Recommendations for new sites to improve representativeness in the New Zealand river environmental monitoring network

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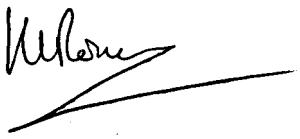

Dr. Helen Rouse

Summary

The New Zealand Ministry for the Environment (MfE) is considering establishing approximately 80 new river monitoring sites for water quality and ecological monitoring. The new sites are intended to augment the current national network, and improve the degree to which the current network represents New Zealand's environmental heterogeneity. The current network consists of approximately 1,500 sites operated by regional and district councils and NIWA. MfE commissioned the study reported here to identify candidates for the new river monitoring sites.

Two primary aims of national scale river monitoring are to estimate the current state and temporal trends in water quality and ecological variables in different environmental classes, and to estimate nation-wide state and trends (i.e., averaged across environmental classes). For both aims, an environmentally representative network of monitoring sites is needed to make accurate estimates. A highly representative network has two attributes: 1) data are available from monitoring sites in each of the major environmental types or classes; and 2) site numbers are in proportion to the abundance of rivers in each class. If an environmental class lacks monitoring sites, or the number of sites is low relative to the abundance of rivers in the class, the class is under-represented. If the number of monitoring sites in a class is high relative to the abundance of rivers in the class, the class is over represented. Under- and over-representation can lead to inaccurate estimation of large-scale water quality conditions. For example, an assessment of stream water quality in an area with a mix of urban and native forest landcover, and with monitoring sites on urban streams only, could indicate that the average water quality state is worse than the true area-wide average.

In this report, we use the term "representativeness" to refer to the distribution of monitoring sites in environmental space in relation to the distribution of rivers in the same space. The representativeness of the river monitoring network was analysed recently, using a set of 991 "core sites" that had sufficient duration and frequency of recent sampling for estimating state and trend in some variables. In the 2012 analysis and in the current report, the River Environment Classification (REC) was used to define environmental classes and to group stream reaches and monitoring sites. The 2012 analysis indicated that, in general, the current river monitoring network is poorly representative of New Zealand's river environments. Some environmental classes, particularly those in lowlands and hill country with pastoral landcover, are over-represented. Other classes are under-represented, particularly those in mountainous areas with natural landcover. Some environmental classes are not represented by any core monitoring sites.

Establishing new river monitoring sites in under-represented environments will improve national-scale representativeness. An alternative approach would be to close sites in over-represented environments, but we did not consider this further because regional councils operate these sites for reasons other than national-scale assessments. In the 2012 representativeness analyses, we estimated that 200-240 new sites would be required to create a highly representative network of approximately 990 sites. For many under-represented and unrepresented classes, only 1-3 monitoring sites are needed in a highly representative network. Such small site-numbers would improve representativeness, but the data from these classes would have low statistical power to characterise differences between class means or between class means and reference guidelines. For the current study, we focussed on classes where the representative number of sites is at least four.

Selecting new river monitoring sites requires two general steps: a desktop analysis to identify sites or groups of sites that meet criteria that can be applied using a geographic information system, and on-site inspections to determine whether individual sites are suitable for collecting samples and making field measurements. The criteria used in the first step include environmental classification, land-cover, stream order, and the geographic distribution of sites. The criteria used in the second step include safe access to sites, land-owner permission and the absence of small-scale anthropogenic influences such as effluent discharges. The current report consists of the desktop analysis, which has been structured to assist field staff making subsequent on-site inspections.

The first step in the desktop analysis was to determine which environmental classes to prioritise for new river monitoring sites. High-priority classes were defined as those that are currently under-represented in the national monitoring network, account for a substantial proportion of the total length of rivers in New Zealand, and have a representative number of monitoring sites > 4. We used the REC classification at the Climate/Source of Flow/Landcover level to identify these environments. The six categories of the Geology level were pooled. The Landcover categories Bare, Indigenous Forest, Tussock, and Scrub were also pooled into a single category, Natural. These pooling steps increased the number of sites per class, while maintaining a relatively high level of environmental resolution.

The second step in the desktop analysis was to extract all river reaches in New Zealand belonging to the high-priority REC classes from the REC geodatabase. In this step, we characterised each reach by location, region or district, distance to the nearest road, stream order, estimated mean annual flow, and percent of the catchment upstream of the reach corresponding to each of 44 landcover classes in the Land Cover Database-3 (LCDB3).

The third step was to identify candidate monitoring sites from among the more than 100,000 reaches in the previous step. Candidate sites were those reaches that met each of the following criteria: stream-order 3 or higher, estimated mean annual flow ≥ 100 L sec^{-1}, a road within 100 m of any point on the reach, and for reaches in the REC Natural land-cover class, ≥ 70% of the land cover in the upstream catchment composed of native land-cover. A total of 11,604 sites met these criteria.

The fourth step was a “manual desktop assessment” to further reduce the list of candidate sites to a number (~100-200) small enough to be tractable for individual on-site inspection. We used maps of candidate sites for each class and our own knowledge of New Zealand rivers to select sites that were distributed as evenly and broadly as possible in both geographic and environmental space, and appeared to have good road access. We also considered candidate sites that are in close proximity to flow recorders, and sites for which water quality and/or ecological data are available from previous monitoring.

Candidate sites fell into one of three broad groups defined by the nature of the road access and proximity to other sites. The first group consisted of isolated sites adjacent to bridge crossings; there are no alternative candidate sites in close proximity. The second group corresponds to situations where a road runs parallel to a river, and there are multiple candidate sites that are equivalent based on the GIS criteria. Field staff will need to assess these reaches to identify the best sites. The third group consists of single candidate sites that lie on each of several rivers that are in close proximity. These sites are also equivalent based on the GIS criteria, and field staff will need to assess each site to identify the best candidate.

The high-priority REC classes identified in the first step of the desktop analysis are listed in the following table. If the target number of new sites in each class is added to the network, there will be 6 to 52 sites in each class, except for class CD/L/N. The increase in site numbers in most classes will improve statistical power as well as representativeness.

Target numbers for proposed new sites in under-represented REC classes. Current monitoring sites refers to the number of sites in the current network of 901 core sites.

REC class	REC class (abbreviation)	Current monitoring sites	Target number of new sites
Cold dry / Hill / Natural	CD/H/N	24	4
Cold dry / Lowland / Natural	CD/L/N	1	1
Cold dry / Mountain / Natural	CD/M/N	3	3
Cold wet / Hill / Exotic forest	CW/H/EF	13	2
Cold wet / Mountain / Natural	CW/M/N	15	22
Cold extremely wet / Glacial mountain / Natural	CX/GM/N	8	7
Cold extremely wet / Hill / Natural	CX/H/N	37	15
Cold extremely wet / Lowland / Natural	CX/L/N	12	3
Cold extremely wet / Mountain/ Natural	CX/M/N	9	19
Warm dry / Lowland / Pasture	WD/L/P	34	4
Warm wet / Lowland / Exotic forest	WW/L/EF	8	1

After applying the GIS criteria and manually evaluating each of the resulting sites, we identified a total of 134 candidates across the 11 REC classes considered in this study. About 35% of these sites are in groups (either multiple sites on single river sections, or single sites on each of multiple rivers in close proximity). If one site is selected from each group, there will be a total of 86 individual sites. Of these 86 sites, 68 (79%) are in the South Island, with 51 (59%) in the West Coast, Canterbury and Otago regions. The distribution of new sites across North Island regions is more even. Candidate sites are located within the boundaries of 13 unitary authorities; no candidate sites were located in the Taranaki and Wellington regions, or in Nelson City.

1 Introduction

A large network of sites is used to monitor water quality and ecological conditions in New Zealand's rivers. Monitoring data from the network are used to produce national-scale assessments of state and trends in river water quality and ecological health. This network is an aggregation of approximately 1,500 sites from 17 monitoring programmes operated by unitary authorities and NIWA. Combining the data from sites operated by different organisations allows analysts to maximise the range of environments covered by their assessments. The specific number of sites in the aggregated network varies based on the screening rules applied by analysts (e.g., rules for minimum monitoring frequencies and periods of record for the sites).

The individual sites that make up the aggregated monitoring network were established for different reasons, including consent monitoring, microbiological monitoring for contact recreation, regional state-of-environment reporting, and regional policy development. The individual sites were established at locations that best serve their purpose. For example, microbiological water-quality sites are located at popular bathing beaches, and many consent monitoring sites are located adjacent to discharge or abstraction points. Regional councils operate approximately 95% of the river monitoring sites in New Zealand, and the council monitoring programs were not designed to contribute to national-scale assessments. The remaining 5% of the monitoring sites (77 sites on 35 rivers) comprise NIWA's National River Water Quality Monitoring Network (NRWQN). Unlike council sites, most of the NRWQN sites were established for the purpose of national-scale assessments; the large rivers in the NRWQN drain about half of New Zealand's land area (Davies-Colley *et al.* 2011). Despite the inclusion of the NRWQN sites, the aggregate network is not optimal for assessing river conditions across the range of environmental settings in New Zealand.

New Zealand's land area has a high level of environmental heterogeneity, with a wide range of climatic, topographic, geological and land-cover conditions. This terrestrial and climatic heterogeneity leads to spatial variability in river hydrology, geomorphology and chemistry, which leads in turn to spatial variability in fish and invertebrate communities and other river biota. Assessing the state of river water quality and ecology across New Zealand requires monitoring data from river reaches in each of the predominant environmental types or classes. However, some common environments in New Zealand lack river monitoring sites. For example, there are no river monitoring sites currently operated in catchments with warm, dry climates and predominately natural, unmodified landcover (e.g., forested streams near Cape Reinga), or in warm, extremely wet climate areas with natural landcover (e.g., forested streams in the southern Coromandel).

The configuration of New Zealand's aggregated river monitoring network was recently analysed in terms of environmental representativeness (Larned & Unwin 2012). Representativeness refers to the distribution of monitoring sites in environmental space in relation to the distribution of rivers in the same space; in a highly representative network, numbers of monitoring sites in different environments are in the same proportions as the abundance of river reaches in those environments. Under- and over-representation can lead to inaccurate estimation of large-scale water quality conditions. For example, in a region with many pastoral streams and few urban streams, the average water quality in a monitoring network dominated by urban streams is likely to be an inaccurate estimate of the true

regional water quality. The variables used to represent river abundance in different environments include river length, river surface area and volumetric flow. River length is used most frequently because length estimates are available for all 576,273 georeferenced reaches in New Zealand (Larned & Unwin 2012, Snelder *et al.* 2006).

The 2012 representativeness analysis was based on a set of 901 regional council and NRWQN monitoring sites. These "core sites" were selected from the approximately 1,500 river sites for which water quality and/or ecological data were available. The core sites are those with sufficient duration and frequency of recent sampling for estimating state and trend in some variables. The River Environment Classification (REC) and Freshwater Ecosystems of New Zealand (FENZ) were used as spatial frameworks in the representativeness analysis. The REC and FENZ classifications are used to group both river reaches and monitoring sites by shared environmental and geographic attributes (e.g., climate, topography, geology, land cover, stream order). The results of the 2012 analysis indicated that, in general, the current river monitoring network is poorly representative of New Zealand river environments. The proportions of monitoring sites in some REC climate/land-cover classes and some FENZ classes far exceed the proportions of river kilometres in the same classes; these classes are over-represented. The proportions of monitoring sites in other REC and FENZ classes are far less than the proportions of river kilometres in the same classes; these classes are under-represented. As noted above, some river classes that occur in New Zealand are not represented by any monitoring sites.

There are three possible steps for improving representativeness (i.e., increasing the degree to which the distribution of monitoring sites represents the distribution of river environments). First, new sites can be established in unrepresented and under-represented environmental classes, which would increase the total number of sites. Second, sites in over-represented classes can be closed, which would decrease the total number of sites. Third, sites can be "shifted" from over-represented classes to under-represented classes, which entails closing some sites and establishing new ones, with no change in the total number. Closing and shifting sites are rarely acceptable approaches for improving representativeness for four reasons. First, most regional-council sites are operated for reasons unrelated to national reporting (e.g., consent monitoring), and these reasons justify their continued operation. Second, excess sites in over-represented classes do not contribute to representative assessments, but they may contribute to other national-scale needs, such as assessing land-use effects on water quality, assessing effects of management actions, and making comparisons among widespread environments (Larned *et al.* 2012). Third, data from existing monitoring sites often increase in value over time as the length of record increases. Long time-series of water quality and ecological data, even in over-represented environmental classes, are needed for assessing temporal trends and detecting the effects of rare events such as droughts. Fourth, assessment problems caused by over-represented environments can be alleviated by omitting the data from some sites from analyses, without closing the sites, although omitting data may also decrease statistical power (Larned & Unwin 2012).

In view of the problems associated with closing and shifting sites, establishing new sites in under-represented and unrepresented environments appears to be the best approach for increasing representativeness, assuming that the costs of new sites are not prohibitive. In the 2012 representativeness analysis, we estimated that 200-240 new sites would be required to create a highly representative network of approximately 990 sites. It is important to note that

a highly representative network will have only small numbers of monitoring sites in rare environmental classes, resulting in low statistical power. For example, rivers in warm-dry, lowland areas with natural landcover (abbreviated WD/L/N) currently account for approximately 0.1% of the river kilometres in New Zealand. A single monitoring site on a reach classed as WD/L/N would provide proportional representation in a network of 990 sites; there are currently no sites in the WD/L/N class. While the representative number of sites in this class is one, a single site is not sufficient for estimating the average water quality state in the class, or for making comparisons with water quality in other classes. These sites have limited value in a representative network.

In March 2014, the New Zealand government announced an increase in its investment in water quality and ecology monitoring in freshwater systems[1]. In part, this investment is intended to increase the representativeness of river monitoring sites, and the accuracy and precision of national scale assessments. To increase representativeness, the Ministry for the Environment (MfE) has proposed establishing new river monitoring sites in environmental classes that are currently under-represented in the national network. In view of the large number of monitoring-site shortages and the cost of establishing and operating new sites, the most severe shortages should be prioritised for new sites. MfE is considering establishing approximately 80 sites, although the final number may vary.

This present study was undertaken in response to a MfE request for a list of candidate sites with the greatest potential to improve the representativeness of the freshwater monitoring network. Specific tasks associated with this request included:

- Identify the most severely under-represented REC classes in the current river monitoring network;
- Carry out a Geographic Information System (GIS) analysis to identify stream reaches in these classes, using agreed selection criteria;
- Produce a list of potential candidate sites, together with spatial and environmental attributes including (but not limited to) reach number, region, grid reference, distance from nearest road, stream order, REC class, percent cover of dominant vegetation, and any existing flow data;
- Compile a technical report documenting these results, including appropriate tables and maps.

The process we used in this project is based solely on desk-top analyses, and all potential candidate sites will require individual on-site inspections before making decisions about site selection. The staff conducting these inspections need to determine the suitability of each candidate site, based on criteria that include safe access and landowner permission. To aid the on-site assessments, we identified groups of reaches in each REC class that met our GIS criteria and are located in the same catchment or on the same river section. Field staff can use these groups to organise their site inspections; in most cases we recommend that one site is selected per group. The total number of candidate sites that we identified in our desk-type assessment, 134, is sufficiently large that field staff can be selective during site inspections.

[1] http://www.beehive.govt.nz/release/govt-invests-further-21-million-community-freshwater-action

2 Methods

2.1 The REC river network

The REC (Snelder & Biggs 2002) is a representation of New Zealand's river network derived from a Digital Elevation Model with a spatial resolution of 50 m. The network comprises ~570 000 unique river segments defined by upstream and downstream confluences with tributaries. Mean segment length is 740 m. Each segment is associated with its own local watershed, allowing the catchment feeding each segment to be characterised by accumulating attributes for all upstream segments. The network is linked to a GIS database describing the climate, topography, geology, land cover and hydrology of New Zealand, including layers for segment-specific catchment characteristics derived from catchment averaged values of each variable. Topographical and network attributes associated with each segment include centroid coordinates; stream order (Strahler 1964); segment length; elevation; catchment area; and modelled mean flow (Woods *et al.* 2006).

Most REC catchment descriptors provide continuous measures, but for many applications it is convenient to condense these into a series of discrete, categorical variables structured to match the underlying hierarchical character of the REC (Snelder & Biggs 2002). We used three of the six available levels in this study, representing climate, source of flow, and landcover[2]. Climate class is defined in terms of mean annual temperature (C = cool, W = warm) and precipitation (D = dry, W = wet, X = extremely wet), yielding six discrete classes (CD, CW, CX, WD, WW, WX). Source of flow is defined using a rainfall weighted measure of catchment elevation together with a measure of the proportion of the catchment draining lakes, yielding a five-level classification comprising GM (glacial mountain); M (mountain); H (hill); L (lowland); and Lk (lake).

Landcover is defined in terms of the Land Cover Database (Snelder *et al.* 2005), the most recent version of which (LCDB3) is based on LUCAS satellite imagery from 2007-2008. For the purposes of this report we created a single class representing natural landcover (class N) by merging 13 LCDB3 classes representing natural or near-natural land cover: classes 12 (landslide), 14 (snow and ice), 15 (alpine grass), 16 (gravel and rock), 43 (tall tussock), 44 (depleted grassland), 50 (fernland), 52 (kanuka and manuka), 54 (broadleafed indigenous hardwoods), 55 (mixed alpine scrub), 56 (mixed exotic scrub; also includes coprosma, manuka, etc.), 58 (matagouri) and 69 (indigenous forest). Other landcover classes relevant to this study were exotic forestry (class EF), and pasture (P).

In the remainder of this report, we use the notation <climate class>/<source-of-flow class>/<landcover class> to identify REC classes representing a specific environment. Thus, class CD/M/N should be read as cold dry/mountain/natural.

2.2 Under-represented classes

Under-represented REC classes were identified on the basis of the 901 river monitoring sites used for water-quality and ecological analyses in the National Environmental Reporting and Reporting (NEMaR) programme (Larned & Unwin 2012, Unwin & Larned 2013). These 901 "core sites" were selected for analyses from the larger pool of approximately 1500 monitoring sites using the following criteria:

[2] Classes representing catchment geology (the third level of the REC hierarchy) were pooled for the purposes of this report.

1. The site was used for SoE monitoring rather than point-source monitoring or short-term investigations;
2. Sites were located on streams of order 2 or greater;
3. Data were available from 1 January 2006 to at least 31 December 2010;
4. For water quality sites, sampling frequency was quarterly or higher, and data available for at least 16 quarters from 2006-1010;
5. For macroinvertebrate sites sampling frequency was at least annual, and data were available for at least 4 years within the study period;

We note that altering these rules would lead to a different set of core sites for analysis; this has been the case in recent analyses (e.g., Clapcott *et al.* 2013). Different sets of core sites will potentially lead to different patterns of REC-class shortages, but the most severe class shortages would probably persist irrespective of the selection criteria used. For example, very few water quality sites in the current network are located on low (1st and 2nd) order streams (Larned & Unwin 2012), so their exclusion is unlikely to significantly impact the final candidate list (see Section 2.3 for further discussion).

We used the REC classification at the Climate/Source of Flow/Landcover level, with landcover pooled as described in Section 2.1), to identify severely under-represented environments. Pooling natural landcover into a single class increased the number of sites per class, while maintaining a relatively high level of environmental resolution; 88 such classes are represented in New Zealand (excluding first-order reaches). Half of these classes are minor; each accounting for < 100 river km in New Zealand (< 0.05% of the total river length), and were omitted from our analysis. We identified under-represented environments based on the remaining 44 major classes. The REC geodatabase was used to identify each river reach in New Zealand in each of the major classes.

Under-represented classes were defined as those major classes for which one or more new sites were needed to make the proportion of monitoring sites in the network equal to the proportion of river kilometres in the same class.

