WEATHERING THE STORM

INVERCARGILL | WAIHŌPAI **1–4 DECEMBER 2020**

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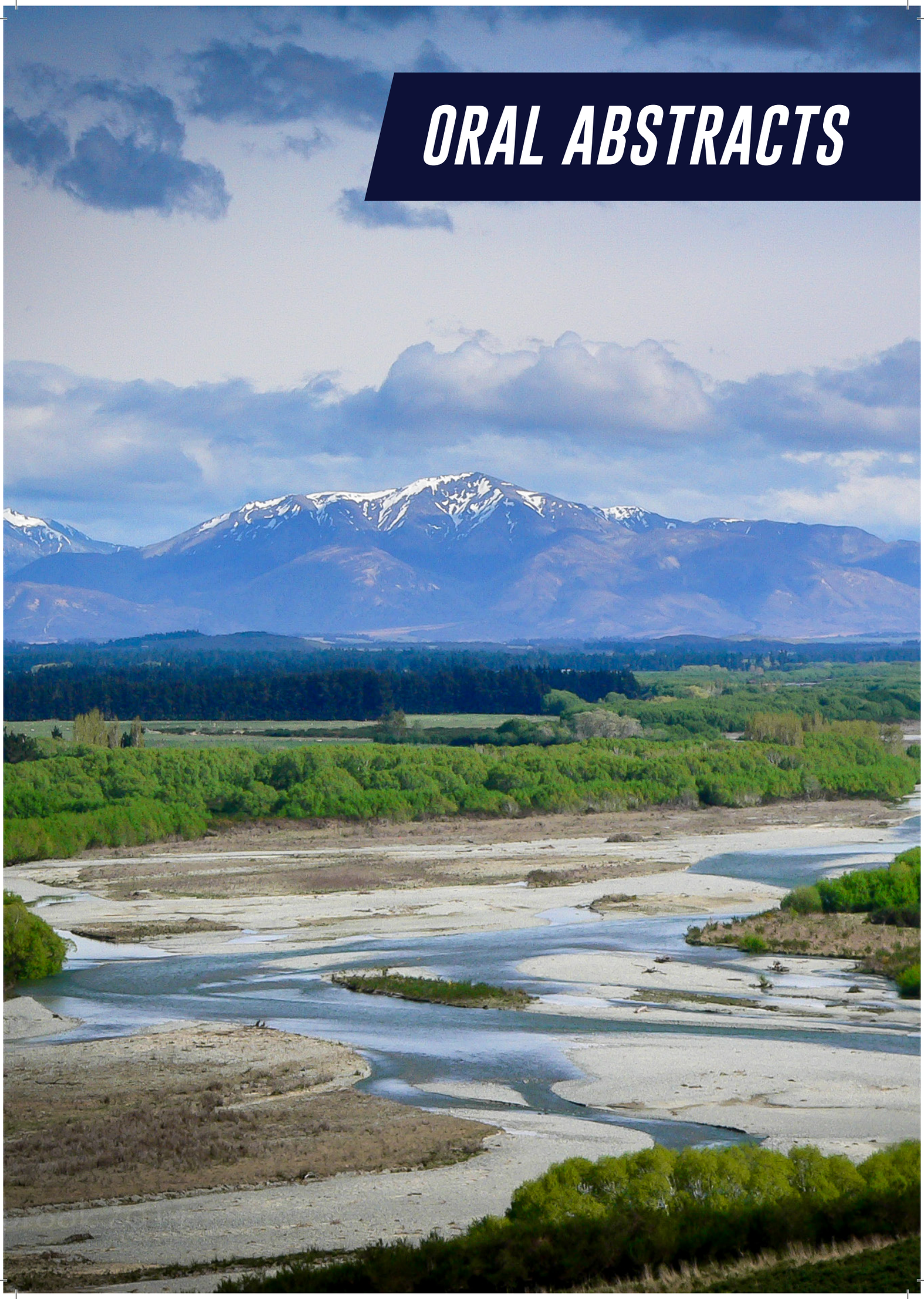
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ORAL ABSTRACTS



KEYNOTE SPEAKERS



DR. SUSIE WOOD

Cawthron Institute

Susie Wood is a Scientist at the Cawthron Institute in Nelson, New Zealand. She obtained her PhD from Victoria University (Wellington, New Zealand) in 2006 specialising in algal blooms in rivers and lakes. Susie leads and contributes to multiple research programmes, supervises students, and regularly undertakes consulting projects for government departments and regional authorities on a range of topics related to cyanobacteria, water quality, molecular ecology and biomonitoring. Her cyanobacterial research is divided between understanding bloom formation and toxin production in New Zealand's lakes, and more recently investigating environmental drivers of benthic toxin-producing cyanobacteria in rivers. She has been particularity active in advocating for the incorporation of molecular tools in biomonitoring and biodiversity projects, including the development of novel molecular-based indices. She co-leads a nationwide programme that aims to obtain an overview of the health for 10% of New Zealand's lakes (www.lakes380.com) using paleo-environmental reconstructions.

TUES 1 DEC | 9:30 - 10:15AM

Rocky rivers and lake learnings

Every summer many of our lakes and rivers experience severe toxic cyanobacteria blooms which impact ecosystem health and compromise human recreational activities. Our team has used a gene to ecosystem approach incorporating field and laboratory-based studies to explore why they bloom, what regulates toxin production and the ecological role of the toxins. Things don't always go as planned....but sometimes this is when we learn the most.

KEYNOTE SPEAKERS



DR. JENNY WEBSTER-BROWN

Our Land and Water National Science Challenge

Jenny Webster-Brown is the current Director of the Our Land and Water National Science Challenge. Her career as a water quality scientist spans nearly 40 years, and encompasses research, teaching and consultancy, focussing on the impacts of land use and mineral/energy extraction on our natural freshwater systems. She is a graduate of Otago University and the University of Western Australia, and began her career with DSIR Chemistry Division in Wellington in 1981, moving with her environmental chemistry colleagues into ESR when the CRIs were formed in 1992. She lectured in water quality, geochemistry and environmental science at the University of Auckland for 13 yrs, before moving to Canterbury in January 2010 to take up the position of Professor of Water Resource Management at the University of Canterbury, and set up the Waterways Centre for Freshwater Management; a teaching and research centre created by the University of Canterbury and Lincoln University to help improve freshwater resource management in New Zealand. She commenced her role with OLW National Science Challenge in May 2020. Based on her experience across the science and research sectors in this country, she sees a critical role for collaborative, interdisciplinary and biculturally-empathetic science, and effective communication and uptake of research findings, in the sustainable management of freshwater resources in Aotearoa.

WED 2 DEC | 8:30 - 9:15AM

Storms to Come: Can science provide a better umbrella than it has in the past?

Even the briefest overview of the man-made “storms” that have assailed our water environment in the past shows that science, even great science, has too often failed to help us avoid, remedy or mitigate their effects. The legacies of these storms are with us still; biodiversity loss, freshwater diversion and depletion, nitrate contamination, faecal contamination, urban stream syndrome, fine sediment deposition … to name but a few of the impacts that we study and (largely) understand, but continue to live with. Common obstacles to the implementation of science-based solutions are also relatively well known; socio-economic drivers, population growth, escalating expectations of our natural resources, traditional practises and various aspects of basic human behaviour… again to name just a few. It seems that there is a counterproductive disconnection between understanding the issue and using this knowledge to solve the problem.

Surveys of recent university science students and graduates reveal their enthusiasm to create a difference in the world, by tackling some of the environmental issues that previous generations have not only found impossible to solve, but have very often exacerbated. We must change those aspects of the traditionally accepted science “system” that actively hinder science’s contribution to society and environment, if we are to help these future scientists contribute more constructively to the protection of our natural resources.

KEYNOTE SPEAKERS



PROF. PETER WILCOCK

Utah State University

Peter Wilcock specializes in erosion and sedimentation processes and their application to stream and watershed restoration and management. His research spans grain-scale mechanics, sediment-channel interactions at the reach scale, and the control and management of sedimentation at the watershed scale. Applications include channel restoration, reservoir and channel response to dam removal, and reservoir operations for downstream channel maintenance. He has worked in experimentation, field observation, and computer simulation of sediment systems and has published more than 100 peer-reviewed articles. Dr. Wilcock provides expert and litigation consultation to industry and government agencies. Dr. Wilcock received his PhD in Earth Science from MIT in 1987. After serving on the faculty of the Whiting School of Engineering at the Johns Hopkins University for 27 years, he joined Utah State University to serve as Head of the Watershed Sciences Department in the Quinney College of Natural Resources from 2014 to 2020. Prof. Wilcock is a Fellow of the American Geophysical Union and received the Hans Albert Einstein Award from the American Society of Civil Engineers for outstanding contributions to the understanding of sediment transport in gravel-bed rivers. He hopes to spend 2021 marveling at the gravel-bed rivers of the Canterbury Plains.

THURS 3 DEC | 8:30 - 9:15AM

River Channel Response to Changes in Water and Sediment Supply

We understand that river channels must adjust their composition, shape, slope, and pattern in response to changes in the supply of water and sediment. It is fair to say that this understanding is more acute after (rather than before) channel change has occurred. We will use principles of mixed-size sediment transport to update the classic concept of channel grade and its application to forecasting channel change. We will consider examples of extreme increases (followed by decreases) in water and in sediment supply to test the controls of channel response and evaluate our understanding.

OUT OF THE DARK: COMMUNICATING GROUNDWATER SCIENCE AT A SECTION LEVEL

Aitchison-Earl, P.,[1] Whalen, M.,[1] Kreleger, A.,[1] van Ness, K.[1]
[1] Environment Canterbury

The Groundwater Science Section at Environment Canterbury (ECan) is passionate about making our science visible by sharing it within our own council, with stakeholders and with the public, and building close connections with industry and academia. Our Section Charter is *'growing and sharing our understanding to help make good decisions'*.

ECan's Science Strategy is to deliver the right information, in the right way, at the right time - which relies on effective Science Communication. The Groundwater Section wanted to look at what actions we could make to complement the Group-wide strategy, so we established a 'SciComm' Working Group. The Working Group brainstormed ideas, identified some 'low hanging fruit', and set up long-term goals.

In the last year the Science Communication group has published two issues of the *'Well Well Well'* newsletter highlighting who we are, what work we are involved in and what we have published. We also hosted a 'Discover Groundwater' session for staff at ECan.

We are working on including science communication in all project scopes, creating a skill summary contact list, writing journal articles for young minds, collaborating with Enviroschools, and creating simple and consistent groundwater graphics.

Going forward we want to support staff to publish their work and to create a groundwater-specific tab on the ECan website. We also want to tackle how we explain uncertainty without calling the validity of our science into doubt, how much science is enough to inform decisions without being overwhelming, and the honest broker versus advocate.

SPRINGS: THE NEXUS BETWEEN GEOLOGY, HISTORY, AND CULTURE – INVESTIGATION OF TE PUNA RERE A MARU

Alexander, K.B.,[1] Rasmussen, C.,[1] Ashby, E.[2]
[1] Beca Ltd
[2] Auckland Council

Beca is assisting Auckland Council with identifying and classifying puna (springs) located in the Auckland region as part of the Council's Māori Cultural Heritage Programme. The initial phase is focused on evaluating the location of a specific puna (Te Puna Rere a Maru) in Te Tii Tutahi (Newmarket) area of Auckland. Te Puna Rere a Maru was an important puna wai (freshwater spring) for the generations of tribes that lived on the Auckland isthmus and its significance is acknowledged by Ngāti Whātua Ōrākei who are partners of the Heritage Programme.

Currently, the exact location of Te Puna Rere a Maru is not known. Based on oral history, the location is believed to be in the vicinity of Khyber Pass Road. In the 19th century, the spring water under Khyber Pass attracted several brewers to the Newmarket area (including the former Lion Brewery). The location has been developed for many years and any existing spring flow is likely routed through stormwater drains and eventually to Waitamata Harbour.

Auckland Council desired to accurately locate the source of Te Puna Rere a Maru using a robust geoscientific method to understand the historic and current hydrological processes. The initial desktop review followed a phased 4-step research approach developed for spring investigation in an urban setting: (1) historical research, (2) topographic analysis, (3) geological analysis, and (4) aerial photos or remote sensing imagery. The methodology that Beca used to try to pinpoint the location of this puna is novel and could be an example for other projects in urban areas where the source of old freshwater springs is lost in time.

USING ADVANCED STATISTICAL ANALYSIS TO OPTIMISE GROUNDWATER MONITORING NETWORKS

Alkhaier, F.,[1] van Ness, K.,[1] Hanson, M.,[2]
[1] Environment Canterbury
[2] Kōmanawa Solutions Ltd

Introduction

Canterbury has extensive groundwater resources but growing demands and pressures on the resource require implementation of an efficient regionwide bore monitoring network that will provide sufficient data to draw conclusions for effective resource management. Monitoring network improvements often involve adding bores to the largest gaps spatially, considering lateral coordinate positions as well as bore depth. If more resources become available, new bores are added to fill in the largest gaps; if monitoring resources are lost, bores are removed from the network. This approach will generally result in an overly expensive monitoring programme that does not optimise the data diversity that could be obtained using the same available resources. There will often be similarities across the sites or 'duplicate' patterns that emerge. Rather than continue spending resources to capture these 'duplicate' patterns, statistical analyses can be used to determine where monitoring resources can be reduced or reallocated most effectively.

Aims

This study reviews the groundwater level monitoring network in the Selwyn-Waihora groundwater management zone in Canterbury. We applied advanced statistical tools to the available time series data to classify bores into groups that share common patterns in water levels. These groupings provide useful guidance in establishing a priority across monitoring sites, particularly when there is a sudden change or reduction in monitoring resources. For example, in times of COVID-19 or shortly after a natural disaster, manual monitoring may suddenly become unavailable. Having a reduced set of bores that can be correlated to the other bores through groupings can prepare a network for periods of decreased monitoring. This can be done in the form of installing remote loggers in a reduced bore list or in having a shortened bore list to quickly take manual measurements at the first available opportunity. These measurements can then be used to guide the 'missing' data in the other bores.

