Advice for application of the physiographic approach to the West Coast Region.

Envirolink Small Advice Grant [1840-WCRC170]

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Land and Water Science
61 Leet Street
Invercargill, 9810

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1. Land and Water Science Ltd., 61 Leet Street, Invercargill, 9810
2. Waterways Centre for Freshwater Management, University of Canterbury, Private Bag 4800 Christchurch

1 Introduction

Land and Water Science Ltd. was contracted to provide services to West Coast Regional Council through an Envirolink Small Advice Grant [1840-WCRC170]. The aim of the project was to provide West Coast Regional Council staff with an understanding of potential benefits of application of the physiographic approach. This information was required prior to commitment of resources and co-funding to the Our Land and Water National Science Challenge, Physiographic Environments of New Zealand (PENZ) project. Transferring of knowledge and provision of advice to West Coast Regional Council on the physiographic approach was achieved through a meeting and presentation to staff by Dr Clint Rissmann, in February 2018, and the summary provided in this short report. Specifically, information provided in this report includes a summary of the key technical aspects of the physiographic approach, resource and sampling requirements, and consideration of that scale at which to apply the approach in the West Coast region.

Overall, the physiographic method seeks to explain 'how' and 'why' water quality varies across a region by identifying the gradients driving key landscape processes that govern water quality outcomes and risk (Rissmann et al., 2016). The importance of understanding the role of the landscape reflects the observation that whilst land use is a prerequisite for poor water quality outcomes, it is the inherent physical, chemical and biological characteristics (attributes) of a landscape that are often responsible for a larger proportion (greater than two times) of the variation in water quality outcomes (Johnson et al., 1997; Hale et al., 2004; Dow et al., 2006; Rissmann et al., 2016). This is particularly true for landscapes such as New Zealand, which are characterised by steep gradients in chemical, physical and biological landscape attributes (Close and Davis-Colley, 1990; Rissmann et al., 2016).

The PENZ project (2017-2019) is seeking to apply the physiographic approach to other regions throughout New Zealand and requires additional sampling to be undertaken by participating regions. So that West Coast Regional Council staff could make an informed decision on participation in the PENZ project, they were provided with a breakdown of the scientific components of the physiographic approach and potential benefits in the context of land use and water resources management. If applied, the physiographic approach has a range of potential benefits to allow West Coast Regional Council, in particular, to more effectively manage and improve the quality of freshwater resources as required under the NPS-Freshwater Management (MFE, 2014).

2 Water quality setting and monitoring summary

The West Coast Region is renowned for its natural and physical attributes, including its lakes, rivers, and coastal areas – and its wet climate. The West Coast Region contains some of the highest annual rainfalls within New Zealand. The rainfall distribution throughout the region has played an important role in forming unique natural landscape features and exerts the primary control over surface water and groundwater resources.

Since the mid-nineties, West Coast Regional Council has operated a surface water quality monitoring program which includes a collection of data on water quality, periphyton (algae on the stream bottom) and stream invertebrates from selected rivers and streams. From 1996 to 2014, 43 sites were sampled for physical, chemical, and bacteriological water quality attributes, as well as periphyton and macroinvertebrate communities. Sites were sampled four to six times per year. Eight of these were paired sites, with one site upstream and one downstream. Additional surface water quality information has been obtained from contact recreation surveys (17 sites in 2014) and other scientific studies carried out in the region. In addition, the National River Water Quality Network operated by National Institute of Water and Atmospheric Research (NIWA), includes five sites within the West Coast region, which have been sampled monthly since 1989. Lake Brunner is an area of focus, and monitoring is conducted at a range of sites in the lake and its tributaries as part of the monitoring program. West Coast Regional Council has regularly undertaken State of the Environment Reporting for surface water quality, on a (generally) three-yearly reporting period (Horrox et al., 2005; Horrox, 2008; Horrox et al., 2011; Horrox et al., 2015).

Groundwater is relied upon as a key resource for municipal drinking water, dairy, agriculture, and industry (James, 2001). The majority groundwater resources in the West Coast Region occur in unconfined, recent alluvial gravel outwash which occurs adjacent to the major rivers (e.g., Grey and Hokitika Rivers). These aquifers are typically 20 – 40 m deep and can occur to 60 – 70 m in the Grey Valley, and are underlain by sandstone, mudstone, and conglomerate (James, 2001). The majority of groundwater extractions in the region are from these alluvial aquifer systems. Depth to groundwater is typically very shallow (e.g., 1.5 – 3.0 m BGL) in spring-fed alluvial systems such as Whataroa, Hokitika, and Westport; whereas further inland groundwater levels can be much deeper (e.g., 30 m BGL in the Grey Valley river terraces). Groundwater quality in the West Coast Region is currently monitored quarterly in 8 National Groundwater Monitoring Programme (NGMP) wells, and bi-annually in 20 West Coast Regional Council monitoring wells. WCRC has previously commissioned groundwater state of the environment reviews, the most recent of which was completed in 2009 (e.g., Daughney, 2004; Zemansky, 2005; Daughney, 2009).