2.3 GIS criteria for candidate monitoring sites

Each of the river reaches in New Zealand belonging to one of the under-represented REC classes was characterised using the following variables: geographic position of the centroid of the reach (NZTM), region or district in which the reach is located, distance from the reach to the nearest road, stream order, and percent of the catchment upstream of the reach corresponding to each of 44 landcover classes. The catchment cover data and classifications were extracted from the Land Cover Database-3 (LCDB3). Cover data in LCDB3 are based on remote imagery taken over summer 2007/2008. Positions, regions, distances to roads and stream orders were extracted from REC shape files. We also used estimated mean annual flow (or runoff) for each reach, derived from models based on precipitation information and estimated evapotranspiration (Woods *et al.* 2006).

The GIS data were used to filter the river reaches based on stream order, distance to a road, and native vegetation cover in the upstream catchment. Candidate sites were defined as those meeting the following criteria: stream-order 3 or higher, estimated mean annual flow ≥

100 L sec^{-1}, a road within 100 m of any point on the reach, and (for reaches in the REC Natural land-cover class) ≥ 70% of the land cover in the upstream catchment composed of native land-cover. The primary aim of the stream-order and mean-annual flow criteria was to ensure that candidate sites were comparable in size to the existing monitoring sites, most of which are third-order or larger (Larned & Unwin 2012). Screening out small streams also minimises the risk of selecting intermittent sites that could be dry on monitoring dates, and ensures that water depth is sufficient for measurements that have a minimum depth requirement (e.g., black-disk clarity). In addition, these criteria ensure that water quality data from the new sites will represent the effects of landcover and land-use over relatively large areas.

The aim of the < 100 m-to-the-road criterion was to filter out inaccessible sites and sites that would require time-consuming overland travel. The GIS-based approach to road access does not eliminate sites where access is prevented by fences, steep embankments or refusal by land-owners. These factors must be assessed during site inspections (Section 4.2). The aim of the ≥ 70% native land-cover criterion was to ensure that new monitoring sites used to assess associations between water quality and natural landcover would be minimally affected by modified landcover upstream. The REC classification rule for natural landcover is that a reach with < 25% pastoral landcover in the upstream catchment, and/or < 15% urban landcover, and/or < 50% exotic forest landcover is classed as natural. Therefore, reaches classed as natural in the REC can have as little as 50% natural landcover in the upstream catchment. The ≥ 70% native land-cover criterion used in the current report is more stringent than the REC rule. This rule will also improve the value of new monitoring sites as sources of data for developing reference conditions.

2.4 Manual desk-top assessments of candidate sites

2.4.1 Assessment criteria

The automated filtering procedure described in section 2.3 generated a list of 11,604 reaches that met the GIS criteria. These 11,604 reaches comprised our long-list of candidate sites. For each of the 18 REC classes, we used standard mapping software[3] to overlay all potential candidate sites on an interactive digital map (www.topomap.co.nz), and to manually browse and compare individual sites. In contrast to the automated GIS-based procedures described in the previous section, the manual assessments were based on the authors' knowledge of New Zealand geography and on criteria that did not lend themselves to automation. In particular, we sought to distribute candidate sites as evenly and broadly as possible in both geographic and environmental space. Additional assessment criteria included the presence or absence of existing monitoring sites in the same catchment or sub-catchment, and accessibility. Other things being equal, we selected sites that are accessible from a main highway in preference to more remote sites accessible from long unpaved roads, and rejected sites in close proximity to existing sites in the same class.

2.4.2 Candidate groups

The candidate site maps for each REC class suggested that most sites fell into one of three broad categories defined by the nature of the road access and proximity to other candidate sites. The first category corresponds to situations where the candidate sites are on river

[3] http://www.integrated-mapping.com/

sections that are intersected by a road at a single point, usually a road bridge. These sites were largely self-selecting. Our analyses did not indicate whether each site in this category is easily accessible from the road, but suggest that if access is available (e.g., via a side track) it is unlikely to be more than a few hundred metres from the mapped site (Figure 2-1).

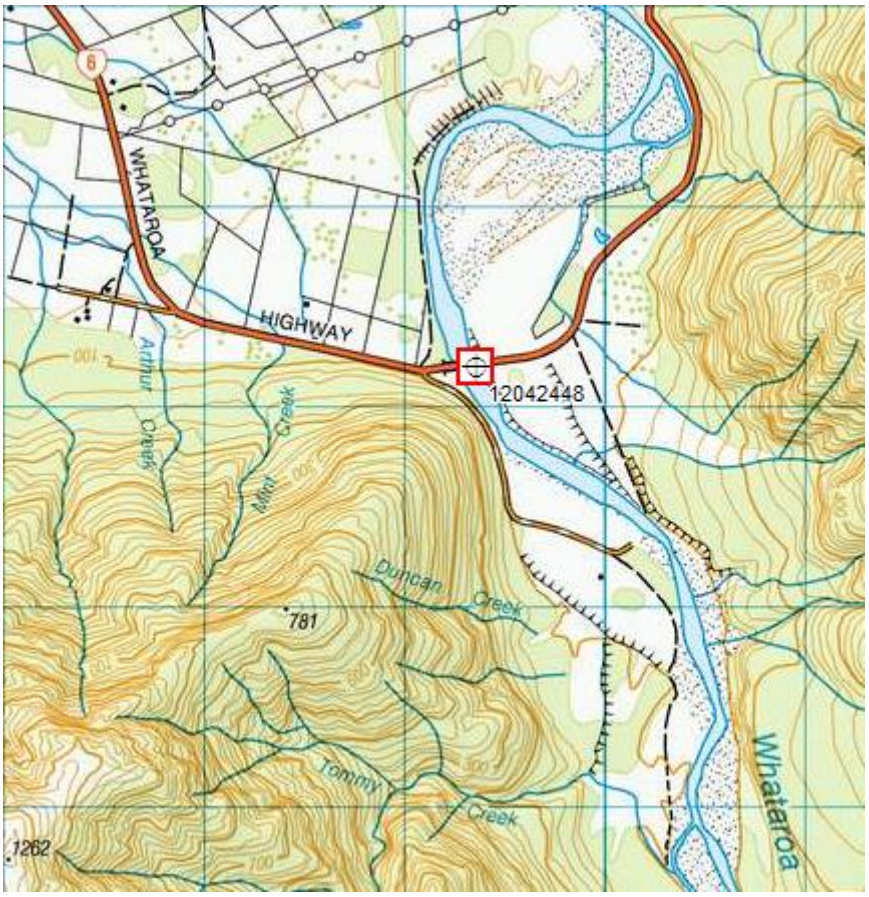

Figure 2-1: An example of a candidate site defined by a single access point, on the Whataroa River (class CX/GM/N) in South Westland. Our analysis does not ensure that the REC reach of interest (NZReach 12042448) is accessible from the road (SH 6), but suggests that access may be possible via either SH 6, or the short gravel road immediately to the south. Map gridline spacing is 1 km.

The second group corresponds to situations where a road follows a river valley so that multiple candidate sites occur along reaches where the road is parallel to and < 100 m from the river. In such cases, our desk-top analysis could not be used to identify the best site from among the candidates. Field staff will need to assess these reaches to identify the best sites. In some of these cases, the road is on a terrace above the river, and the only suitable sites are those that can be accessed by tracks down the embankment; relatively few of these tracks are represented in our GIS. A case in point is the Hollyford River in Fiordland, where our familiarity with the steep terrain in this area suggests that at most one or two of the mapped candidate sites are suitable. However, we are aware of at least three additional locations where unmarked tracks provide direct access to the river by vehicle or foot (Figure 2-2).

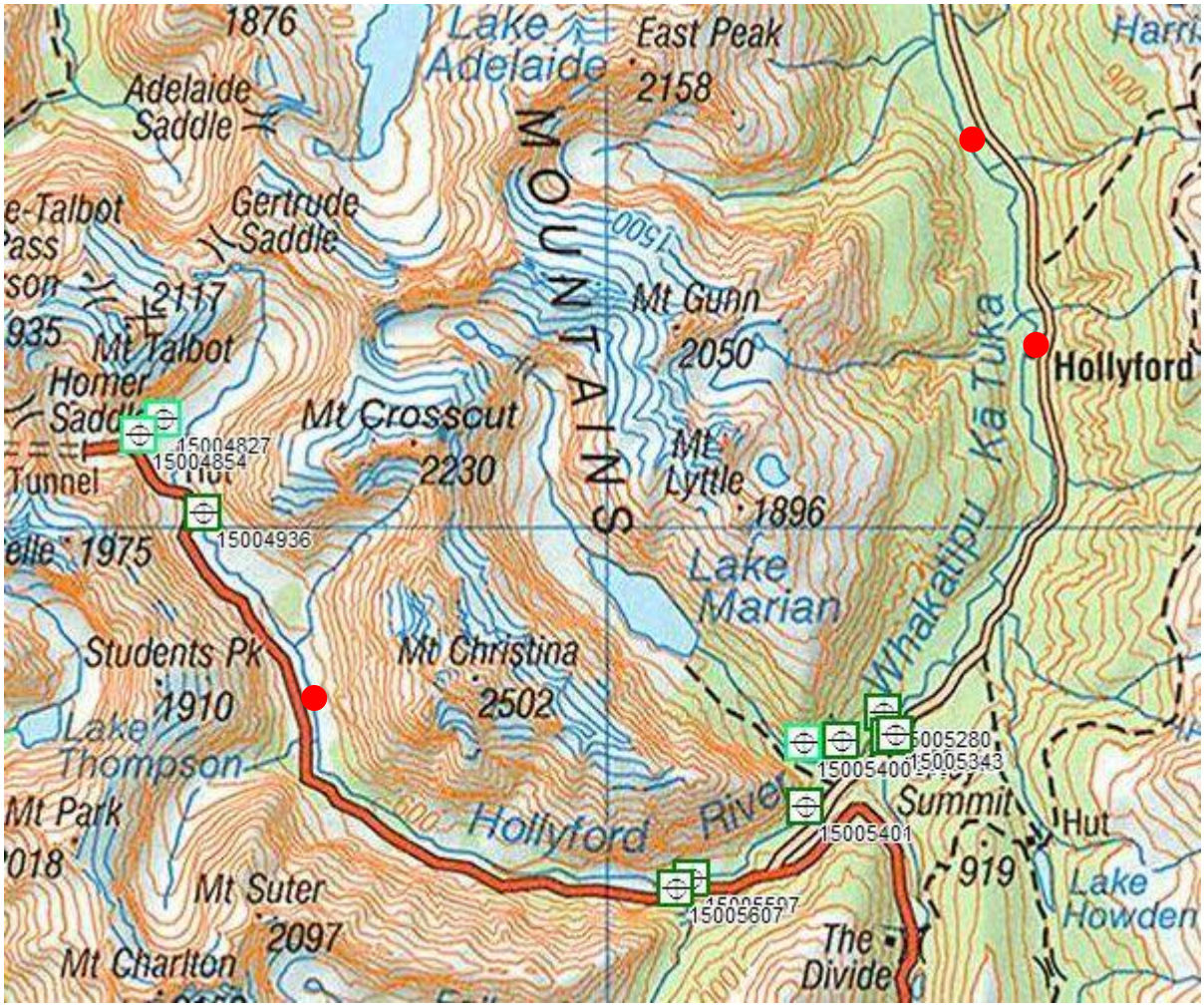

Figure 2-2: An example of a candidate site defined by multiple access points on a single river reach, the Hollyford River (class CX/GM/N) in Fiordland. Candidate sites identified by GIS analysis are marked by numbered squares. In addition to those sites, the red circles represent river reaches with good access from Milford Sound Highway; these reaches are likely to be suitable for monitoring sites. Map gridline spacing is 10 km.

The third group consists of single candidate sites (as per group 1) that lie on several streams in close proximity (Figure 2-3). At the level of detail of our desktop study, we have insufficient information to identify which of the 2-4 candidate sites in each group are suitable for monitoring, and which is the optimal site. As in the case of multiple candidate sites on single river sections, final site selection should be based on site visits by field staff.

To accommodate the second and third categories in our results, we identified each group of candidate sites in summary tables. These groups are necessarily informal, but provide the most practical way to present our data in a format that will inform any subsequent field assessment.

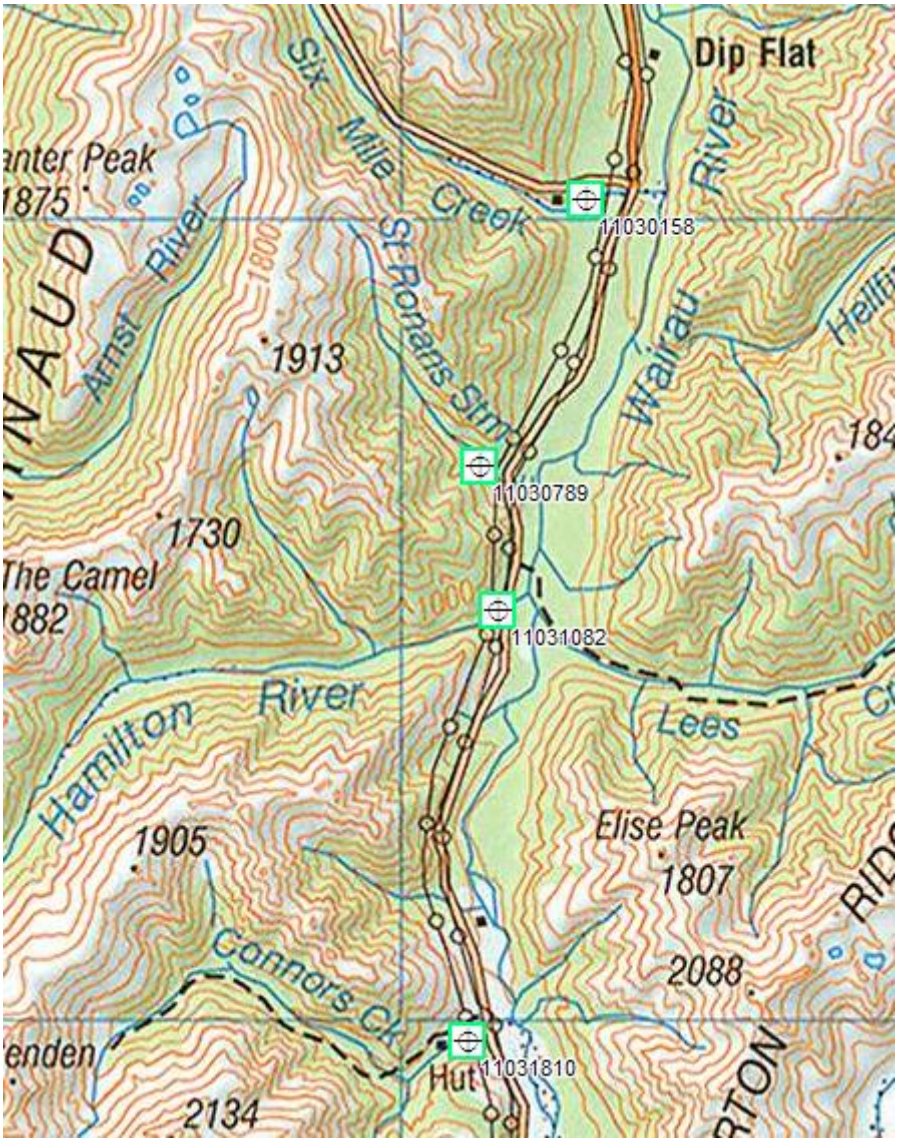

Figure 2-3: An example of multiple candidate sites, each defined by a single access point, on four tributaries of the Wairau River, Marlborough (class CX/M/N). Our analyses provide insufficient detail to determine which of these candidates are suitable for monitoring sites. Map gridline spacing is 10 km.

2.4.3 Use of non-core sites

In addition to the sites identified by our GIS analysis, we also considered other potential candidates that were included in the ~1,500 site database compiled for the NEMaR programme (Larned & Unwin 2012, Unwin & Larned 2013), but were not usable as core sites. Some of these "non-core" sites are no longer operational or are used only for monitoring benthic invertebrates, but others are well established and were rejected only because they did not pass the date-filtering rules we set for the NEMaR water quality analyses. Where possible, we included any such sites in our candidate list for each REC class so as to maximise use of existing sites rather than develop completely new sites.

3 Results

3.1 Under-represented classes

In consultation with MfE, we selected 11 REC classes in which approximately 80 new river monitoring sites are to be established. The 11 classes consist of the largest under-represented REC classes, plus class CD/L/N (Table 3-1). Rivers in the CD/L/N class are not abundant and there is one monitoring site in this class among the core sites. However, more sites in CD/L/N class are needed to generate reference-condition data for evaluating water quality in rivers from the CD/L/P class, which is the most common class in the national network. With the exception of the CD/L/N class, establishing the target number of new sites in the other classes will ensure that there are at least six sites in each class.

The target numbers in Table 3-1 represent a total of 81 new sites across all classes, comprising 74 sites in landcover class N, 3 in landcover class EF, and 4 in landcover class P. Including these sites, an expanded national network would comprise approximately 990 sites.

Table 3-1: Under-represented REC classes and the rationale for establishing one or more new monitoring sites in each class. Target numbers refer to the proposed distribution of new site numbers. Current monitoring sites refers to the number of sites in the current network of 991 core sites.

REC class	Target number of new sites	Current monitoring sites	Rationale
CD/H/N	4	24	5th most under-represented class
CD/L/N	1	1	One site in the core-site network; more are needed for comparisons with the most common class, CD/L/P
CD/M/N	3	3	8th most under-represented class
CW/H/EF	2	13	9th most under-represented class
CW/M/N	22	15	Most under-represented class
CX/GM/N	7	8	4th most under-represented class
CX/H/N	15	37	3rd most under-represented class
CX/L/N	3	12	7th most under-represented class
CX/M/N	19	9	2nd most under-represented class
WD/L/P	4	34	6th most under-represented class
WW/L/EF	1	8	Tied for 10th most under-represented class

3.2 Identification and assessments of candidate sites

In this section we report results for each of the 11 REC classes identified as being under-represented in the current network. For each class, our presentation consists of a brief overview of its occurrence and distribution, the extent to which it is represented in the current network, and a review of the most obvious gaps in geographical coverage. We also include a map of New Zealand showing the distribution of reaches in the class, existing sites, and potential candidate sites; and a table identifying key attributes of the suggested candidate reaches for establishing new sites within that class. Space limitations preclude listing all relevant site attributes in these tables, but full details for all sites are given in Appendix A.

Our results are ordered by REC Landcover class (natural, exotic forest, pasture), and within each landcover class by Climate and Source-of-Flow class. Climate classes are ordered from cold to wet, and then by decreasing rainfall: thus, the ordering is CX, CW, CD, WX, WW, WD. Source-of flow classes are in order of decreasing elevation, i.e., GM, M, H, L; source-of-flow class Lk (lake) is well represented in the current network, and was not considered further. For each class, we include a map showing the extent of the class across New Zealand, and the location of all potential candidate sites identified by our GIS analysis (Section 2.3) before manual inspection (Section 2.4). Sites which remained after manual inspection are then listed separately in tabular form.

3.3 Natural landcover classes

3.3.1 Cold-extremely wet/glacial mountain/natural (class CX/GM/N)

Class CX/GM/N is confined to rivers draining the spine of the Southern Alps from Arthur's Pass to Lake Te Anau, and accounts for 2% of total river length in New Zealand. Many such rivers lose their glacial character as they descend from the mountains, but two east coast rivers (Rakaia, Rangitata) and several on the West Coast (e.g., Whataroa, Waiho, Cook, Karangarua) remain in this class over their entire length (Figure 3-1).

