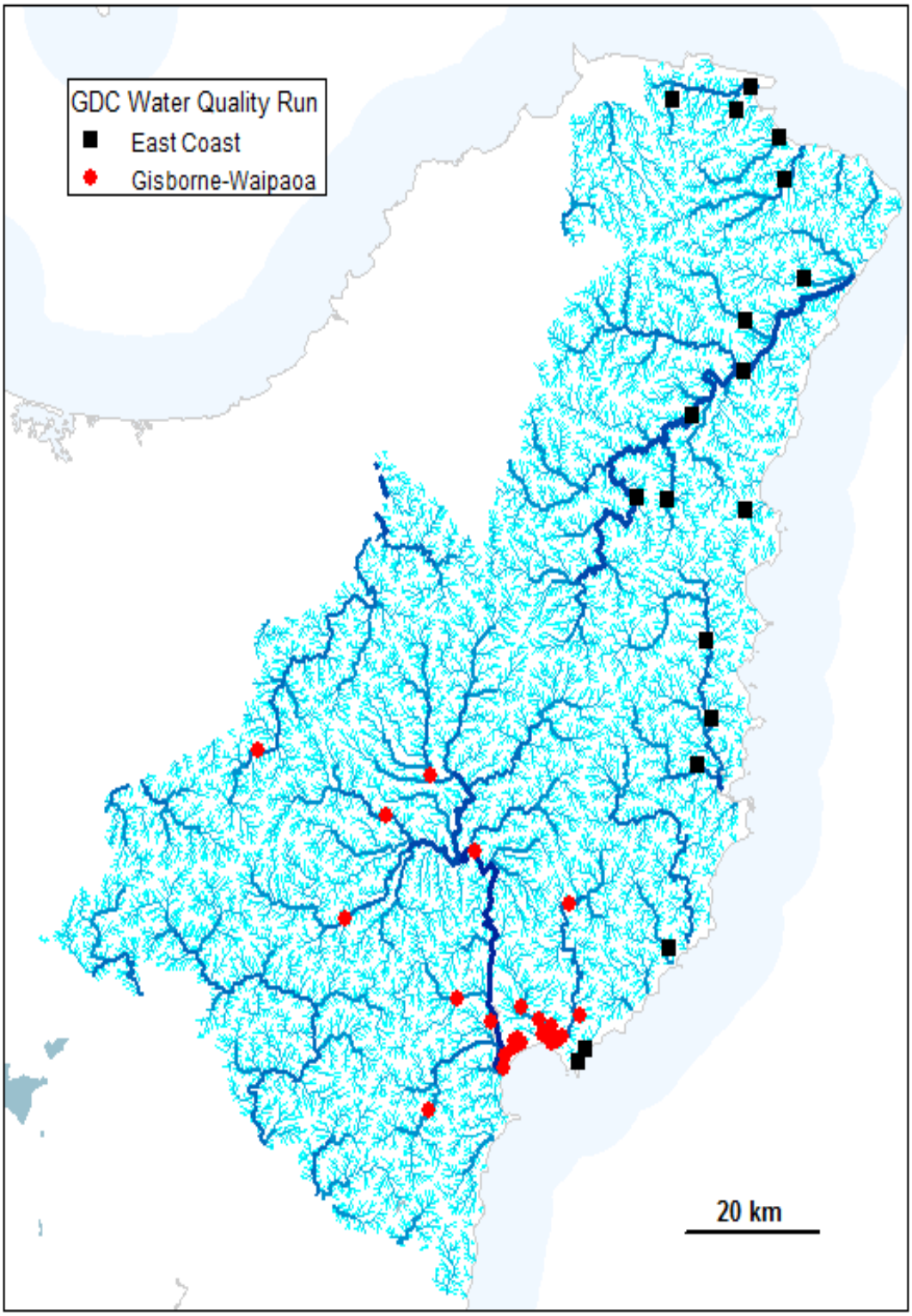

Figure 4-1: GDC water quality monitoring sites. Gisborne-Waipaoa sites are visited monthly and East coast sites bimonthly.

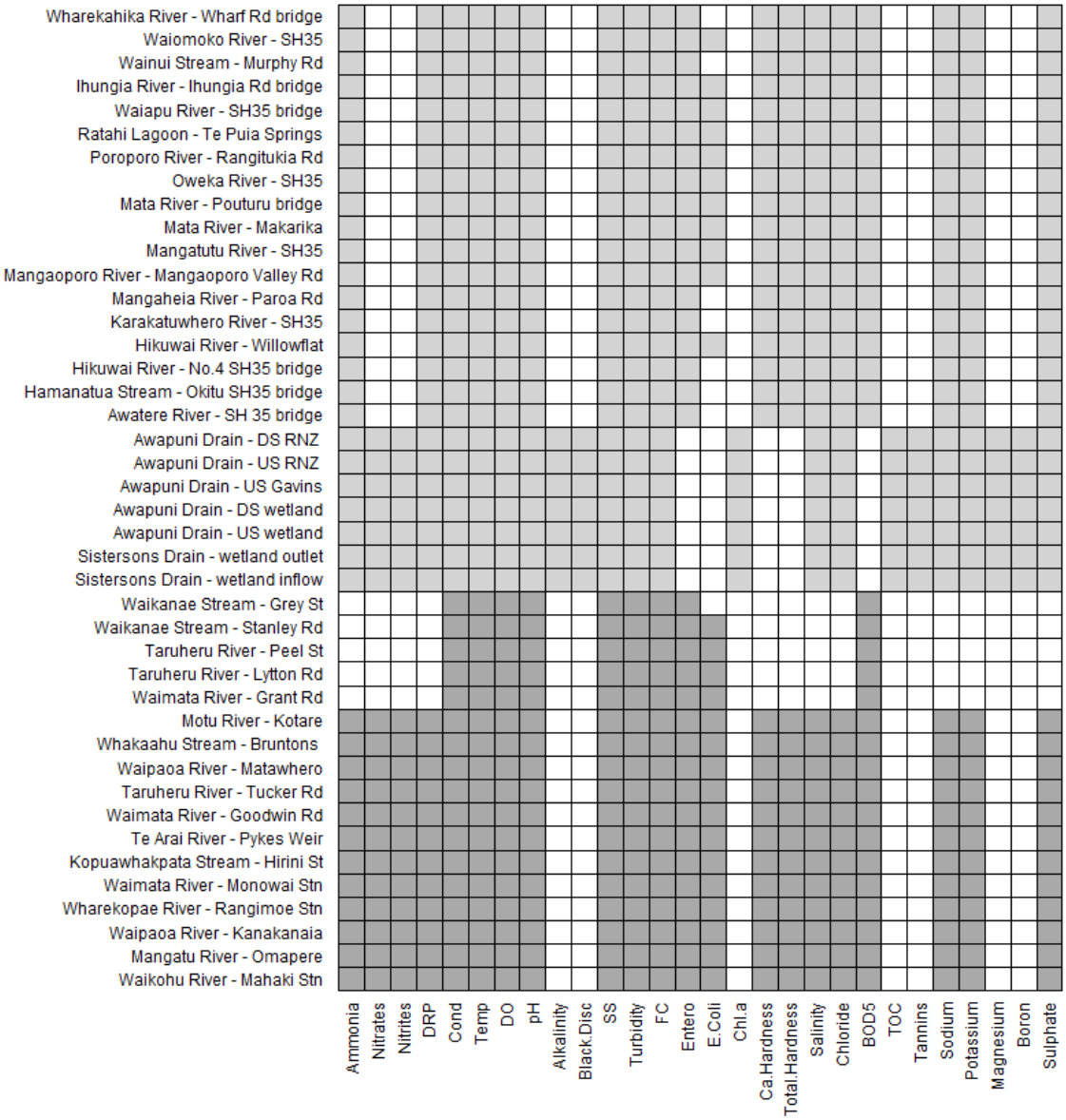

Figure 4-2: Water quality parameters measured by GDC at 42 monitoring sites. Dark grey indicates monthly measurements, light grey indicates bimonthly measurements. SS: suspended sediment, FC: Faecal coliforms, Entero: Enterococci, Chl.*a*: Chlorophyll *a*, TOC: total organic carbon.

For a monitoring network to be a useful indicator of region-wide environmental state or to be able to detect differences in environmental parameters between sites or groups of sites the individual parameters need to be measured in a sufficient number of locations. A patchy monitoring network where a wide range of parameters are each monitored at only a few sites makes it very difficult to compare conditions between sites or groups of sites or to report region-wide conditions. However, it is also not cost-effective to monitor all parameters at all sites. The proposed NOF recommends a compromise where a core set of compulsory parameters are measured at all sites and specific additional parameters are also measured at some sites, depending on the additional values associated with that waterway.

GDC currently collects information on 28 different water quality parameters. Many of these are measured at most sites: water temperature, conductivity, dissolved oxygen, pH,

suspended solids, turbidity and faecal coliforms are measured at all sites, at least bimonthly (Figure 4-2). Ammonia, dissolved reactive phosphorus (DRP), enterococci, salinity, chloride, BOD5, sodium, potassium and sulphate are measured at more than 80% of sites, at least bimonthly (Figure 4-2). This means that these parameters can be used to give a relatively robust picture of the state of rivers across the region. The high number of sites at which they are measured also improves our ability to detect differences between groups of sites or between the mean of a specific group and guideline values for a parameter.

However, seven sites on Sistersons and Awapuni drains are the only sites at which alkalinity, black disk water clarity, chlorophyll *a,* total organic carbon, tannins, magnesium and boron levels are monitored. The collection of this information at these specific sites may be useful for reasons such as resource consent compliance. However, if the goal of the monitoring is to report on conditions across the region, then monitoring these parameters at only seven sites is not particularly effective.

Similarly, consideration should be given to the reasons for measuring sites on different time-frames. It may make sense for areas that are under more pressure from stressors, such as the Gisborne-Waipaoa sites, to be monitored more frequently than other sites, e.g., the East Coast sites, so that changes in condition or trends can be detected more rapidly. However, if the sole purpose of the network is to report region-wide state and trends then monitoring all sites on a similar time-frame may be more cost-effective.