3 Physiographic approach

The fundamental basis of the physiographic approach is the recognition and mapping of gradients in those key landscape attributes that control variation in water quality outcomes, in addition to land use. For example, gradients in soil drainage class are known to strongly influence the degree to which nitrate is attenuated via denitrification (Webb et al., 2010; Killick et al., 2015; Beyer et al., 2016; Beyer and Rissmann, 2016); gradients in soil permeability and depth to slowly permeable (<4 mm/hr) layer determine the pathway water takes across the landscape and influence the potential for entrainment of contaminants via subsurface drainage and overland flow (Nash et al., 2002; Vidon and Hill, 2004; Soana et al., 2017) and; gradients in hydrological connectivity also determine the flushing potential of aquifers, streams, estuaries and lagoons (Volk et al., 2006; Larsen, 2012; Roselli et al., 2013; Outram et al., 2016). An understanding of the landscape level controls that govern variability in those key attributes that drive spatial variation in water quality, therefore, is fundamental to the physiographic approach (Figure 2) (Rissmann et al., 2016).

Water quality can vary spatially across the landscape, even when there is similar land uses or pressures in a catchment. These differences occur because of natural spatial variation in landscape attributes, which alters the composition of the water through coupled physical, chemical and biological processes. Previous research has demonstrated that spatial variation in landscape attributes can account for more than twice the variability in water quality than land use alone (Johnson et al., 1997; Hale et al., 2004; King et al., 2005; Dow et al., 2006; Shiels, 2010; Becker et al., 2014). The role of landscape variability over water quality outcomes is especially true for countries such as New Zealand, which is often recognised as one of the most complex geological regions in the world (Johnson et al., 1997).

Until recently, a systematic approach to mapping the integrated landscape controls over surface and shallow groundwater quality in New Zealand has been lacking. A conceptual overview of the Physiographic Method for identifying and mapping the critical attributes of the landscape that determine spatial variation in water quality outcomes is presented in Figure 1. The Physiographic Method provides a greater opportunity to target and implement mitigations that are both environmentally meaningful and cost-effective, in addition to providing critical context to calibrate existing tools that seek to better understand and model land use losses (SFF, 2017). Additional detail on the physiographic method can be obtain the key references including Physiographics of Southland Project (Rissmann et al., 2016; Hughes et al., 2016); Physiographic Environments of New Zealand Information Document for Regional Councils (Rissmann & Pearson 2018); physiographic mapping for the Waituna Catchment (Rissmann et al., 2018). The physiographic method is proposed to have a natural home in supporting existing tools that seek to understand and minimise land use losses by providing critical context as to the role of the landscape over spatial variation in surface and shallow groundwater.