The class is currently represented by eight core sites, with a further seven required to achieve representativeness. Five of these core sites are on the Rakaia and Rangitata rivers, leaving the class poorly represented over much of its geographic range. In particular, the current network includes only one West Coast river (Haast @ Roaring Billy), and none of the headwater glacial rivers referred to in the previous paragraph.

One ORC site in this class (OTA7520709: Dart River @ Glenorchy - Routeburn Rd, NZTM 1230163, 5031456), which did not meet our original data filtering rules, is an obvious candidate for inclusion in an updated network. Viable options for filling the remaining six sites include the Hokitika River, Wanganui River, Whataroa River, Waiho River, Cook River, Karangarua River (draining to the West Coast); the Hooker River, Ahuriri River, and Earnslaw Burn (draining to the east); and the Hollyford River in northern Fiordland (Table 3-2). Most of the candidates are large mainstem rivers, but we also include four smaller rivers (e.g., Omoeroa River, Earnslaw Burn) representing the smaller glacial rivers (mean flow < 10 $m^3 s^{-1}$), which are absent from the current network.

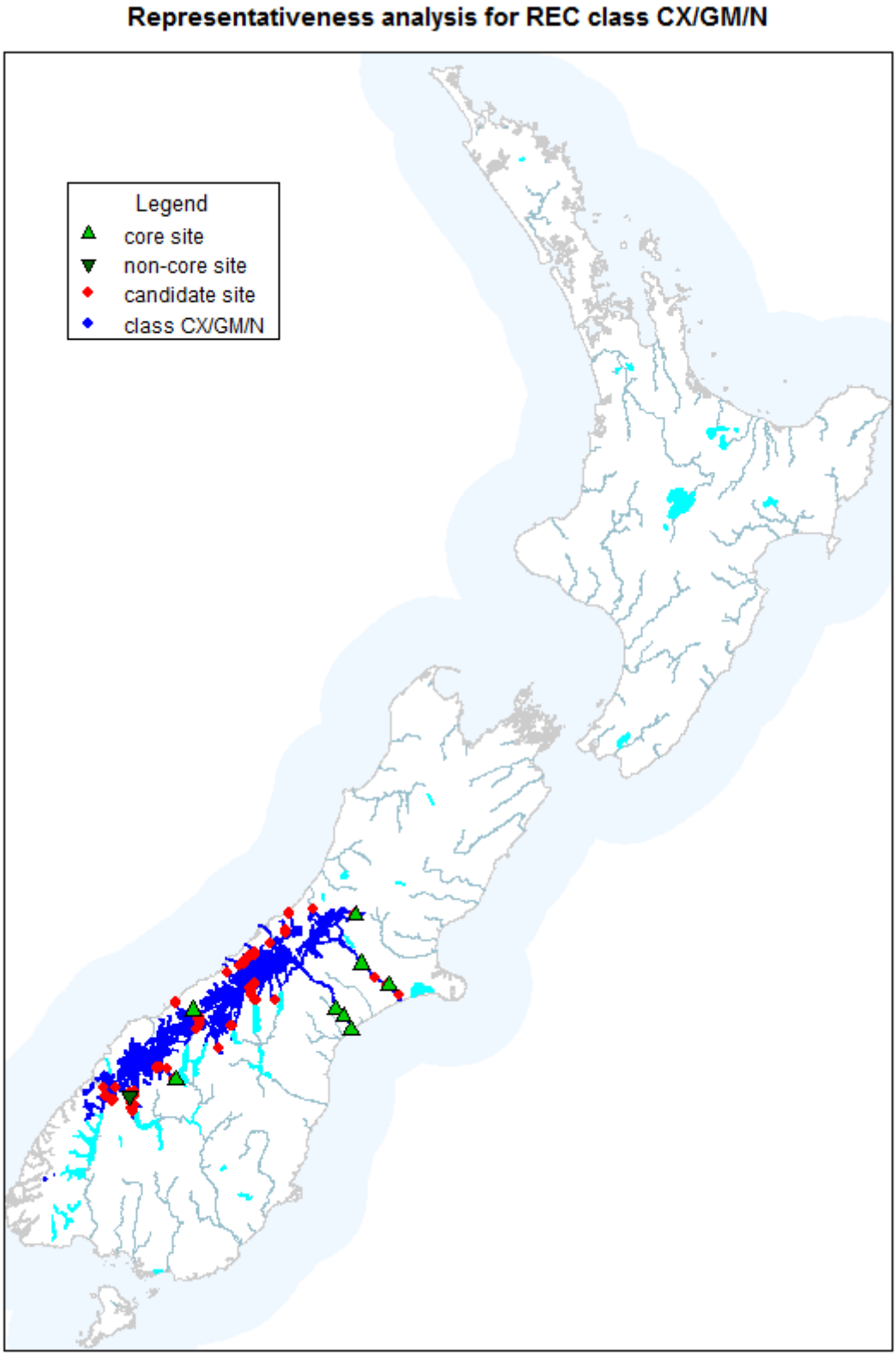

Figure 3-1: Distribution of rivers in REC class CX/GM/N, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

Table 3-2: Potential candidate sites representing REC class CX/GM/N in an expanded national network. A total of seven new sites are required to establish representativeness; site groups are subjective, but have been chosen so that choosing one site from each group would maximise geographical coverage.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
12037213	West Coast	1	Hokitika River	Hokitika Gorge	6	1438261	5242213	98
12040386	West Coast	2	Wanganui River	at SH 6	5	1406952	5219051	99
12042448	West Coast	2	Whataroa River	at SH 6	6	1389366	5204229	99
12044006	West Coast	2	Waiho River	at SH 6	6	1371815	5191406	99
12044213	West Coast	3	Omoeroa River	at SH 6	3	1364974	5189557	99
12044690	West Coast	3	Waikukupa River	at SH 6	3	1363064	5185934	100
12045393	West Coast	4	Fox River	at SH 6	4	1360624	5180040	99
12045501	West Coast	4	Cook River	at SH 6	5	1354655	5179438	99
12046351	West Coast	4	Karangarua River	at SH 6	6	1341948	5170530	98
13503195	Canterbury	5	Hooker River	at Hooker Corner	5	1369049	5152723	95
13513678	Canterbury	5	Ahuriri River	any access point u/s Snowy Gorge Creek (NZTM 1330410, 5085250)	5	1330421	5085252	86
14017708	Otago	5	Dart River	ORC OTA7520709 (Dart River @ Glenorchy - Routeburn Rd)	6	1230163	5031456	95
14016544	Otago	6	Earnslaw Burn	via gravel track to start of Earnslaw Burn foot track	3	1235641	5035169	94
15005607	Southland	7	Hollyford River	any access point from Lyttles Farm (NZTM 1206310, 5027730) d/s to Humboldt Creek (NZTM 1213800, 5039630)	4	1210889	5025534	100

3.3.2 Cold-extremely wet/ mountain/natural (class CX/M/N)

Class CX/M/N is the dominant class along the main ranges of the South Island, and also extends into the high-elevation regions of northwest Nelson. In the North Island this class is limited to isolated high-elevation regions around Mt Taranaki, Mt Ruapehu, the Raukumara Ranges, and the Tararua Range (Figure 3-2). It is currently represented by 11 core sites, with a further 18 required to achieve representativeness. The nine core sites are highly clustered, with three in the Tongariro catchment, three in Canterbury, two in northern Fiordland, and one in Golden Bay. Two non-core sites are potentially available, but both candidates (in the Tongariro catchment and Golden Bay, respectively) are in close proximity to core sites. The primary geographic range of the CX/M/N class, over the ~350 km from Arthurs Pass to Fiordland, lacks monitoring sites.

Essentially all potential new North Island sites lie west and north of Mt Ruapehu and Mt Tongariro, with access via SH 4 and SH 47 (Table 3-3). Both groups represent headwater tributaries of the Whanganui River, the western group via the Manganuioteao catchment, and the northern group via the Whakapapa catchment. We recommend adding at most three new sites from these two groups.

Assuming three new sites are established in the North Island, at least 15 sites are required in the South Island. Excluding rivers which are already represented in the current network (e.g., the Waimakariri River), candidate sites are widespread over most of the area in this class, albeit with some tendency to cluster (e.g., Buller and Lewis Pass areas and Clutha River headwaters), as well as a few notable gaps (e.g., mid Canterbury and most of Fiordland). We have therefore made a liberal allowance for redundancy in areas where potential candidate sites are most abundant, so as to provide plenty of choice during site inspections. At the same time, we note that a few candidate sites provide isolated opportunities in otherwise unrepresented areas, making them natural suggestions for an expanded network. Sites in this group include the Rolling River, Taipo River, Kokatahi River, Jacobs River, and Borland Burn.

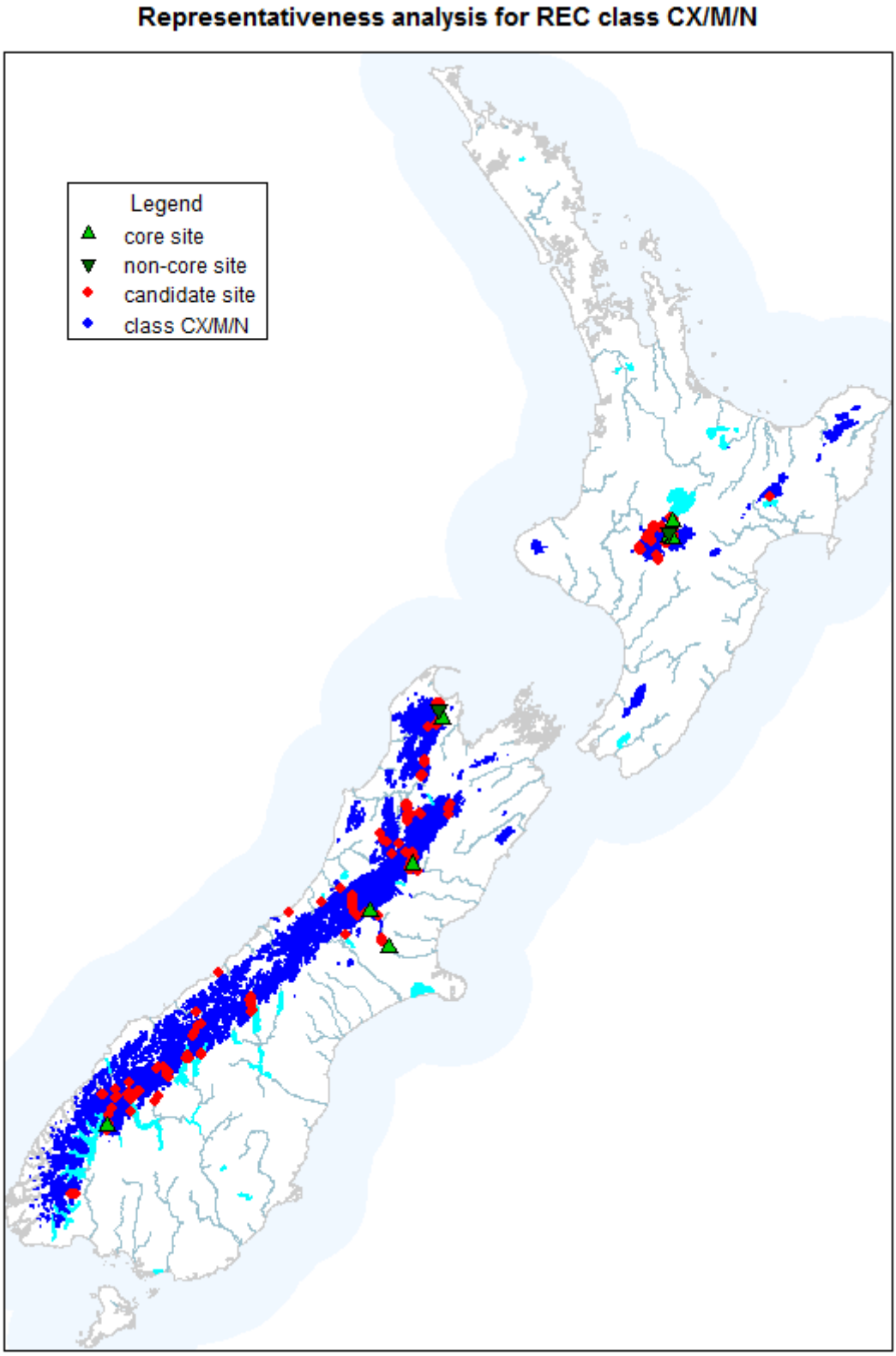

Figure 3-2: Distribution of rivers in REC class CX/M/N, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

Table 3-3: Potential candidate sites representing REC class CX/M/N in an expanded national network. A total of 18 new sites are required to establish representativeness; site groups are subjective, but have been chosen so that choosing one site from 18 of the 19 available groups would maximise geographical coverage.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
7010679	Manawatu-Wanganui	1	Whakapapanui Stream	at SH 47	5	1816733	5663904	99
7011239	Manawatu-Wanganui	1	Whakapapaiti Stream	at SH 47	4	1813423	5661067	100
7013349	Manawatu-Wanganui	2	Makatote River	at SH 4	4	1806754	5651142	99
7013638	Manawatu-Wanganui	2	Manganui-o-te-ao River	at SH 4	3	1805768	5649641	98
7014189	Manawatu-Wanganui	2	Mangaturuturu River	at SH 4	3	1805079	5646700	100
8002584	Hawke's Bay	3	Waiotukupuna Stream	at SH 4	3	1953961	5707859	100
10003157	Tasman	4	Anatoki River	any point off McCallum Road u/s fish farm (NZTM 1580230, 5474280)	4	1579865	5474314	98
10004171	Tasman	4	Waingaro	TDC (Waingaro @ Hanging Rock)	4	1578963	5467904	99
10016606	Tasman	5	Rolling River	any point u/s Rolling Junction Shelter (NZTM 1564960, 5411960)	4	1564635	5411568	99
11030158	Marlborough	6	Six Mile Creek	via Wairau Hanmer Springs Hydro Road	3	1592244	5360226	97
11030789	Marlborough	6	Saint Ronans Stream	via Wairau Hanmer Springs Hydro Road	3	1591142	5356853	99
11031082	Marlborough	6	Hamilton River	via Wairau Hanmer Springs Hydro Road	3	1591253	5355119	100
11031810	Marlborough	6	Connors Creek	via Wairau Hanmer Springs Hydro Road	3	1590979	5349910	98
12007225	Tasman	7	Owen River	any point u/s of Brewery Creek (NZTM 1560220, 5392250), Owen Valley East Road	4	1560542	5392469	96
12017315	Tasman	8	Matakitaki River	any point from Blue Rock (NZTM 1543420, 5361030) u/s to Horse Terrace (NZTM 1547700, 5348810)	5	1547356	5348686	94

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
12017470	Tasman	8	Glenroy River	any point off Glenroy Road	5	1545132	5348049	96
12022162	West Coast	9	Rough or Tobin Stream	at SH 7, upper Inangahua River	4	1512888	5328263	98
12024006	West Coast	9	Crate Creek	at SH 7, upper Inangahua River	3	1517448	5318841	99
12024727	West Coast	10	Maruia River	at SH 65, Springs Junction	5	1534382	5315429	98
12033649	West Coast	11	Taipo River	at SH 73	4	1468802	5265573	98
12036110	West Coast	12	Otira River	any point accessible from SH 73	3	1482038	5250401	100
12036286	West Coast	13	Kokatahi River	at Middlebranch Road	4	1447179	5249403	99
12046368	West Coast	14	Jacobs River	at SH 6; also known as Makawhio River	5	1331877	5170170	96
13504246	Canterbury	15	Freds Stream	at SH 80	3	1367390	5143240	89
13504849	Canterbury	15	Bush Stream	at SH 80	4	1368163	5139669	98
13505760	Canterbury	15	Twin Stream	at SH 80	4	1368149	5133307	95
14001320	Otago	16	Camerons Creek	at SH 6; good access via picnic area	5	1304575	5103913	99
14017255	Otago	17	Scott Creek	via Routeburn Road, Glenorchy	3	1228632	5032821	99
14017286	Otago	17	Twelve Mile Creek	via Rees Valley Road, Glenorchy; also known as Ox Burn	3	1238327	5032587	96
15005158	Southland	18	Pass Creek	via Lower Hollyford Road	4	1214988	5029067	98
15005165	Southland	18	Sunny Creek	via Lower Hollyford Road	3	1215031	5028903	98
15036249	Southland	19	Borland Burn	any point on South Branch u/s of NZTM 1169630 4920121	3	1165691	4920057	100

3.3.3 Cold-extremely wet/hill/natural (class CX/H/N)

Class CX/H/N dominates the West Coast of the South Island, and is also well defined in the Tararua Ranges, Taranaki, Ruapehu, the Raukumara Ranges, and East Cape. It accounts for 7.6% of total river length. The class is currently represented by 36 core sites but their distribution is very uneven, with 10 in Taranaki, five in Tasman, and four in the Buller and Grey regions of the West Coast. In contrast, there are no core sites over the lower two thirds of the South Island, a distance of over 500 km (Figure 3-3). A further 14 sites are required to achieve representativeness.

A total of eight non-core sites are potentially available, but all of these lie in close proximity to existing core sites. Even with the addition of 14 new sites, bringing the total to 50, site distribution would still be skewed by the high concentration of sites in Taranaki and Tasman, which would jointly account for 30% (15 out of 50) of sites in an expanded network.

As with class CX/M/N, relatively few new sites are likely to be required in the North Island (Table 3-4). The two most obvious gaps are west of Mt Ruapehu, and the Raukumara Ranges, both of which could potentially justify up to two new sites. The most promising candidate in the Ruapehu area is the Manganuioteao River upstream of Orautoha. Other potential candidates may exist south and west of Turangi, but most of these catchments include exotic as well as indigenous forest making them less attractive for long term monitoring. Potential candidate sites in the vicinity of East Cape/Gisborne include Opato Stream in the Waioeka Gorge (on SH2), and the Tapuaeroa River approximately 20 km upstream from Ruatoria. However, the NEMaR3 dataset on which these analyses are based did not include site data for the Gisborne District, and potentially misses suitable sites in the GDC network. If so, no additional sites would be required in this region, reducing the total of new sites for this class to 12.

Potential candidate sites in the South Island are confined to northwest Nelson, West Coast, and Fiordland. Given the paucity of current sites south of Greymouth, we recommend at most three new sites north of Greymouth, to fill gaps in the vicinity of Karamea and Maruia/Reefton, with the remainder in South Westland and Fiordland. Viable candidate rivers include the Oparara, Karamea and Little Wanganui Rivers near Karamea; the Rappahannock, Inangahua, and Waitahu Rivers near Maruia and Reefton; the Kakapotahi, Waitangitaona, Ohinetamatea, Mahitahi, Paringa, Moeraki, Whakapohai, Okuru and Jackson Rivers and Potters Creek in South Westland; and the Spey and Grebe Rivers and Kiosk Creek in Fiordland. The Spey River is a particularly attractive candidate, representing perhaps the most remote Fiordland site with any form of road access, but this river may be impractical as a long term monitoring site because reaching the road requires a boat trip to the head of Lake Manapouri.