4.3 Comparison of current water quality parameters measured by GDC with proposed NOF attributes

The following sections provide an overview comparison of the proposed attributes in the NOF with the parameters that GDC currently measures, including:

1. Attributes that are included in the proposed NOF
2. Proposed NOF attributes that GDC currently measure
3. Recommendations for addition of parameters that are in the proposed NOF but not currently monitored by GDC
4. The current spatial extent of monitored parameters
5. The indicated required monitoring frequency in the proposed NOF
6. Recommended priorities for continued monitoring of parameters currently monitored by GDC but no in the proposed NOF, and
7. The importance of hydrological information associated with water quality parameters.

Please see Section 4.4 for more a more detailed discussion of individual parameters.

4.3.1 Environmental parameters recommended in the NOF

The proposed NOF is currently a discussion document with some values identified and attributes and bands or states assigned to a subset of those. Additional future attributes have been identified for which attribute states will be assigned once further information is collated. Two values, ‘ecosystem health’ and ‘human health – secondary contact’, have been

identified as compulsory for all waterways (Table 4-1). Additional values, including non-compulsory values in the proposed NOF and any others that are regionally important, also need to be considered for water bodies. Thus, a core set of compulsory attributes are proposed to be measured at all monitoring sites with an additional set of attributes for each site depending on the additional values that have been assigned to that location.

Table 4-1: Measureable attributes associated with values identified in the NOF. C indicates confirmed attributes that have states (bands) assigned in the proposed amendment to the National Policy Statement for Freshwater Management. F indicates likely future attributes. Attributes are yet to be assigned to other Values.

	Attributes																
Values	Nitrate toxicity	Ammonia toxicity	Dissolved oxygen	Temperature	pH	*E. coli*	Periphyton	Cyanobacteria (planktonic)	Cyanobacteria (benthic)	Cyanobacteria (not defined)	Clarity	Sediment	Heavy metals	Organic contaminants	Pathogens	Fish	Invertebrates
Ecosystem health*	C	C	C	F	F		C					F				F	F
Human health-secondary contact*						C		C	F								
Mahinga kai	F	F					F			F	F	F	F	F	F	F	

*Compulsory values for all sites.

Currently the compulsory attributes with assigned states are nitrate toxicity, ammonia toxicity, dissolved oxygen downstream of point sources of pollution, *E. coli,* periphyton and planktonic cyanobacteria (Table 4-1). Under the proposed NOF these attributes would need to be monitored at all sites. Additional proposed compulsory attributes that may require monitoring include temperature, pH, benthic cyanobacteria, sediment, fish and invertebrates (Table 4-1).

River sites at which mahinga kai is considered an important value will likely need to be monitored for nitrate toxicity, ammonia toxicity, periphyton, fish, sediment, cyanobacteria, clarity, heavy metals, organic contaminants and pathogens (Table 4-1). It should be noted that while some of these attributes have the same name as attributes assigned to other values, the methods for measuring these attributes and the numerical assignation of attribute state bands may vary by value. For example, the abundance or edibility of particular mahinga kai species may be affected by different levels of suspended sediment (i.e., a different attribute state) than overall ecosystem health.

4.3.2 Proposed NOF attributes currently measured by GDC

GDC currently measures nine of the 16 attributes that are included in the proposed NOF, in at least seven sites (Table 4-2). These parameters are nitrate, ammonia, dissolved oxygen, temperature, pH, *E. coli,* periphyton, sediment and clarity. This includes indicated future attributes and those that have proposed attribute states already assigned. The 16 attributes also includes those that are indicated as being compulsory for the values ‘ecosystem health’ and ‘human health-secondary contact’ and attributes assigned to the optional value ‘mahinga kai’.

Table 4-2: Comparison of current and indicated future NOF attributes with parameters GDC measures. The columns indicate whether the attributes have states assigned, are compulsory, the indicated units and the indicated limit in the proposed NOF. The next columns are the sampling frequency required to provide data relevant to the limit, whether Gisborne District Council (GDC) currently measures the attribute and the number of sites and sampling frequency.

	Proposed NOF					GDC	
	Have states?	Compulsory?	Indicated units	Indicated limit based on	Sampling frequency estimate	GDC currently measure?	No sites /frequency
Nitrate toxicity	Y	Y	NO3-N mg/L	Annual median	>annual	Y	12 monthly 7 bimonthly
Ammonia toxicity	Y	Y	NH4-N mg/L	Annual median	>annual	Y	12 monthly 25 bimonthly
Dissolved oxygen	Y	Y (below point sources)	mg/L	7 day mean minimum and 1 day minimum over summer	Continuous over summer? Subset of sites?	Y	17 monthly 25 bimonthly
Temperature	N	Y			Continuous over summer? Subset of sites?	Y	17 monthly 25 bimonthly
pH	N	Y			Continuous over summer? Subset of sites?	Y	17 monthly 25 bimonthly
E. coli	Y	Y	no/100 ml	Annual median	>annual	Y	16 monthly 14 bimonthly
Periphyton	Y	Y	chl *a* mg/m^2 visual estimates?	Annual maximum	monthly	Y	7 bimonthly
Cyanobacteria (planktonic)	Y	Y	cells/L or mm^3/L	Two year average	?	N	
Cyanobacteria (benthic)	N	Y				N	
Clarity	N	N				Y (black disk) Y (Turbidity)	Black disk: 7 bimonthly Turbidity: 17 monthly 25 bimonthly
Sediment	N	Y				Y (SS)	17 monthly 25 bimonthly
Heavy Metals	N	N				N?	
Organic contaminants	N	N				N	
Invertebrates	N	Y				N	
Pathogens	N	N				N?	
Fish	N	Y				N	

Of the 12 attributes that are proposed to become compulsory for all sites, GDC currently measures eight of these, in at least seven sites (Table 4-2). The eight proposed compulsory parameters that GDC measure are nitrate, ammonia, dissolved oxygen, temperature, pH, *E. coli*, periphyton and sediment.

4.3.3 Proposed NOF attributes not currently monitored by GDC

The proposed compulsory attributes that GDC do not currently measure are planktonic and benthic cyanobacteria, aquatic invertebrates and fish (Table 4-2). The other additional attributes that are associated with non-compulsory values that GDC does not currently monitor are heavy metals, organic contaminants and pathogens (Table 4-2).

Below we provide some general information regarding each of these parameters, please see section 4.4 for further details regarding monitoring priorities for these and other parameters.

Very few details are provided in the proposed NOF for heavy metals, organic contaminants and pathogens. These attributes contain a large groups of measurable indicators and we cannot provide advice on the specific parameters that should be monitored. These decisions should be made on a case-by case basis using knowledge of the local environment.

Planktonic and benthic cyanobacteria are currently monitored at relatively few sites nationwide and generally only in locations known to have a problem with cyanobacteria and/or that have high recreation value. Guidelines are available that provide information regarding how to monitor cyanobacteria (see Ministry for the Environment and Ministry of Health 2009).

Most regional councils sample aquatic macroinvertebrates as a standard part of their biomonitoring programme. For example, Environment Waikato, Environment Southland, Taranaki Regional Council and Horizons Regional Council started biological monitoring in the 1990s and monitor at least annually in summer, when river flow is generally the lowest and ecological stress the greatest (Snelder et al. 2010). Invertebrate monitoring is an indicated future attribute in the compulsory value ‘ecosystem health’.

The proposed NOF currently has very few guidelines regarding sediment. Both suspended sediment and sediment settled on the stream-bed can cause ecological and aesthetic problems in waterways. Suspended sediment load can be measured by total suspended sediment and water clarity by the black disc method, as GDC currently does. Guidelines for stream-bed sediment measurements can be found in Clapcott et al. (2011).

Monitoring fish communities is indicated as a future compulsory attribute in the proposed NOF, however, routine fish monitoring is a relatively new development for SOE reporting, with less than half of councils currently undertaking fish monitoring as part of their SOE monitoring (Davies-Colley et al. 2012). Fish monitoring involves operators trained in the use of electric fishing machines and in fish identification. While monitoring fish communities is proposed as a compulsory attribute in the NOF, we recommend the GDC seeks further advice before beginning a fish monitoring programme due to the recent addition of this parameter to SOE monitoring and the relatively high cost of the initial training of staff. Standardised guidelines for fish sampling have recently been developed (see Joy et al. 2013).

Additional parameters that are not included in the proposed NOF but that may be useful to monitor include total N and total P, which are monitored by many other councils and are useful indicators of total nutrient loads. Davies-Colley et al. (2012) and Kelly et al. (2014) recommend that total N and total P be included in SOE monitoring programmes. Similarly, for sites where macrophytes are a potential issue, monitoring would be beneficial. Consideration could also be given to monitoring physical habitat, as suggested in Davies-Colley et al. (2012). In McBride et al. (2013) other potentially useful parameters to measure infrequently, perhaps every five years, include major ions and coloured dissolved organic matter (CDOM), which is an indicator of river plumes and useful for interpreting light attenuation data.

4.3.4 Current spatial extent of monitored parameters

Many of the proposed compulsory attributes in NOF that are currently monitored by GDC are already monitored at most sites. For example, ammonia and dissolved oxygen are measured in 37 sites at least bimonthly. However, several of the proposed compulsory values are only measured in a few sites and over a relatively limited spatial extent. For example, periphyton is only measured bimonthly in seven sites within the Sistersons and Awapuni drains (Figure 4-2). Likewise nitrate levels are monitored monthly at 12 sites and bimonthly at seven monitoring sites. Under the proposed NOF these parameters will likely be compulsory at all sites.

4.3.5 Indicated monitoring frequency for attributes in the proposed NOF

Few details are provided in the proposed NOF regarding recommended frequency of sampling of different parameters. The indicated limits for nitrate and ammonia toxicity and *E. coli* in the proposed NOF are based on annual median values, indicating that monitoring must occur more frequently than annually. The chlorophyll *a* limits for periphyton are based on an annual maximum that can be exceeded no more than twice, based on a monthly monitoring regime.