Method

Water level time series records vary significantly across start dates, end dates, and data frequency for each bore. Due to these differences, analysis methods were used to fill gaps within the monthly water level records and bores were separated into several subsets based on the length of the record. Bores were only considered if they were still in the current monitoring network. Principal Components Analysis (PCA) (Jolliffe, 1986) was applied to the time series records to create a scatter plot of the bores. PCA is a powerful tool for analyzing data. It recognizes patterns in data and reveals similarities and differences across the bore records. In data of high dimension (long time series of groundwater level for many wells) it is often difficult to find patterns. PCA provides the ability to present the main characteristics (principal components) of these time series graphically on two or more orthogonal axes (Figure 1). Using Cluster Analysis (CA), a numerical classification method (Sneath and Sokal, 1973), we can objectively classify bores into different groups based on the distance of their principal component values on the three first axes, where each group contains bores with similar patterns in their water levels.

Results

Utilizing PCA and CA on the water level records allowed us to group bores together that have common behaviors. This approach provides a way to find patterns across many sets of water level records rather than analyzing individual time series independently. By finding patterns in sets of bores, reasons behind these patterns can be explored to provide new insights on the hydrogeological system of the catchment. As an example, Figure 2 presents the results of this analysis in the Selwyn Te Waihora catchment and the separation of wells into four main groups (clusters). A potential interpretation for these groups is that there is a group of wells in the confined system (yellow dots), a group of shallow/intermediate depth wells throughout the inland unconfined/semi-confined system (red dots), a smaller inland group of deeper wells in the semi-confined system (green dots), and finally a group near the Waimakariri that carry the river recharge signature (blue dots). These results can be used to solidify or improve the conceptual understanding of the aquifer system by confirming or finding new connections between the bores in a catchment. Additionally, these results can be useful when calibrating groundwater models by guiding their calibration targets.

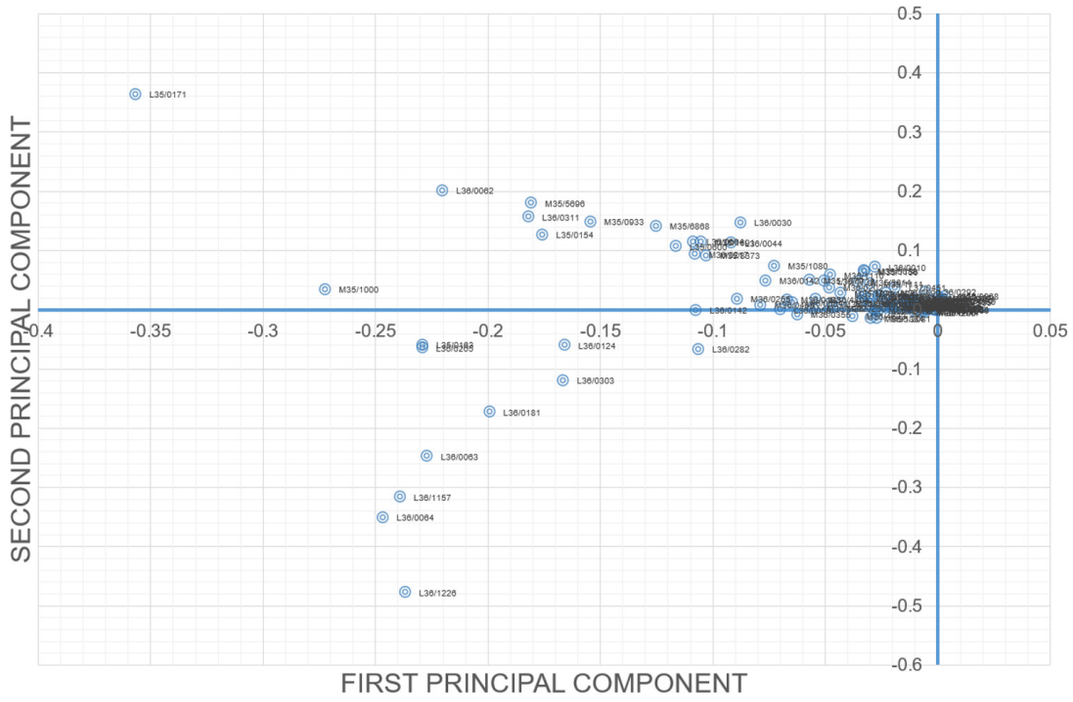


Figure 1. Principal components analysis for groundwater levels records in Selwyn / Te Waihora zone, Canterbury

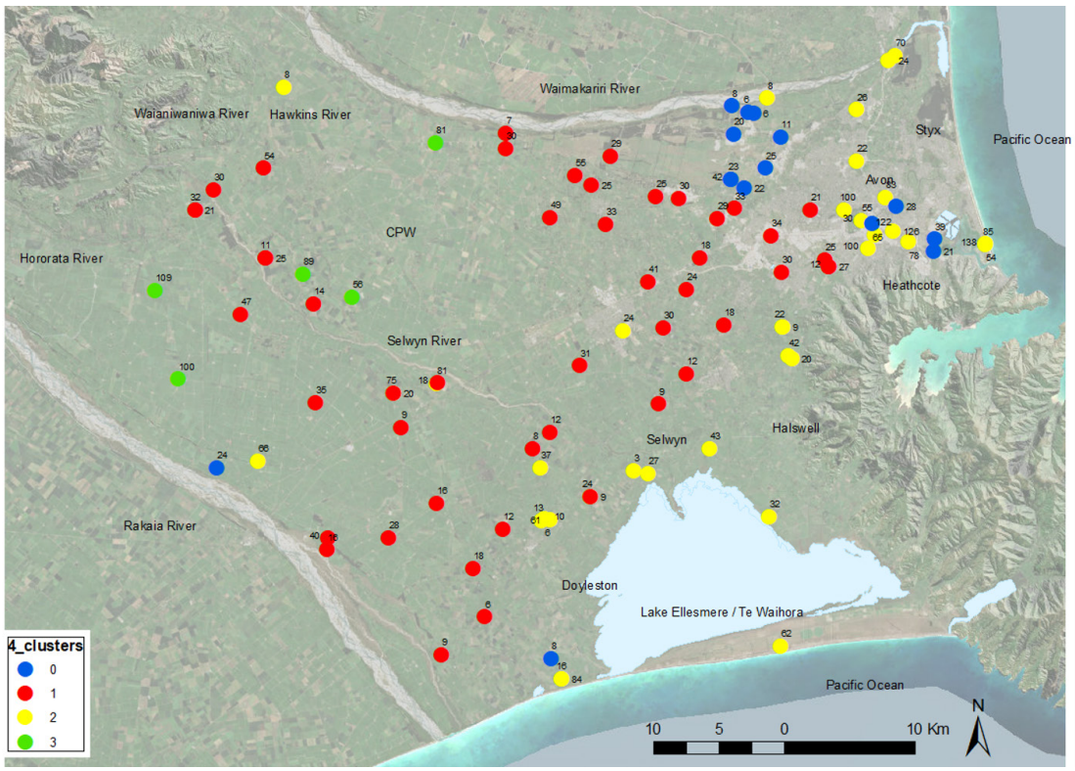


Figure 2. Four classes for wells in Selwyn zone Canterbury based on principal components analysis

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CONSEQUENCES OF LANDLOCKING FOR BODY SHAPE OF NEW ZEALAND COMMON SMELT, RETROPINNA RETROPINNA

Ara, M.G.[1]
[1] Department of Zoology, University of Otago, New Zealand

Transitions between marine and freshwater habitats are important events for the evolution and diversity of fish species. Diadromous species may become landlocked when they colonise or are translocated into lakes, and where access to the ocean is restricted through behavioural mechanisms or landscape modification. Long-term isolation and exposure to these selective pressures may cause evolutionary or environmentally induced changes in fish body shape, ecology, or life history. Common smelt (*Retropinna retropinna*) is widespread around New Zealand including Chatham Island (Rēkohu or Wharekauri) and is ancestrally diadromous and caught as whitebait in some areas. However, it can also form landlocked populations that complete their life cycle in a lake. The aim of this study is to determine the consequences of landlocking for the body shape of common smelt from Chatham Island. I hypothesized that landlocked populations would show different morphological traits than their migratory counterparts. Geometric morphometric analysis was conducted to compare body shape of Chatham landlocked populations to Chatham and mainland diadromous populations, while accounting for allometry. I found that body shape was highly variable by having longer and deeper head size, bigger eyes, wider mouth gape, and narrower body depth and caudal fin base in landlocked population than coastal population. Significant differences in body shape were also found among population types (Rsq=0.17038, *P* value = 0.001**) as well as among different sites (Rsq=0.20124, *P* value = 0.001**).The outcomes of this study have several implications for the management and conservation of common smelt as an important customary fishery.

MONITORING THE FRESHWATER BENEFITS OF MANAGEMENT ACTIONS: MONITORING DESIGN FRAMEWORK

Ausseil O.,[1] Aporo, N.,[2] McDowell R.,[2,3] Houlbrooke D.[2]
[1] Aquanet Consulting Ltd
[2] AgResearch
[3] Lincoln University

The recent National Policy Statement for Freshwater Management (NPS-FM, 2020) revolves around the fundamental concept of Te Mana o Te Wai, the fundamental importance of freshwater and the need to sustain itself and its living ecosystems. The NPS-FM requires that the quality of freshwater be maintained, or improved where it is degraded, and introduces additional monitoring and reporting requirements. In this context, land stewards need to be confident that their actions will be effective. Water stewards also need confidence that improvements in the state of our freshwater resource are identified robustly and in a timely manner, and that causal links can be established between management actions and freshwater outcomes.

In partnership with central government, the Our Land and Water (OLW) National Science Challenge (Toitū te Whenua Toiora te Wai) has identified critical knowledge gaps in the design of environmental monitoring capable of verifying the impact of action on the ground as well as the most appropriate technologies for facilitating verification of actions. In response, OLW has instigated three working groups.

Working Group 1 aims to develop a "Monitoring Design Framework" to specifically answer the question: have management actions taken on land or in the water body resulted in improved freshwater outcomes? The Framework will be based on a decision support system to guide the design of monitoring programmes, while dealing with the complexity of temporal and spatial influences.

The project timeline is July 2020 – February 2021. Input from stakeholders and end-users viewed as critical to the success of this project and will be sought throughout the project to identify needs and expectations, determine the nature and format of the final deliverables and test the applicability and workability of the deliverables.

The presentation will focus on the draft Monitoring Design Framework and the integration with the other two Working Groups, focusing on Monitoring Technologies and Maori Konwledge Systems.

RESTORING LAKE HAYES – A COMMUNITY JOURNEY INTO CATCHMENT MANAGEMENT

Badenhop, A.,[1] Johnstone, S.,[1] Davis, G.,[1] Bloomberg,S.,[1] Hanff, M.[2]
[1] e3Scientific Ltd
[2] Friends of Lake Hayes Society

Lake Hayes, near Arrowtown, is prized for its beautiful vistas and recreational value for locals and tourists alike. Over the past 25 years, numerous investigations have been completed to understand the causes of poor water quality and algal blooms in the Lake, and propose solutions. Phosphorous loads carried with sediment into Mill Creek are highest during peak flows whilst groundwater provides a fairly constant source of nitrate discharging to the lake; these nutrients combine to degrade the Lake. Nutrient migration into creeks and groundwater has been exacerbated by land use change, removal of native vegetation, stock access to waterways, draining of wetlands, channelisation of water courses and streambank erosion.

Local community group, the Friends of Lake Hayes Society has campaigned and fundraised over many years to see real action in restoring the Lake. e3Scientific are working with FOLH to provide concrete conceptualisation of nutrient mitigation options using a suite of methods including riparian fencing and planting, sediment traps, wetland enhancement and construction of wetlands to reduce nutrients from Mill Creek prior to discharge. With this community driven work, we have needed to bridge the gaps between government stakeholders, local landholders, and community groups, providing clear vision of the aims for the catchment. The largest part of the project has been the design of a wetland near the outlet of Mill Creek to the lake. Wetland design has been guided by the large water quality dataset collected by the ORC since 2018, combined with data collected by FOLH during large events. This has provided evidence of a critical flow threshold, above which sediment mobilisation, and hence phosphorous concentrations rapidly increase. Unlike most wetland designs, the wetland is not aiming to treat stormwater or wastewater and therefore cannot be designed using standard guidelines. The wetland design is heavily constrained by the available land area, depth to groundwater and the available hydraulic gradient, and has required thoughtful optimization to ensure that the wetland can provide significant nutrient reduction whilst maintaining the amenity of the lake foreshore.

TRACING THE SOURCES OF NITRATE USING ISOTOPES: 10 YEARS OF PROGRESS FOR NEW ZEALAND FRESHWATER

Baisden, W.T.,[1] Clough, T.,[2] Rissmann, C.,[3] Wells, N.,[4] Stewart, S.,[1,5] Phillips, A.,[6] Rayner, S.,[2] Murray, R.,[1] Chris Eager,[1,7] Eyberg, C.,[1] Yulanti, M.[1]
[1] University of Waikato
[2] Lincoln University
[3] Land and Water Science
[4] Southern Cross University, NSW, Australia
[5] Cawthron Institute
[6] GNS Science
[7] NIWA Hamilton

Introduction

The use of nitrogen and oxygen isotopes in nitrate ($\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$, respectively) has developed over the past 30 years to provide powerful tracer value, identifying sources and tracking processes related to nitrogen fluxes through the atmosphere, biosphere and hydrosphere. Globally, the high $\delta^{18}O\text{-}NO_3$ values associated with atmospheric sources and oxidation processes has been most powerful in source identification for polluted northern hemisphere regions. In these regions, the signal in $\delta^{18}O\text{-}NO_3$ is immense but highly variable, and therefore obscures nuanced studies of nitrogen cycling. Over a decade of intensive New Zealand studies have shown signatures dominated by nitrogen cycle processes without substantial atmospheric inputs, therefore offering unique potential to drill into the detail of controls on ecosystem nitrogen retention.