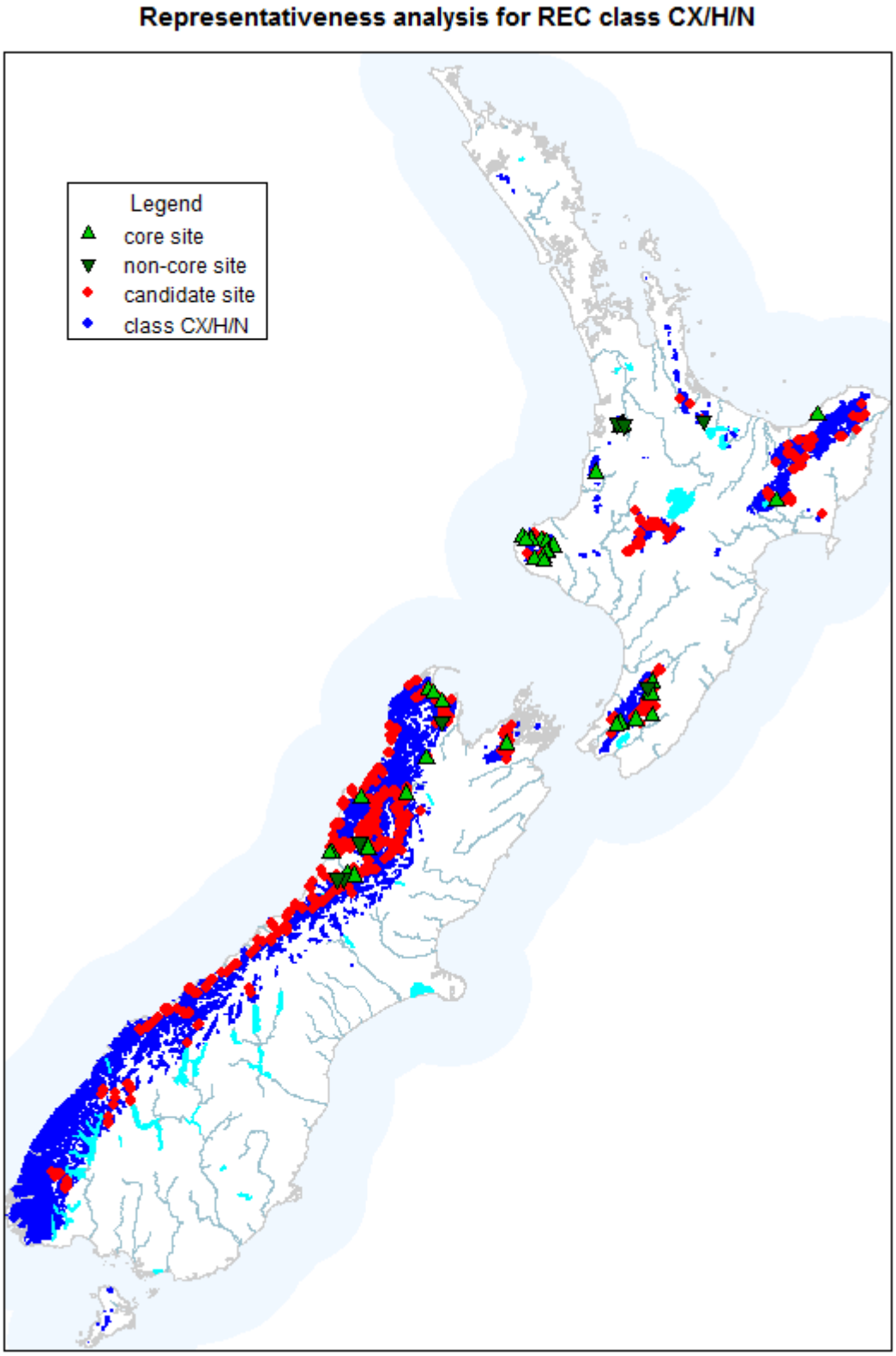

Figure 3-3: Distribution of rivers in REC class CX/H/N, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

Table 3-4: Potential candidate sites representing REC class CX/H/N in an expanded national network. A total of 14 new sites are required to establish representativeness; site groups are subjective, but have been chosen so that choosing one site from 18 of the 19 available groups would maximise geographical coverage.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
3049204	Waikato	1	Whitikau Stream	at Rangipo Prison Road	4	1845911	5672282	95
4018667	Bay of Plenty	2	Opato Stream	first accessible point u/s Waioeka confluence	5	1979968	5754419	97
7014500	Manawatu-Wanganui	3	Manganui-o-te-ao River	first accessible point u/s Orautoha	5	1792601	5645318	78
8002663	Hawke's Bay	4	Hopuruahine Stream	any point off Waikaremoana Road	5	1952978	5707481	99
12002771	West Coast	5	Oparara River	any point off Oparara Road	5	1528112	5437265	98
12003284	West Coast	5	Karamea River	u/s of tidal limit	6	1527383	5431727	98
12004502	West Coast	5	Little Wanganui River	u/s of Te Namu	5	1524222	5418933	96
12016661	West Coast	6	Inangahua River	any point from Inangahua Junction to Reefton	6	1507967	5351392	91
12019126	Tasman	7	Rappahannock River	any point u/s SH 67	4	1537352	5341370	93
12036682	West Coast	8	Mikonui River	at SH 6	5	1417983	5246895	98
12037645	West Coast	8	Kakapotahi River	at SH 6	4	1413435	5238994	94
12040211	West Coast	9	Poerua River	at SH 6	4	1396812	5219671	93
12042362	West Coast	9	Waitangi-taona River	at SH 6	4	1381568	5204685	95
12043284	West Coast	9	Potters Creek	at SH 6	3	1373457	5197085	88
12045364	West Coast	10	Ohinetamatea River	at SH 6; also known as Saltwater Creek	3	1349564	5180358	98
12047250	West Coast	11	Mahitahi River	at SH 6	5	1324608	5162459	96
12048418	West Coast	11	Paringa River	at SH 6	5	1317404	5154398	97
12048893	West Coast	11	Whakapohai River	at SH 6; also known as Little River	4	1297921	5151143	99
12049212	West Coast	11	Moeraki River	at SH 6	4	1303176	5149130	99
12051866	West Coast	12	Okuru River	u/s tidal limit off Nolan or North Bank Road	5	1275322	5130702	95
12054586	West Coast	12	Jackson River	any point off Jackson River Road	4	1256550	5113021	95
15008128	Southland	13	Kiosk Creek	at Knobs Flat visitor centre	3	1207018	5007683	97
15027181	Southland	14	Spey River	via West Arm, Lake Manapouri; requires boat access	4	1152601	4942613	99
15030464	Southland	15	Grebe River	via Borland Road	5	1160226	4934295	95

3.3.4 Cold-extremely wet/lowland/natural (class CX/L/N)

Class CX/L/N is primarily confined to the West Coast of the South Island, although fragmented reaches in this class also occur in lowland areas of Golden Bay, the Marlborough Sounds, and – very rarely – in the North Island (Figure 3-4). The class is currently represented by 16 core sites, most of which are clustered around Golden Bay and the Grey Valley. One Waikato Regional Council site in the headwaters of the Awakino River also falls into this class. A further three sites are required to achieve representativeness.

Potential non-core sites are available in the Marlborough Sounds and the Grey District, but only one of these (a 3rd order stream draining into Duncan Bay in Tennyson Inlet) represents a sufficiently unmodified catchment (100% natural landcover) to justify selection.

The need to extend the geographic range of the sites in this class to include more southern rivers suggests adding two West Coast sites south of Greymouth, supplementing the one existing site in this area (Okutua Creek, a 2nd order stream in Okarito Forest). We suggest adding one additional site from each of two groups, comprising four streams between Ross and Karangarua (Totara River, McCullouchs Creek, MacDonalds Creek, Black Creek), and two (The Windbag and Ship Creek) between Lake Paringa and Haast. All of these streams have essentially unmodified catchments (natural landcover ≥ 98%), and are readily accessible from SH 6 (Table 3-5).

Table 3-5: Potential candidate sites representing REC class CX/L/N in an expanded national network. A total of 3 new sites are required to establish representativeness; site groups are subjective, but have been chosen so that choosing one site from each of the three proposed groups would maximise geographical coverage.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
11007732	Marlborough	1	Duncan Bay Stream	Existing non-core site MDC DNC-1 (Duncan Bay Stream)	3	1663894	5446671	100
12036507	West Coast	2	Totara River	at Woolhouse Road, via Totara Valley Road, SH 6	4	1425916	5248201	98
12040492	West Coast	2	McCullouchs Creek	via Cron Road off SH 6, u/s of landfill	3	1395918	5217846	99
12042708	West Coast	2	MacDonalds Creek	at SH 6	4	1375328	5202636	99
12045603	West Coast	2	Black Creek	at SH 6	3	1347153	5178807	99
12049231	West Coast	3	The Windbag	any point off SH 6 from NZTM 1307970, 5147840 d/s to Lake Paringa (1310240, 5151280)	3	1308729	5149019	100
12049427	West Coast	3	Ship Creek	at SH 6; access via DoC viewpoint at NZTM 1289890, 5147840	4	1290018	5147788	98

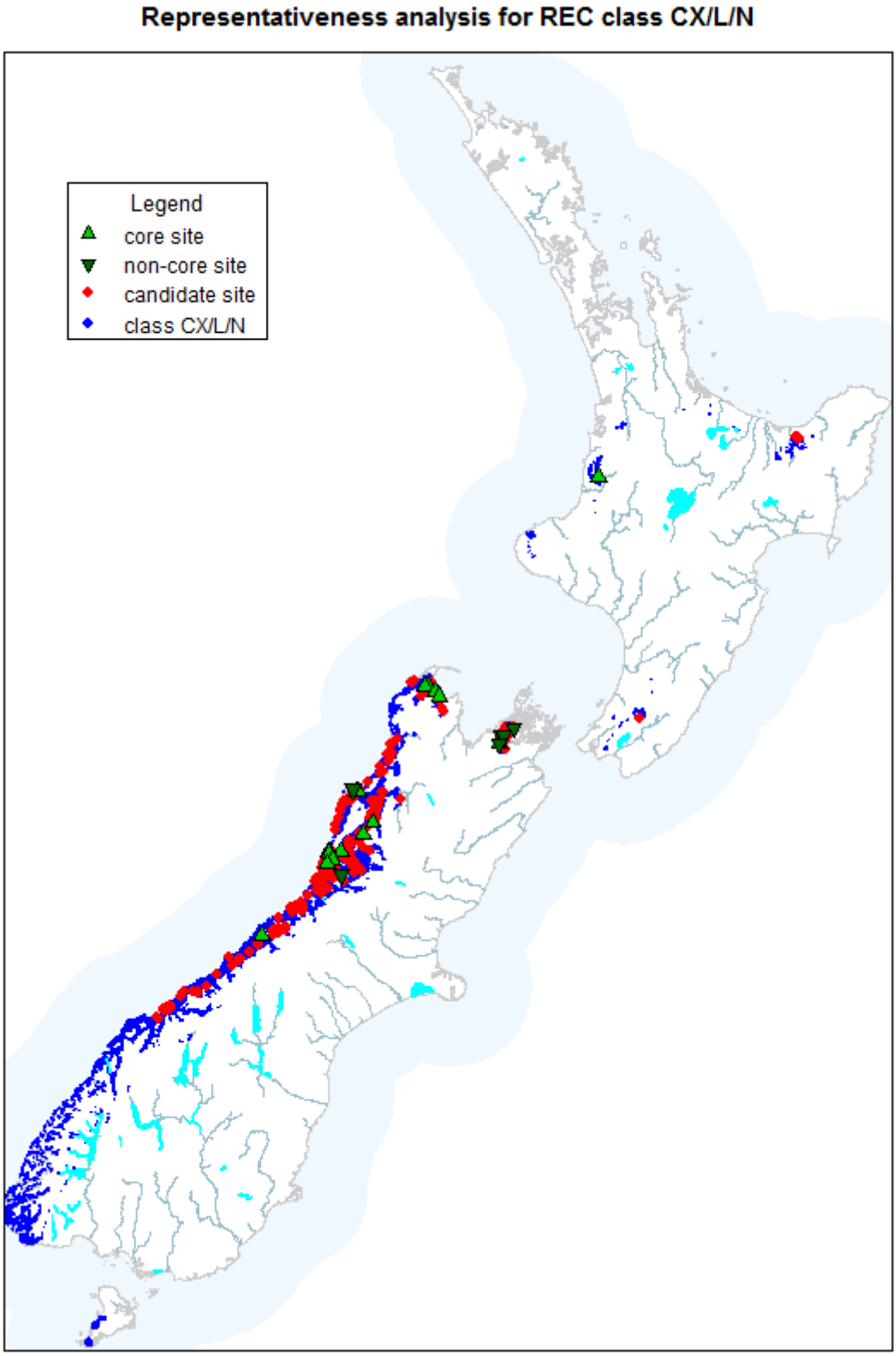

Figure 3-4: Distribution of rivers in REC class CX/L/N, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

3.3.5 Cold- wet/ mountain/natural (class CW/M/N)

Class CW/M/N includes most of the eastern foothills of the Southern Alps, together with the Kaikoura and Richmond Ranges, and (in the North Island) the Ruahine, Kaimanawa, and Kaweka Ranges (Figure 3-5). It accounts for 6.8% of total river length in New Zealand and is currently represented by 16 core sites, but remains the most severely under-represented REC class in the current network. A further 20 sites are required to achieve representativeness.

Four existing non-core sites are potentially available for an expanded network, three of which (MDC: Branch River @ flow recorder; ORC: Nevis @ Wentworth, Arrow @ Morven Ferry Road) are on high-order catchments which are currently unrepresented. In the central North Island we have limited our suggestions to two sites, the upper Waikato Stream at SH 1, and Omarae Stream at Karioi (Table 3-6). We rejected several potential candidate sites in the upper Wangaehu catchment because many of these were in sub-catchments with up to 25% exotic forest cover, making them unattractive for representing natural landcover.

South Island candidate sites are primarily confined to Canterbury and Otago, the exceptions being two sites in Marlborough and one in Southland (Table 3-6). At many of these sites natural vegetation accounts for between 80% and 95% of catchment landcover, with the remainder of the catchment under either pasture or, less commonly, exotic forest. The dominant landcover in most catchments is tall tussock, followed by gravel and rock, and subalpine scrub. Indigenous forest cover rarely exceeds 25%, and may be absent altogether.

The geographical constraints imposed by climate/source-of flow (which limits most potential sites to inter-montane basins), and the need for road access, creates a candidate list which includes many streams with rather similar characteristics. This trend is particularly apparent in Otago, where eight of the candidate sites (from which up to five are required) lie on tributaries of the upper Clutha source lakes. In such cases, we have grouped streams which lie in close proximity to ensure that at most one candidate is selected.

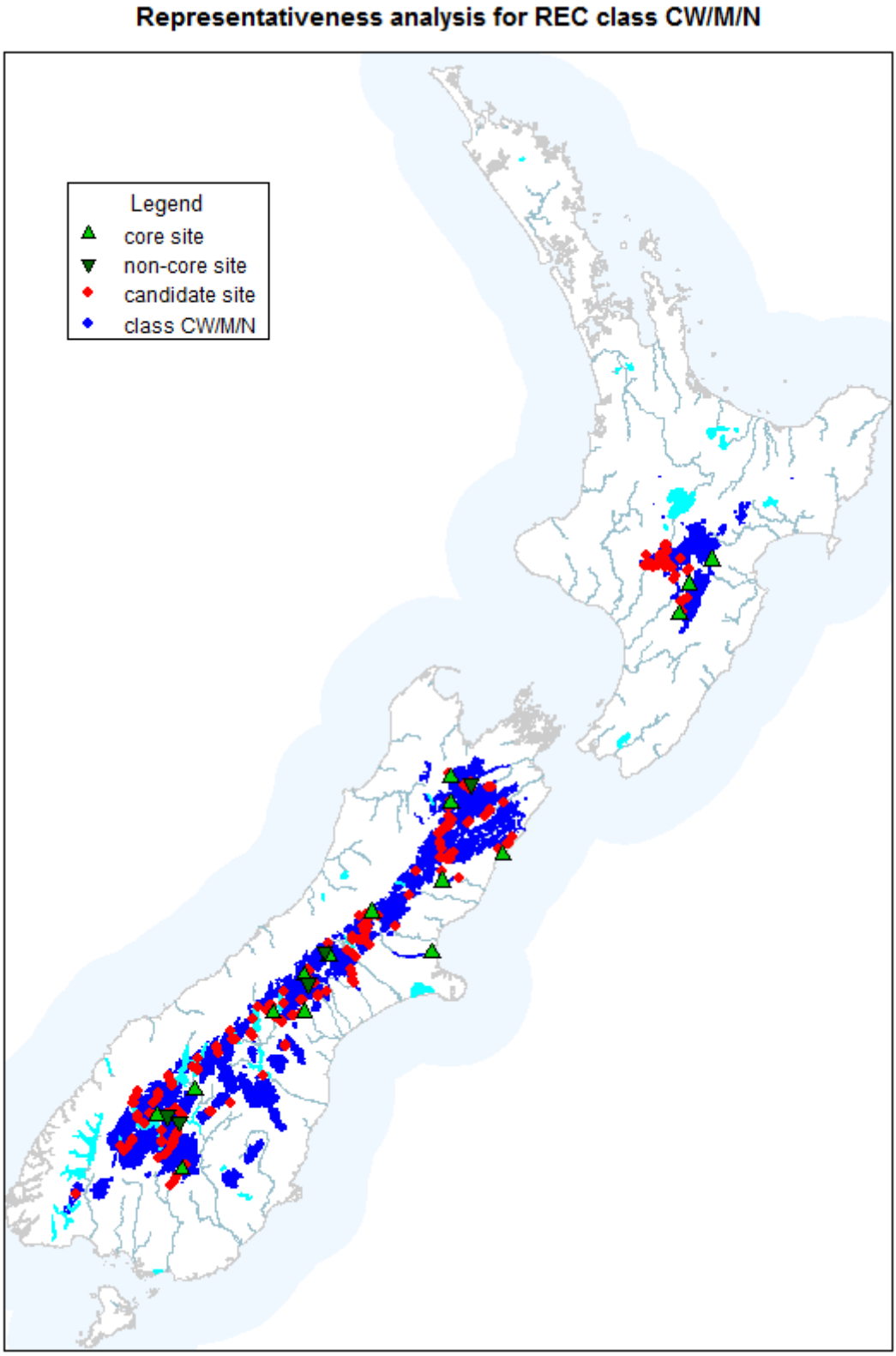

Figure 3-5: Distribution of rivers in REC class CW/M/N, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

Table 3-6: Potential candidate sites representing REC class CW/M/N in an expanded national network. A total of 20 new sites are required to establish representativeness; site groups are subjective, but have been chosen so that choosing one site from 20 of the 22 groups listed would maximise geographical coverage.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
3050798	Waikato	1	Upper Waikato Stream	at SH 1	3	1836369	5647579	100
7017890	Manawatu-Wanganui	2	Omarae Stream	via Karioi Station Road, Karioi, off SH 49	3	1816281	5630740	96
11024066	Marlborough	3	Branch River	MDC BNR-1 (Branch River flow recorder)	6	1615259	5383408	88
11025019	Marlborough	3	Waihopai River	any point u/s Spray River confluence (NZTM 1639045, 5380240)	5	1638863	5380109	84
13010715	Canterbury	4	Clarence River	any point Jacks Pass (NZTM 1586830, 5299445) d/s to Acheron (NZTM 1596505, 5306065)	5	1592325	5299538	84
13021598	Canterbury	5	Hurunui River S Branch	at Lake Sumner Road	5	1546463	5258352	86
13035022	Canterbury	6	Broken River	at SH 73	4	1497236	5216586	79
13037923	Canterbury	6	Ryton River	at Harper Road	4	1481526	5207153	82
13047785	Canterbury	7	Pudding Hill Stream	via Hart Road	3	1480904	5174281	94
13048416	Canterbury	8	Potts River	at Hakatere Potts Road, Erewhon	4	1434486	5173079	91
13057544	Canterbury	9	Hewson River	at Lochaber Road	5	1444318	5143823	92
13058549	Canterbury	9	North Opuha River	via Fox Peak Ski Field access road	4	1426280	5139043	81
13052672	Canterbury	10	Forest Creek	ECAN SQ00134 (Forest Creek)	5	1432241	5158942	94
13503517	Canterbury	10	Coal River	at Lilybank Road	4	1404728	5148994	77
13510622	Canterbury	11	Twizel River	between Lake Poaka and Rhoboro Downs Road	5	1368089	5102490	95
13514675	Canterbury	12	Birch Creek	at Birchwood Road	4	1330754	5080076	74
14008385	Otago	13	Timaru River	at Peter Muir Bridge	5	1307625	5061879	96

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
14012386	Otago	14	Mototapu River	at Wanaka Mount Aspiring Road	5	1279229	5047482	86
14018599	Otago	15	Temple Burn	at Glenorchy Paradise Road	3	1236364	5028701	86
14020931	Otago	15	Buckler Burn	at Glenorchy Paradise Road	4	1237076	5022227	91
14020172	Otago	16	Shepherds Creek	via Shepherds Flat Road, Cambrians; may be prone to drying up	3	1344332	5024052	85
14024579	Otago	16	Thomsons Creek	via Thomson Gorge Road at old stone hut; winter access may be limited	3	1322502	5014139	94
14022649	Otago	17	Cardrona River	any point u/s of NZTM 1282043, 5017941	4	1282043	5017941	80
14034586	Otago	18	Wye Creek	via SH 6 (access to beach at mouth)	4	1266634	4992841	97
14040151	Otago	18	Staircase Creek	at SH 6	4	1266932	4980700	94
14027074	Otago	19	Twenty Five Mile Creek	at Glenorchy Queenstown Road; also known as Simpsons Creek	4	1239856	5006107	85
14031259	Otago	19	Twelve Mile Creek	at Glenorchy Queenstown Road	3	1248305	5000092	98
14026683	Otago	20	Arrow River	Site OTA7520743 (Arrow River @ Morven Ferry Rd)	4	1273378	5009615	81
14030193	Otago	21	Nevis River	Site OTA7521306 (Nevis River @ Wentworth Station)	6	1287523	5002114	80
15016693	Southland	22	Oreti River	at Mt Nicholas Road	5	1224703	4969284	81

3.3.6 Cold-dry/ mountain/natural (class CD/M/N)

Class CD/M/N has a fragmented distribution among the higher elevation regions of Central Otago, the Waitaki Valley above Lake Benmore, and the Inland Kaikoura Ranges and their western outliers (Figure 3-6). It is currently represented by one core site (Otematata River @ SH 83). A further three sites are required to achieve representativeness.