Often the frequency of monitoring varies for individual parameters. For example, many councils conduct monthly water quality and periphyton monitoring (e.g., Environment Canterbury; Kelly et al. 2014), while aquatic invertebrate sampling is generally either annual or biannual. Aquatic invertebrates can be monitored less frequently than water quality parameters as aquatic invertebrate communities reflect environmental conditions over a longer period of time than chemical parameters. Kelly et al. (2014) in a recent review of Environment Canterbury's state of the environment water quality monitoring programme recommended monthly monitoring at all sites for all parameters except aquatic invertebrates (see Appendix A).

Certain other water quality parameters, such as temperature and dissolved oxygen vary over the course of a day, meaning that one-off measurements at a site are not comparable between sites or over different site visits to the same site. Davies-Colley et al. (2013) suggests that continuous monitoring of temperature, dissolved oxygen and pH parameters would be ideal, particularly during mid-summer when conditions are likely to be most stressful. Monitoring such parameters continuously will require investment in data loggers. As this is a new expense it may be an option at a subset of sites, or at sites that are likely to be close to any indicated thresholds between attribute states. In the proposed NOF it is currently indicated that continuous dissolved oxygen measurements may only be required below wastewater inputs. One-off spot measurements are still likely to be useful as they can

be used to calibrate continuous monitoring, but ideally they should be collected at the same time of day (± 1 hour) on each site visit (Davies-Colley et al. 2013).

The National Environmental Monitoring and Reporting (NEMaR) programme recommended monthly monitoring for their proposed core set of water quality parameters, ideally with continuous monitoring of flow, temperature and dissolved oxygen (See Appendix B of this report for a copy of the core parameters recommended in Davies-Colley et al. 2012 and Schmidt 2012). They also recommended monthly periphyton measurements and annual invertebrate monitoring with fish, macrophytes and physical habitat monitored less frequently, as resources allow.

The frequency of monitoring for some parameters may also vary throughout the year. For example, for the purposes of SOE monitoring, monthly monitoring of *E. coli* may be sufficient to detect long-term trends and to report on region-wide patterns. However, more frequent monitoring may be required over summer in order to detect conditions that may be hazardous to recreational users of a waterway. This more intensive monitoring may be conducted over the period of greatest risk and only at sites with high recreational value.

See section 4.4 for details for individual parameters.

4.3.6 Priority for continued monitoring of parameters measured by GDC but not currently included in the proposed NOF

GDC currently monitors 18 parameters that are not included as attributes in the proposed NOF. However, the NOF is not finalised, with more attributes likely to be added. Thus, the attributes listed in the proposed NOF should not be used as the complete list of parameters to monitor. In addition, there are multiple reasons for including environmental parameters in a monitoring programme. For example, long-term records are very important for assessing trends over time and small changes in protocols or the parameters measured can mean that meaningful time trend analysis is not possible (Davies-Colley et al. 2012). Factors to take into account when deciding whether to continue monitoring parameters not currently included in the proposed NOF include 1) the value of a long-term record of a parameter at a site, 2) whether the parameter relates to other relevant values in a catchment, such as drinking water quality and 3) whether the parameter is measured for reasons such as resource consent monitoring and should continue to be monitored, but can be funded by the resource consent holder.

We are aware that GDC is in the process of determining values and attributes for certain catchments. This will be a very useful process for determining additional attributes (parameters) to the current proposed NOF attributes that could be measured at all, or a subset, of sites.

In order to meet the proposed NOF, GDC will most likely need to add attributes to their current monitoring programme. Some of these may be relatively expensive, such as invertebrate monitoring, which involves 1 to 2 hours of processing time by a skilled technician (see Section 4.4, McBride et al. 2013 and Storey 2012 for estimated costs). The spatial extent of other currently monitored parameters will most likely need to expand. For example, in order to meet the proposed NOF guidelines monitoring of nitrate and periphyton monitoring will most likely need to be increased beyond the 7 and 19 sites respectively that they are currently monitored at.

To assist in prioritising which parameters to continue monitoring we have prepared Table 4-3. This table lists the parameters that GDC monitor that are not in the current version of the proposed NOF. Parameters are ranked as either high, moderate or low priority for continued monitoring. The priorities are assigned based on assessed value of the parameter to SOE monitoring. The additional reasons for monitoring parameters listed above should also be considered when deciding whether to continue monitoring a parameter.

See section 4.4 for detailed discussions of these parameters, as well as those included in the proposed NOF.

Table 4-3: Summary and recommendations for monitoring of parameters currently monitored by GDC but not included in the proposed NOF. The number of sites and the parameter is measured at monthly, bimonthly and in total are included, as well as a description of the usefulness of the parameter and a recommended priority for continued monitoring based on the parameter's usefulness for an SOE monitoring network.

	Current monitoring				
Parameter	**Sites monthly**	**Sites bimonthly**	**Sites total**	**Description**	**Priority to continue monitoring**
DRP	12	25	37	Dissolved Reactive Phosphorus, measure of instream nutrients, available for uptake by plants	HIGH
Nitrite	12	7	19	Nitrite-N, rapidly converts to nitrate in most rivers	LOW
Conductivity	17	25	42	Field measurement easy, measured by many other councils. Can indicate temporal trends in nutrient inputs.	HIGH
Calcium hardness (CaCO3)	12	18	30	Can influence toxicity of pollutants to organisms and taste of drinking water.	LOW for river SOE monitoring, but HIGH for drinking water standards. Monitor in locations where drinking water is extracted?
Total hardness	12	18	30	Can influence toxicity of pollutants to organisms and taste of drinking water. Has an aesthetic guideline value for drinking water (Ministry of Health 2008)	LOW for river SOE monitoring, but HIGH for drinking water standards. Monitor in locations where drinking water is extracted?
Magnesium†	0	7	7	Influences water hardness	LOW
Chloride†	12	25	37	Indicator of salinity. Has an aesthetic guideline value for drinking water (Ministry of Health 2008)	LOW for river SOE monitoring MODERATE for ground and surface water in areas where drinking water is extracted
Salinity	12	25	37	Has an aesthetic guideline value for drinking water (Ministry of Health 2008)	LOW for river SOE monitoring MODERATE for ground and surface water in areas where drinking water is extracted
Sulphate	12	25	37	Has an aesthetic guideline value for drinking water (Ministry of Health 2008)	LOW for river SOE monitoring MODERATE for ground and surface water in areas where drinking water is extracted
Sodium†	12	25	37	Important cation in New Zealand rivers, influences water taste Has an aesthetic guideline value for drinking water (Ministry of Health 2008)	LOW for river SOE monitoring MODERATE for ground and surface water in areas where drinking water is extracted

	Current monitoring				
Parameter	**Sites monthly**	**Sites bimonthly**	**Sites total**	**Description**	**Priority to continue monitoring**
BOD5	17	18	35	The amount of dissolved oxygen required by microorganisms to break down organic matter in a water sample. A measure of organic pollution	LOW for SOE, MODERATE below wastewater discharges
Faecal coliforms	17	25	42	Faecal coliforms group (includes *E. coli*) indicates that organic, possibly faecal contamination may have occurred.	LOW. *E. coli* is identified as the preferred faecal indicator organism in freshwater (MfE 2002)
Enterococci	17	18	35	Preferred faecal indicator organism for marine waters. Should not be used in freshwaters as Enterococci can multiply from natural sources, such as leaf decay (MfE 2002)	LOW for freshwater SOE
Alkalinity	0	7	7	Buffering capacity: capacity to neutralise acid or alkalines	LOW, reconsider for sites where known acidic inputs occur
Total organic carbon	0	7	7	Recommended by ANZECC (2000), can influence toxicity of metals etc	LOW for SOE monitoring, MODERATE in locations with known organic matters discharges.
Tannins	0	7	7	Natural organic compound that leaches from decaying vegetation, turns water a tea-like colour and reduces water clarity.	LOW
Potassium	12	25	37	Found in certain fertiliser, influences plant growth	LOW
Boron	0	7	7	Trace element of volcanic rocks and sedimentary rocks from marine waters. Used in industrial chemical manufacturing.	LOW for freshwater SOE monitoring, retain in freshwater sites where values are close to or exceed ANZECC guidelines of 370 µg/L for freshwaters. Retain in Resource consent monitoring if required

† Note that Environment Southland reported in 2012 that they were adding monitoring of major cations and anions, including chloride, bromide, magnesium, potassium and iron to their river monitoring programme to characterise their chemistry in more detail, as a way to determine surface-groundwater interactions and identify sources of contamination.

4.3.7 The importance of hydrological data

The timing and magnitude of high and low river flows often have pervasive effects on river ecosystems. For example, floods and droughts affect aquatic invertebrate and periphyton communities, the amount of sediment suspended in the water column or on the stream bed, the input of nutrients into a stream and many other factors. Because many water quality parameters are subject to either dilution (decreasing concentration with increasing river flow) or land run-off (increasing concentration with increasing river flow, e.g., total phosphorus), it is important to have flow measurements associated with each water quality measurement. This means that data can be flow adjusted before looking for temporal trends in water quality to remove the effect of changes in flow on water quality parameter concentrations. More directly, the discharge of a river can be used to calculate nutrient and sediment loads for a site. Thus, it is recommended that, where possible, continuous hydrological data are collected at or near water quality monitoring sites (e.g., Kelly et al. 2014). However, having

continuous water level monitoring stations at all sites is generally not feasible. Thus, sites could that are not continuously gauged could have discharge readings taken during water quality measurement visits or a water height staff-gauge installed at the site that is read on every site visit. If a water height staff gauge is installed several discharge recording will be necessary to create relationships between water height and discharge readings but ultimately, as long as floods do not reshape the channel, just water stage can be recorded (Davies-Colley et al. 2012). Where these direct methods are not possible, models that predict river flow from nearby gauging stations may be able to be developed (e.g., Booker and Woods 2014). However, the relationships and the uncertainties inherent in such models should be quantified (Snelder et al. 2010).

4.4 Recommended continued monitoring priorities for individual parameters currently measured by GDC and included in the proposed NOF

Below we include a summary of recommended monitoring priorities for all parameters currently monitored by GDC as part of their water quality monitoring network and the parameters included in the proposed NOF. Please note that our recommendations relate to the usefulness of parameters for SOE monitoring purposes. There may be additional reasons which alter the priority of different parameters, such as for monitoring drinking water quality or outputs from known pollution sources. These reasons, plus the value of long-term data sets, should also be taken into consideration when deciding on the final priority of parameters to measure.