Methods

A range of programmes and activities have collected nitrate isotope samples with a 100 mL target size, preserved for indefinite storage at pH 3 with 1 mL 10% HCl. Sulfanilic acid is added to remove nitrite prior to nitrate analysis, which is performed according to a modified Cd-Azide two step reduction method for analysis as N_2O at GNS Science's Stable Isotope Laboratory in Gracefield. Precision and reproducibility is generally ≤0.3 ‰ for samples over 30 ppb NO_3-N with lower limits for analysis ~3-5 ppb. Collections were generally aligned with monitoring or experiments measuring nitrate or total oxidized nitrogen using standard methods.

Results and Discussion

New Zealand's observed pattern of dual-isotope nitrate suggests that many pastoral soils have good nitrate retention, such that added urine or urea intensifies nitrate leaching that remains buffered through the soil organic nitrogen pool, as indicated by $\delta^{15}N\text{-}NO_3$. Within a variability of 1–2 ‰, nationwide studies find nitrate matching these conditions sits on a 1:1 line in bi-plots (see Figure 1) from $\delta^{15}N\text{-}NO_3$ = 4 ‰ and $\delta^{18}O\text{-}NO_3$ = 0 ‰ along a gradient of increasing agricultural intensity to $\delta^{15}N\text{-}NO_3$ = 8‰ and $\delta^{18}O\text{-}NO_3$ = 4 ‰. This defines a denitrification and mixing (DAM) line for integrated soil processes characteristic of good ecosystem nitrogen retention.

In contrast, where highly permeable soils are found, the low $\delta^{15}N\text{-}NO_3$ values of urea and urine (typically -2 to +2 ‰) can dominate localized sources and decrease the catchment integrated $\delta^{15}N\text{-}NO_3$ in rivers and streams by 2 ‰ or more. Occasional shifts in localized sources to higher $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ reflective of denitrified effluents are also observed. These isotopic patterns are commonly associated with elevated nitrate concentrations that exceed thresholds for freshwater ecological health. When observed, this pattern points to opportunities to alter land use and management to reduce nitrate leaching reaching freshwater.

Adding recent data from the Rotorua Te Arawa Lakes catchments to datasets from Manawatu, Wairarapa, Canterbury and Southland reinforces these interpretations, suggesting that source signatures dominate integrated catchment $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$. For inflows to Rotorua from pastoral areas on permeable pumice soils, $\delta^{15}N\text{-}NO_3$ values are typically offset 2 ‰ lower than than the DAM line. Heavier soils associated with the 'Rotomahana mud' eruptives generally do not show this offset. Dual-isotope nitrate signatures associated with other distinctive sources are locally evident, including waster-water treatment, farm effluents, geothermal activity. Inflows from lakes where phytoplankton uptake has altered $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ can also be evident, and helpful in confirming the source of lake-fed springs.

Why do integrated samples from large catchments rarely show a 'denitrification' signal characterised by $\delta^{15}N\text{-}NO_3$ and $\delta^{18}O\text{-}NO_3$ increasing along a 2:1 line? Is this surprising when localised sampling from shallow groundwater bores or 1st-order streams shows this denitrification signature? The obvious answer is that the removal of the nitrate by denitrification tends to go nearly to completion, thereby removing the $\delta^{15}N\text{-}NO_3$ to negligible levels when against background flows with appreciable concentrations. A secondary explanation in some environments could be that

diffusion rather than denitrification could be the rate-limiting process suppressing the expected signal. Regardless, integrated source signatures are well-preserved in large catchments – enabling cost-effective characterisation and monitoring.

To better target mitigation, can dual-isotope nitrate measurements clarify hot spots and hot moments of nitrate production, mobilisation and loss? In soils, the δ^{15}N-NO_3 and δ^{18}O-NO_3 appear to go through a highly variable sequence following urine addition or wet up. But leached nitrate observed in flows from rain events appears to have relatively stable signatures that allows good soil nitrogen retention to be contrasted with other sources, such as direct outflow of urine/urea or effluent N isotope signatures. Nevertheless, high-resolution or continuous concentration measurements combined with the use of water isotopes or other tracers to confirm flowpaths may more directly target mitigation opportunities – augmenting the integrated potential of dual-isotope nitrate at catchment scales.

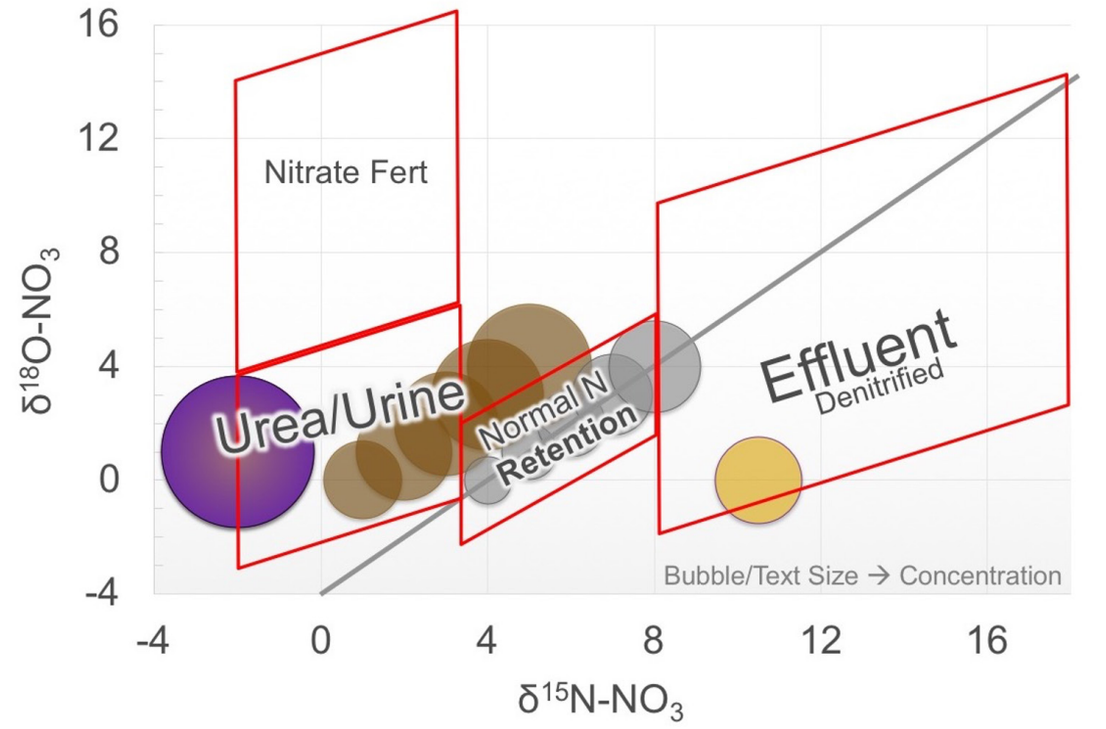


Figure 1. Indicative positions of dual-isotope nitrate categories discussed in the text.

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Eyberg CE (2020) *Variation in nitrate sources and delivery in space and time within the 389 ha Lake Ōkaro catchment.* Masters, The University of Waikato, Hamilton, New Zealand.

MURIHIKU KANAKANA MONITORING – WHAT HAVE WE LEARNT?

Baker, C.,[1] Kitson, J.,[2,3] Tuwairua, M.,[3] Leith, J.,[3,4] Leith, V.,[3,4] Russell, C.,[3] Parata, R.,[3] Williams, P.,[1] White, E.,[1] Pyper, N.[1]

[1]National Institute of Water and Atmospheric Research, Hamilton, New Zealand
[2]Kitson Consulting Limited, Waihōpai/Invercargill
[3]Ngai Tahu ki Murihiku
[4]Waikawa mana whenua

Kanakana/piharau (lamprey) can be regarded as a "living fossil" with records dating back over 360 million years. Kanakana/piharau is the sole lamprey species in New Zealand, with migratory adults forming an important cultural fishery and a taonga (treasured) species for Māori. Presently, piharau/kanakana are classified as as "Threatened - Nationally Vulnerable" in the New Zealand Threat Classification System, with populations exhibiting a nationwide on-going decline. Conservation of pouched lamprey is limited by a poor understanding of their ecology, in particular their reproductive ecology. In 2013, NIWA documented the first spawning site for a Southern Hemisphere lamprey species in Banks Peninsula (Baker et al. 2017), where lamprey pairs created concealed nests beneath large boulders. Our current research in the Waikawa River catchment focuses on adaptability of spawning habitats, especially in modified landscapes where boulders are limited or absent. This presentation provides an overview of research findings to date, outlining spawning habitat requirements, which will be critical to protecting and restoring kanakana/piharau populations under the new National Policy Statement of Freshwater Management (2020).



Adult lamprey upon entry to freshwater

References

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DEVELOPMENT OF LAMPREY PASSAGE STRUCTURES

Baker, C.,[1] Franklin, P.,[1] Williams, P.,[1] White, E.,[1] Pyper, N.,[1] Tieman, G.[1]
[1]National Institute of Water and Atmospheric Research, Hamilton, New Zealand

The pouched lamprey (piharau/kanakana; *Geotria australis*), is one of five Southern Hemisphere lamprey species, and New Zealand's only representative of the agnathans. In New Zealand, migratory adult pouched lamprey constitue an important cultural fishery, and are considered a taonga (treasured) species by indigenous Māori. New Zealand pouched lamprey are presently classified as Threatened, with populations exhibiting a nationwide on-going decline. Although lamprey develop at sea, the final stage of their lifecycle is migrating back to freshwater to breed. During this migration, manmade barriers (e.g. dams and other high-head barriers) prevent lamprey reaching critical breeding habitats. Globally, a major factor in the conservation and management of anadromous lamprey species is improving passage past high-head dams through the construction of lamprey-adapted fishways. These fishways take advantage of the swimming or climbing ability of the lamprey and provide adequate attachment surfaces (e.g., aluminium ramps, baffled surfaces, rounded corners). Presently, only three lamprey species, the Pacific lamprey (*Entosphenus tridentatus*), the Short-headed lamprey (*Mordacia mordax*) and our piharau/kanakana are known to possess the ability to climb vertical surfaces using their oral disc with their body completely out of water. This climbing ability has led to the successful development of lamprey passage structures (LPS) to enable Pacific lamprey to migrate past hydro-electric dams on the Columbia River. In order to develop a robust and effective lamprey passage structure for piharau/kanakana, better knowledge of their climbing behaviour at obstacles is required. This presentation provides an overview of laboratory trials to determine effective design criteria for promoting lamprey climbing behaviour, knowledge crucial to enhancing the distribution of piharau/kanakana populations and protecting a declining taonga species.

PUMPED HYDRO FOR ENERGY STORAGE: ONSLOW AND NGARURORO

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On July 26, Energy & Resources Minister Megan Woods announced a $30 million business case review of pumped storage in New Zealand, with particular reference to the Onslow Scheme (Bardsley, 2005).

Having sufficient energy storage as pumped storage can provide buffer through dry years, enabling 100% renewable power generation at all times. The Onslow scheme would be a multi-billion dollar project, capable of energy storage in excess of 5 TWh. Part of the review process will be to define upper and lower water levels as a trade-off between energy storage and ecological impact. One option may be a water level range between 700 and 770 metres, with a connecting horizontal tunnel at 750 metres through to the Manorburn Basin.

The business case review is also likely to overview Ngarururoro pumped storage, which appears to be the largest achievable energy-based pumped storage in the North Island (2.7 TWh). This would require a 30 km tunnel linking Taupo to a constructed upper reservoir in the upper Ngarururoro River. This scheme has the advantage of North Island location, but has less energy storage capacity and greater environmental impact than Onslow.

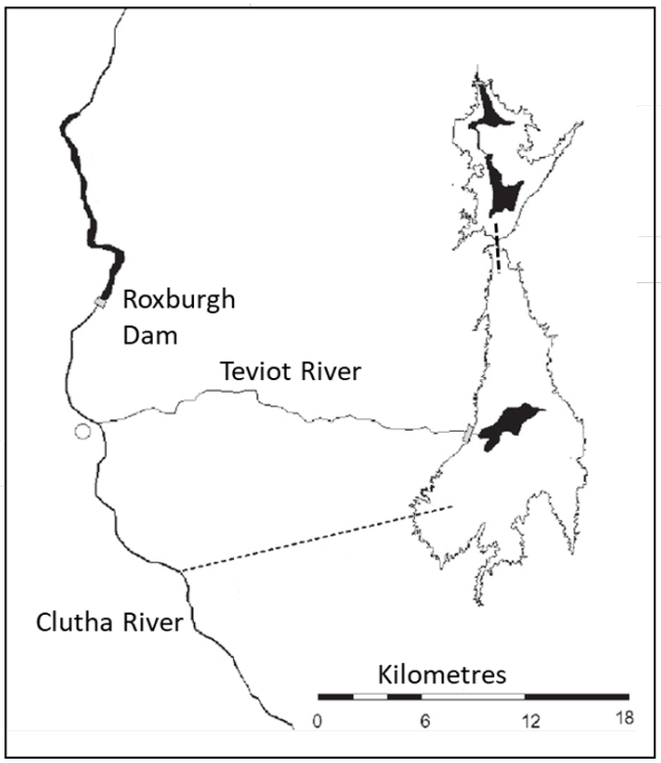


Figure 1. Onslow Scheme configured at 800 metres maximum elevation. Tunnels indicated by dashed lines.