Candidate sites for this class are rare. One non-core site (Dunstan Creek @ Beatties Road) is potentially available, but we are reluctant to recommend it as a permanent site because the upstream catchment includes 30% pastoral landcover. The three most viable candidates appear to be Five Mile Stream, a tributary of the Acheron River in Marlborough; the Mackenzie River on the eastern side of the McKenzie Basin, Canterbury; and the Sow Burn, a headwater tributary of the Taieri River which joins the latter at Patearoa (Table 3-7). Natural landcover is 76% for the McKenzie River, and 84%-85% for the other two sites.

Table 3-7: Potential candidate sites representing REC class CD/M/N in an expanded national network. A total of 3 new sites are required to establish representativeness.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
13007682	Marlborough	1	Five Mile Stream	via Molesworth Road, Acheron; check access permissions	4	1599236	5313336	85
13510382	Canterbury	2	Mackenzie River	via Mackenzie Pass Road d/s Mackenzie Memorial	4	1405630	5103911	76
14039826	Otago	3	Sow Burn	at Aitken Road, Patearoa	4	1368773	4981767	84

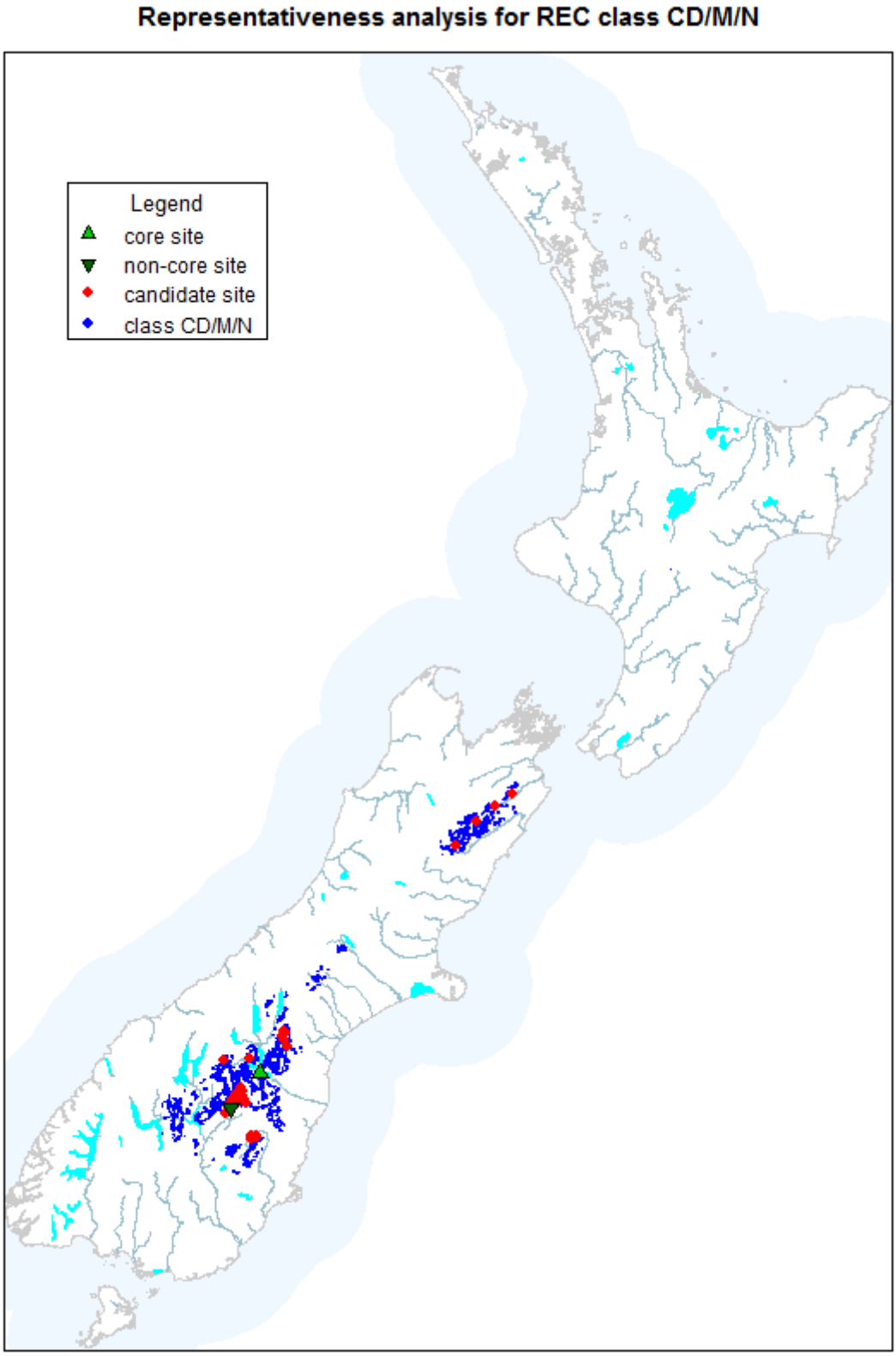

Figure 3-6: Distribution of rivers in REC class CD/M/N, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

3.3.7 Cold-dry/hill/natural (class CD/H/N)

Class CD/H/N is most commonly associated with Central Otago and the McKenzie Basin, with a more fragmented presence along the Canterbury foothills (predominantly in the Rangitata and Waiau catchments), and in the lower elevation ranges north of the Inland Kaikoura Ranges above the Awatere Valley. In the North Island it is limited to a small number of reaches on the southern edge of the volcanic plateau, all within a 5 km radius of Waiouru (Figure 3-7).

The class is currently represented by three sites in the core network (including two on the upper Taieri River). A further four sites are required to achieve representativeness. Six non-core sites are potentially available to meet this need, but five of these fall into two tightly clustered groups (in Marlborough, and the Ida Valley, Central Otago), and we recommend selecting only one from each of these two groups (Table 3-8). A third non-core site, on the lower Teviot River at Roxburgh, may be a viable choice for a third site, leaving only one new site to be established. Our preferred choice for this site, Gentle Annie Creek in the Kawarau Gorge, is particularly appealing because it has 99% natural landcover, well above the 70% - 80% which characterises most of the other candidate sites (Table 3-8).

Table 3-8: Potential candidate sites representing REC class CD/H/N in an expanded national network. A total of 4 new sites are required to establish representativeness; site groups are subjective, but have been chosen so that choosing one site from 4 of the 5 groups listed would maximise geographical coverage.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
11024343	Marlborough	1	Black Birch Stream	MDC BBS-1 (Black Birch Stream)	4	1672842	5382876	97
13514755	Canterbury	2	Hakataramea River	via Hakataramea Road u/s of NZTM 1414009, 5079142	5	1414009	5079142	78
14010040	Otago	2	Pass Burn	at SH 6, any point with permanent flow u/s Dip Creek	3	1326061	5055315	71
14022625	Otago	3	Hills Creek	ORC IB1 (OTA7520038)	5	1356449	5018403	73
14023527	Otago	3	Kye Burn	off Danseys Pass Road u/s of NZTM 1388156 5016599	4	1388155	5016541	75
14051047	Otago	4	Teviot River	ORC OTA7520642 (Teviot @ Roxburgh East)	6	1312592	4950573	73
14028373	Otago	5	Gentle Annie Creek	via vehicle track off SH 6	3	1288110	5006079	99

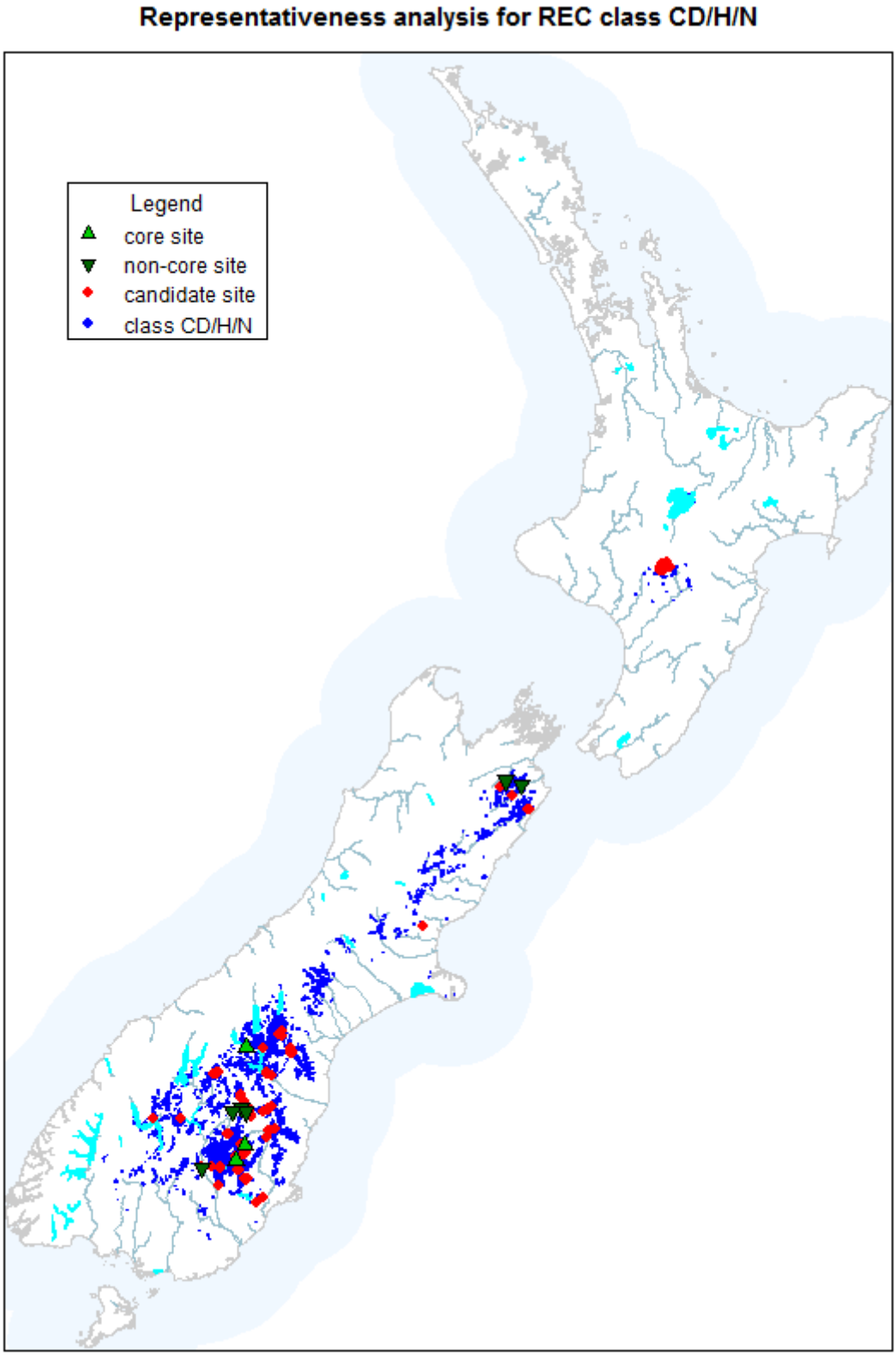

Figure 3-7: Distribution of rivers in REC class CD/H/N, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

3.3.8 Cold-dry/lowland/natural (class CD/L/N)

Class CD/L/N is primarily limited to a few fragmented sub-catchments along the east coast of the South Island, although isolated reaches in this class occur as far north as Wanganui (Figure 3-8). However, the class is important because it provides a reference class for the most common impacted class, CD/L/P (c.f. Table 3-1).

An existing non-core site on Silver Stream, draining the Silver Peaks area north of Dunedin, may be a suitable candidate site (Table 3-9). However, the upstream catchment at this point includes 17% exotic forestry and 5% pasture, making it less than ideal as a reference site. Sites with up to 96% natural landcover are available 4-5 km upstream near Whare Flat, and may be more appropriate as a reference site.

Table 3-9: Potential candidate sites representing REC class CD/L/N in an expanded national network. One new site is required to establish representativeness.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% natural landcover
14059378	Otago	1	Silver Stream	better than OTA 7430344; u/s catchment is 96% indigenous	4	1399333	4923553	96
14060378	Otago	1	Silver Stream	ORC OTA7430344 (Silverstream @ Three Mile Hill Rd Bridge); possibly unsuitable; u/s catchment is 17% exotic forestry, 5% pasture	4	1398228	4919815	76

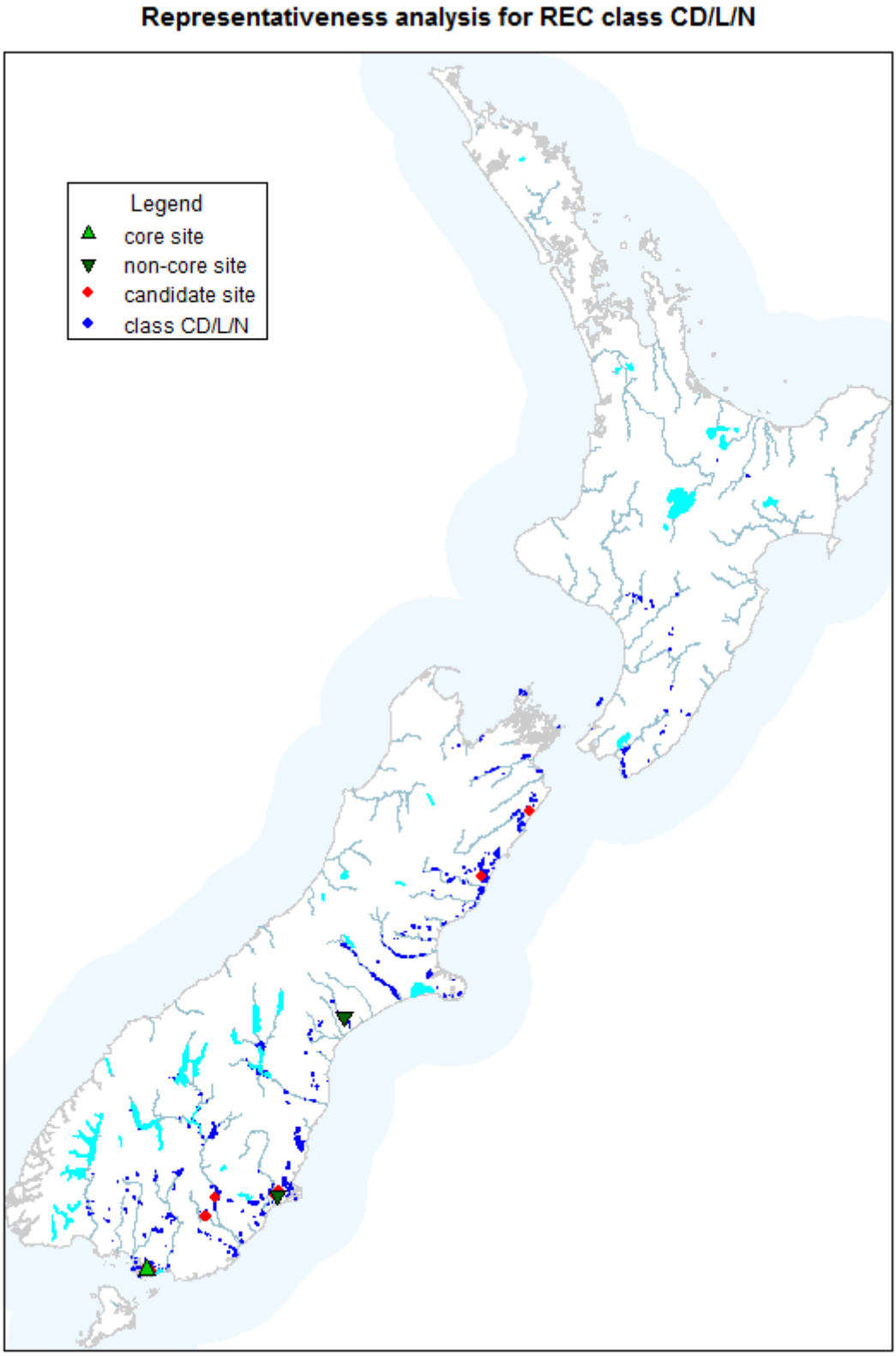

Figure 3-8: Distribution of rivers in REC class CD/L/N, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

3.4 Exotic forest landcover classes

3.4.1 Cold-wet/hill/exotic forestry (class CW/H/EF)

Class CW/H/EF is by far the most abundant of any of the exotic forest classes considered in this study. It includes most of the North Island central volcanic plateau, with more fragmented but still substantial pockets to the east (East Cape and Hawkes Bay), and southwest (to the south of Mt Ruapehu). It also occurs in the South Island, taking in much of the forested land in Nelson, and extending as far south as Venlaw Forest in Southland (Figure 3-9). It is moderately well-represented in the core site network, but two additional sites are required to achieve representativeness (Table 3-1).

Existing core sites in this class ensure it is well-represented in the South Island, and the central North Island. Taking this into account, while also seeking otherwise unrepresented regions in which exotic forest cover was as high as possible, the most suitable sites are in the Gisborne District (Table 3-10). Exotic forest landcover exceeds 76% at all four suggested candidate sites (three in the Waipaoa catchment and one on a tributary of the Mata River), with a maximum cover of 87% at the uppermost Waipaoa site (accessible via a vehicle ford at NZTM 2025450, 5754040.