For comparison and interest Appendix A lists the parameters recommended for river SOE monitoring in a recent review of Environment Canterbury's monitoring network (Kelly et al. 2014). Appendix B lists the core parameters recommended for river water quality monitoring by the NEMaR project (Davies-Colley et al. 2012). Further details of the sampling procedures of other councils can be found in Davies-Colley et al. (2012). For example, 11of 16 councils conduct monthly water quality SOE sampling while the others sample either bi-monthly or quarterly.

McBride et al. (2013) provides a breakdown of costs for some components of SOE monitoring. Costs per site for macroinvertebrate sampling, including a specific site visit to collect samples, laboratory processing costs and analysis were estimated to be approximately $1500 (see McBride et al. 2013). Storey (2012) in a report prepared for GDC quoted invertebrate sample processing costs at ~$250 per sample, not including quality control (valid in 2012). Cost estimates are also provided for fish and physical habitat surveys, continuous temperature data loggers and hydrometric monitoring.

4.4.1 Conductivity

NOF level:	Not currently included
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, 17 sites monthly, 25 sites bimonthly
Priority for continued measurement:	HIGH

Conductivity is a measure of the ability for water to conduct an electrical current. It is correlated with the concentration of dissolved organic ions in the water. These ions may be from naturally occurring minerals, but also include human contaminants such as nutrients. Thus, conductivity can be influenced naturally by the geology of the catchment, but also by inputs of nutrients and organic matter.

Conductivity is not currently included as an attribute in the proposed NOF. However, trends in conductivity can indicate changes in water quality caused by human activities. Measuring conductivity using a meter in the field is relatively quick. Conductivity is also routinely measured by other councils (Snelder et al. 2010, Kelly et al. 2014) and has been historically measured by GDC. For these reasons, we recommend that conductivity should be given a high priority for continued measurement.

Please note that as conductivity varies with temperature, any field meters should have probes that correct for temperature.

4.4.2 Temperature, dissolved oxygen and pH

NOF level:	Dissolved oxygen has attribute states, pH and temperature are indicated future attributes
NOF value:	Ecosystem health
NOF indicated measurement frequency:	Potentially short term continuous measurements over high stress periods with additional spot measurements for calibration.
GDC measures:	Yes, 17 sites monthly, 25 sites bimonthly
Priority for continued measurement:	HIGH for spot measurements Recommend investigating options for continuous records using loggers.

Water temperature alters the rates of physical and chemical processes, for example the solubility of dissolved oxygen, and also affects the metabolic rate and growth of most aquatic organisms. High temperatures can impose thermal stress and be lethal to aquatic organisms.

Dissolved oxygen is an essential component of freshwater as it is a measure of the life-supporting capacity of waters. Low dissolved oxygen levels can impair growth or respiration of organisms and very low oxygen levels (anoxia) can kill aquatic organisms. Dissolved oxygen is subject to many influences such as natural variation in water temperature, water flow, salinity, plant growth and bacterial decomposition. In addition, in waterways with high levels of organic material low oxygen levels can occur when bacterial use of oxygen is greater than the production of oxygen by photosynthesis and replenishment from the atmosphere.

pH is a measure of the concentration of hydrogen ions in water. The pH scale is a base-10 logarithmic scale and ranges from 0 to 14. The surrounding geology and source of water often determines the pH at a river site. pH of water generally has few direct effects on aquatic organisms, but does influence many other variables, such as the toxicity of ammonia and metals to aquatic organisms.

Water temperature, dissolved oxygen and pH co-vary daily. Dissolved oxygen and pH fluctuate in response to the metabolic cycles of plants and temperature changes over time as solar radiation levels vary. Due to these natural fluctuations, spot measures of dissolved

oxygen, pH or temperature have relatively little value for comparisons between sites. However most current SOE monitoring in New Zealand involves only 'snap-shot' measurements of these parameters during daytime hours. This likely under-estimates potentially stressful periods and conditions. Davies-Colley et al. (2013) prepared a report for the Ministry for the Environment outlining how to protect the value 'ecosystem health' for the attributes temperature, pH and dissolved oxygen and recommended that continuous monitoring of pH, temperature and dissolved oxygen were ideally required, at least during potentially stressful periods, such as mid-summer. However, the authors also recognised that while continuous measurement of temperature using loggers is feasible, continuous monitoring of dissolved oxygen and pH are significantly more challenging (Davies-Colley et al. 2013).

Most councils currently measure water temperature, pH and dissolved oxygen in their SOE water quality monitoring programmes using spot measurements (Kelly et al. 2014), with several councils also undertaking limited continuous monitoring of some attributes at a subset of sites. For example, since 2010, Environment Canterbury (Kelly et al. 2014), Horizons Regional Council (Snelder et al. 2010) and Greater Wellington Regional Council (Perrie et al. 2012) have been monitoring continuous water temperature in a range of sites.

Continuous measurements of temperature over summer is indicated as required in the proposed NOF while guidelines for pH and dissolved oxygen have not been released yet. Dissolved oxygen measurement may only be required below point sources of pollution.

While spot measurements of water temperature, dissolved oxygen and pH may not capture stressful conditions they do help calibrate any loggers that are used (Davies-Colley et al. 2013; McBride et al. 2013). In addition, as collection of the data using field meters is relatively quick, we recommend that spot measurements of pH, dissolved oxygen and pH should continue to be collected. Ideally these measurements would be collected at the same time of day (± 1 hour) each time a site is visited. Short-term continuous measurements in a subset of sites should also be considered for the future. While this option is unlikely to be cost effective in all sites at all times of the year, continuous measurement of some parameters may be possible during periods at which conditions are likely to be most extreme, i.e., mid-summer, or in regions that are close to key thresholds values.

Further information regarding protocols for continuous monitoring of dissolved oxygen and temperature in freshwaters can be found in the National Environmental Monitoring Standards documents:
http://www.lawa.org.nz/media/16576/nems-dissolved-oxygen-recording-2013-06-1-.pdf.
http://www.lawa.org.nz/media/16588/nems-water-temperature-recording-2013-06-2-.pdf.

4.4.3 Alkalinity

NOF level:	Not a current attribute
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, 7 sites bimonthly
Priority for continued measurement	LOW, reconsider for sites where known acidic inputs occur.

Alkalinity is the acid buffering capacity of water and defines resilience to pH change. Water with a high alkalinity is strongly buffered and will have a narrow pH range. Rivers with highly

buffered waters include those draining limestone catchments, as they have high $CaCO_3$ concentrations. Rivers with rainwater or glacial water sources often have low alkalinities and may vary more in pH. Alkalinity is important to measure when acidic inputs are likely to a waterway, such as from wastewater or a mine site. Measuring alkalinity has low priority for SOE monitoring, but could be reconsidered for sites where acidic inputs are known to occur.

4.4.4 Sediment and water clarity

Sediment enters waterways through a variety of pathways including natural erosion and increased run-off due to land use intensification, irrigation and a lack of fencing and riparian planting. Sediment can be suspended in the water column and/or deposited on the stream bed. Some waterways can have little suspended sediment and good water clarity water during base-flow but have high amounts of deposited stream bed sediment. This sediment may become suspended in the water column during flood events or when weeds are cleared from a waterway.

Sediment suspended in the water reduces water clarity and light penetration, leading to a reduction in plant growth and altering the aesthetic and recreational value of a river. Sediment can also clog or abrade fish and invertebrate gills. Sediment that settles out on the river bed fills the gaps between substrate particles and can smother habitat for aquatic invertebrates and fish eggs. Sediment can also carry other contaminants such as nutrients and heavy metals that are attached to the sediment.

NOF guidelines do not currently exist for sediment, other than to indicate that some will be released in the future. These may vary depending on whether suspended sediment or sediment on the stream bed is the main problem in a waterway.

We have divided the discussion of sediment into suspended sediment that affects turbidity and water clarity and sediment on the stream-bed.

Suspended sediment, turbidity and water clarity

NOF level:	A generic ‘sediment’ attribute is an indicated future attribute
NOF value:	Ecosystem health, Mahinga kai
NOF indicated Measurement frequency:	Not indicated yet
GDC measures:	Suspended sediment (TSS): Yes, 17 sites monthly, 25 bimonthly Black disc visual clarity: Yes, 7 sites bimonthly Turbidity: Yes, 17 sites monthly, 25 bimonthly
Priority for measurement:	HIGH, for suspended sediment (TSS) and black disc, MODERATE for turbidity and HIGH at sites where development of a relationship with TSS or water clarity is useful.

Suspended sediment is the amount of sediment suspended in the water column and is often measured in g/m^3. Total suspended sediment (TSS) is a measure of the mass of suspended organic and inorganic particles and is a useful measure of the yield of sediment in a waterway.

Visual clarity is an important parameter when managers are concerned about the effects of suspended sediment on visual feeders, on the growth of algae and macrophytes and on

visual clarity for swimming. Visual clarity can be measured directly by measuring the horizontal distance at which black discs of standard sizes can be seen underwater. In 2012 11 out of 16 councils measured water clarity using the black disc method at their SOE sites (Davies-Colley et al. 2012). Further recommendations regarding the use of the black disc method can be found in Davies-Colley et al. (2012).

Turbidity is a measure of the degree to which light that is shone through water is scattered by the particles within it. The particles can include inorganic particles such as silt and clay or organic substances such as algae or plant debris. Turbidity is measured using a light meter and is expressed in Nephelometric Turbidity Units (NTU). Turbidity can be monitored continuously and may be used as a surrogate for continuously monitoring suspended sediment concentrations, however individual sensors must be well calibrated for accurate results. See the NEMS report on continuously measuring turbidity for further details if required: http://www.lawa.org.nz/media/16586/nems-turbidity-recording-2013-06.pdf.

For estimates of sediment and nutrient inputs and load in a river it is useful to measure TSS, which many councils currently do. However, while a NEMaR report (Davies-Colley et al. 2012) identified TSS as a 'core' parameter that should be monitored at all sites, some debate still surrounds this recommendation (McBride et al. 2013). TSS is often highly correlated with visual clarity, which may lead to some redundancy if visual clarity is also measured. In addition, TSS should be monitored during extreme flow events as well as base flow to be a valuable indicator of sediment load (McBride et al. 2013). Given that routine monitoring is unlikely to occur or be able to be completed during high flows, routine monthly monitoring of TSS may only be recommended for particular sites of regional interest. However, because TSS is currently monitored at many of the GDC sites and does provide useful information we recommend that a high priority is given to continued monitoring, although the frequency or spatial extent of monitoring may be able to be reduced in the future.