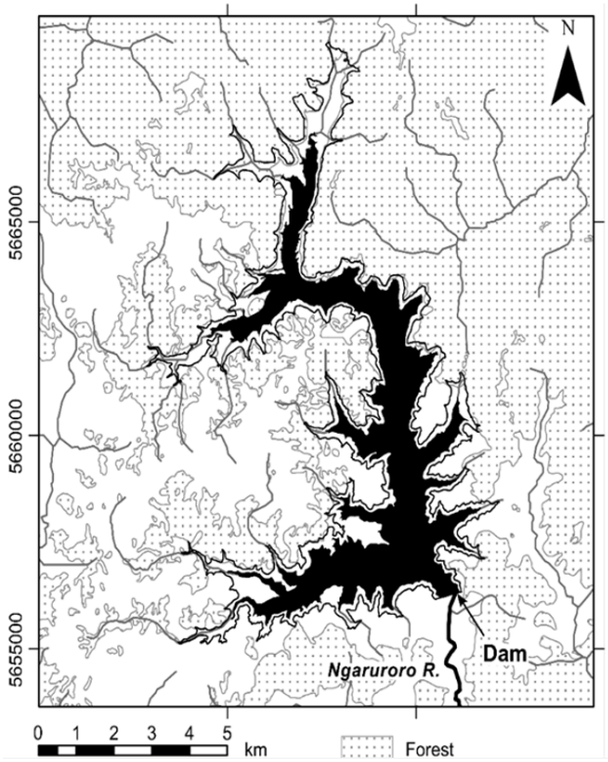


Figure 2. Ngarururoro upper reservoir at 1000 metres (black), with maximum water level at 1040 metres (surrounding contour)

MBIE will soon be announcing details of all dry year options to be evaluated, with the business case reviews to be completed by the end of 2021.

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REIGNITING HEALTHY RESILIENCE: USING DISTURBANCE TO OVERCOME NEGATIVE RESISTANCE AND RESILIENCE IN STREAM RESTORATION

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'Resistance' and 'resilience' describe the capacity of an ecosystem to withstand and recover from disturbance. Often associated with 'good' ecological health, these regularly underpin restoration goals. However, degraded ecosystems can also be resistant and resilient to disturbance (negative resistance and resilience) making their communities highly stable and thus resistant to restoration. We investigated this post-restoration scenario (i.e., physical recovery without biological recovery) using a mesocosm experiment, demonstrating that presence of a persistent degraded community can hinder biological recovery. To facilitate biotic recovery, we propose that degraded communities must first be destabilised. This requires an understanding of how degraded communities are assembled, underpinned by trait-environment relationships. We conducted a meta-analysis of New Zealand streams to investigate how environmental gradients influence community assembly, using data across both anthropogenic and natural disturbance gradients. Trait-based ordination of communities using non-metric multidimensional scaling indicated different disturbance gradients work to shape communities along orthogonal axes in trait space. This knowledge can inform restoration by identifying novel disturbances that could be artificially applied to disrupt existing trait-environment relationships, thereby displacing less desired taxa. We tested this theory in a further mesocosm experiment to investigate how different community types responded to additional disturbance. Response to disturbance depended on disturbance history: if more of the same stress was applied, community composition remained relatively stable; if novel environmental filters were applied, community composition changed. Thus, there is potential to alter communities and overcome negative resistance and resilience in restoration by applying artificial disturbance as a tool to direct community recovery.

DRONES IN FRESHWATER SCIENCES: REMOTE SENSING TOXIC CYANOBACTERIA AND RIVER FLOW

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Drones provide an effective deployment platform for obtaining high resolution remote sensing data. They are useful for investigating finer scale processes (mm to cm), compared to the landscape scales covered by aircraft and satellites. The use of drones in Freshwater Sciences is growing exponentially, since they provide a cost-effective way to digitise our physical environment. The remote sensing data from drones (comprising billions of measurement points) can be combined with complementary point sampling of biological processes to address a wide range of research questions. This talk begins with an overview of the use of drones in Freshwater Sciences, then focuses on recent breakthroughs in the use of drones for aerial monitoring of toxic cyanobacteria cover with multispectral and hyperspectral camera systems. Methods for converting from cover to biomass based on ground truth measurements are also provided. Although 2D maps of toxic cyanobacteria cover are useful for policy makers and river managers, biomass distributions may provide a better indicator of public health risk, since they incorporate information on mat thickness, which is important for detachment, drift and accumulation at river margins. This talk concludes with methods for remote sensing river flow and physical habitat from the air using the novel 'drone flow' system.

WHAKAMATAARA AHURIRI – THE JOURNEY TOWARDS REINSTATING AND RESTORING A ONCE THRIVING CULTURAL ECOSYSTEM AND HABITAT

Martin-Paul, M.,[1,2,3] Blakely, T.J.[1]
[1] Boffa Miskell
[2] Ngāi Tahu – Ngāi Te Ruahikihiki
[3] Te Arawa – Ngāti Pikiao

Ahuriri Lagoon is a former open water wetland and significant mahinga kai located on the Huritini / Halswell River in the Te Waihora / Lake Ellesmere catchment. For Ngāi Tahu whanui, Ahuriri is associated with their longstanding settlement and occupation the Port Hills, Te Waihora and the wider Canterbury Plains.

Boffa Miskell consultants were tasked with designing and delivering a Mātauranga Māori Monitoring Programme as part of the wider Whakaora Te Ahuriri project. The objectives of the Mātauranga Māori Monitoring Programme were to demonstrate how to measure the cultural outcomes of the Whakaora Te Ahuriri project and determine whether the reinstated Ahuriri Lagoon has improved cultural outcomes for Ngāi Tahu Papatipu Rūnanga.

The Mātauranga Māori Monitoring Programme sought to integrate cultural values and aspirations into the design and construction of the wetland, with a particular focus on improving mahinga kai, by providing a catalytic wetland system that tests both its probability and value in restoring the lagoon, its habitats, and some of its original functions for Ngāi Tahu.

The design and implementation of the monitoring programme involved working in collaboration with Papatipu Rūnanga representatives to monitor six sites across the Ahuriri area, in the Huritini / Halswell River and within the reconstructed Ahuriri Lagoon, using various cultural monitoring tools such as the Takiwā tool, the Cultural Health Index and monitoring of the fish communities. Throughout the Whakaora Te Ahuriri project, mātauranga Māori has been identified as critical to successful design and reconstruction of the traditional wetland, and an essential tool to monitor the wetland's progress and performance.

GROUNDWATER BIODIVERSITY: BIG BUGS, LITTLE BUGS AND EVERYTHING IN BETWEEN

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Groundwater is an important source of drinking water in Aotearoa. Within groundwater, there is a complex ecosystem from micro to macro-scale. These groundwater organisms, including stygofauna, are thought to provide ecosystem services including maintaining water quality by processing contaminants, and groundwater flow paths. However, these subterranean systems remain one of the most understudied in New Zealand. This is partly because of the nature of sampling methodologies and difficulties in accessing sites.

There is now slow but growing acceptance of there being "life under the ground", and information is being rapidly generated in this emerging area of research. In particular, research suggests that there are three pillars that contribute towards understanding groundwater dependent ecosystems: physico-chemical, microbiological and fauna monitoring.

Here, we present stygofaunal data from several wells across the country and an in-depth set of arrays. We discuss the ecosystem distribution and ask the following questions:

- What does a single groundwater sample tell us in terms of biodiversity (macro-fauna) and is it representative of the aquifer system?
- What could determine the macro-fauna distribution?
- Does sampling technique affect the biodiversity recovered?
- What are the dominant and potentially key organisms found across all sites from eDNA

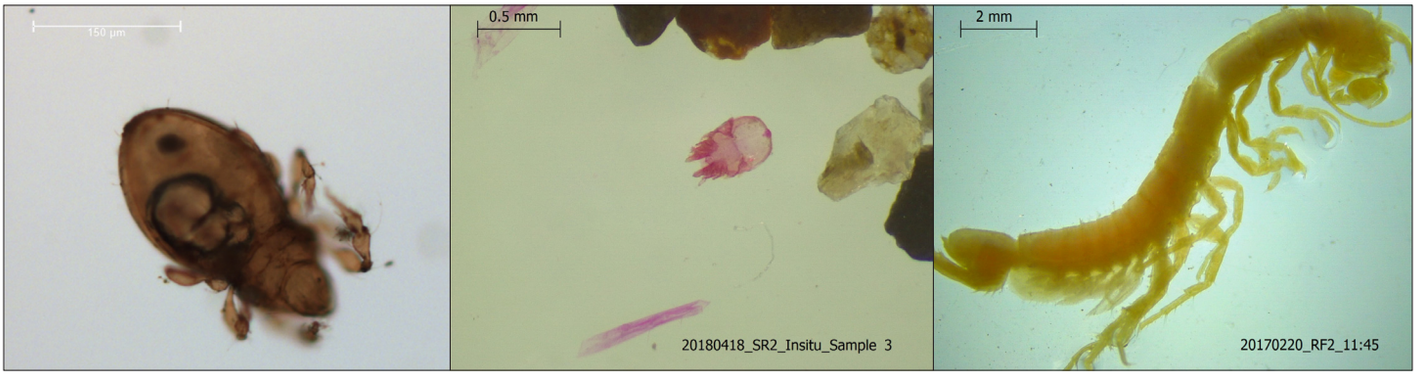


Figure shows a mite (left), nauplii (juvenile crustacean, centre) and isopod (right)

The differences between sites are discussed in terms of aquifer hydrogeology, water chemistry, organic carbon inputs and ecology. The advantages and limitations of the eDNA and manual netting techniques are also discussed including the merits of combining these techniques. Finally, we highlight the next steps and remaining challenges.

ARE CANTERBURY RIVERS WARMER DURING LOWER FLOWS WHEN ALL OTHER CONDITIONS ARE EQUAL?

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Aims

River water temperature is known to be important for water quality and ecosystem processes. In this work we aimed to quantify the degree to which lower river flows are associated with warmer river water, after accounting for seasonality and other influential factors such as solar radiation, air temperature and earth temperature.

Method

We applied a three-step methodology to analyse observed synchronous data on mean daily river water temperature and mean daily river flow from many sites across the Canterbury region. We fitted regression models to remove seasonal patterns from all variables (Step 1), then removed correlations between water temperature and each of three primary predictors (solar radiation, air temperature, and earth temperature) separately (Step 2) before quantifying water temperature-flow relationships (Step 3).

Results

Strong seasonal patterns were present in water temperature and its predictor variables across all sites. Many sites also showed strong seasonal patterns in river flows. We demonstrated that these seasonal patterns must be removed before day-to-day associations between water temperature and its predictors can be quantified. Lower flows were associated with warmer river water for 46 of our 47 sites, even after having accounted for seasonality and other factors. This finding has important implications for management of water abstractions because it indicates that increased river water temperatures would accompany reduced river flows

RESTORING LAKE HAYES – A COMMUNITY JOURNEY INTO CATCHMENT MANAGEMENT

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[1] e3Scientific Ltd
[2] Friends of Lake Hayes Society

Lake Hayes, near Arrowtown, is prized for its beautiful vistas and recreational value for locals and tourists alike. Over the past 25 years, numerous investigations have been completed to understand the causes of poor water quality and algal blooms in the Lake, and propose solutions. Phosphorous loads carried with sediment into Mill Creek are highest during peak flows whilst groundwater provides a fairly constant source of nitrate discharging to the lake; these nutrients combine to degrade the Lake. Nutrient migration into creeks and groundwater has been exacerbated by land use change, removal of native vegetation, stock access to waterways, draining of wetlands, channelisation of water courses and streambank erosion.

Local community group, the Friends of Lake Hayes Society has campaigned and fundraised over many years to see real action in restoring the Lake. e3Scientific are working with FOLH to provide concrete conceptualisation of nutrient mitigation options using a suite of methods including riparian fencing and planting, sediment traps, wetland enhancement and construction of wetlands to reduce nutrients from Mill Creek prior to discharge. With this community driven work, we have needed to bridge the gaps between government stakeholders, local landholders, and community groups, providing clear vision of the aims for the catchment. The largest part of the project has been the design of a wetland near the outlet of Mill Creek to the lake. Wetland design has been guided by the large water quality dataset collected by the ORC since 2018, combined with data collected by FOLH during large events. This has provided evidence of a critical flow threshold, above which sediment mobilisation, and hence phosphorous concentrations rapidly increase. Unlike most wetland designs, the wetland is not aiming to treat stormwater or wastewater and therefore cannot be designed using standard guidelines. The wetland design is heavily constrained by the available land area, depth to groundwater and the available hydraulic gradient, and has required thoughtful optimization to ensure that the wetland can provide significant nutrient reduction whilst maintaining the amenity of the lake foreshore.

CURRENT AND FUTURE RISKS OF SALTWATER INTRUSION IN COASTAL GROUNDWATER DUE TO LAND USE CHANGES AND SEA LEVEL RISE

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[1] Golder Associates NZ Ltd
[2] University of Canterbury
[3] Reeftide Ltd

High salinity groundwater is present around the low-lying coastal Tūranganui-a-Kiwa / Poverty Bay, and there are concerns about future decrease in water quality and potential effects on agricultural production.

A former lagoon (Awapuni Moana) was drained and a long history of modification in land use activities followed. To enable the current farming activities the land is continuously drained at low tide via a network of land drains. The main driver for the increasing trend of salinity is the extensive drainage network to drain the area, and Waipaoa River flood control structures, both of which cause a reduction in freshwater recharge. This causes the saltwater wedge, which was initially only present beneath the sea and dune area, to move inland. The saline groundwater has currently reached the centre of the Awapuni area and is likely to propagate into the land drains under low recharge conditions during dry periods.

Rising coastal groundwater and salinisation can both have a significant impact on land use and water resources in the foreseeable future. These impacts can be exacerbated by coastal hazard risks arising from climate change induced sea-level rise. The assessment of current and future land use management shows that flood and salinisation susceptibilities have a direct impact on the Awapuni area and are likely to render parts of the area unsuitable for agricultural use in the future.

Options such as changes to land and farm management or water management, are currently being explored and could potentially form part of a long-term climate adaptation strategy.

PRIORITISING DOC'S FISH PASSAGE MANAGEMENT

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Many of New Zealand's freshwater fishes migrate between the sea and freshwater, and/or move within freshwater environments. Instream structures, like culverts, weirs, fords, dams and gates, that are not designed, maintained and installed correctly can restrict, delay or stop fish moving in our waterways. With a high number of our freshwater fish species in decline, there is increasing concern about how migration barriers impact on their numbers and distribution. Latest estimates suggest we have around 100,000 structures currently in our waterways in New Zealand. Our waterways need to be carefully managed so that our freshwater fish and other instream organisms like aquatic invertebrates can access the habitats they need to complete their lifecycles. To begin to address this, the Department of Conservation started undertaking assessments of the risk to fish passage at instream structures along DOC tracks in 2019. Results of these assessments to date from the Fish Passage Assessment Tool will be summarised. A framework of how this data along with other information and guidance from the National Fish Passage Guidelines is being used to prioritise fish passage remediation and the next steps for fish passage management for the Department will be presented.