Table 3-10: Potential candidate sites representing REC class CW/H/EF in an expanded national network. A total of 2 new sites are required to establish representativeness; site groups are subjective, but have been chosen so that choosing one site from each group would maximise geographical coverage.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% exotic forest landcover
5006739	Gisborne	1	Weraroa Stream	at Weraroa Road ford	3	2024421	5754058	78
5006790	Gisborne	1	Waipaoa River	ford u/s of Weraroa Stream confluence	4	2025413	5753982	87
5007146	Gisborne	1	Waipaoa River	at Armstrong Road bridge	5	2024064	5751338	76
5004811	Gisborne	2	Whakoau Stream	at Mata Road bridge	4	2043026	5773116	78

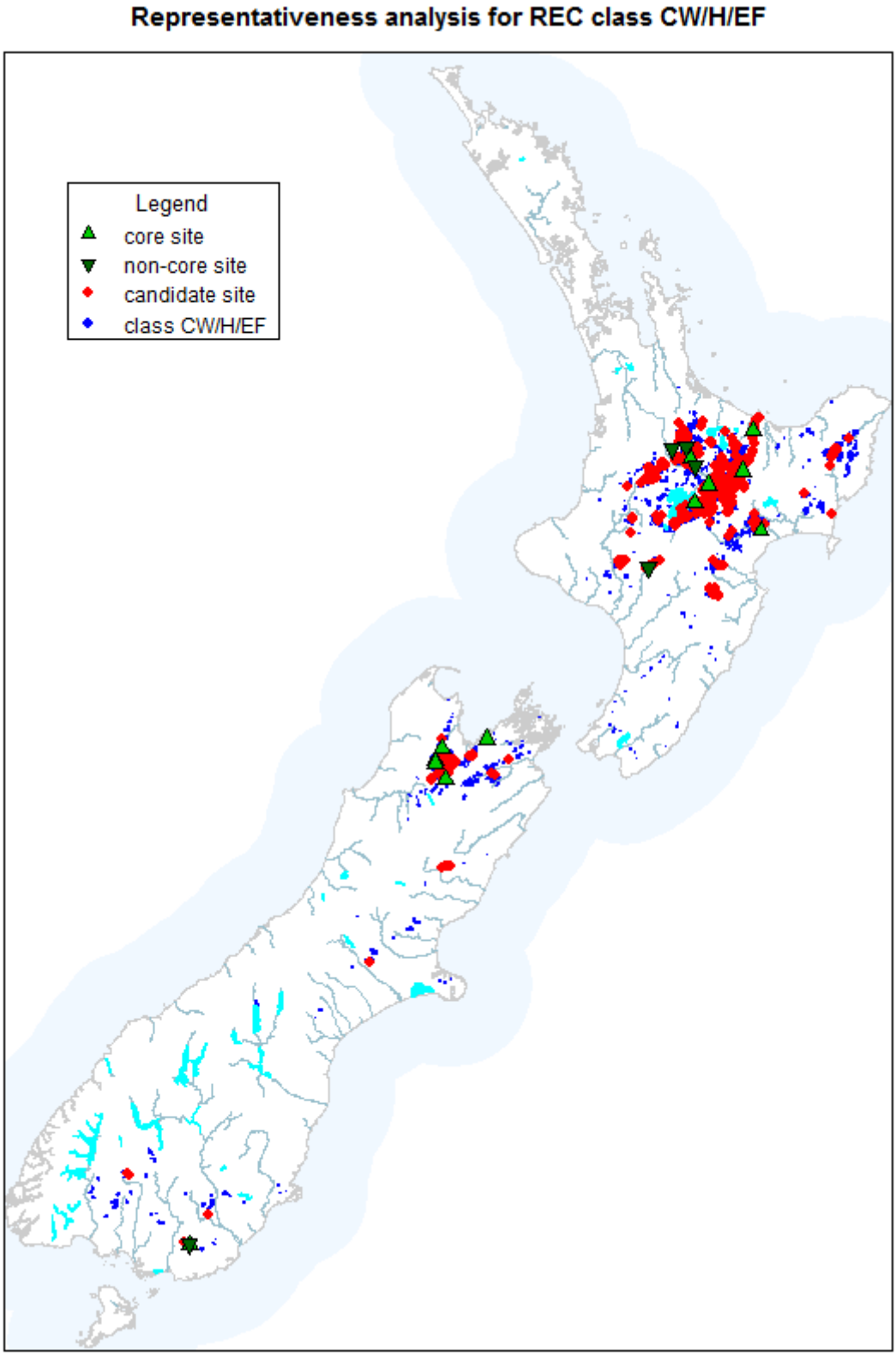

Figure 3-9: Distribution of rivers in REC class CW/H/EF, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

3.4.2 Warm-wet/lowland/exotic forestry (class WW/L/EF)

Class WW/L/EF is almost entirely confined to the upper North Island, where it is abundant and widely distributed in Hawkes Bay, Gisborne, Bay of Plenty, and Northland (Figure 3-10). It is currently represented by eight core sites, and requires one additional site to achive representativeness.

At least 12 non-core sites are potentially available to meet this need, one of which (Mangate Stream, a Bay of Plenty benthic invertebrate site; Table 3-11) has 95% exotic forest cover and appears to be accessible from multiple points along a forestry road within 10 km of Kawerau, including a vehicle track at NZTM 1920943, 5772693. Another potential area with suitable sites is Gisborne, where class WW/L/EF is widespread but unrepresented. Our analysis suggests two candidates in this region, on 4th order tributaries of the Uawa River within 10 km of Tolaga Bay.

Table 3-11: Potential candidate sites representing REC class WW/L/EF in an expanded national network. One new site is required to establish representativeness.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% exotic forest landcover
4012847	Bay of Plenty	1	Mangate Stream	Tarawera Forest near Kawerau	3	1920923	5772366	95
5007660	Gisborne	2	Mangatokerau River	any point u/s Paroa Road	4	2059807	5747753	81
5008554	Gisborne	2	Mangaheia River	any point u/s Takapau Bridge	4	2054459	5741988	70

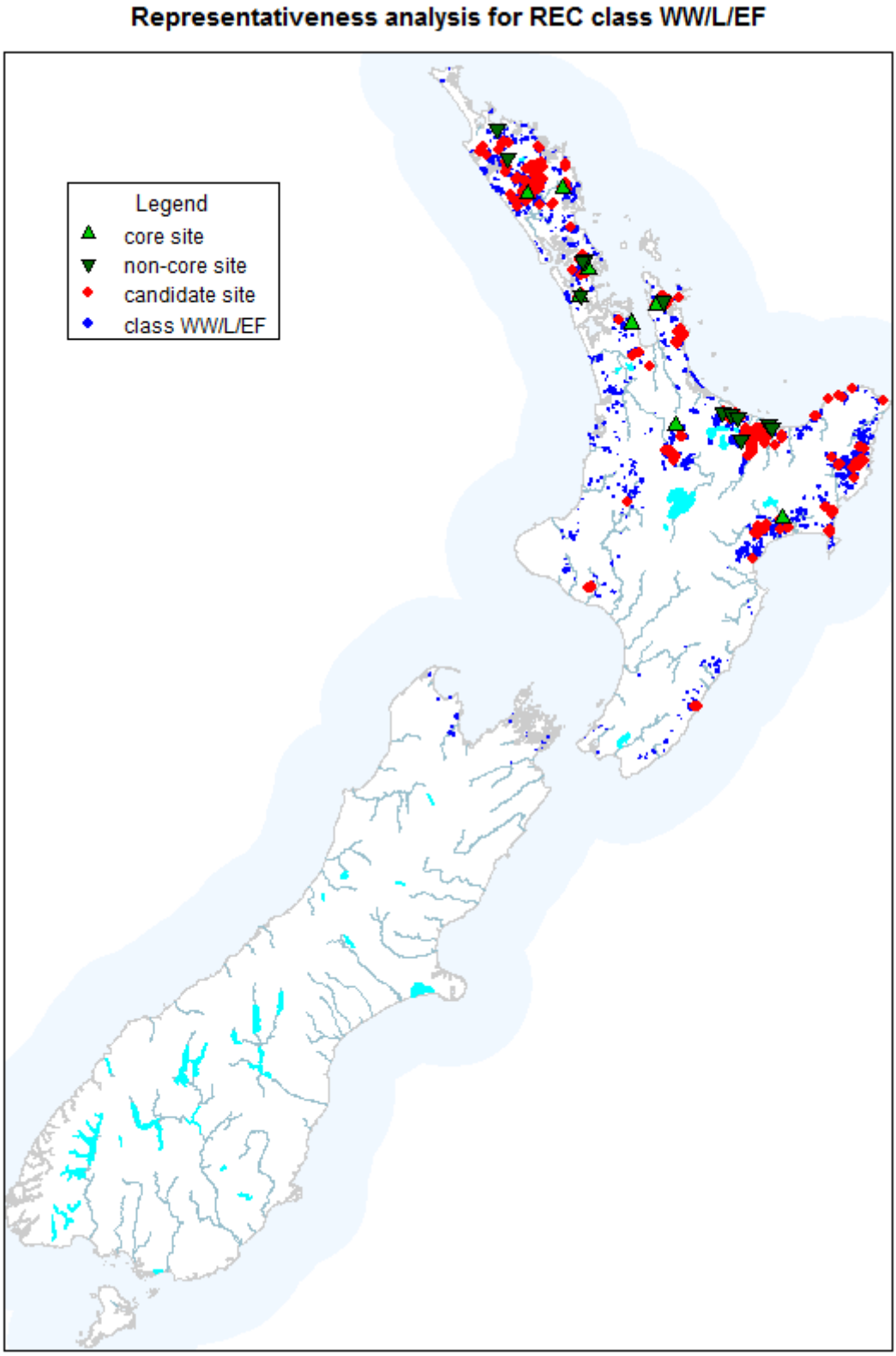

Figure 3-10:Distribution of rivers in REC class WW/L/EF, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

3.5 Pastoral landcover classes

3.5.1 Warm-dry/lowland/pasture (class WD/L/P)

Reaches in the WD/L/P class are abundant throughout much of the lowland North Island, forming large contiguous areas in the far north, Kaipara, Waikato/Thames Valley, Gisborne, southern Hawkes Bay, Manawatu/Rangitikei, and the Wairarapa (Figure 3-11). Reaches in this class also occur in the South Island, in Tasman and coastal Marlborough from Cloudy Bay to Cape Campbell. Four additional sites in this class are required to achive representativeness (Table 3-1).

As many as 30 non-core candidate sites are available, but our manual inspection suggests that most of the non-core sites are unsuitable. Common reasons for rejection were low stream order (i.e., first or second order stream with minimal flow), and proximity to existing core sites.

Our suggested candidate list emphasises the most obvious gaps in the present network, and comprises nine sites in five groups across four North Island regions (Table 3-12). This list is tentative: of all the classes considered in this study, WW/L/EF is easily the most volatile in that – with 990 sites remaining after applying our GIS filtering rules – slight changes to any of these rules would have a large effect on the number of sites available for manual review. The Arawhata Drain site listed below is a case in point: mean discharge (0.096 m^3 s^{-1}) is slightly below our 0.1 m^3 s^{-1} threshold, but it served as a Horizons Regional Council water quality site for at least 10 years (from 2000-2010) and could potentially be reinstated.

Table 3-12: Potential candidate sites representing REC class WD/L/P in an expanded national network. A total of 4 new sites are required to establish representativeness; site groups are subjective, but have been chosen so that choosing one site from 5 of the 5 groups listed would maximise geographical coverage.

NZReach	Region	Site group	River	Location/access details	Stream order	NZTM east	NZTM north	% exotic forest landcover
1022121	Northland	1	Kaihu River tributary	at Babylon Coast Road	4	1672885	6026066	75
1023857	Northland	2	Aratapu Creek	u/s of Aratapu; check tidal influence	4	1680414	6014998	86
1024978	Northland	2	Naumai Creek	u/s Naumai; check tidal influence	4	1689025	6006586	94
1025554	Northland	2	Awaroa River	at Fryberg Road; check tidal influence	4	1696812	6001839	92
2008658	Auckland	3	Te Hihi Creek	at Linwood Road	3	1761481	5890254	100
3015120	Waikato	4	Komakorau Stream	EW 258_31 (Komakorau Stm @ NZR08704-089)	5	1803370	5828565	99
3015932	Waikato	4	Komakorau Stream	EW 258_30 (Komakorau Stm @ NZR08704-025)	4	1805545	5824990	99
7046139	Manawatu-Wanganui	5	Arawhata Drain	Arawhata Drain at Hokio Beach Road	4	1790084	5500787	91

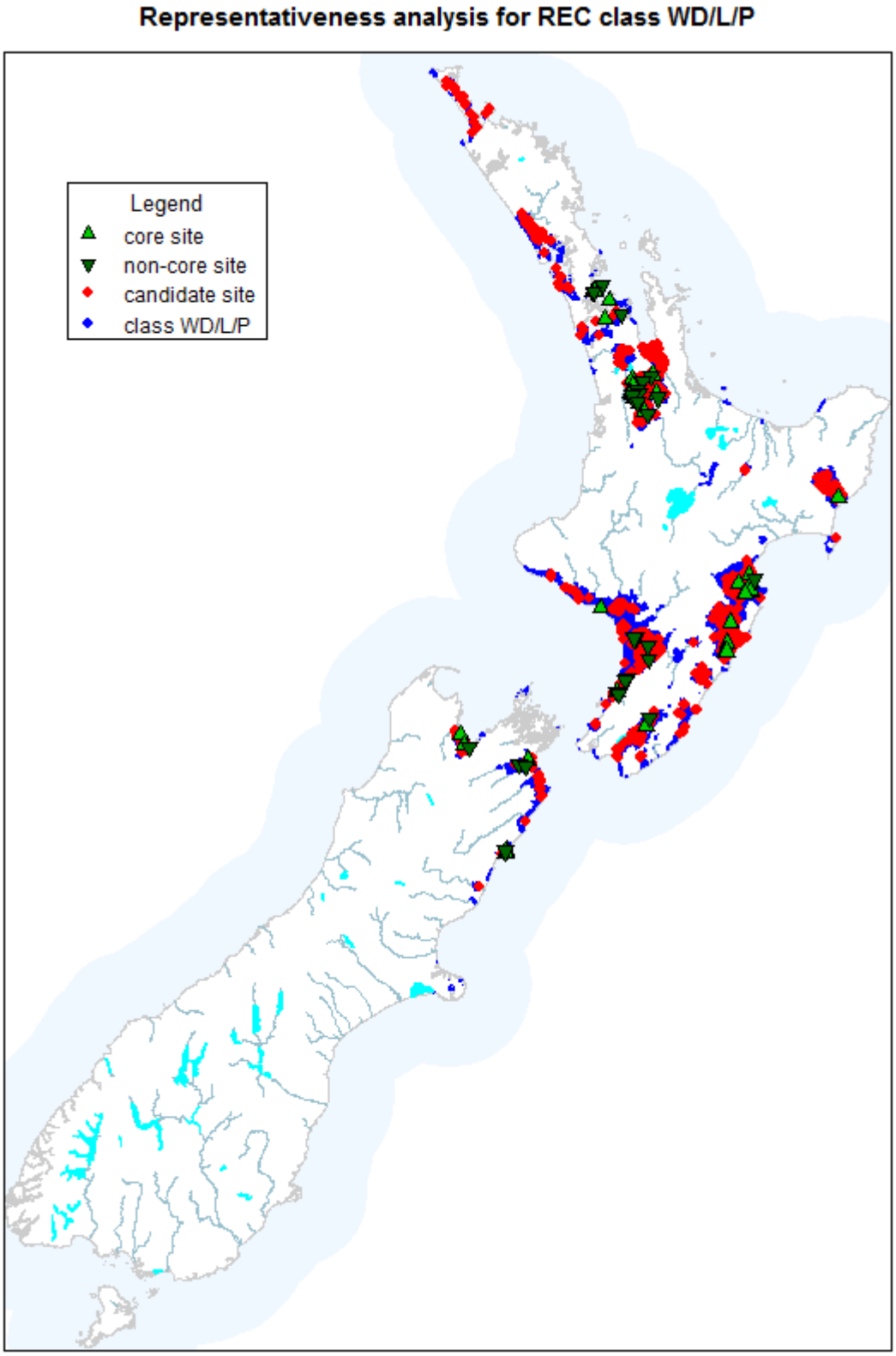

Figure 3-11:Distribution of rivers in REC class WD/L/P, showing all current sites, and potential candidate sites for inclusion in an expanded national network.

3.6 Distribution of candidate sites

The geographical distribution of candidate sites is highly skewed towards South Island rivers (Table 3-13, Figure 3-12). We identified a total of 134 candidates across the 11 REC classes considered in this study, representing 86 individual sites assuming that one site is selected from each group of candidate sites. Of these 86 sites, 68 (79%) are in the South Island, with 51 (59%) in the West Coast, Canterbury and Otago regions. The distribution of new sites across North Island regions is more even. Candidate sites are located within the boundaries of 13 regional or unitary authorities; no candidate sites were located in the Taranaki and Wellington regions, or in Nelson City.

Table 3-13: Distribution of candidate water quality monitoring sites by region. The columns for each region show the total number of candidate sites (including all sites within each site group), and the number of site groups. The number of site groups is an estimate of the actual number of new sites required in each region, depending on choices within individual groups.

Region	Number of candidate sites	Number of candidate site groups
Northland	4	2
Auckland	1	1
Waikato	4	3
Bay of Plenty	2	2
Gisborne	6	3
Hawke's Bay	2	2
Manawatu-Wanganui	8	5
Tasman	7	5
Marlborough	9	5
Canterbury	19	13
West Coast	38	19
Otago	26	19
Southland	8	7
Total	**134**	**86**

This uneven distribution of candidate sites on the North and South Islands is attributable to the current site shortages in the relatively small number of REC classes which dominate much of the South Island. The most prominent of these are CW/M/N (20 sites required); CX/M/N (18 required); CX/H/N (14 required), and CX/GM/N (7 required); but contributions from other classes predominately associated with South Island (CD/H/N (4 required); CD/M/N, and CX/L/N (3 required from each)) are also significant. This, in turn, reflects a national need for better representation of catchments with unmodified landcover, which are much more extensive in the South Island than in the North Island. By contrast, the three under-represented classes most common in the North Island, CW/H/EF, WD/L/P, WW/L/EF, are all associated with modified landcover and collectively require only seven new sites.