TSS is generally not a good indicator of light attenuation, which may be of concern for recreational or ecological reasons. Measurements of water clarity and turbidity are better measurements of the light attenuation rate in water. Davies-Colley and Smith (2001) suggest that visual clarity using a black disc is a more ecologically relevant measure of optical parameters than turbidity as it more directly measures light attenuation. Similarly, Kelly et al. (2014) in a review of Environment Canterbury's SOE monitoring programme suggested that Environment Canterbury should move progressively towards monitoring water clarity using the black disc method. The authors also recommended a period of overlap between turbidity and black disc methods in sites where turbidity was historically measured to investigate relationships between the two methods. Davies-Colley et al (2012) recommend that turbidity is measured as a 'supporting' variable additional to core parameters as it can provide a backup value to the visually estimated water clarity methods such as black disc (also see McBride et al. 2013). In a summary of the NEMaR project findings Schmidt (2012) reports that visual clarity should be routinely monitored, TSS should also be monitored and that turbidity was optional.

For measurements of sediment load in rivers we recommend that total suspended solids (TSS) are given a high priority. For measurements of light attenuation and visual clarity the black disc method is more highly recommended than turbidity. However, continued long-term records of turbidity in a site would be useful, at least until relationships between black disc

and turbidity have been investigated. In general we would recommend that flexibility and some redundancy is maintained in the sediment monitoring component of GDCs biomonitoring network. Further recommendations are likely to be released as part of the NOF project at some point in the future.

Please also note that a black disc should be used in preference over a black and white Secchi disc.

Stream-bed sediment

NOF level:	Not currently included
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	No
Priority for measurement:	HIGH.

Measurement of stream-bed sediment is not currently conducted by the GDC or by many other councils as part of their SOE monitoring. It is also currently unclear if stream-bed sediment will be included in the NOF attributes. However, stream-bed sediment can be a serious problem in some waterways and in many sites will not be accurately measured by water clarity or TSS.

We recommend that this attribute is given a high priority for measurement.

Methods for assessing stream-bed sediment can be found in Clapcott et al. (2011).

4.4.5 Nutrients

Nutrients stimulate the growth of plants, including algae. 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 waterways also have detrimental effects on aesthetics and human uses causing changes to water colour, odour, and the general physical nature of the environment. Such growths can also choke water waterways and reduce dissolved oxygen levels creating stressful conditions for invertebrates and fish. Nitrate and ammoniacal nitrogen can also be toxic to ecosystems and human health. Monitoring nutrients is important as expansion and intensification of agricultural land use continues.

Most bioavailable nitrogen in rivers is dissolved inorganic nitrogen. Dissolved inorganic nitrogen (DIN) is made up of several forms in rivers; nitrate and nitrite nitrogen (NOx-N) and ammoniacal nitrogen (NH4-N). DIN provides essential nutrients for plant growth, however large amounts can lead to excessive and nuisance periphyton growth in waterways. The nitrate component of DIN is also potentially toxic at high levels to aquatic organisms and to humans. Ammoniacal nitrogen is also potentially toxic to aquatic life depending on the availability of two species: $NH3$ and $NH4^{+}$, which are influenced by pH and temperature.

Phosphorus is an important element for plant growth and, in some locations, may be a factor limiting plant growth. Phosphorus can be both dissolved in the water and also attached to suspended particles.

Outputs from the NEMaR projects recommend that five forms of nutrients should be routinely monitored (Schmidt 2012). These are total nitrogen and total phosphorus, dissolved reactive phosphorus, oxidised nitrogen (nitrate and nitrite N) and ammoniacal nitrogen.

Ammoniacal nitrogen (NH4-N)

NOF level:	Has attribute states for toxicity
NOF value:	Ecosystem health
NOF indicated measurement frequency:	> annual
GDC measures:	Yes, 12 sites monthly, 25 sites bimonthly
Priority for measurement	HIGH.

All councils measure ammoniacal nitrogen (Kelly et al. 2014) and ammonia toxicity is included as an attribute in the compulsory 'ecosystem health' value in the proposed NOF. We recommend that ammoniacal nitrogen has a high priority for continued measurement.

Nitrate

NOF level:	Has attribute states for toxicity
NOF value:	Ecosystem health
NOF indicated measurement frequency:	> annual
GDC measures:	Yes, 12 sites monthly, 7 sites bimonthly
Priority for measurement	HIGH.

Nitrate (NO3-N) is included as a compulsory attribute in the proposed NOF and is measured as nitrate-nitrite N by most councils. Nitrite readily transforms to nitrate in river water and nitrate-nitrite N is often reported as NOx-N or referred to as nitrate N. We recommend that nitrate has a high priority for continued monitoring.

Nitrite

NOF level:	NA
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, 12 sites monthly, 7 sites bimonthly
Priority for measurement	LOW, unless near a wastewater discharge.

Nitrite and nitrate are the inorganic oxidised form of nitrogen. In most rivers nitrite is generally an insignificant component of nitrate-nitrite N because nitrite is readily oxidised to nitrate. We recommend that nitrite be given low priority for measurement for SOE monitoring. However in locations with wastewater discharges both nitrate-nitrite N and nitrite should be considered.

Total Nitrogen

NOF level:	Not currently an attribute for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	No
Priority for measurement	MODERATE-HIGH.

Total nitrogen (which includes both the organic and inorganic forms) is monitored by most councils and in the National River Water Quality Monitoring Network (NRWQN) monitoring

conducted by NIWA (Kelly et al. 2014). Most bioavailable nitrogen in rivers is dissolved inorganic nitrogen (DIN; i.e., nitrate-nitrite N and ammoniacal N) rather than the organic component However, Environment Canterbury recommended continued monitoring of total nitrogen in their SOE sites as the data is useful for investigating the effects of total nutrients on in-stream values using nutrient dynamic models. A report prepared for the NEMaR project recommended that total N is included in routine SOE monitoring (Schmidt 2012). We recommend that total N is given a moderate to high priority.

Dissolved reactive phosphorus (DRP)

NOF level:	Not currently an attribute for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, 12 sites monthly, 25 sites bimonthly
Priority for measurement	HIGH.

Most regional councils and NIWA monitor dissolved reactive phosphorus (DRP) and total phosphorus (TP). Phosphorus is an important element for plant growth and in some locations, may be a factor limiting plant growth. GDC currently monitors DRP in most sites and recommend that it is given a high priority for continued measurement.

Total phosphorus

NOF level:	Not currently an attribute for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	No
Priority for measurement	MODERATE-HIGH.

Total phosphorus is a measure of both dissolved and phosphorus associated with suspended particles. Most other regional council's measure total phosphorus and it may provide useful information for nutrient dynamic models. A report prepared for the NEMaR project recommended that total P is included in routine SOE monitoring (Schmidt 2012). We recommend total phosphorus be given a moderate to high priority for measurement.

4.4.6 Faecal coliforms: Enterococci and *E. coli*

NOF level:	*E. coli* has attribute states
NOF value:	Human health – secondary contact
NOF indicated measurement frequency:	> annual
GDC measures:	Yes, 16 sites monthly, 14 sites bimonthly
Priority for measurement	HIGH for *E. coli,* LOW for enterococci.

The faecal coliforms group (including enterococci and *Escherichia coli; E. coli*) indicate that organic and possibly faecal contamination has occurred. The main risk to people is from drinking water or ingesting water during recreation activities such as swimming.

E. coli is the standard indicator bacterium used in freshwaters while enterococci is the preferred faecal indicator organism for marine waters. Using enterococci as an indicator in freshwaters is generally not recommended as it can multiply from natural sources such as leaf decay (MfE 2002).

E. coli has attribute states set for the value 'human health – secondary contact'. We recommend that *E. coli* is given a high priority and enterococci a low priority for measurement.

It should also be noted that while monitoring for SOE reporting may require a relatively infrequent but continuous record of *E. coli* levels, additional intensive short-term monitoring may be required over summer at popular recreational sites or if regular monitoring indicates a potential problem.

4.4.7 Biological monitoring: periphyton, invertebrates, fish

Kelly et al. (2014) recommended that aquatic ecosystem health monitoring should be conducted at all water quality monitoring sites to improve understanding of how ecosystem health relates to water quality. GDC currently measures chlorophyll *a* at 7 sites and does not monitor invertebrates or fish. Also see Storey (2012) for recommendations for biological monitoring specific to the Gisborne region.

Periphyton and chlorophyll *a*

NOF level:	Chlorophyll *a* has attribute states
NOF value:	Ecosystem health
NOF indicated measurement frequency:	Monthly
GDC measures:	Yes, 7 sites bimonthly
Priority for measurement	HIGH Recommend that sites are investigated for their ability to grow periphyton. Highly turbid sites or those with soft sediment stream beds are generally not suitable for excessive periphyton growths. With detailed evidence a case may be made for reduced or no monitoring of this parameter at some locations. Developing regional-specific relationships between chlorophyll *a* and visual estimate methods (see Kilroy et al. 2013) may enable cheaper visual estimate methods to be used in many sites much of the time.

Periphyton is the layer of algae and other organic matter found on the bed of rivers and streams. Healthy rivers are often characterised by a relatively low amount of periphyton, but nutrient inputs, a lack of floods, high light levels and warm temperatures can cause excessive periphyton growth. Such growths can reduce the aesthetic and recreational value of the waterway and reduce the diversity and productivity of invertebrates and fish.

Soft bottomed lowland streams are often not a suitable habitat for periphyton due to the instability of their beds (Snelder et al. 2013). Waterways with turbid water may also not grow very much periphyton due to a lack of light reaching the stream bed. Given that some waterways in the Gisborne region are turbid and have soft sediment the applicability of the described measurement options may need to be investigated further. Initial monitoring is at least required to investigate whether sites are likely to be suitable for periphyton growth.