AGILE, ADAPTIVE WATER ALLOCATION POLICY

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[2] NIWA

Current water allocation policy must set a minimum flow or level and an associated water allocation limit for each water body. This policy is usually given effect to by including conditions in each water take consent that:

- Limit the maximum take such that the sum of all takes from the water body doesn't exceed its allocation limit, and
- Require the water take to cease if the residual flow-rate drops, or would drop, below the minimum flow at specified flow-rate monitoring sites.

At face value this approach provides an effective method for managing water takes to deliver the values balance made explicit by Te Mana o te Wai, which prioritises (a) maintaining the health of a water body over (b), providing water to meet human health needs over (c), any other water uses.

However its ability to adapt effectively, and in a timely and cost-efficient manner, to climate-change-driven changes in the values balance has not been assessed.

This paper will describe research in progress that aims to answer these questions in the context of projected future climate:

1. To what degree might minimum flow-rates and allocation limits need to change in order to maintain the key characteristics of the current flow regime and thus the existing level (at least) of water body health?
2. What would be the impact on capacity to meet human health needs and the needs of other uses?
3. What changes to water allocation policy design would be necessary to enable agile adaptation to future climate?

RADIOCARBON GROUNDWATER AGES PROVIDE INSIGHT TO RECHARGE RATES FOR THE LOESS-COVERED SOUTH CANTERBURY DOWNLANDS

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[1] Institute of Environmental Science and Research Ltd. (ESR)
[2] Institute of Geological and Nuclear Sciences (GNS)

Aims

Loess is a defining Quaternary geological feature of the South Canterbury downlands region, particularly throughout the coastal zone extending between the townships of Timaru and Waimate. Extensive loess sheets, measuring up to 20 m total thickness, cap the Tertiary sediments, the youngest of which is the Kowai Formation (also known as the Cannington Gravels). The Kowai Formation hosts much of the freshwater of the region that is exploited for drinking water and irrigation. Little is known of the hydrogeological function of the Tertiary aquifer systems or rates of water infiltration through the loess.

In 2014, Environment Canterbury commissioned a hydrochemical field study of deep groundwater with the South Canterbury coastal zone, anticipating useful knowledge about groundwater flow paths and recharge processes might be gained from the general groundwater chemistry. The initial results of the hydrochemical study have been presented previously (Burbery et al., 2016). Here we present the groundwater age results from the 2014 field-study campaign, as a second chapter of the deep groundwater investigation. In particular, we demonstrate how we have incorporated the radiocarbon age results with the pre-existing water chemistry data to derive some initial estimates of groundwater recharge rates under the loess covered downlands.

Method

In the 2014 field sampling campaign, 81 wells across the South Canterbury coastal zone were sampled and the general hydrochemistry of the groundwater samples analysed. Water-typing methods reliant on major ion composition results were applied to the chemistry dataset, from which 12 hydrochemical facies were identified. Importantly, we were able to distinguish groundwater in the Kowai Formation that had a river recharge provenance from that sourced from land surface (i.e. rainfall) recharge. A select subset of 33 groundwater samples were subsequently radiocarbon dated in 2016 (Van der Raiij, 2016).

We have assessed groundwater age-depth profiles for those 33 samples at the river catchment scale and for discrete hydrochemical facies, somewhat akin to the idea of physiographical modelling. The categorical hydrogeological (physiographical) settings we have identified are: i) groundwater underlying the valleys of present day rivers that drain water from the Hunter Hills; ii) groundwater underlying the valleys of lowland streams that are sourced from run-off from loess interfluves; iii) groundwater under loess-capped interfluves, also under Mount Horrible.

We applied the following simplifying assumptions: i) recharge is uniformly distributed over the aquifers for the different settings; ii) the aquifers themselves are homogeneous and isotropic, and iii) pseudo steady-state hydrological conditions prevail. Consequently, we assume a uniform depth-age relationship should hold for each condition and vertical recharge rates can be inferred from radiocarbon age-depth gradients, which we determined applying simple linear regression.

Results

Much groundwater that is being exploited from the Kowai Formation in the South Canterbury coastal zone is old. Beyond areas where Quaternary alluvium is mapped and river recharge is active, the groundwater being abstracted is estimated to be in the range of 3,000 to 9,000 years old. A distinct body of paleowater (12,000 – 22,000 years old) is located near Waimate, underlying the loess-covered interfluve that separates Waimate Stream and Hook River.

With exception of the aforementioned interfluve near Waimate, depth-age profiles for groundwater under loess interfluves was reasonably consistent between the different river catchments, and also under Mount Horrible where both loess and basalt cap the Kowai aquifer system. From the observed depth-age gradients, we propose groundwater recharge rates under the loess covered downlands may well be in the order of 12-21 mm/year. In valley settings where lowland streams have incised the loess (e.g. Horseshoe Bend Creek, Kowhai Stream, Pig Hunting Creek) enhanced rates of groundwater recharge were detected that we estimate to be around 38-48 mm/year.

Water losses from the main rivers whose headwaters are in the Hunter Hills represent a significant recharge mechanism to the local groundwater resource. The groundwater flow paths in the aquifer systems underlying those rivers are highly modified due to the long history of pumped abstraction. This compromises somewhat the simplifying assumption of a pseudo steady-state hydrological condition. Notwithstanding this limitation, groundwater recharge rates inferred from depth-age relationships for those settings are: circa 100 mm/year in the Waimate Stream valley, circa 200 mm/year in the Makikihi River valley, and over 500 mm/year in the Pareora River catchment.

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HYDROGEOPHYSICS APPLIED TO EXAMINE THE FUNCTION OF A WOODCHIP DENITRIFICATION WALL

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[3] Padova University, Italy
[4] Southern Geophysical Ltd., New Zealand

In November 2018 we installed an experimental woodchip denitrification wall, in a shallow gravel aquifer, at Silverstream Reserve, North Canterbury (Burbery et al., 2018). So far, the wall has proved effective at providing enhanced, *in situ*, natural attenuation of groundwater nitrate. The hydraulic properties of the shallow aquifer in which the wall is emplaced were initially estimated from a constant-rate pump test, conducted prior to the wall installation. The hydraulic properties of the media constituting the reactive fill in the wall were tested *ex-situ*, using a large permeameter apparatus. Collectively, these data were used in construction of a numerical groundwater model of the site, from which we predicted the woodchip wall enhanced flow by 15%. The hydraulic residence time of groundwater in the denitrification wall was estimated to be around 39 hours (Burbery et al., 2020). In June 2020 we conducted a salt tracer test at the site, in conjunction with time-lapse electrical resistivity measurements, for the purpose of examining the hydraulic function of the woodchip wall. Results from the hydrogeophysics has revealed a complex and unexpected flow pattern about, and through the woodchip wall. We are currently exploring a number of hypotheses that explain such behaviour.

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CAN WE PREDICT THE POTENTIAL DISTRIBUTION AND EFFECTS OF INVASIVE ZOOPLANKTON (DAPHNIA SPP.) IN NEW ZEALAND?

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Planktonic 'water fleas', *Daphnia spp.*, play an important role in lakes as intermediaries, consuming algal biomass and, in turn, falling prey to planktivorous fish. Over the past three decades, New Zealand lakes have been invaded by two species of Northern Hemisphere *Daphnia: D. galeata* and *D. pulicaria* ('*pulex*'). These invaders have established thriving populations in increasing numbers of New Zealand's lakes, often to the detriment of our indigenous Daphnia spp. and wider plankton biodiversity. However, the broader effects of these invaders on New Zealand's lake ecosystems have yet to be determined.

The species of *Daphnia* in c. 200 lakes throughout New Zealand in the *Lakes380* project were related to geographical and limnological variables (physical, chemical, biological and geomorphological) measured during the project or derived from the *Freshwaters of New Zealand* (FENZ) database for the lakes and their catchments. Multivariate analyses and boosted regression trees were used to determine associations. Models were sought that might allow the spread and colonization of New Zealand's lakes by the two invasive *Daphnia* species to be predicted and thereby allow appropriate steps to be taken to retain or enhance lake water quality and indigenous biodiversity.

MEETING THE NEEDS OF FISH AND PEOPLE: LESSONS LEARNT FROM DREDGING A TIDAL RIVER

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[1] Instream Consulting

This paper discusses the challenges and lessons learnt from managing ecological effects of dredging the Ōpāwaho / Heathcote River in Christchurch, New Zealand. Diggers were used to dredge 4.5 km of river length over 19 months. Key environmental concerns were associated with fine sediment generation and physical destruction of fish and aquatic habitat. Silt curtains were initially used to isolate discrete locations of digging, to minimise suspended sediment impacts downstream and to allow for fish to be trapped and relocated prior to digging. However, the curtains were abandoned as they were unable to effectively seal the dredging sites, mainly due to tidal flow reversals. Fish trapping and relocation continued prior to dredging each site, coupled with increased checks of dredged sediments for fish, continuous monitoring of turbidity, and a shortened work week to reduce the amount of time the river was turbid. A total of 16,091 fish were caught and relocated from 135 site/date fishing combinations. Impacts on native eels (*Anguilla* spp.) were of concern, due to their propensity to burrow into fine sediment when disturbed, rather than swim away. Fish relocation was effective at reducing the number of larger eels prior by dredging, provided trapping occurred immediately prior to digging. A total of 248 live fish and 36 dead fish were found during 100 hours of searching through dredged sediments. Turbidity levels were high during dredging and declined to background levels within approximately two tidal sequences. Monitoring is underway to assess impacts on fish communities and fish spawning habitat.

REAL TIME STREAM DEPLETION ANALYSIS AND RIVER FLOW NATURALISATION

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[1] Pattle Delamore Partners Limited

Aims

Groundwater abstraction effects on surface waterways are typically quantified using a stream depletion calculation based on the total depletion effect at the end of a prolonged period of pumping (e.g. 30 days, 90 days, or 150 days). However, the cumulative build-up of the actual stream depletion effect on a river is not typically quantified in real time. As a result, the effect of groundwater abstraction effects to correct for determination of naturalized flow or for the implementation of low flow restrictions is not often taken into account.

The aim of this paper is to describe a methodology to describe the real time impact of groundwater abstractions on the flow in a surface waterway. Of particular interest is the effect of stream depleting groundwater takes and their actual effect on the river flow based on measured data, compared to estimates based on consented rates of abstraction. This approach could assist with improved water allocation management in surface waterways.

Method

Stream depletion effects can be calculated using a wide variety of methods, including analytical models as well as numerical models. In areas where there is a database of pumping test results including parameters used to quantify stream depletion effects, analytical models of stream depletion can be arranged to define cumulative effects on a day to day basis where measured use data is available.

As an example, stream depletion estimates using the Hunt (2003) analytical solution were carried out using an example dataset for all the bores in a test case area where data are available based on a set of measured, variable pumping rates. Hunt (2012) used a Microsoft Excel Workbook with custom functions written in Visual Basic for Applications (VBA) to represent the mathematical formulae to solve the stream depletion problem. We translated the functions into Python, which allowed the drawdown and recovery for each days pumping to be calculated. The sum of the daily drawdown and recovery from each bore represented the effect of variable pumping rates over a season.

Once the stream depletion effect from all bores that could affect flow in the river was determined, the cumulative effect of groundwater pumping could be quantified in real time. If flow naturalisation was required, the river flow could be adjusted in a similar manner to adjustments for direct surface water takes.

Results

The results of the actual stream depletion analysis are instructive in considering the real time effects of groundwater pumping and the timing of the delayed recovery of stream depletion effects due to groundwater abstraction. The analysis indicated that in some years, recovery may not be complete by the start of the following irrigation seasonal. This approach to estimating river flow naturalisation is achievable in circumstances where good records of measured flows and the results of pumping test analysis are available.

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CONSERVATION OF THREATENED FRESHWATER-DEPENDANT PLANTS: CASE STUDIES

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There are currently 38 freshwater-dependent plant taxa in the highest national threat category – Nationally Critical, with a further 10 data-deficient taxa likely to be in nationally threatened classes (additional to 36 more species in the other two nationally threatened classes, Nationally Endangered and Nationally Vulnerable). The recent "Essential Fresh Water" regulatory reform package requires compulsory management of aquatic habitats that support the continued presence and survival of nationally threatened species, adopted as a new ecosystem health attribute in the National Policy Statement for Freshwater Management 2020.

This talk provides geospatial information on these Nationally Critical plants, including the following:

- current population structure (number of populations, population size/area)
- location and extent
- taxonomic uniqueness
- habitat constraints
- threats
- management interventions and response to management

Research undertaken on four of Nationally Critical taxa; *Sebaea ovata, Juncus holoschoenus, Trithuria inconspicua* and *Utricularia australis* will be presented, discussing the current knowledge gaps and conservation actions required for their management.

DEVELOPMENT OF A MOLECULAR APPROACH TO DETECT FRESHWATER FISH COMMUNITIES IN AOTEAROA NEW ZEALAND

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Environmental DNA analysis is transforming biodiversity monitoring globally. In aquatic environments, the possibility of detecting the presence and potential relative abundance of species using discreet water samples is rapidly becoming a reality. However, it is important to understand the benefits and limitations of different molecular methods to ensure their appropriate application. Here we describe the development of a whole community assessment method (eDNA metabarcoding) to monitor freshwater fish in streams in Aotearoa NZ. Steps included i) development of a fish eDNA sample collection protocol, ii) identification of a universal primer pair for high throughput sequencing of fish communities, iii) sequencing of missing species to build a fish database, iv) development of a bioinformatics pipeline to analyse sequences from fish communities and v) field validation of the eDNA methods alongside standard fishing methods. We found that a backpack pump facilitated the filtering of large volumes of water through 5 µm self-preserving filters and maximised fish eDNA collection. We selected a region of the 12S gene that in-silico trials showed would distinguish NZ fish species. Fish tissue samples were sourced and the 12S region sequenced to build a reference database. Field trials at 13 sites demonstrated that the method confidently identified most of the species that electric-fishing methods detected. However, some sequences could not be assigned confidently beyond genus, which may be the result of inter- and intra-specific genetic variation that is not yet represented in the reference database. Ongoing sequencing of genetic material from NZ native fish will expand the database and improve taxonomic assignments going forward. Some questions remain, particularly regarding the transport and degradation of eDNA in flowing waters and the relationships between biomass and eDNA concentrations. These should be priority areas for future research. Overall, we suggest that eDNA metabarcoding is a useful tool to monitor the fish biodiversity in rivers and streams.