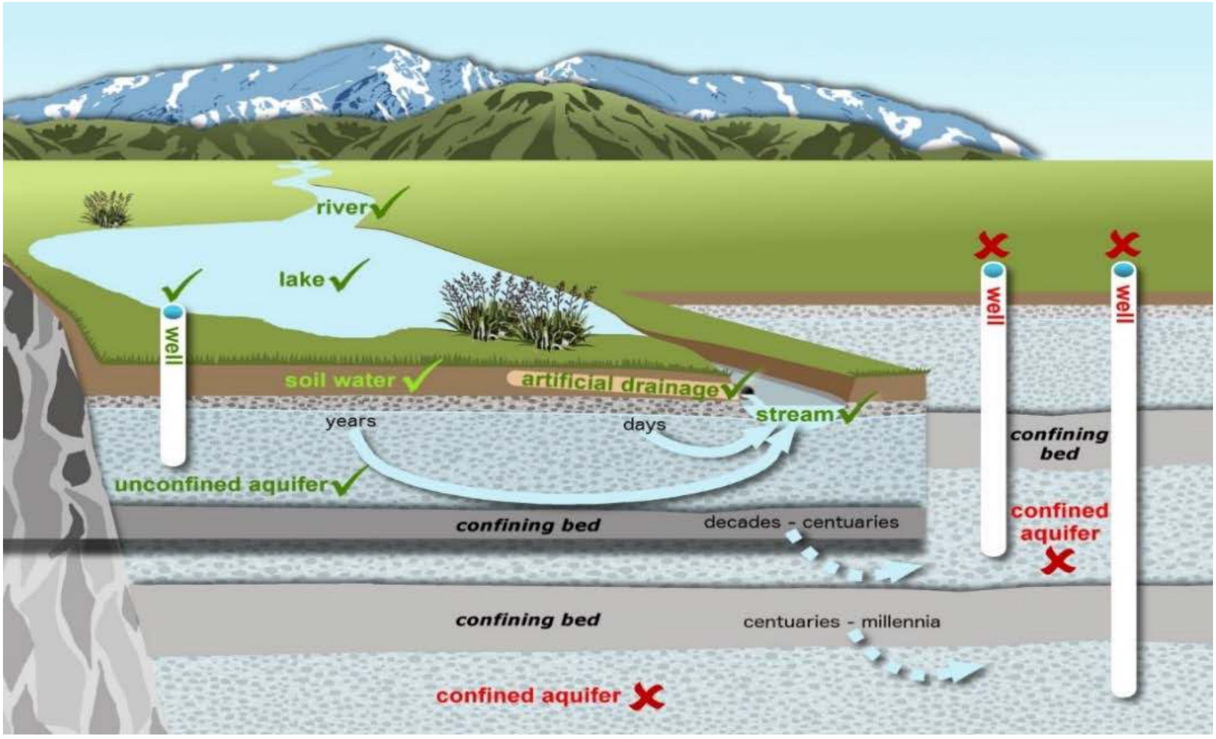

Figure 1: Illustration of the connectivity of near-surface water resources (Rissmann et al., 2016; Hughes et al., 2016). Green tick marks show hydrologically connected settings included in the physiographic approach, whereas red crosses identify settings that are excluded.

4 Consideration of scale

A particular strength of the physiographic approach is the ability to apply the method to a range of resolutions (e.g., property, catchment, regional, and national scales). There are several considerations to make when selecting which scale to apply the method, including: 1) costs for assessing data availability and collating datasets; 2) costs associated with collection and analysis of additional hydrochemical sampling; and 3) Geographic Information Systems (GIS) processing. Much of the GIS processing is the same for a catchment or regional scale, however collection of additional hydrochemical data is necessary for the classification and validation of the approach. Accordingly, when considering the collection of new datasets, in locations where additional water quality data is required, then the scale at which the method will be applied will be of far greater importance. For example, the cost associated with collation of existing datasets at the catchment scale will be less than collection at the regional scale. Another benefit of application of the physiographic method at the catchment scale is that it can be directed at a certain land-use and or water quality issue.

5 Application of physiographic approach to the West Coast region

The physiographic approach utilises existing geospatial data sets and historical water quality monitoring data during the initial hypothesis testing phase. Additional hadrochemical measures are used to refine, classify, and validate the original mapping.

An evaluation of the geospatial and water composition data for the West Coast region suggests that the necessary information for region and/or catchment scale physiographic mapping are available. Additional sampling required by West Coast Regional Council will be dependent on whether the physiographic method is to be undertaken at the regional or catchment scale. An estimated number of additional water quality samples required (in addition to existing sampling) would be six surface water and six shallow groundwater samples per management region. The total number of samples for each catchment would be dependent on the hydrological system and the current monitoring sites.

A key consideration for West Coast Regional Council to make is whether they embark upon catchment or regional scale physiographic mapping. Specifically, the GIS processing is largely the same for the entire region, but collation of historical data sets and additional sampling of surface and shallow groundwater analytes are more affordable at the catchment scale. Therefore, it is recommended that West Coast Regional Council undertake regional scale GIS mapping to produce an unvalidated physiographic model. Following this, one to three key catchments can be selected to prioritise physiographic sampling for validation and refinement. The value of this approach is the that uncalibrated mapping provides a platform for targeted sampling within the target area(s), thereby minimising sampling cost. Other catchments or unvalidated physiographic settings can then be strategically sampled over a longer period. This approach enables some direct outputs for the region to occur rapidly and adds value to the larger region by providing better insight into the key physiographic settings that require compositional sampling and enables a better assessment of the number of locations for sampling.