Periphyton is often measured in a range of ways;

1. chlorophyll *a* concentrations
2. ash free dry mass (AFDM)

3. visual observations of the percentage cover of different forms of periphyton.

Chlorophyll *a* is the most commonly recognised standard method for estimating stream periphyton biomass (Snelder et al. 2013) and is the measure included in the proposed NOF. Chlorophyll *a* values are obtained by quantitative sampling of periphyton and subsequent laboratory analysis. Snelder et al. (2013) recommended chlorophyll *a* measures as the standard measure of periphyton as it has been used extensively in New Zealand, has guideline values (Biggs 2000) and has been used successfully in statistical models. However, the authors also suggest that a significant proportion of monitoring could be conducted using the less costly visual estimate method (Snelder et al. 2013). Kilroy et al. (2013) has recently developed protocols to allow generation of estimates of chlorophyll *a* from visual estimates. Thus, visual estimates may be able to be used in many locations with chlorophyll *a* samples additionally collected if visual estimates indicate that periphyton is approaching a relevant threshold level.

In 2012 twelve councils monitored periphyton routinely at all sites as part of their SOE monitoring (Davies-Colley et al. 2012). All except three councils monitored periphyton more than once a year, but only three monitored all sites monthly (Davies-Colley et al. 2012).

The frequency of periphyton monitoring has been indicated as monthly in the proposed NOF. This is the same frequency that some regional councils and NIWA monitor periphyton currently. We recommend that periphyton monitoring be given a high priority. We also recommend that the practicality of both visual estimates and chlorophyll *a* measures are investigated for the Gisborne region. Recommendations for monitoring of periphyton for SOE purposes can be found in Davies-Colley et al. (2012).

Planktonic and benthic cyanobacteria

NOF level:	Planktonic: Has attribute states Benthic : Indicated future attribute
NOF value:	Human health – secondary contact
NOF indicated measurement frequency:	Not indicated yet
GDC measures:	No
Priority for measurement	HIGH

Cyanobacteria (commonly known as blue-green algae) are photosynthetic prokaryotic organisms that are integral parts of many aquatic and terrestrial ecosystems. If favourable conditions occur in rivers and lakes these organisms can multiply and form planktonic blooms suspended in the water column (planktonic) or dense mats that grow on stream-bed substrate (benthic). Some cyanobacterial strains are known to produce natural toxins, called cyanotoxins. This toxins can harms animals and humans when ingested through drinking water or during contact in recreational activities. In New Zealand, *Phormidium* is the cyanobacteria that we have most information on and has strains that are capable of producing cyanotoxins.

Cell counts or biovolume per volume of water are the methods proposed in the NOF to measure planktonic cyanobacteria. Attribute states are based on two year average data. Methods and attribute states for benthic cyanobacteria are not yet included in the proposed NOF. The human health risks associated with benthic cyanobacteria are less well known than for planktonic cyanobacteria (Wood et al. 2013).

Currently very few sites are monitored for cyanobacteria nationally. The sites that are monitored are locations that are known to have problems with cyanobacteria and/or that are popular recreation sites. Blooms are more common in summer but planktonic and benthic cyanobacteria can vary greatly over time within a site, to such a degree that they regularly move between the proposed NOF attribute bands (Wood et al. 2013). It is likely that relatively long collection periods (i.e., greater than 1 year) are required before the cyanobacteria level in a waterway can be adequately characterised (Wood et al. 2013). Wood et al. (2013) recommend that the document 'New Zealand's Guidelines for Managing Cyanobacteria in Recreational Freshwaters' (Ministry for the Environment 2009), which provides actions to monitor and manage cyanobacteria, be used in conjunction with any proposed NOF objectives, attributes and monitoring.

Wood et al. (2013) note that monthly monitoring may miss periods where cyanobacteria coverage is highest. They also observed that weekly data identified periods of high cyanobacteria levels that some monthly monitoring had missed. Monitoring frequency may depend on the recreational value of a site and any known problems relating to cyanobacteria. Currently the proposed NOF does not provide recommendations regarding monitoring frequency.

We recommend that investigation of methods to monitor benthic and planktonic cyanobacteria is given a high priority.

Invertebrates

NOF level:	Indicated future attribute
NOF value:	Ecosystem health
NOF indicated measurement frequency:	NA
GDC measures:	No
Priority for measurement	HIGH.

Aquatic invertebrates are commonly used in New Zealand and internationally to assess and monitor the conditions of rivers and streams. Invertebrates are suitable indicators as they are found in almost all freshwater environments, are relatively easy to sample and different taxa vary in their sensitivity to pollution and other impacts (Stark et al. 2001). Monitoring aquatic invertebrate communities also provides an additional benefit over many other water quality parameters as they reflect the recent history of water quality at a site and thus provide a time-integrated appraisal of water quality. For this reason monitoring can also occur less frequently than for many other water quality parameters.

Specific metrics based on the macroinvertebrate community, such as the Macroinvertebrate Community Index (MCI) and percentage EPT (Ephemeroptera, Plecoptera and Trichoptera, which are generally sensitive to organic pollution), are commonly used to assess water quality. These metrics provide single numbers that can be examined for differences or trends in water quality between and within sites. Most other regional councils already currently monitor aquatic invertebrates. In 2001 eleven regional councils responded to a survey regarding macroinvertebrate sampling for SOE monitoring purposes (Stark et al. 2001). At that time 70% of the 11 councils undertook macroinvertebrate sampling annually, while 30% undertook bi-annually sampling in spring and autumn each year. In 2012 all but one of the 16 councils undertook macroinvertebrate sampling as part of their SOE programme (Davies-Colley et al. 2012). Invertebrate samples are indicated as a proposed future attribute within

the compulsory value ‘ecosystem health’. We recommend that macroinvertebrate sampling is given a high priority for monitoring in the future.

Standard protocols for the collection of aquatic invertebrates in wadeable streams can be found in Stark et al. 2001. These protocols were designed to be used by regional council monitoring programmes. There is some variability in how the collection and sample processing protocols are applied between councils; discussion of these points and recommendations are provided in Davies-Colley et al. (2012). We also recommend that GDC seeks additional specific advice regarding the sampling methods most suitable to their waterways before instigating an invertebrate monitoring programme.

Fish

NOF level:	Indicated future attribute
NOF value:	Ecosystem health
NOF Indicated measurement frequency:	NA
GDC measures:	No
Priority for measurement	MODERATE, but likely a HIGH priority in the future.

Monitoring New Zealand’s fish populations is important as we have many endemic species and some of these have restricted distributions or are known to be in decline. Monitoring fish populations provides information about the distribution and trends in individual species. However, the development of useful fish community based-indicators to evaluate effects in New Zealand streams and rivers is still in progress.

In 2011, eight councils monitored fish as part of their SOE monitoring with sites visited on a rolling rotational basis over several years (Davies-Colley et al. 2012).

While the information on fish communities provided by such sampling is valuable and standard protocols for wadeable streams are now available (Joy et al. 2013), fish sampling is relatively time consuming and requires experts skilled in fish identification. For these reasons we recommend that monitoring fish populations is given a moderate priority currently, but this may need to be revised to a high priority in the future.

Protocols for sampling freshwater fish in wadeable rivers and streams can be found in Joy et al. (2013). Recommendations for fish monitoring for SOE purposes can also be found in Davies-Colley et al. (2012). Estimated costs for fish surveys are included in McBride et al. (2013) and in the report Storey (2012) prepared for GDC.

4.4.8 Calcium hardness and total hardness

NOF level:	NA
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, both at 12 sites monthly, 18 sites bimonthly
Priority for measurement	LOW for SOE monitoring, HIGH for drinking water standards.

Water with high magnesium and calcium content is described as hard. The hardness of water can affect the taste, colour, appearance and lathering ability of the water. Water hardness is either measured as total hardness (both magnesium and calcium) or as calcium

hardness. Hardness can also influence the toxicity of pollutants to organisms. Total hardness has an aesthetic guideline value for drinking water (Ministry of Health 2008)

Hardness has not been indicated as a potential NOF attribute currently and we recommend a low priority for SOE monitoring. However, in sites where water may be used for drinking total hardness and calcium hardness may be important attributes to measure.

4.4.9 Magnesium

NOF level:	Not currently an attribute for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, 7 sites bimonthly
Priority for measurement:	LOW

The magnesium content in water influences water hardness, which influences alkalinity and the toxicity of pollutants, especially metals, to organisms. Magnesium is not a current or future NOF attribute and, for sites that are drinking water supplies, measurement of total or calcium hardness should be sufficient. We recommend that magnesium is given a low priority for measurement for SOE monitoring.

However, note that Environment Southland reported in 2012 that they were adding the monitoring of major cations and anions, including chloride, bromide, magnesium, potassium and iron to their river monitoring programme to characterise their chemistry in more detail, to determine surface-groundwater interactions and identify sources of contamination. Major ions are also recommended for occasional measurement (say once every 5 years) at NEMaR SOE sites as they can be useful for tracing groundwater-surface water exchange (Davies-Colley et al. 2012).

4.4.10 Salinity

NOF level:	Not currently an attribute for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	12 sites monthly, 25 sites bimonthly
Priority for measurement	LOW for SOE, HIGH for sites used for drinking water.

Salinity is a measure of saltwater intrusion and is important to measure in groundwater aquifers, particularly those used for drinking water supplies. Salinity has an aesthetic guideline value for drinking water (Ministry of Health 2008). The proposed NOF does not currently include salinity for riverine sites, and groundwater values and attributes have not been set yet. We recommend that salinity is given a low priority for SOE monitoring, but that this is re-evaluated in sites used for drinking water or in sites where the salinity is predicted to change over time.

4.4.11 Sulphate, sodium and chloride

NOF level:	Not currently attributes for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	All measured monthly at 12 sites, bimonthly at 25 sites

Priority for measurement:	LOW for SOE, MODERATE-HIGH for sites used for drinking water.

Sodium is an important cation in New Zealand rivers and influences water taste. Chloride is an indicator of salinity. Sulphate, sodium and chloride are not current or future indicated NOF attributes and we recommend they have low priority for SOE monitoring. However, they do all have aesthetic guideline values for drinking water (Ministry of Health 2008) and may have a higher priority in locations used for drinking water. We recommend that sulphate, sodium and chloride are given low priority for SOE monitoring, but this should be re-evaluated for sites used for drinking water.