INTEGRATED ASSESSMENT OF STREAM ECOSYSTEM HEALTH IN THE TUKITUKI CATCHMENT

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There have been increasing calls for the holistic assessment of river condition, moving beyond the traditional focus on water quality and biology alone. Legislation in New Zealand now requires integrated assessments of freshwater ecosystem health. Here we report on the application of a framework for New Zealand freshwater assessment, which includes 5 core components—water quality, water quantity, aquatic biota, physical habitat, and ecological processes—in the Tukituki River catchment. Indicators of ecological processes included ecosystem metabolism and cellulose decomposition potential, which were measured and reported alongside other river-health metrics to provide an integrated picture of river ecological integrity at site, stream-type, and catchment scales. Every site in the Tukituki catchment failed to meet bottom-line benchmarks for at least 1 assessment metric. When aggregated by stream type, warm-wet lowland streams in the Tukituki River catchment had the poorest ecosystem health because of poor water quality and quantity. At the catchment scale, the Tukituki scored highly in overall ecosystem health despite 20% of the targeted network failing bottom-line benchmarks for 11 out of 22 metrics. This study demonstrates the value of 1) a probabilistic sampling design for predicting the spatial extent of stream condition, 2) accounting for environmental variation through a process of data harmonization informed by site-specific reference conditions and bottom-line benchmarks, and 3) involving resource-management practitioners in the development of the assessment framework to ensure that the level of detail is achievable in practice and to provide examples of how the results can inform management actions. Applications could include directing land-use mitigations and stream restoration towards warm-wet lowland areas, where excess phosphorus and aquatic plants proliferate. Finally, we demonstrate how a report-card approach can simultaneously provide information across multiple components and avoid the loss of information. The framework is adaptable and can be used across contrasting spatial scales, it is consistent and representative, and it is easily understood.

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KŌURA AND AGRICHEMICALS IN AOTEAROA NEW ZEALAND.

Clearwater, S.,[1] Kusabs, I.,[2] Parata, R.,[3] Boubee, J.,[4] Ling, N.,[5] Collier, K.,[5] Forrest, E.,[6] Kelly, J.,[7] Parkyn, S.,[8] David, B.,[9] Francis, L.,[10] Ratana, K.,[11] Albert, A.,[11] Thoms, C.,[12]
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[2] Kusabs & Associates
[3] Hokonui Rūnanga
[4] Vaipuhi Freshwater Ltd.
[5] University of Waikato
[6] Ngāti Tahu-Ngāti Whaoa Runanga Trust
[7] Alchemists Ltd.
[8] Moehau Environmental Group
[9] Waikato Regional Council
[10] Wildlands
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In recent years several mass mortalities of native freshwater crayfish (*Paranephrops planifrons, P. zealandicus*)(also known as kōura or kēwai) in streams have been documented by council emergency response teams, and crayfish researchers commonly encounter anecdotal reports of others. For example, in two consecutive years in both December 2016 and December 2017 there was a mass kōura kill affecting Oraka Stream, in the central North Island. On both occasions hundreds of dead and dying kōura were observed drifting downstream. Waikato Regional Council (WRC) subsequently identified pesticide spraying using alpha-scud (contains cypermethrin, a synthetic pyrethroid) of a nearby eucalyptus forest as the probable cause and is working with the forestry company to ensure no repetition of the event. WRC has also applied to the Environmental Protection Authority (NZ) to have alpha-scud reassessed. More recently similar events involving agrichemicals have been documented in Southland and in Rotorua.

There is concern that along with other pressures, the use of some agrichemicals is negatively affecting freshwater crayfish populations, particularly in small upland wadeable streams where the risk of overspray and spray drift with minimal dilution is higher than in larger water bodies. On the other hand, we have minimal collated knowledge about the current status and trend of koura populations to evaluate the 'size' of this issue relative to other pressures on koura. The issue will be briefly introduced and followed by a short, facilitated discussion about the knowledge gaps and actions researchers and agencies can take to ensure ongoing koura management takes this potential risk into account.

DOGS DETECT PEST FISH SCENT IN WATER WITH REMARKABLE SENSITIVITY

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[1] University of Waikato

Common carp (*Cyrprinus carpio*) are an invasive species that pose a significant threat to freshwater ecosystems due to their destructive feeding behaviour, large size and ability to reach high densities. In shallow lakes, carp biomass can exceed 400 kg/ha with negative impacts occurring at biomasses above 50 kg/ha (biomass equivalent to 2.5 mg/L in a lake of average depth of 2 m). Currently, boat electrofishing, netting, and environmental DNA (eDNA) are used to survey for carp. These methods are expensive and often ineffective when fish are at low densities. Scent detection dogs have been used in terrestrial settings for conservation and biosecurity programmes, yet there is limited information on their ability to detect aquatic targets. This study aimed to determine dogs' olfactory detection thresholds to common carp scent using a multiple-probe design experiment. A single dog trained to use an automated carousel assessed water samples from aquaria containing no fish scent (n = 3, negative), goldfish (*Carassius auratus*) scent (n = 5, negative) or carp scent (n = 9, target). The goldfish samples and six of the target samples were presented to the dog at a standard biomass concentration of 15.5 mg/L. The remaining three target samples (probes) were systematically diluted to determine dogs' detection thresholds. Our results demonstrate that dogs can: (1) detect carp at a biomass concentration of 0.46 mg/L (≈9.3 kg/ha) and, (2) effectively discriminate between carp and goldfish samples. Further research will seek to determine if scent-detection can be used as an inexpensive, robust method for aquatic invasive species detection.

FORESEEABLE IMPACTS OF CLIMATE CHANGE ON NEW ZEALAND'S FRESHWATERS FROM LEGAL AND SCIENTIFIC PERSPECTIVES

Collins, D.B.G.

In setting environmental flows and limits on water resource use, the National Policy Statement for Freshwater Management requires councils to have regard to the foreseeable impacts of climate change, using the best information available at the time. What constitutes 'foreseeable impacts' is a matter for both law and science. To offer guidance to decision makers and scientists alike, this policy requirement is considered in light of case law, statutory law, and current scientific knowledge, with an emphasis on projected impacts on New Zealand's freshwaters. Case law holds that for impacts to be foreseeable they need only be plausible, not necessarily probable. This is echoed by the Resource Management Act 1991, which includes within the definition of 'effect' low probability but high-consequence outcomes. This imposes conditions on climate change science in several ways, including the use of multiple scenarios of future climate change, suitable statistical analysis, and clear treatment of uncertainties. Implications of this combined legal and scientific approach is illustrated by proposing foreseeable impacts of climate change on New Zealand's freshwater systems, resources, and hazards.

QUANTIFYING THE ELUSIVE: USING A RADON MASS BALANCE APPROACH TO ESTIMATE GROUNDWATER DISCHARGE INTO A LARGE COASTAL LAGOON

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Coastal lagoons are found on coastlines throughout the world and have a diverse set of ecological, cultural, economic, social and recreational values. Groundwater inflow may significantly influence lagoon water quality, yet it is a poorly understood part of lagoon hydrology. This research tests the question of whether groundwater seepage to a large coastal lagoon in Canterbury is only a small proportion of the overall lagoon water budget, as estimated in previous work based on seepage meter measurements. The current study used a broad-scale radon mass balance approach to estimate groundwater discharge to the lagoon in two seasons, by accounting for all inputs and outputs of the noble gas ^{222}Rn – a naturally occurring groundwater tracer. Given the highly wind-affected nature of this site, atmospheric evasion of ^{222}Rn is a significant component of the radon mass balance. Therefore, groundwater discharge estimations are provided for several evasion scenarios. In-depth uncertainty analysis was carried out on each component of the radon budget. Results from the radon mass balance revealed groundwater discharge to the lagoon to be 1-2 orders of magnitude higher than earlier estimates. Where it was previously thought that direct groundwater seepage into the lagoon was a small proportion of the water balance, it appears now that it may be an important component of the water budget. These results also reveal that there may be more exchange of water through the barrier between the lagoon and sea than previously thought.

LINKING MULTI-DISCIPLINARY RESEARCH TO PRACTICAL APPLICATION: A CASE STUDY FOR RIVER MANAGEMENT IN THE MANAWATŪ

Conn, S.,[1] Boyte, S.,[2] Whale, E.,[2] Quilter, B.,[1] Bell, J.,[2]
[1] Tonkin & Taylor
[2] Horizons Regional Council

Aims

Over the past decade, HRC have commissioned numerous studies and investigations to understand sediment processes in the Manawatū and Ōroua Rivers and the wider catchment. Some of this research identified a dramatic increase in sediment delivery to the river network under predicted changes in climate.

Our aim was to synthesise this research, understand and identify possible river response to a changing climate, and provide potential reach scale management actions to help reduce the impact of sediment on the lower Manawatū and Ōroua River flood schemes.

The findings from the sediment study helped HRC develop a 'sediment response plan' which informed prioritised river management actions.

Results

Through an assessment of geomorphic processes and river character, 13 river types were identified in the Manawatū and Ōroua Rivers. It was identified that these different river types will respond differently to different drivers of change, and this formed the basis of an assessment of sediment dynamics and the development of river type specific management options in both rivers.

An assessment of geomorphic trends in the Manawatū River suggested that there has been an overall degradation trend since the late 1800s. However, this overall degradation trend appeared to be disrupted following large rainfall events, potentially linked to short-term climate cycles. This had implications for understanding long-term climatic changes.

Major tributaries such as the Kiwitea Stream, and Tamaki and Pohangina Rivers were not included in the assessment but were identified as having a major influence on river character and behaviour in the main stem rivers. The influx of sediment from these tributaries resulted in temporary aggradation in certain river types (namely the wandering gravel river types), with the sediment accumulations 'flushed' through the system during subsequent higher flow events (e.g. annual flood events).

A key sedimentation process identified in the Ōroua River was overbank deposition between the top of bank and stopbanks, which appeared to have increased over a 10 year period (from 2005 – 2016). As large volumes of sediment are taken out of the system (and deposited out of channel), there is less sediment available for transport in downstream reaches and this instigates bed degradation.

Recent and historic river management has involved the construction of stopbanks along the lower reaches of the Manawatū and Ōroua Rivers. The aim of the schemes was to narrow channels, promote channel incision and reduce the risk of flooding. These stopbanks have reduced the width of the available floodplain for high flows meaning more frequent and larger flow events are confined to the channel. This confinement of flows to the channel has likely contributed to the degradation of the bed and incised channels, as evident in the Ōroua River. Conversely, the confinement of flows can also reduce the area available for floodplain deposition, increasing the volume of in-stream sediment storage, which can be potentially linked to the cyclical aggradation response observed in some river types.

Under a changing climate, there is predicted to be an increase in the rainfall, varying spatially across the catchments. This may lead to an increase in the frequency of landslides and therefore an increase in the sediment load entering the rivers. River response will be different based on river type, and the severity of response will depend on the degree of climate change. Existing Sustainable Land Use Initiative (SLUI) targets are unlikely to be sufficient to reduce sediment loads under existing climate change predictions.

The geomorphic assessments identified a lack of uniformity in both rivers, and highlighted how the geomorphic processes and responses to drivers of change are different for the 13 river types identified. This means that different sediment management options will be required for each river type identified. More than ten concept level interventions were developed as part of a river type specific sediment management 'tool box' and included the extension of existing programmes like SLUI, and riparian planting, as well as more targeted options such as two-stage channels, wetland construction/creation/enhancement, and dual benefit in-stream structures such as rock riffles, weirs, rock chutes and

groynes which can assist with moderating geomorphic processes and have an ecological benefit. Lastly large-scale infrastructure works were also included in the 'tool box' which included actions such as the relocation of stopbanks, increasing floodplain width, ox-bow (re)engagement, and channel realignment.

Following the delivery of T+T's lower Manawatū sediment study, a multi-disciplinary team of researchers and consultants attended a half day workshop with the science, river management and environmental data teams at HRC. The workshop was to prioritise and refine a series of river management actions to help improve the long-term resilience of the lower Manawatū and Ōroua River flood schemes. The initial management actions were chosen by HRC based on the findings of the Manawatu sediment study and other research, as well as operational opportunities and constraints. The prioritised management actions formed a part of HRC's 'shovel ready' funding application, with the intention for some of these projects to be implemented over the next five years.

SYSTEMS THINKING – WHAT IT IS AND WAYS TO APPLY IT

Connolly, J.[1]
[1] Deliberate

Systems Thinking. It's a term that has been around for some time and is currently enjoying a resurgence, as we seek to address the many complex issues being dealt with in freshwater. While many people rightly recognise themselves as holistic or 'systemic' thinkers, there remains a wide variety of interpretations as to what 'systems thinking' actually is and how to apply it. In the pursuit of a more consistent understanding and application of System Thinking, this presentation offers one useful interpretation based on the discipline of System Dynamics. Further it outlines how this can be used in conjunction with existing analytical approaches.

The presentation will focus on a simple definition of systems thinking and the core concepts that sit at the core of its application: circular causality (feedback); accumulation; and delays. Drawing on practical and pragmatic examples, it will outline a spectrum of increasing complexity for the application of Systems Thinking. This ranges from simple qualitative diagramming to complex quantitative simulation modeling, and a demonstration of how each of these may be practically applied.