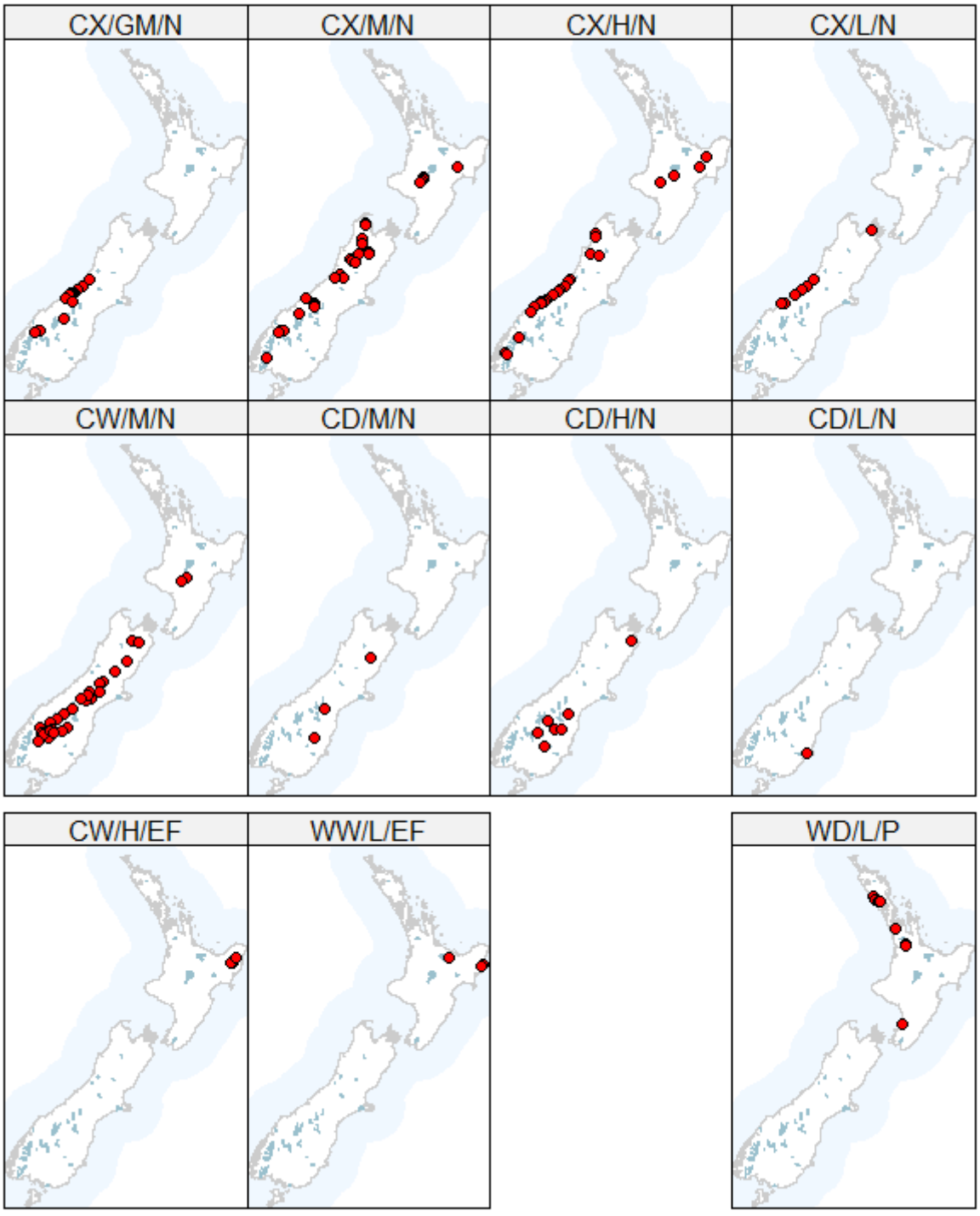

Figure 3-12:Candidate sites for an expanded national water quality network, based on a desktop GIS analysis, by REC climate/source-of-flow/landcover class. A total of 134 candidate sites are shown. The top two rows of panels represent classes with natural land cover; the third row represents those with modified landcover (exotic forest or pasture).

3.7 Effects of filtering criteria

The filtering criteria we used to develop and refine our candidate site list were relatively severe, and may well have missed some viable candidates. Of the existing core sites in the 18 REC classes we considered, only 66% met the criteria that we used to identify candidate sites. In particular, several long-term NRWQN sites did not meet our filtering criteria. Specific examples include the Tongariro River at Turangi; Ngaruroro River at Kuripapango; Wairau River at Dip Flat; Buller River at Te Kuha; Grey River at Dobson; Waimakariri River at Old Highway Bridge; Haast River at Roaring Billy; and Shotover River at Bowens Peak. For at least some of these sites, a likely reason for their omission is that they lie further than 100 m from the nearest road represented on TopoMap and in our GIS database, despite being readily accessible via vehicle track (Figure 3-13).

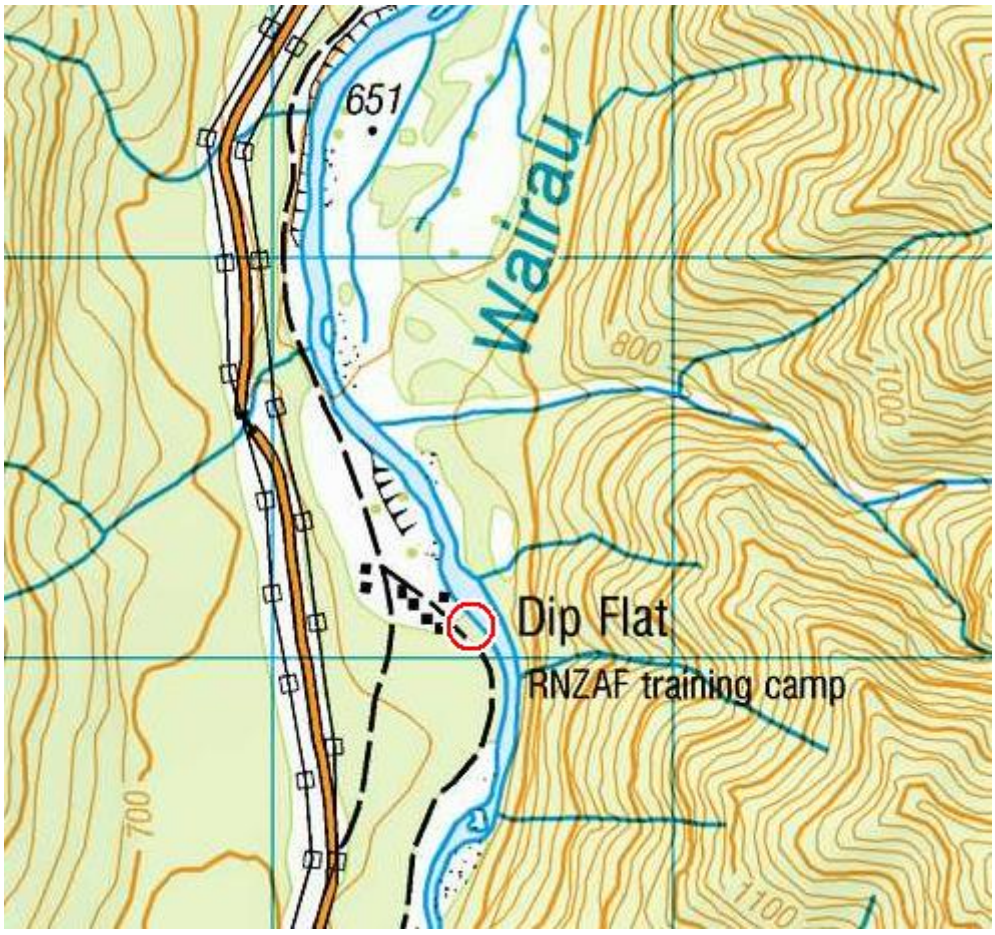

Figure 3-13:Location of the NRWQN site NN3, Wairau at Dip Flat, Markborough. This site has been operating since 1989, but was not identified as a potential candidate site because it lies more than 100 m from the nearest road represented in our GIS database.

The fact that 34% of the current core sites would be rejected by our filtering criteria suggests that the 11,604 sites in our starting list was a under-estimate of the number of candidate sites, and that the 134 which remained after applying our selection rules probably missed many potentially suitable sites. This does not undermine the value of our analyses, which were intended to identify optimal sites using relatively stringent criteria. As noted in the introduction, the criteria used to select the great majority of sites in the aggregate national network were based on local requirements such as compliance monitoring. In addition, our

GIS-based approach automated site selection to the point where the number of available candidates was small enough to be tractable for manual screening, and for subsequent site inspections.

4 Discussion

4.1 Overview

A striking feature of our results is the uneven geographical distribution of the 134 candidate sites that were selected by our filtering criteria, with 76% of candidate sites located on the South Island, and 56% of the sites within the three regions (West Coast, Canterbury, Otago) that encompass the main axial ranges of the Southern Alps. This uneven distribution of sites reflects the uneven distribution of under-represented environments, which occur most frequently in areas with cool-temperate climate conditions, medium to high elevations, and natural landcover. These conditions correspond to large areas of the South Island. The uneven distribution of candidate sites also reflects the original purposes for establishing regional-council monitoring sites. Many sites were originally established in urban, pastoral and exotic forest areas for consent monitoring, and these sites now comprise a large proportion of the aggregate network. Establishing monitoring sites in natural landcover-dominated catchments for the purpose of regional state-of-environment monitoring is much more recent, and these sites comprise a much smaller proportion of the aggregate network.

4.2 Site inspections and ground-truthing

The desk-top assessment of potential river-monitoring sites reported here is the first of two phases in the site-selection process. The second phase entails site visits to assess the suitability of candidate sites based on criteria such as safe access; these assessments must be carried out on-site (Collier *et al.* 2007). Our approach in the desk-top phase was to identify isolated sites and groups of sites in close proximity, all of which met the GIS criteria for road access, minimum size and mean flow, and minimum natural landcover. For the site inspections, a comparable list of on-site criteria can be used to evaluate the individual sites within each group, as well as the isolated sites.

There are many on-site criteria to consider, and the specific criteria used in site selection will vary with the type of monitoring that is intended (e.g., suitable substrate and flow conditions for fish monitoring). Most on-site criteria fall into three general classes: safe access, suitability of the channel and flow regime for monitoring, and absence of localised anthropogenic activities in the upstream catchment that may have influence measurements (e.g., point-source discharges; Table 4-1). The effects of localised anthropogenic activities are most problematic for sites in natural landcover classes, because data from these sites are used as reference conditions against which data from other landuse classes are compared (Larned & Roulston 2013, Winterbourn & Ryan 1994).

The list in Table 4-1 is not comprehensive. For the site inspections, local knowledge of land-owners, tracks and roads, and small-scale activities such as placer mining will be essential. Experience in setting-up and operating monitoring sites will also be essential for selecting new sites. One potential option is to use NIWA field staff for this exercise. NIWA has staff at 14 field offices carrying out quality-assured river monitoring across New Zealand. These staff can be made available for the field visits, to ensure a nationally consistent approach. In

addition to local knowledge, general guidance for developing on-site selection criteria is given in publications on water-quality network design (e.g., Strobl & Robillard 2008, Ward *et al.* 1990).

Table 4-1: Criterion classes, and example criteria from each class, to be used when assessing candidate monitoring sites during field visits.

Criterion class	Example criteria
Access	Road status (e.g., paper versus real roads, locked gates, fords)
	Land-owner permission
	Cliffs, unstable banks and other foot-access hazards
	Safe parking areas
	Site security
	Travel distance
	Year-round access (e.g., consider winter road closures)
Suitability for sampling	Cross-section is wholly or partly wadeable
	Depth and flow velocity sufficient for in-situ water quality measurements, invertebrate sampling, and visual estimates of periphyton and macrophytes
	Channel geometry is suitable for flow-gauging, including at high flows
	Upstream of tidal influence
	Proximity to river flow recorder
Anthropogenic influences upstream of reach and sampling point	Effluent pipes
	Presence of stock, or stock tracks or pugging
	Recreational vehicle disturbances
	Gravel extraction
	Active or inactive underground mines with adits or spoils near channels
	In-stream placer mining and bank-side tailing piles
	Herbicide and pesticide use in riparian zone

4.3 Representativeness and statistical power

Establishing a very small number of new sites (e.g., 1-2 sites) in small REC classes such as CD/M/N and WW/L/EF would improve representativeness of the aggregate national network, but statistical power to enable comparisons of water quality between classes or between the average of a class and guideline values would be very low. Power analyses to estimate the required numbers of sites for inter-class comparisons and for precise estimates of average water quality state were carried out previously, using the 901 core sites (Larned & Unwin 2012). The power analyses indicated that 3-4 sites in each class was the absolute minimum for moderately precise estimates of water quality state, and for detecting inter-class differences; power analysis is not possible for classes with 1-2 sites.

The limitations caused by very small site numbers in some environmental classes suggest that new river monitoring sites should not be established in a class unless the final number of sites in the class is four or more. This approach represents a compromise between increasing the representation of relatively small environmental classes in the national

network, and ensuring that individual classes have adequate statistical power. If the targeted numbers of candidate sites listed in Table 3-1 are added to the national network, each of the 11 REC classes will have at least six sites, which should ensure at least moderate statistical power.

5 Acknowledgements

We thank Sheree De Malmanche (Ministry for the Environment) for initiating and supporting project. We thank Michelle Greenwood and Helen Rouse (NIWA) for report reviews.

6 References

Clapcott, J.E., Goodwin, E., T, S. (2013) Predictive models of benthic macroinvertebrate metrics. *Cawthron Insititute Report,* 2301*.* 35 p.

Collier, K.J.,Haigh, A.; Kelly, J. (2007) Coupling GIS and multivariate approaches to reference site selection for wadeable stream monitoring. *Environmental Monitoring and Assessment,*127: 29–45.

Davies-Colley, R.J., Smith, D.G., Ward, R., Bryers, G.G., McBride, G.B., Quinn, J.M., Scarsbrook, M.R. (2011) Twenty years of New Zealand's National Rivers Water Quality Network: benefits of careful design and consistent operation. *Journal of the American Water Resources Association,* 47: 750-771.

Larned, S.T., Roulston, H. (2013) Recommendations for new sites in the New Zealand river environmental monitoring network. *NIWA Client Report,* CHC2013-029*.* 33 p.

Larned, S.T., Snelder, T., Schmidt, J. (2012) National Environmental Monitoring and Reporting (NEMaR): Network design principles for National Freshwater Monitoring. *NIWA Client Report,* CHC2012-027*.* 61 p.

Larned, S.T., Unwin, M.J. (2012) Representativeness and statistical power of the New Zealand river monitoring network. *NIWA Client Report,* CHC2012-079*.* 55 p.

Snelder, T., Hurren, H., Dey, K. (2005) Conversion of land-cover categories of the River Environment Classification to Land-Cover Database Version 2. *NIWA Client Report,* CHC2005-065*.* 7 p.

Snelder, T., Scarsbrook, M., Larned, S.T. (2006) Assessment of the national pool of river water quality monitoring sites using the River Environment Classification. *NIWA Client Report,* CHC2006-060*.* 49 p.

Snelder, T.H., Biggs, B.J.F. (2002) Multi-scale river environment classification for water resources management. *Journal of the American Water Resources Association,* 38: 1225-1240.

Strahler, A.N. (1964) Quantitative geomorphology of drainage basins and channel networks. *In*: Chow, V.T. (ed.). Handbook of Applied Hydrology, McGraw-Hill, New York, New York, pp. 439-476.

Strobl, R.O., Robillard, P.D. (2008) Network design for water quality monitoring of surface freshwaters: a review. *Journal of Environmental Management,* 87: 639-648.

Unwin, M.J., Larned, S.T. (2013) Statistical models, indicators and trend analyses for reporting national-scale river water quality (NEMAR Phase 3). *NIWA Client Report,* CHC2013-033*.* 55 p.

Ward, R.C., Loftis, J.C., McBride, G.B. (1990) *Design of Water Quality Monitoring Systems*. Van Nostrand Reinhold, New York.

Winterbourn, M.J., Ryan, P.A. (1994) Mountain streams in Westland, New Zealand: benthic ecology and management issues. *Freshwater Biology,* 32: 359-373.

Woods, R., Hendrikx, J., Henderson, R., Tait, A. (2006) Estimating mean flow of New Zealand rivers. *Journal of Hydrology (New Zealand),* 45: 95-110.

Appendix A Attributes of the 134 candidate sites

The table below lists selected attributes for the 134 candidate sites identified in the body of this report. Sites are ordered alphabetically by REC class, then by site group within class, then by NZReach within each site group. Site status is either “new” (for sites to be established at new locations), or “non-core” (for sites which are represented in the NEMaR database but were not used in the core NEMaR dataset).

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CD/H/N	1	11024343	Marlborough	Black Birch Stream	MDC BBS-1 (Black Birch Stream)	new	1672842	5382876	4	0.54		226	97	97	0	4	0
CD/H/N	2	13514755	Canterbury	Hakataramea River	via Hakataramea Road u/s of NZTM 1414009, 5079142	new	1414009	5079142	5	1.47	99	526	78	78	0	19	0
CD/H/N	2	14010040	Otago	Pass Burn	at SH 6, any point with permanent flow u/s Dip Creek	new	1326061	5055315	3	0.25	0	539	71	71	0	24	0
CD/H/N	3	14022625	Otago	Hills Creek	ORC IB1 (OTA7520038)	new	1356449	5018403	5	1.20		592	73	73	0	27	0
CD/H/N	3	14023527	Otago	Kye Burn	off Danseys Pass Road u/s of NZTM 1388156 5016599	new	1388155	5016541	4	0.73	85	600	75	75	0	24	0
CD/H/N	4	14051047	Otago	Teviot River	ORC OTA7520642 (Teviot @ Roxburgh East)	non-core	1312592	4950573	6	4.61	0	94	73	73	6	15	0
CD/H/N	5	14028373	Otago	Gentle Annie Creek	via vehicle track off SH 6	new	1288110	5006079	3	0.22	0	301	99	99	0	0	0
CD/L/N	1	14059378	Otago	Silver Stream	better than OTA 7430344; u/s catchment is 96% indigenous	new	1399333	4923553	4	0.33	0	94	96	96	3	1	0
CD/L/N	1	14060378	Otago	Silver Stream	ORC OTA7430344 (Silverstream @ Three Mile Hill Rd Bridge); possibly unsuitable; u/s catchment is 17% exotic forestry, 5% pasture	non-core	1398228	4919815	4	0.72	0	38	76	76	17	5	0

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CD/M/N	1	13007682	Marlborough	Five Mile Stream	via Molesworth Road, Acheron; check access permissions	new	1599236	5313336	4	0.93	0	764	85	85	0	15	0
CD/M/N	2	13510382	Canterbury	Mackenzie River	via Mackenzie Pass Road d/s Mackenzie Memorial	new	1405630	5103911	4	0.23	0	630	76	76	0	18	0
CD/M/N	3	14039826	Otago	Sow Burn	at Aitken Road, Patearoa	new	1368773	4981767	4	0.73	0	421	84	84	0	11	0
CW/H/EF	1	5006739	Gisborne	Weraroa Stream	at Weraroa Road ford	new	2024421	5754058	3	1.10	0	197	78	23	78	0	0
CW/H/EF	1	5006790	Gisborne	Waipaoa River	ford u/s of Weraroa Stream confluence	new	2025413	5753982	4	3.72	0	184	87	10	87	4	0
CW/H/EF	1	5007146	Gisborne	Waipaoa River	at Armstrong Road bridge	new	2024064	5751338	5	6.69	0	159	76	14	76	10	0
CW/H/EF	2	5004811	Gisborne	Whakoau Stream	at Mata Road bridge	new	2043026	5773116	4	1.49	0	319	78	4	78	16	0
CW/M/N	1	3050798	Waikato	Upper Waikato Stream	at SH 1	new	1836369	5647579	3	0.37	0		100	100	0	0	0
CW/M/N	2	7017890	Manawatu-Wanganui	Omarae Stream	via Karioi Station Road, Karioi, off SH 49	new	1816281	5630740	3	1.62	0	632	96	96	2	0	0
CW/M/N	3	11024066	Marlborough	Branch River	MDC BNR-1 (Branch River flow recorder)	new	1615259	5383408	6	17.79		382	88	88	7	4	0
CW/M/N	3	11025019	Marlborough	Waihopai River	any point u/s Spray River confluence (NZTM 1639045, 5380240)	new	1638863	5380109	5	6.98	0	378	84	84	0	15	0
CW/M/N	4	13010715	Canterbury	Clarence River	any point Jacks Pass (NZTM 1586830, 5299445) d/s to Acheron (NZTM 1596505, 5306065)	new	1592325	5299538	5	17.73	51	754	84	84	0	13	0
CW/M/N	5	13021598	Canterbury	Hurunui River S Branch	at Lake Sumner Road	new	1546463	5258352	5	15.97	0	455	86	86	0	11	0