Note that Environment Southland reported in 2012 that they were adding the monitoring of major cations and anions, including chloride, bromide, magnesium, potassium and iron to their river monitoring programme to characterise their chemistry in more detail, to determine surface-groundwater interactions and identify sources of contamination. Major ions are also recommended for occasional measurement (say once every 5 years) at NEMaR SOE sites as they can be useful for tracing groundwater-surface water exchange (Davies-Colley et al. 2012).

4.4.12 Potassium

NOF level:	Not currently an attribute for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	12 sites monthly, 25 sites bimonthly
Priority for measurement:	LOW.

Potassium is found in certain fertilisers and influences plant growth. It is not currently included in the proposed NOF as an attribute and is generally found in relatively low levels in rivers. Potassium is not currently in the proposed NOF and we recommend a low priority for monitoring.

4.4.13 Boron

NOF level:	Not currently an attribute for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, 7 sites bimonthly
Priority for measurement	LOW.

Boron is a trace element of volcanic rocks and sedimentary rocks from marine waters and is used in industrial chemical manufacturing. The main source of anthropogenic boron in rivers is from the use of sodium perborate in the manufacture of detergent formulations as well as from other industrial chemical manufacturing processes (ANZECC 2000).

We recommend a low priority for boron for SOE monitoring. Boron measurements may be retained for resource consent compliance in a limited number of sites, or in locations that are close to or exceed the ANZECC guidelines of 370 µg/L for freshwaters (ANZECC 2000).

4.4.14 Tannins

NOF level:	Not currently an attribute for rivers
NOF value:	NA

NOF indicated measurement frequency:	NA
GDC measures:	Yes, 7 sites bimonthly
Priority for measurement	LOW.

Tannins are a natural organic compound that leaches from decaying vegetation, turns water a tea-like colour and reduces water clarity. Tannins are not currently included in the proposed NOF and we recommend a low priority for SOE monitoring. However, coloured dissolved organic matter (CDOM) was recommended for occasional monitoring (say once every 5 years) by the NEMaR working panel (Davies-Colley et al. 2012) as it can be used to differentiate water clarity caused by suspended sediment and that caused by CDOM.

4.4.15 BOD5

NOF level:	Not currently an attribute for rivers
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, 17 sites monthly, 18 sites bimonthly
Priority for measurement	LOW for SOE monitoring, MODERATE-HIGH below wastewater discharges.

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen needed by microorganisms to break down organic matter present in a given water sample. BOD is measured over 5 days at 20°C, hence BOD5. BOD5 provides a measure of the amount of organic pollution in a waterway. It is now relatively uncommonly measured by regional councils (Kelly et al. 2014). NIWA discontinued BOD measurements at the NRWQN sites in 2002, except at sites affected by wastewater discharges. BOD5 may be useful in conditions where organic matter input into waterways is high, for example below waste water treatment plants.

BOD5 provides a useful indicator of organic pollution, however is not currently measured by many other agencies and is likely to be relatively expensive due to the 5 days laboratory processing time. BOD5 readings at sites not below wastewater discharges are often very low and it is not considered an important parameter for SOE monitoring (Davies-Colley et al. 2012). For these reasons we recommend that BOD5 is given a low priority for SOE monitoring, although this should be re-evaluated for sites below wastewater discharges.

Kelly et al. (2014) proposed that dissolved organic carbon (DOC; see description below in total organic carbon section) could be used as a potential surrogate for BOD, although this requires further investigation. DOC tests are much faster than BOD, although still relatively expensive.

4.4.16 Total organic carbon

NOF level:	Not currently an attribute
NOF value:	NA
NOF indicated measurement frequency:	NA
GDC measures:	Yes, 7 sites bimonthly
Priority for measurement	LOW, reconsider for sites known to have organic matter inputs.

Total organic carbon is a measure of the organic carbon in a water sample. Organic carbon occurs naturally in waterways from sources such as peat bogs, decaying vegetation and

bacterial growths but can also be increased through the intensification of land used, disposal of organic matter on adjacent land or the use of effluent ponds. Three councils currently measure total organic carbon (Kelly et al. 2014).

Total organic carbon is influenced by the amount of particles suspended in the water. Dissolved organic carbon (DOC) is the portion of the organic carbon that is left after the sample is passed through a filter, and is currently only monitored routinely by Environment Canterbury. A review of the Environment Canterbury SOE water quality monitoring sites recommends that while dissolved organic carbon should be monitored at all sites, the high analytical cost of samples means that they may omit this parameter until appropriate trigger values are established (Kelly et al. 2014).

Neither dissolved nor total organic carbon are currently included in the proposed NOF and are monitored by few other councils. In addition, while organic carbon may usefully indicate land use change it is relatively expensive to measure and is not considered necessary for national reporting (Davies-Colley et al. 2012). However, if may be useful in locations known to have high organic matter inputs. We recommend that either TOC or DOC are given low priority for monitoring, but moderate priority in sites that may be affected by organic carbon inputs, such as effluent ponds.

4.4.17 Heavy metals, organic contaminants and pathogens

NOF level:	Indicated future attributes
NOF value:	Mahinga kai (non-compulsory)
NOF indicated measurement frequency:	NA
GDC measures:	No?
Priority for measurement	LOW, except in areas where mahinga kai is a high priority or where potential contamination may occur

Heavy metals, organic contaminants and pathogens are included in the proposed NOF as potential future attributes for the non-compulsory value ‘mahinga kai’. However, very few details are provided in the proposed NOF for these attributes. Heavy metals, organic contaminants and pathogens are large groups of measurable indicators and the relevant parameters to measure will likely vary depending on the organism targeted for consumption. We cannot provide advice on the specific parameters that should be monitored. These decisions should be made on a case-by case basis using knowledge of the local environment and type of mahinga kai.

4.4.18 Additional parameters for consideration

Additional parameters that could be considered for monitoring but are not currently monitored by GDC, or included in the current NOF guidelines include:

- total N and total P
- Macrophytes (aquatic weeds) in locations where they are a potential issue.
- Physical habitat, as suggested in Davies-Colley et al. (2012).
- Major ions (some of which are currently monitored by GDC), perhaps monitored every 5 years (suggested by McBride et al. 2013)

- Coloured dissolved organic matter (CDOM) may be useful for interpreting light attenuation data. CDOM does not often change markedly so could also be monitored once every five years (McBride et al. 2013).

4.5 Monitoring priorities for environmental parameters: Summary

GDC currently measures nine of the 16 attributes included in the proposed NOF and eight of the 12 proposed compulsory attributes.

The proposed compulsory attributes that GDC would need to add to their monitoring to align with the proposed NOF are planktonic and benthic cyanobacteria, invertebrates and fish. The proposed NOF does not currently provide guidelines for benthic cyanobacteria, invertebrates or fish. There are standard sampling methodologies for these parameters (see Section 4.4) and we suggest GDC investigate how these could be applied in the Gisborne District. Advice specific to the Gisborne District is also provided in Storey (2012).

The additional proposed NOF attributes that GDC may need to monitor in some sites, depending on the values assigned to those sites, are heavy metals, organic contaminants and pathogens. Total N, total P, coloured dissolved organic matter (CDOM) and physical habitat are not included in the proposed NOF, but could be considered for addition to a monitoring programme. A number of values do not have attributes assigned currently. Local knowledge and the values identification programme that GDC is undertaking will help identify additional parameters to monitor at all, or a subset of sites.

The parameters that GDC currently monitor, but that need relatively significant expansion to include more sites are nitrates, periphyton and measures of water clarity such as black disc. Currently these parameters are only monitored in 19 sites for nitrates and seven sites on two drains for periphyton and visual water clarity.

Parameters that we assess as having a relatively low priority for continued monitoring for SOE purposes include alkalinity, magnesium, salinity, sulphate, sodium, chloride, hardness, nitrite, enterococci, potassium, boron and tannins. However, there may be other reasons for continuing to monitor some of these which GDC will need to assess. See details in section 4.4.

Consideration of measurements of river flow at monitoring sites is also recommended. This could be a continuous recording gauge at a site, the installation of a stage height staff that can be read on site visits (and development of stage-discharge relationships), spot discharge readings taken during sites visits and/or the development of models relating flow at nearby gauges to site locations.

The proposed NOF currently provides little information regarding monitoring frequencies required to assess attribute states. Many councils currently conduct monthly water quality and periphyton assessments and assess aquatic invertebrate communities either annually or biannually. Also see Davies-Colley et al. (2012) for further recommendations from the NEMaR project. The final decision for monitoring frequency should take into account reasons other than SOE monitoring for individual parameters. In some cases it may be beneficial to have regular relatively infrequent (e.g., monthly or bimonthly) monitoring that is used for SOE reporting and additional more frequent monitoring that occurs only when a problem is identified or over particularly stressful time periods. For example, increased *E. coli* monitoring

may be required over summer in popular recreation sites or if threshold values are close to being exceeded.

In accordance with many councils, GDC currently measures pH, DO and temperature as one-off measurements during site visits. However, under the proposed NOF continuous measurements of temperature may be required at a subset of sites over summer. DO and pH may have the same recommendations when their attribute states are released. Investigating the use of continuous loggers for temperature, dissolved oxygen and pH would be beneficial. Temperature is the most straight-forward attribute to investigate first. Continuous readings may only be required at certain locations over summer (i.e., below wastewater discharges for dissolved oxygen) and monthly spot measurements may be sufficient for the rest of the year. Ideally these spot measurements would be collected at the same time of day (±1 hour) on each site visit.

Further investigation may be required before monitoring programmes can be developed for some attributes. These include sediment, for which little information is included in the proposed NOF. Monitoring of sediment load (suspended sediment), water clarity (black disc method) and stream bed sediment coverage (see Clapcott et al. 2011 for guidelines) would be valuable. Consideration should be given to overlapping methods for a reasonable time (say 12 months) when an existing method is being replaced by a new method so that time trend analyses are potentially still possible. There is much inherent value in long-term data sets at a site and small changes in methodology or parameters can mean that temporal trend analyses are not possible. For example, GDC currently measures turbidity in most sites and black disc in 7 sites. If the black disc method was chosen to replace turbidity measurements at most sites it would be valuable to have overlapping data from both for a time. This could enable the generation of relationships between black disc and turbidity values, which would mean that the historical turbidity measurements could still be used for long-term trend analyses.