This will be a useful presentation for anybody with an interest in understanding complex problems or systemic thinking, regardless of any pre-existing understanding or experience in this area.

USING CATCHMENT COLLECTIVES TO ACHIEVE WATER QUALITY OUTCOMES: INSIGHTS FROM A LEADING-EDGE APPROACH IN THE HAWKE'S BAY (TANK)

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There is growing interest in providing a regulatory framework for self-organising catchment groups in a plan and the role they play in meeting objectives for water quality. Various international examples exist, yet this is a fairly new concept for New Zealand. A collaborative water management process in the Hawke's Bay (Tutaekuri, Ahuriri, Ngaruroro and Karamu (TANK) catchments) has led to agreement that provisions for community responsibility for water quality and ecosystem health should be included within a proposed water management plan developed under the NPS FM.

This paper outlines the stakeholder developed proposal to promote self-organising catchment groups for environmental management as the accountable mechanism in the plan, not an 'optional extra'. Guided by what international research tells us makes self-organising groups successful, it also reports on research with stakeholders in the TANK catchments about the perceived barriers to the adoption of these groups. This provides valuable insights for other regions considering a collective approach and the important difference between this approach and traditional (yet still important) 'optional extra' volunteer catchment groups.

FILAMENTOUS ALGAE NUTRIENT SCRUBBERS FOR TREATMENT AND NUTRIENT RECOVERY FROM AGRICULTURAL DRAINAGE

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Filamentous Algae Nutrient Scrubbers (FANS) are a novel treatment system for agricultural drainage that grow filamentous algae and recover nutrients for beneficial reuse. Essentially, they take the problem – nuisance growth of filamentous algae, and turn it into a solution, removing eutrophication causing nutrients from surface water for beneficial reuse back on the farm.

Filamentous algal systems have been used to treat agricultural drainage in the USA, where they have also been used to treat agricultural drainage water, agricultural effluents and domestic and industrial wastewaters. FANS consist of a gently sloping floway that is lined with an impermeable liner to which filamentous algae attach. The water flows down the floway and under/between the algae filaments and is treated through a combination of algal photosynthesis and growth (nutrient assimilation, oxygenation) and physical filtration (settling, adsorption and precipitation).

This talk will discuss the potential to use FANS systems for agricultural drainage treatment in New Zealand and the constraints and benefits of the technology including beneficial algae use options that are culturally acceptable to Māori (e.g., fertilizer, animal fodder). It will present the results of initial trials conducted as part of a 5-year MBIE funded programme which will develop FANS using NZ filamentous algae species with high affinity for nutrients.

The project is being conducted in consultation with iwi partners who will host field-scale demonstrations during which the downstream ecosystem benefits of FANS will be assessed, as well as the habitat benefits of the FANS floway (e.g. for wading birdlife).

EFFECTS OF TEMPERATURE ON SWIMMING CAPABILITIES OF NATIVE NEW ZEALAND FISHES

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In recent years, the importance of fish passage has become increasingly relevant across the world, with special emphasis placed on the ability of fishes to migrate upstream through manmade barriers to their spawning or rearing grounds. In New Zealand, little is known about the swimming capabilities of native fishes that would allow them to migrate past these barriers, namely instream culverts. New Zealand has a mean longitudinal range of freshwater temperatures from 8° to 26°C, and it is important to understand how fish swimming performance may be impacted by this temperature range, and with future implications of climate change. Here we assess the swimming capabilities and the effects of temperature on native New Zealand fish species. The critical swimming speeds were calculated for juvenile life stages of *Galaxias maculatus, Galaxias fasciatus, Gobiomorphus huttoni, Retropinna retropinna*, across a range of temperatures. To calculate critical swimming speeds, individual fish were placed in a swim tunnel. The water velocity was increased by one body length per second every five minutes, until the fish reached fatigue. Preliminary results show that at 16°C, inanga (*G. maculatus*), have a lower critical swimming speed than that of the redfin bully (*G. huttoni*) and the common smelt (*R. retropinna*). We will further discuss the results of these experiments at the conference.

COMPARISON OF KŌKOPU POPULATION CHARACTERISTICS BETWEEN WHITEBAITED AND REFUGE AREAS

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Investigating the effects of New Zealand's whitebait fishery on harvested species is vital to ensure a sustainable fishery that does not threaten the conservation of component species. We tested whether whitebaiting influenced the population characteristics of three native freshwater fish species: the non-threatened banded kōkopu (*Galaxias fasciatus*), declining giant kōkopu (*Galaxias argenteus*), and nationally vulnerable shortjaw kōkopu (*Galaxias postvectis*). The West Coast of the South Island has 'refuge' areas that have been closed to whitebaiting for several decades. Using spotlighting to sample fish communities, we measured the abundances, sizes, weights, movements, and growth rates of the three nocturnal kōkopu species across three closed and five fished areas bimonthly. To isolate the effects of whitebaiting between closed and fished waterways, the influence of additional variables such as food availability, intra- and inter-specific interactions, forest canopy cover, and in-stream habitat on population dynamics were also measured. Initial findings indicate that there are differences in kōkopu population size class structure between treatments, with closed stream populations having a smaller median fish length, a greater biomass of small fish, but a lower biomass of larger fish than fished streams. These findings suggest that whitebaiting does affect the population characteristics of kōkopu populations on the West Coast, however, there is so far little evidence for recruitment limitation associated with whitebaiting. These findings will be useful in determining the influence of whitebaiting on population dynamics and ultimately how to best manage the threatened species.

INTEGRATED WATER MANAGEMENT FOR REGIONAL DEVELOPMENT

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Aims

Irrigation is typically thought of as an input to improve average annual production in an agricultural system. However for high-value horticultural land-uses the emphasis can shift to risk mitigation and providing certainty to investors.

A feasibility study was carried out for a water supply and storage scheme at Raukōkore, Eastern Bay of Plenty, to support a transition to high-value land-uses. An integrated water management approach was used to ensure that cultural and environmental effects were understood, and that land-owners understood the options available to them as infrastructure designs were developed.

Method

The Raukōkore area is predominantly Māori-owned agricultural land on coastal terraces, approximately 65 km north-east of Opotiki. At present the land-use is primarily maize, sheep and beef. The area has potential for high-value horticultural land-uses; existing kiwifruit orchards in the area are successful. Irrigation demands are relatively low: one of the existing orchards does not have irrigation installed. The capital requirements for development of gold kiwifruit orchards are high, up to $650,000 per hectare for a greenfield site (ANZ, 2019). External investment is required to support development, however investors are unlikely to commit without a reliable water supply in place to ensure that returns are maintained in extremely dry years.

The first step of the feasibility study, funded for Te Whānau a Maruhaeremuri Hapū Trust by the Provincial Growth Fund, was modelling to determine water availability and crop demands. A daily water balance model was used to determine the storage volume required to provide a highly reliable water supply.

A key input to modelling the water storage requirements was determining the minimum flow and the size of the allocation block for the Raukōkore River, which had no specific allocation. An IFIM study was commissioned, and the results presented to the Hapū Trust, who selected a level of habitat protection that they were comfortable with. This resulted in a minimum flow slightly higher than the default value.

A parallel study by WSP looked at land-use options for each block of land within the potential command area, using a multi-criteria analysis framework.

A cultural impact assessment was commissioned to document the Te Whānau a Maruhaeremuri tikanga associated with land and natural resources within the rohe, and to assess the actual and potential effects of the proposed land-use change and water supply scheme on tikanga. A unique aspect of the project was that the people potentially affected by the project are predominantly those involved in proposing the land-use change and irrigation development.

Infrastructure options were designed, initially to a pre-feasibility level, and a preferred option was then designed and costed to feasibility level. Several iterations of total irrigated area were considered, based on land-owner expressions of interest.

The water requirements modelling, IFIM study and cultural assessment, along with the preliminary infrastructure designs, were used as supporting information for the application for resource consent to take and use water. Securing this consent was an important step to give government funders confidence in the project.

Results

Based on the results of the feasibility study, a loan from the Provincial Growth Fund was secured to support the detailed design and build of a 320 ha water supply scheme. This is currently (August 2020) in the pre-construction phase.

Ultimately the project is not an irrigation scheme, it is a land-use change scheme which will provide jobs and skills, and an incentive for whānau members to return home. Water is a key ingredient, but the pipes in the ground will be a means to an end. There is scope for the infrastructure to also provide water for potable use, and for industry (e.g. horticultural processing) that may develop alongside high-value land uses.

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USE OF SYMBOLIC REGRESSION TO ESTIMATE GROUNDWATER AGE DISTRIBUTIONS FROM HYDROCHEMISTRY, HERETAUNGA PLAINS

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[1] National Institute of Water and Atmospheric Research
[2] GNS Science

Aims

Understanding groundwater age is useful for a variety of reasons, such as identification of past and present impacts of land use, assessing the security of water supplies from contamination, and calibration of groundwater flow models (Daughney et al., 2010). Any groundwater sample contains a mixture of ages representing the different transit times along the various flow paths that converge at the sampling point. Thus, for all the aforementioned applications, it is crucial to determine the distribution of ages in the water sample, not just the mean age (Beyer et al. 2016).

Groundwater age distributions are ideally estimated by fitting a model (such as a lumped parameter model) to time series measurements of the concentrations of tracers such as tritium, chlorofluorocarbons and sulphur hexafluoride (Daughney et al., 2010). Previous studies have also used hydrochemistry and/or well construction as complementary methods to aid with or constrain the estimation of groundwater age distribution (Daughney et al., 2010; Beyer et al., 2016). To date, however, no study has successfully demonstrated the accurate reproduction of the entire age distribution solely from commonly measured hydrochemical parameters.

Method

The aim of this study was to estimate the full groundwater age distribution based on hydrochemistry, using 83 samples collected from 75 wells in the Heretaunga Plains.

The age distribution for each sample was estimated using a lumped parameter model (either an exponential-piston flow model or a binary mixing model) as described by Morgenstern et al (2018) and Morgenstern and van der Raaij (2019). In addition, each sample had been analysed for 21 hydrochemical parameters including major ions, minor/trace elements, field parameters and $\delta^{18}O$ and $\delta^{2}H$ of water.

Genetic programming via symbolic regression (SR) was performed to establish relationships between any/all of the hydrochemical parameters and nine selected percentiles in the modelled age distribution. SR was selected as the preferred machine learning approach because it generates equations for the relationships of interest thereby enabling predictions to be generated for sites without available tracer data. SR settings allowed a maximum tree depth and length of 12 and 150, respectively, based on a multi-symbolic expression crossover and grammar rules permitting arithmetic, exponential and logarithmic functions combined with conditionsals (e.g. if/then statements). Goodness of fit was assessed using Pearson R2 and the mean absolute error (MAE).

Results

The SR expressions achieved good matches to all nine modelled percentiles in the age distribution for the majority of sites. MAE ranged from 2.0 to 10.6 years for individual sites, with an average MAE of 5.0 years across all 83 samples (see Figure 1). For most sites, the SR equations usually provided slightly better matches to the modelled age distributions at the lower percentiles, such as the 5^{th}, 10^{th} and 20^{th}, compared to the higher percentiles, such as the 80^{th}, 90^{th} or 95^{th}.

The hydrochemical parameters weighted most strongly in the SR equations were pH, dissolved reactive phosphorus, $\delta^{18}O$ and fluoride, whereas most major ions and NO_3N had weak weightings in the SR equations. For the few sites that had been sampled on more than occasion, there were cases where the modelled age distributions were inferred to vary temporally or seasonally, based on observed shifts in the concentrations of the age tracers; these sites also displayed temporally variable hydrochemistry and so the SR equations also indicated time-varying age distributions.

Overall, this study has shown that SR is a useful tool for codifying the relationships between hydrochemistry and specific percentiles in the distribution of groundwater age at the aquifer scale. This approach could be extended to the estimations of groundwater age distributions in other aquifers, or even at the national scale.

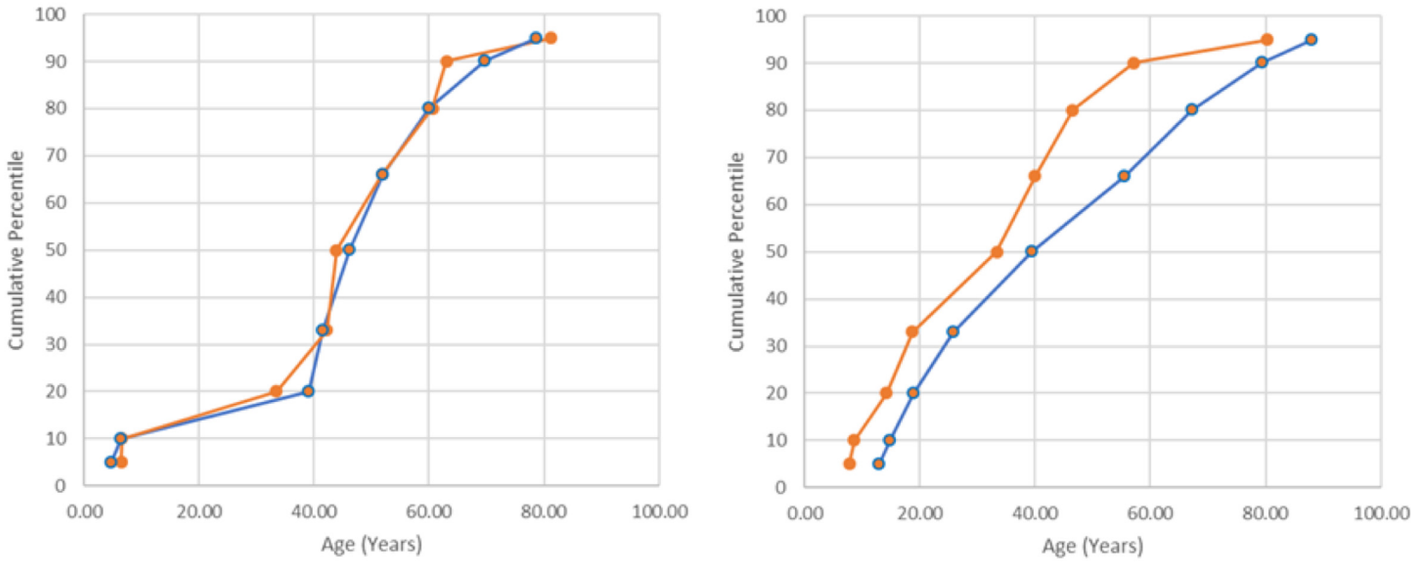


Figure 1. Cumulative groundwater age distributions for two sites in the Heretaunga Plains. Blue lines indicate age distributions inferred from lumped parameter models fitted to time series tracer concentrations; orange lines depict the estimated age distributions derived from symbolic regression (the same SR equations are used for both sites). Left graph is for Site 15465 and has MAE = 2.29 years, right graph is for Site T2 and has MAE = 10.63 years.