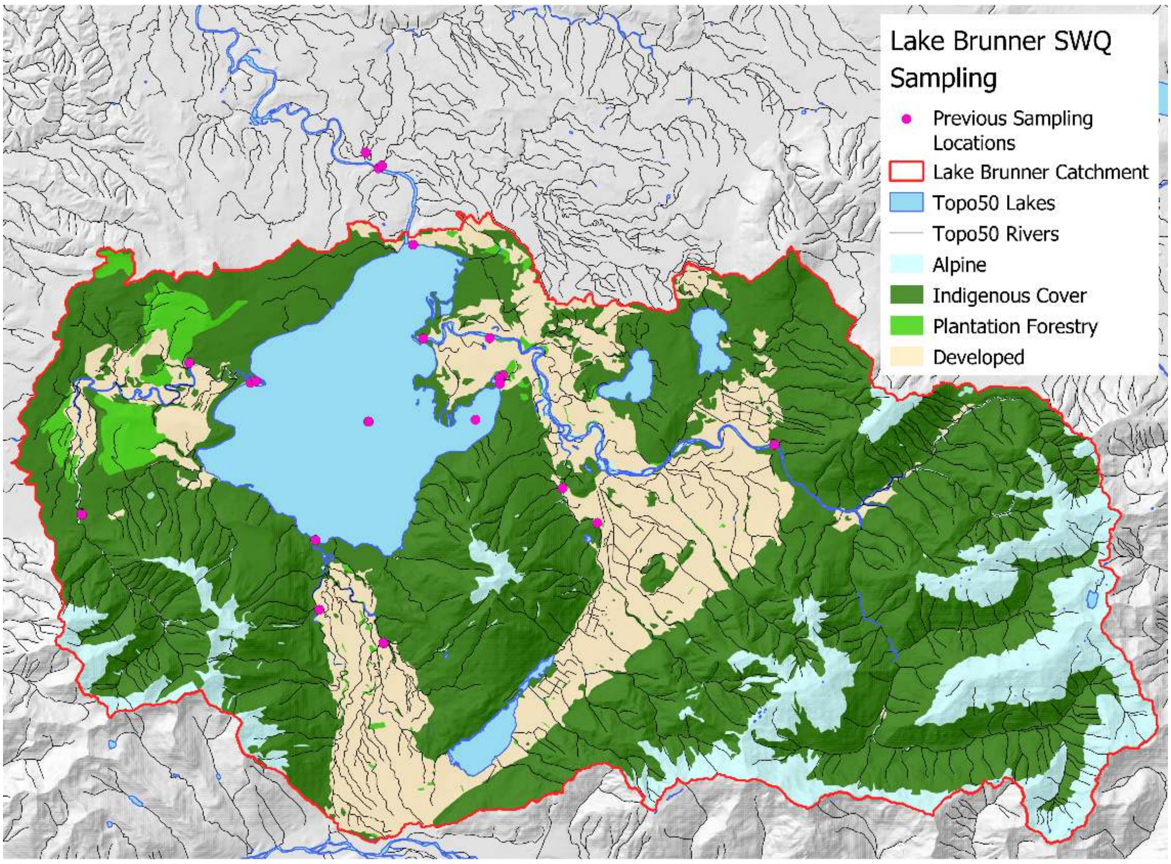

Figure 1: Location of surface water monitoring sites in the Lake Brunner catchment.

In Figure 1, the Lake Brunner catchment has been classified into Alpine, Forested (Indigenous and Plantation - Hill Country), and developed pastoral land across Lowland areas. This classification can be used to guide physiographic sampling for the Lake Brunner catchment. Specifically, although small, Alpine areas are often a key volumetric recharge source. Sampling of flowing streams during winter in the main Alpine areas is important for constraining inputs to lowland streams and ultimately Lake Brunner. It is recommended that 'one-off' winter time surface water sampling be focused on the three most significant Alpine areas. It is also important to isolate and sample three or more forested streams (i.e. no Alpine headwater) for constraining inputs to lowland streams and ultimately Lake Brunner. For forested streams, three repeat measures are recommended, low, median and an event flow. Some of WCRC established monitoring sites appear to meet the criteria of being exclusively Hill Country (forested) fed and as such are useful sites. However, it would be of value to sample two other exclusively Hill country (forested) sites, at low, median, and during an event flow. Isolating the signature of each of these key recharge domains is critical for understanding 'how' and 'why' water quality varies spatially and temporally across the catchment.

Most larger streams in lowland areas have mixed Alpine, Hill (forested), and Lowland inputs. Current WCRC monitoring sites appear to capture the main inflows to Lake Brunner. For these sites, three repeat measures of the physiographic analytical suite are recommended (e.g., low, median, and during an event flow). Groundwater sampling should focus on the shallow aquifer that is most coupled to the stream network. Sampling of five shallow groundwater sites across the lowland area would suffice. One sample for each site is adequate, although two repeat samples at minimum and maximum groundwater level is optimal.

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