Other parameters which may require further investigation before inclusion or expansion in a monitoring network include periphyton, invertebrates and fish. There may be key locations that can be prioritised for monitoring of these parameters and different sampling methodologies may be relevant to individual sites or groups of sites. We recommend that GDC seeks more specific advice before initiating large-scale periphyton, invertebrate and fish sampling programmes. This could, for example, help address 1) whether all sites are suitable for periphyton growth and thus require monitoring and 2) if visual assessments of periphyton cover can be used as a surrogate for chlorophyll *a* values in some sites. We also recommend that GDC seeks advice regarding appropriate methods and locations for aquatic invertebrate and fish sampling in their region. Storey (2012) provides recommendations of techniques appropriate to the Gisborne region and an estimate of costs for adding biological monitoring to the GDC network.

Our recommendations for parameters to prioritise for monitoring are based on their use in a SOE monitoring programme. The final decision of parameters to include in a monitoring programme should also include consideration of the value of long-term data sets and additional reasons for measurement of a particular parameter, for example to monitor drinking water quality. The addition of parameters that are not currently in the proposed NOF will likely be beneficial in some locations. Local knowledge of the system and its stressors and regional policy will help these decisions.

Additions to the NOF may not occur until 2016 or 2019, and/or may occur in part as information is collated over the next few years. It would benefit GDC to have a monitoring programme that is flexible so that the parameters and their frequency of measurement can be altered in response to these changes. Short term investigations of relationships between discontinued parameters and newly instigated ones could also be conducted with a flexible monitoring programme.

5 Recommended processes and next steps

Above we have provided the results from two separate analyses that may help GDC to consider updating their current monitoring network for SOE purposes. The first was a representativeness study based on one simple criterion, namely whether sites are representative of key environmental factors such as climate, source of flow, sediment type, and land-use. The second analysis was based on the suitability of current monitored parameters for delivering GDC's requirements for the NPSFM and NOF.

We suggest the following steps are considered in this order for evaluating GDC's biomonitoring site locations and parameters:

1. Identify the components of the biomonitoring network that need expansion and addition. This includes 1) the parameters that need either increased spatial extent of monitoring or addition to the network and 2) environmental classes that are under-represented in the current monitoring network.

2. Assuming the aim is to attempt to remain cost-neutral, identify parameters or sites that can be removed from the sampling network to balance out the addition requirements from step 1. This second step involves consideration of several different issues including:

   - Because of the value of long-term data sets for detecting trends over time, removing sites or environmental parameters from a monitoring network requires detailed consideration. Depending on the overarching purpose of your monitoring network some sites or parameters may be more likely candidates for removal than others. For example, all 7 sites on Sistersons and Awapuni drains may not be required for the purpose of SOE monitoring. In addition, monitoring some parameters, such as boron, are unlikely to be required for SOE monitoring purposes.

   - You could also considerif it is possible to source additional funding for continued monitoring. For example, several sites and many of the parameters measured at the sites on the Sistersons and Awapuni drains may be monitored as part of a resource consent. The necessity of this monitoring could be reassessed or options for it to be funded by the resource consent holder investigated (if this is an external client).

   - Sites that are in environmental classes that are currently over-represented may also be candidates for removal from a monitoring network. Similarly, there may be parameters that have low priority for SOE monitoring purposes. However, representativeness of the monitoring network and SOE monitoring should not be the only consideration when deciding whether to add or remove sites or environmental parameters in the monitoring network. We recommend that the benefit of long-term data sets, the need to monitor locations that are more likely to be prone to anthropogenic impacts and the need to monitor parameters that are related to values not currently in the proposed NOF also be considered.

We also recommend that GDC considers the following:

- We suggest that the GDC water quality and biomonitoring programme would benefit from increased flexibility over the next few years. This is likely to be beneficial for several reasons: firstly, the proposed NOF is a work in progress and attributes may be added, removed or altered. Secondly, a period of overlap of parameters that are to be discontinued with related and newly instigated parameters may allow the development of relationships that allows conversion between the parameters and preserves some of the value of historic data sets. Thirdly, the frequency of monitoring of some parameters may be required to vary depending on the season, for example, monthly monitoring of *E. coli* may be sufficient for SOE purposes, but more frequent monitoring may be required at popular recreation sites over summer to ensure areas are suitable for contact recreation
- Investigation of the usefulness of REC classes to help develop freshwater management units could be considered. The current use of sub-catchments as freshwater management units by GDC is sensible given that these areas are often prone to the same stressors. However, consideration could be given to also incorporating some of the REC climate, topography, geology or land classes and creating geographically independent units.
- Investigation of periphyton, invertebrate and fish sampling techniques relevant to the Gisborne region (see Storey 2012 for a summary including predicted costs for the Gisborne region).
- Investigation of the use of loggers for continuous temperature, dissolved oxygen and pH recording.

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7 Glossary of abbreviations and terms as defined in the proposed NOF

Attribute state	is the level to which an attribute is to be managed for those attributes that have states currently defined
Attribute	are measurable characteristics of fresh water, including physical, chemical and biological properties, which support particular values
Compulsory values	mean the national values relating to ecosystem health and to human health (secondary contact recreation)
Freshwater management unit	is the water body, multiple water bodies or any part of a water body determined by the regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management
Secondary contact	means contact with fresh water that does not involve immersion and includes wading or boating (except boating where there is high likelihood of immersion).
State	a range in the level of an attribute that may be described as a narrative or numerically. Four different states are specified for attributes (A, B, C or D).
Values	those intrinsic qualities, uses or potential uses that people and communities appreciate about water bodies and wish to see recognised in the on-going management of those water bodies

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Appendix A Parameters recommended during review of Environment Canterbury SOE river monitoring network

Table A-1. Recommendations from a review of ECan's SOE water quality monitoring network. This table is from Kelly et al. (2014) and summarises the core recommended environmental parameters to be measured at Environment Canterbury's SOE water quality monitoring sites. Please note that these recommendations were made before the proposed NOF attributes were released and is provided as an example of what other councils have decided to monitor.

Parameter / measure	Units	Field-based	Lab-based
Dissolved oxygen saturation	(%)	Y	
Dissolved oxygen concentration	mg/L	Y	
pH		Y	
Temperature	^{o}C	Y	
Conductivity	mS/m	Y	
Total suspended solids	mg/L		Y
Black disc distance	m	Y	
E. coli	/100 ml		Y
Dissolved reactive phosphorus	mg/L		Y
Total phosphorus	mg/L		Y
Nitrate nitrogen	mg/L		Y
Ammoniacal nitrogen	mg/L		Y
Total nitrogen	mg/L		Y
Fine sediment	% bed cover	Y	

Appendix B Core variables recommended for river water quality monitoring NEMaR 2012

The information below comes from reports prepared for the National Environmental Monitoring and Reporting (NEMaR) project (Schmidt 2012; Davies Colley et al. 2012).

Table B-1. Table 1-1 from Davies-Colley et al. (2012) 'Minimal set of water quality variables ('Core' variables) for rivers'. This table shows the recommended core water quality variables for monitoring as proposed in the National Environmental Monitoring and Reporting (NEMaR) project (Davies-Colley et al. 2012). Several other supporting parameters would also normally be monitored, for example conductivity as an indicator of total ionic content, pH, major ions and coloured dissolved organic matter (CDOM). See Table B-2 for recommended biological components.

River water quality variable	Needed for?
Discharge	State-of-flow for WQ interpretation and load calculation
Temperature	Thermal conditions (climate change)
Dissolved oxygen	Oxygen conditions for aquatic life
Black disc visibility	Measure of visual clarity (aquatic life and human use)
Total suspended solids (TSS)*	Relevant to sediment effects and sediment loads
Ammoniacal nitrogen	Nutrient (immediately bioavailable), toxic (as NH3)
Oxidised nitrogen (NOx)	Nutrient (immediately bioavailable), toxic
Total nitrogen	Nutrient
DRP	Nutrient (bioavailable)
Total phosphorus	Nutrient
E. coli	Indicator of faecal microbial pollution

*TSS and visibility are inversely correlated so there is a degree of redundancy in measuring both

Table B-2. Table 1-3 from Davies-Colley et al. (2012) 'Biological components ('Core' variables) for biomonitoring of rivers' This table shows the recommended core biological variables for monitoring as proposed in the National Environmental Monitoring and Reporting (NEMaR) project (Davies-Colley et al. 2012). Periphyton would generally be assessed monthly at water quality sites. Other biotic variables would generally be monitored annually (probably in late summer) or less often – depending on resources. Macrophytes would be done (if at all) as part of physical habitat. Hydrological indices need to be defined to support biomonitoring.

Biotic component	Needed for?
Macro-invertebrates (annually)	Well established 'integrating' indicator of stream 'health'
Periphyton (monthly, warm months)	Basis of stream primary production, nuisance growths
Fish (2-5 year rotation?)	Valued component of biota, biodiversity issues
Macrophytes (annually?)	Flow and water quality effects, habitat
Physical habitat (annually?)	Important influence on stream ecology

The following points are copied from Schmidt (2012) and summarise the recommendations of reports prepared for the NEMaR project.

- Gross organic indicators such as organic carbon and BOD5 were not considered necessary for routine, indefinite monitoring of rivers.
- Several variables are valuable for characterisation of local issues, but are not needed for national reporting. These variables include CDOM, major ions, and certain toxic metals (Zn, Cu, Cd). They might be added in temporary local campaigns or measured for one-year-in-five rather than routinely.
- Macroinvertebrate monitoring (suitable for QMCI calculation) is strongly recommended for routine annual, indefinite river biomonitoring.
- Fish are considered an essential component of monitoring, probably annual, but protocols need development.
- Periphyton monitoring is strongly recommended for annual routine, indefinite monitoring.
- Physical habitat monitoring (annually) is recommended.
- Hydrological underpinning of biomonitoring is recommended, probably based on continuous flow recording at nearby sites. However advice is needed on suitable hydrological indices.