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CW/M/N	6	13035022	Canterbury	Broken River	at SH 73	new	1497236	5216586	4	1.85	0	639	79	79	0	21	0
CW/M/N	6	13037923	Canterbury	Ryton River	at Harper Road	new	1481526	5207153	4	3.43	0	534	82	82	0	13	0
CW/M/N	7	13047785	Canterbury	Pudding Hill Stream	via Hart Road	new	1480904	5174281	3	0.79	39	511	94	94	1	4	0
CW/M/N	8	13048416	Canterbury	Potts River	at Hakatere Potts Road, Erewhon	new	1434486	5173079	4	5.74	0	544	91	91	0	7	0
CW/M/N	9	13057544	Canterbury	Hewson River	at Lochaber Road	new	1444318	5143823	5	2.27	0	436	92	92	0	9	0
CW/M/N	9	13058549	Canterbury	North Opuha River	via Fox Peak Ski Field access road	new	1426280	5139043	4	1.79	41	636	81	81	0	19	0
CW/M/N	10	13052672	Canterbury	Forest Creek	ECAN SQ00134 (Forest Creek)	new	1432241	5158942	5	3.86		569	94	94	4	3	0
CW/M/N	10	13503517	Canterbury	Coal River	at Lilybank Road	new	1404728	5148994	4	2.94	46	735	77	77	0	22	0
CW/M/N	11	13510622	Canterbury	Twizel River	between Lake Poaka and Rhoboro Downs Road	new	1368089	5102490	5	2.11	65	529	95	95	0	2	0
CW/M/N	12	13514675	Canterbury	Birch Creek	at Birchwood Road	new	1330754	5080076	4	0.48	31	785	74	74	0	24	0
CW/M/N	13	14008385	Otago	Timaru River	at Peter Muir Bridge	new	1307625	5061879	5	3.36	0	359	96	96	0	4	0
CW/M/N	14	14012386	Otago	Mototapu River	at Wanaka Mount Aspiring Road	new	1279229	5047482	5	4.86	0	326	86	86	0	13	0
CW/M/N	15	14018599	Otago	Temple Burn	at Glenorchy Paradise Road	new	1236364	5028701	3	0.91	0	375	86	86	0	14	0
CW/M/N	15	14020931	Otago	Buckler Burn	at Glenorchy Paradise Road	new	1237076	5022227	4	2.59	0	361	91	91	0	10	0
CW/M/N	16	14020172	Otago	Shepherds Creek	via Shepherds Flat Road, Cambrians; may be prone to drying up	new	1344332	5024052	3	0.21	0	502	85	85	0	12	0
CW/M/N	16	14024579	Otago	Thomsons Creek	via Thomson Gorge Road at old stone hut; winter access may be limited	new	1322502	5014139	3	0.16	0	788	94	94	0	5	0
CW/M/N	17	14022649	Otago	Cardrona River	any point u/s of NZTM 1282043, 5017941	new	1282043	5017941	4	0.38	56	659	80	80	0	19	0

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CW/M/N	18	14034586	Otago	Wye Creek	via SH 6 (access to beach at mouth)	new	1266634	4992841	4	0.87	0	369	97	97	0	1	0
CW/M/N	18	14040151	Otago	Staircase Creek	at SH 6	new	1266932	4980700	4	1.18	0	380	94	94	0	5	0
CW/M/N	19	14027074	Otago	Twenty Five Mile Creek	at Glenorchy Queenstown Road; also known as Simpsons Creek	new	1239856	5006107	4	0.69	0	274	85	85	0	14	0
CW/M/N	19	14031259	Otago	Twelve Mile Creek	at Glenorchy Queenstown Road	new	1248305	5000092	3	0.69	0	370	98	98	0	1	0
CW/M/N	20	14026683	Otago	Arrow River	Site OTA7520743 (Arrow River @ Morven Ferry Rd)	non-core	1273378	5009615	4	3.60	70	342	81	81	1	17	2
CW/M/N	21	14030193	Otago	Nevis River	Site OTA7521306 (Nevis River @ Wentworth Station)	new	1287523	5002114	6	11.12		267	80	80	0	17	0
CW/M/N	22	15016693	Southland	Oreti River	at Mt Nicholas Road	new	1224703	4969284	5	4.47	0	589	81	81	0	17	0
CX/GM/N	1	12037213	West Coast	Hokitika River	Hokitika Gorge	new	1438261	5242213	6	94.14	68	78	98	98	0	0	0
CX/GM/N	2	12040386	West Coast	Wanganui River	at SH 6	new	1406952	5219051	5	91.90	0	82	99	99	0	0	0
CX/GM/N	2	12042448	West Coast	Whataroa River	at SH 6	new	1389366	5204229	6	120.58	0	74	99	99	0	0	0
CX/GM/N	2	12044006	West Coast	Waiho River	at SH 6	new	1371815	5191406	6	44.64	81	153	99	99	0	0	0
CX/GM/N	3	12044213	West Coast	Omoeroa River	at SH 6	new	1364974	5189557	3	2.87	0	271	99	99	0	2	0
CX/GM/N	3	12044690	West Coast	Waikukupa River	at SH 6	new	1363064	5185934	3	5.26	0	197	100	100	0	0	0
CX/GM/N	4	12045393	West Coast	Fox River	at SH 6	new	1360624	5180040	4	22.63	78	228	99	99	0	0	0
CX/GM/N	4	12045501	West Coast	Cook River	at SH 6	new	1354655	5179438	5	32.16	0	103	99	99	0	0	0
CX/GM/N	4	12046351	West Coast	Karangarua River	at SH 6	new	1341948	5170530	6	100.23	0	31	98	98	0	0	0
CX/GM/N	5	13503195	Canterbury	Hooker River	at Hooker Corner	new	1369049	5152723	5	28.43	0	685	95	95	0	2	0

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CX/GM/N	5	13513678	Canterbury	Ahuriri River	any access point u/s Snowy Gorge Creek (NZTM 1330410, 5085250)	new	1330421	5085252	5	17.39	99	734	86	86	0	11	0
CX/GM/N	5	14017708	Otago	Dart River	ORC OTA7520709 (Dart River @ Glenorchy - Routeburn Rd)	non-core	1230163	5031456	6	71.41	0	309	95	95	0	3	0
CX/GM/N	6	14016544	Otago	Earnslaw Burn	via gravel track to start of Earnslaw Burn foot track	new	1235641	5035169	3	2.52	87	342	94	94	0	5	0
CX/GM/N	7	15005607	Southland	Hollyford River	any access point from Lyttles Farm (NZTM 1206310, 5027730) d/s to Humboldt Creek (NZTM 1213800, 5039630)	new	1210889	5025534	4	8.38	89	391	100	101	0	0	0
CX/H/N	1	3049204	Waikato	Whitikau Stream	at Rangipo Prison Road	new	1845911	5672282	4	1.60	0	475	95	95	4	1	0
CX/H/N	2	4018667	Bay of Plenty	Opato Stream	first accessible point u/s Waioeka confluence	new	1979968	5754419	5	7.00	0	123	97	97	0	2	0
CX/H/N	3	7014500	Manawatu-Wanganui	Manganui-o-te-ao River	first accessible point u/s Orautoha	new	1792601	5645318	5	14.99	76	310	78	78	2	15	0
CX/H/N	4	8002663	Hawke's Bay	Hopuruahine Stream	any point off Waikaremoana Road	new	1952978	5707481	5	5.17	91	598	99	99	0	0	0
CX/H/N	5	12002771	West Coast	Oparara River	any point off Oparara Road	new	1528112	5437265	5	15.60	50	11	98	98	1	1	0
CX/H/N	5	12003284	West Coast	Karamea River	u/s of tidal limit	new	1527383	5431727	6	120.82	0	5	98	98	0	1	0
CX/H/N	5	12004502	West Coast	Little Wanganui River	u/s of Te Namu	new	1524222	5418933	5	10.69	0	14	96	96	0	4	0
CX/H/N	6	12016661	West Coast	Inangahua River	any point from Inangahua Junction to Reefton	new	1507967	5351392	6	61.51	5	100	91	91	2	6	0
CX/H/N	7	12019126	Tasman	Rappahannock River	any point u/s SH 67	new	1537352	5341370	4	3.59	0	333	93	93	0	7	0

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CX/H/N	8	12036682	West Coast	Mikonui River	at SH 6	new	1417983	5246895	5	40.22	0	14	98	98	0	3	0
CX/H/N	8	12037645	West Coast	Kakapotahi River	at SH 6	new	1413435	5238994	4	20.75	0	26	94	94	2	3	0
CX/H/N	9	12040211	West Coast	Poerua River	at SH 6	new	1396812	5219671	4	28.46	0	51	93	93	0	6	0
CX/H/N	9	12042362	West Coast	Waitangi-taona River	at SH 6	new	1381568	5204685	4	18.04	0	84	95	95	0	1	0
CX/H/N	9	12043284	West Coast	Potters Creek	at SH 6	new	1373457	5197085	3	3.24	0	113	88	88	0	12	0
CX/H/N	10	12045364	West Coast	Ohinetamatea River	at SH 6; also known as Saltwater Creek	new	1349564	5180358	3	4.24	0	65	98	98	0	3	0
CX/H/N	11	12047250	West Coast	Mahitahi River	at SH 6	new	1324608	5162459	5	39.73	0	6	96	96	0	2	0
CX/H/N	11	12048418	West Coast	Paringa River	at SH 6	new	1317404	5154398	5	56.97	0	14	97	97	0	1	0
CX/H/N	11	12048893	West Coast	Whakapohai River	at SH 6; also known as Little River	new	1297921	5151143	4	9.31	28	28	99	99	0	0	0
CX/H/N	11	12049212	West Coast	Moeraki River	at SH 6	new	1303176	5149130	4	18.27	60	11	99	99	0	0	0
CX/H/N	12	12051866	West Coast	Okuru River	u/s tidal limit off Nolan or North Bank Road	new	1275322	5130702	5	49.01	0	2	95	95	0	1	0
CX/H/N	12	12054586	West Coast	Jackson River	any point off Jackson River Road	new	1256550	5113021	4	21.35	42	14	95	95	0	1	0
CX/H/N	13	15008128	Southland	Kiosk Creek	at Knobs Flat visitor centre	new	1207018	5007683	3	0.34	0	350	97	97	0	2	0
CX/H/N	14	15027181	Southland	Spey River	via West Arm, Lake Manapouri; requires boat access	new	1152601	4942613	4	14.26	20	180	99	99	0	0	0
CX/H/N	15	15030464	Southland	Grebe River	via Borland Road	new	1160226	4934295	5	30.65	0	220	95	95	0	0	0
CX/L/N	1	11007732	Marlborough	Duncan Bay Stream	Existing non-core site MDC DNC-1 (Duncan Bay Stream)	new	1663894	5446671	3	0.14		34	100	100	0	0	0
CX/L/N	2	12036507	West Coast	Totara River	at Woolhouse Road, via Totara Valley Road, SH 6	new	1425916	5248201	4	10.18	71	35	98	98	0	1	0

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CX/L/N	2	12040492	West Coast	McCullouchs Creek	via Cron Road off SH 6, u/s of landfill	new	1395918	5217846	3	5.37	0	72	99	99	0	2	0
CX/L/N	2	12042708	West Coast	MacDonalds Creek	at SH 6	new	1375328	5202636	4	3.87	0	71	99	99	0	1	0
CX/L/N	2	12045603	West Coast	Black Creek	at SH 6	new	1347153	5178807	3	1.62	0	76	99	99	0	0	0
CX/L/N	3	12049231	West Coast	The Windbag	any point off SH 6 from NZTM 1307970, 5147840 d/s to Lake Paringa (1310240, 5151280)	new	1308729	5149019	3	3.03	98	39	100	100	0	0	0
CX/L/N	3	12049427	West Coast	Ship Creek	at SH 6; access via DoC viewpoint at NZTM 1289890, 5147840	new	1290018	5147788	4	4.42	0	8	98	98	0	0	0
CX/M/N	1	7010679	Manawatu-Wanganui	Whakapapanui Stream	at SH 47	new	1816733	5663904	5	4.87	0	829	99	99	0	0	0
CX/M/N	1	7011239	Manawatu-Wanganui	Whakapapaiti Stream	at SH 47	new	1813423	5661067	4	2.76	0	862	100	100	0	0	0
CX/M/N	2	7013349	Manawatu-Wanganui	Makatote River	at SH 4	new	1806754	5651142	4	2.43	0	749	99	99	0	0	0
CX/M/N	2	7013638	Manawatu-Wanganui	Manganui-o-te-ao River	at SH 4	new	1805768	5649641	3	1.47	0	768	98	98	0	2	0
CX/M/N	2	7014189	Manawatu-Wanganui	Mangaturuturu River	at SH 4	new	1805079	5646700	3	1.89	0	760	100	100	0	0	0
CX/M/N	3	8002584	Hawke's Bay	Waiotukupuna Stream	at SH 4	new	1953961	5707859	3	0.80	0	599	100	100	0	0	0
CX/M/N	4	10003157	Tasman	Anatoki River	any point off McCallum Road u/s fish farm (NZTM 1580230, 5474280)	new	1579865	5474314	4	10.07	79	40	98	98	0	1	0
CX/M/N	4	10004171	Tasman	Waingaro	TDC (Waingaro @ Hanging Rock)	new	1578963	5467904	4	17.24		93	99	99	0	0	0

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CX/M/N	5	10016606	Tasman	Rolling River	any point u/s Rolling Junction Shelter (NZTM 1564960, 5411960)	new	1564635	5411568	4	3.32	48	295	99	99	0	0	0
CX/M/N	6	11030158	Marlborough	Six Mile Creek	via Wairau Hanmer Springs Hydro Road	new	1592244	5360226	3	0.63	0	738	97	97	0	1	0
CX/M/N	6	11030789	Marlborough	Saint Ronans Stream	via Wairau Hanmer Springs Hydro Road	new	1591142	5356853	3	0.31	94	819	99	99	0	0	0
CX/M/N	6	11031082	Marlborough	Hamilton River	via Wairau Hanmer Springs Hydro Road	new	1591253	5355119	3	1.65	0	755	100	101	0	0	0
CX/M/N	6	11031810	Marlborough	Connors Creek	via Wairau Hanmer Springs Hydro Road	new	1590979	5349910	3	0.93	0	819	98	98	0	2	0
CX/M/N	7	12007225	Tasman	Owen River	any point u/s of Brewery Creek (NZTM 1560220, 5392250), Owen Valley East Road	new	1560542	5392469	4	2.62	71	344	96	96	1	3	0
CX/M/N	8	12017315	Tasman	Matakitaki River	any point from Blue Rock (NZTM 1543420, 5361030) u/s to Horse Terrace (NZTM 1547700, 5348810)	new	1547356	5348686	5	31.29	87	316	94	94	0	6	0
CX/M/N	8	12017470	Tasman	Glenroy River	any point off Glenroy Road	new	1545132	5348049	5	15.03	91	326	96	96	1	3	0
CX/M/N	9	12022162	West Coast	Rough or Tobin Stream	at SH 7, upper Inangahua River	new	1512888	5328263	4	2.87	0	288	98	98	1	0	0
CX/M/N	9	12024006	West Coast	Crate Creek	at SH 7, upper Inangahua River	new	1517448	5318841	3	0.51	0	540	99	99	0	0	0
CX/M/N	10	12024727	West Coast	Maruia River	at SH 65, Springs Junction	new	1534382	5315429	5	14.95	16	410	98	98	0	1	0
CX/M/N	11	12033649	West Coast	Taipo River	at SH 73	new	1468802	5265573	4	35.25	0	123	98	98	0	1	0
CX/M/N	12	12036110	West Coast	Otira River	any point accessible from SH 73	new	1482038	5250401	3	2.06	7	791	100	101	0	0	0
CX/M/N	13	12036286	West Coast	Kokatahi River	at Middlebranch Road	new	1447179	5249403	4	26.69	0	69	99	99	0	2	0
CX/M/N	14	12046368	West Coast	Jacobs River	at SH 6; also known as Makawhio River	new	1331877	5170170	5	31.78	0	4	96	96	0	4	0

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
CX/M/N	15	13504246	Canterbury	Freds Stream	at SH 80	new	1367390	5143240	3	1.88	0	616	89	89	0	9	0
CX/M/N	15	13504849	Canterbury	Bush Stream	at SH 80	new	1368163	5139669	4	1.56	24	589	98	98	0	3	0
CX/M/N	15	13505760	Canterbury	Twin Stream	at SH 80	new	1368149	5133307	4	0.60	0	605	95	95	0	1	0
CX/M/N	16	14001320	Otago	Camerons Creek	at SH 6; good access via picnic area	new	1304575	5103913	5	5.96	0	372	99	99	0	0	0
CX/M/N	17	14017255	Otago	Scott Creek	via Routeburn Road, Glenorchy	new	1228632	5032821	3	0.42	0	513	99	99	0	1	0
CX/M/N	17	14017286	Otago	Twelve Mile Creek	via Rees Valley Road, Glenorchy; also known as Ox Burn	new	1238327	5032587	3	2.03	0	428	96	96	0	2	0
CX/M/N	18	15005158	Southland	Pass Creek	via Lower Hollyford Road	new	1214988	5029067	4	0.96	10	231	98	98	0	0	0
CX/M/N	18	15005165	Southland	Sunny Creek	via Lower Hollyford Road	new	1215031	5028903	3	0.50	0	243	98	98	0	0	0
CX/M/N	19	15036249	Southland	Borland Burn	any point on South Branch u/s of NZTM 1169630 4920121	new	1165691	4920057	3	0.98	77	727	100	100	0	1	0
WD/L/P	1	1022121	Northland	Kaihu River tributary	at Babylon Coast Road	new	1672885	6026066	4	0.42	0	18	75	0	22	75	0
WD/L/P	2	1023857	Northland	Aratapu Creek	u/s of Aratapu; check tidal influence	new	1680414	6014998	4	0.37	0	14	86	10	4	86	0
WD/L/P	2	1024978	Northland	Naumai Creek	u/s Naumai; check tidal influence	new	1689025	6006586	4	0.46	0	10	94	4	1	94	0
WD/L/P	2	1025554	Northland	Awaroa River	at Fryberg Road; check tidal influence	new	1696812	6001839	4	0.40	0	11	92	7	1	92	0
WD/L/P	3	2008658	Auckland	Te Hihi Creek	at Linwood Road	new	1761481	5890254	3	0.14	0	15	100	0	0	100	0
WD/L/P	4	3015120	Waikato	Komakorau Stream	EW 258_31 (Komakorau Stm @ NZR08704-089)	non-core	1803370	5828565	5	0.93	0	24	99	0	0	99	1
WD/L/P	4	3015932	Waikato	Komakorau Stream	EW 258_30 (Komakorau Stm @ NZR08704-025)	non-core	1805545	5824990	4	0.29	0	32	99	0	0	99	1

REC class	Site group	NZReach	Region	River	Details	Status	NZTM east	NZTM north	Order	Mean flow ($m^3 s^{-1}$)	Distance from road (m)	Elevation (m)	Catchment landcover				
													%dominant	%natural	%ef	%pastoral	%urban
WD/L/P	5	7046139	Manawatu-Wanganui	Arawhata Drain	Arawhata Drain at Hokio Beach Road	non-core	1790084	5500787	4	0.10	0	20	91	0	1	91	8
WW/L/EF	1	4012847	Bay of Plenty	Mangate Stream	Tarawera Forest near Kawerau	non-core	1920923	5772366	3	0.69	81	70	95	5	95	0	0
WW/L/EF	2	5007660	Gisborne	Mangatokerau River	any point u/s Paroa Road	new	2059807	5747753	4	1.33	0	18	81	16	81	2	0
WW/L/EF	2	5008554	Gisborne	Mangaheia River	any point u/s Takapau Bridge	new	2054459	5741988	4	1.54	0	33	70	12	70	18	0