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RAPID SURVEY OF TRANSIENT PLUMES IN COASTAL WATERS WITH A PORTABLE UNDERWAY FLOW-THROUGH SAMPLER (PUFTS-RAPID)

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Contaminants from land are the major source of coastal water degradation in New Zealand (Dudley et al. 2020). Plumes produced by the river floods that convey the vast majority of diffuse pollution from land, are episodic and transient and therefore difficult to survey and sample. We wished to improve on existing methods, such as moorings and ship cruises (e.g., Wolanski et al. 2003) for surveying and sampling river flood plumes in coastal waters.

Aims

Our aim was to develop an improved method for rapid survey and sampling of transient muddy plumes in coastal waters, notably those from river floods.

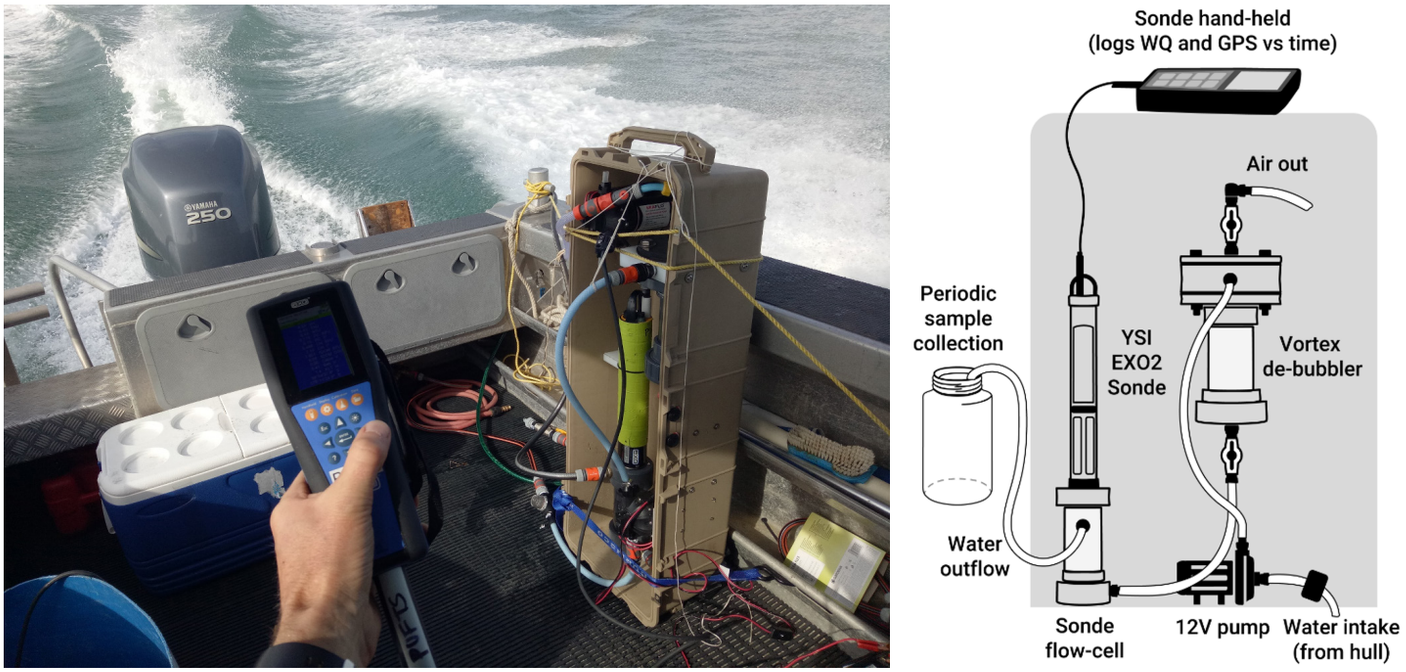


Figure 1. PUFTS-rapid operated in the stern of one of NIWA's small research boats travelling on the plane. The sampler is built into a Pelican case (cover removed), and the EXO2 sonde (green fluoro cylinder) is controlled by the hand-held unit in the foreground. The schematic shows the layout of components within PUFTS-rapid, in order: water intake, 12 V pump, vortex debubbler, and sonde with flow-cell.

Method

We modified an existing 'ferry box' type system for rapid deployment in small multi-purpose vessels. One of us (MG) had previous experience with the Portable Underway Flow-Through Sampler (PUFTS) on NIWA's smaller research and survey vessels, which was our starting point. Design constraints for the new PUFTS included rapid setup (within 1 hour) in small, fast boats (traveling up to 25 knots). The PUFTS-*rapid* sampler described here, was the result (Gall & Davies-Colley 2020 submitted). All the components of the new sampler are permanently connected with hosing and built into a Pelican® case (Figure 1).

Key components of the new sampler are: a 12 V self-priming pump that collects ambient surface water via a pickup tube on the boat hull; a vortex unit that efficiently removes air bubbles entrained in the water flow, and a water quality sonde operated with a flow-cell attachment. Sonde sensors include: conductivity (salinity), temperature, turbidity, fluorescence of coloured dissolved organic matter (CDOM). Map position is logged by a GPS in the sonde hand-held unit, that also displays water quality data (Figure 1). Water samples may be collected as needed from the continuous flow – for laboratory analyses of necessarily lab-based variables, such as concentrations of suspended particulate matter and fecal indicator bacteria, as well as analyses to validate or locally calibrate sonde sensors.

All that is required to deploy PUFTS-*rapid* is to lash the sampler (case cover removed) into the stern of the survey boat (Figure 1), connect the intake hose to a pickup tube fixed to the boat hull, and power-up the diaphragm pump from a 12 V battery.

Results

The capabilities of the PUFTS-*rapid* sampler were assessed with survey of a muddy, contaminated flood plume from the Hutt River dispersing into Wellington Harbour, New Zealand on 24 September 2019 (Gall & Davies-Colley 2020 submitted). Salinity and turbidity along boat tracks with PUFTS-*rapid* are shown in Figure 2. Depth profiling showed the plume to be quite thin, ranging from about 2m near the jet from the Hutt River mouth (top right of both panels in Figure 2) to only about 0.5 m near the plume front with ambient harbor water. Salinity outlines the low salinity plume and CDOM (not shown) had a mirror image pattern to salinity. Turbidity also shows an inverse relationship to salinity, but not the simple inverse expected for conservative mixing – probably reflecting salt-flocculation and changed particle optics within the plume as well as rapidly changing turbidity over the hydrograph in the river.

Water samples taken from PUFTS-*rapid* while underway were analysed for *E. coli* bacteria as an indicator of faecal pollution. The pattern of *E. coli* was similar to that of turbidity (Figure 2), being highest in the river mouth (maximum ~ 1000 cfu/100 mL) with faecal contamination in the plume impinging on the beaches and reefs near Eastbourne on the eastern side of the harbour.

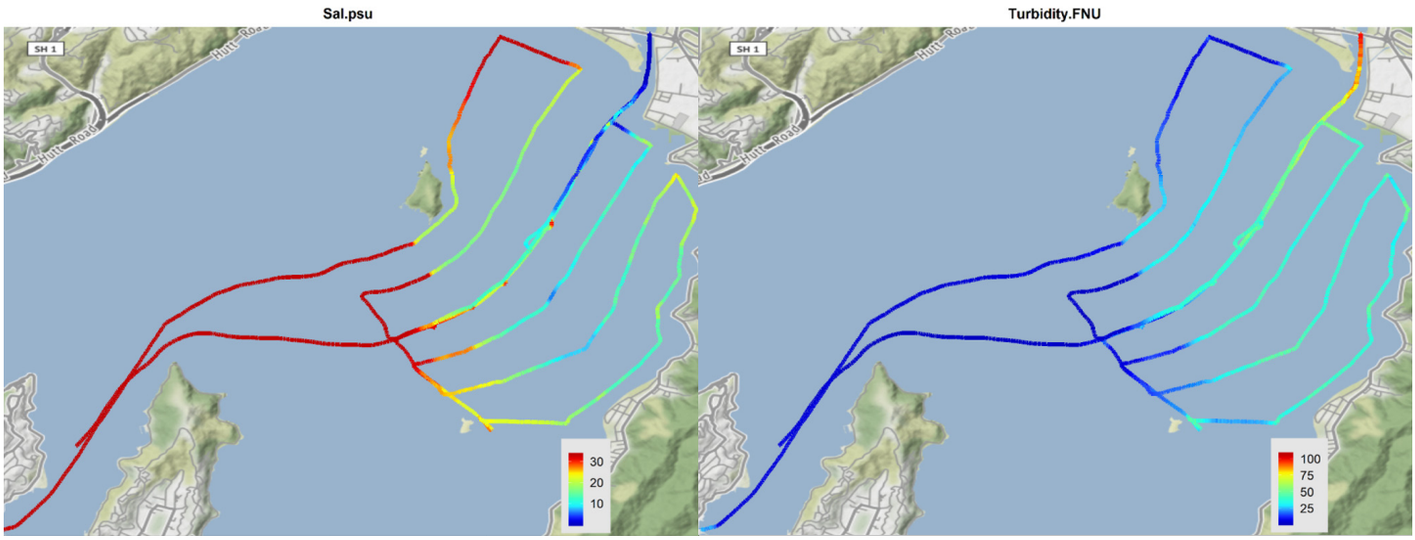


Figure 2. Boat tracks with PUFTS-rapid across a flood plume from the Hutt River within Wellington Harbour on 24 September 2019. The boat tracks, for salinity on the left and turbidity on the right, are colour-coded, going from red for high values through the spectrum of hues to blue at low values. The river enters the harbour from Petone in the top-right of each panel, where salinity is very low (blue) and turbidity high (red – up to 160 FNU). Ambient harbour water (seen in boat tracks to and from the NIWA-Wellington campus in Evans Bay – bottom left)) has high salinity (red) and low turbidity (blue), and the plume is outlined by intermediate (yellow to green) hues for both variables.

Conclusion

'Capture' of turbid plumes from river floods (or wave action or dredging) is probably *the* most 'demanding' application of PUFTS-*rapid*, and we expect the sampler will be valuable in our on-going research on these features. However, more broadly the sampler is expected to be valuable in various other coastal water quality applications, including calibration and validation of hydrodynamic models and 'sea-truthing' of remote sensing imagery.

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NEPHELOMETRIC TURBIDITY APPLICATIONS IN WATER QUALITY – RAMIFICATIONS OF POOR SENSOR COMPARABILITY

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Aims

- To compare the numerical output of turbidity sensors of the same design (compliant with the ISO7027 standard) in different natural suspensions.
- To outline the ramifications for the application of field and laboratory turbidity data.

Background

Turbidity, a measure of haze in water due to light scattering, is a very common measurement in water quality and related fields such as erosion-sediment management. Because suspended particulate matter (SPM) dominates light scattering in natural waters (e.g., Davies-Colley & Smith 2001), turbidity provides a useful index of SPM concentration. In water quality, turbidity is used as a relative index of water clarity, but the relationship is seldom quantified. Continuous *in situ* monitoring of turbidity can provide very useful indication of visual clarity or, total phosphorus or even *E. coli* (over stormflows) with local calibration (Davies-Colley & Hughes 2019). Specific local calibration is required because the light scattering properties of SPM vary with location.

Turbidity sensors are usually calibrated (entirely arbitrarily) to the intensely light scattering material, formazin. Turbidity measurements in FNU, NTU, or other 'informal' units based on formazin, cannot be converted to light scattering in proper (SI) physical units (m^{-1} $steradian^{-1}$) because of the variation in SPM optics. This arbitrary and informal character of turbidity seems to have gone largely unrecognized or has been forgotten by water quality practitioners.

The relationship of SPM to turbidity depends on particle size and other properties. So turbidity is routinely (locally) calibrated to SPM concentration by sediment researchers and managers. But water quality practitioners often fail to recognize that turbidity does not reliably indicate water clarity unless and until similarly (locally) calibrated. Use of turbidity data in water quality is further weakened because different sensors give numerically different outputs even when calibrated identically to formazin (e.g., Rymszewicz et al. 2017). We expected that turbidity sensors compliant with the ISO 7027 standard (specifying side scattering of NIR radiation) would agree more closely than the wider range of designs tested by Rymszewicz et al. (2017) – which varied 5-fold. Accordingly, as a follow-up to an earlier study (Hughes et al. 2019), we conducted a series of tank experiments to compare ISO 7027 turbidity sensors that are commonly used in NZ.

Methods

We tested four different field-type (*in situ*) sensors plus two cuvette instruments over a 100-fold range of concentration in river silt, kaolinite (layer clay), plus pond water laden with green algae. A 170 L volume well-mixed tank was used for the comparisons. All the sensors were pre- and post-calibrated with freshly-made formazin standards so as to put all the comparisons on the same basis.

Results

We found that the outputs (in Formazin Turbidity Units: FNU) of different turbidity sensors were very strongly linearly related, but ranged about two-fold in magnitude for all three tested suspensions (Figure 2 shows data for river silt). Apparently even sensors meeting the same design standard cannot be relied on to output the same numerical turbidity in FNU despite being calibrated identically to formazin. This variation in sensor output seems to arise from small design differences (within the defined tolerance of the ISO 7027 standard) in combination with the very different light scattering properties of natural suspensoids compared to formazin.

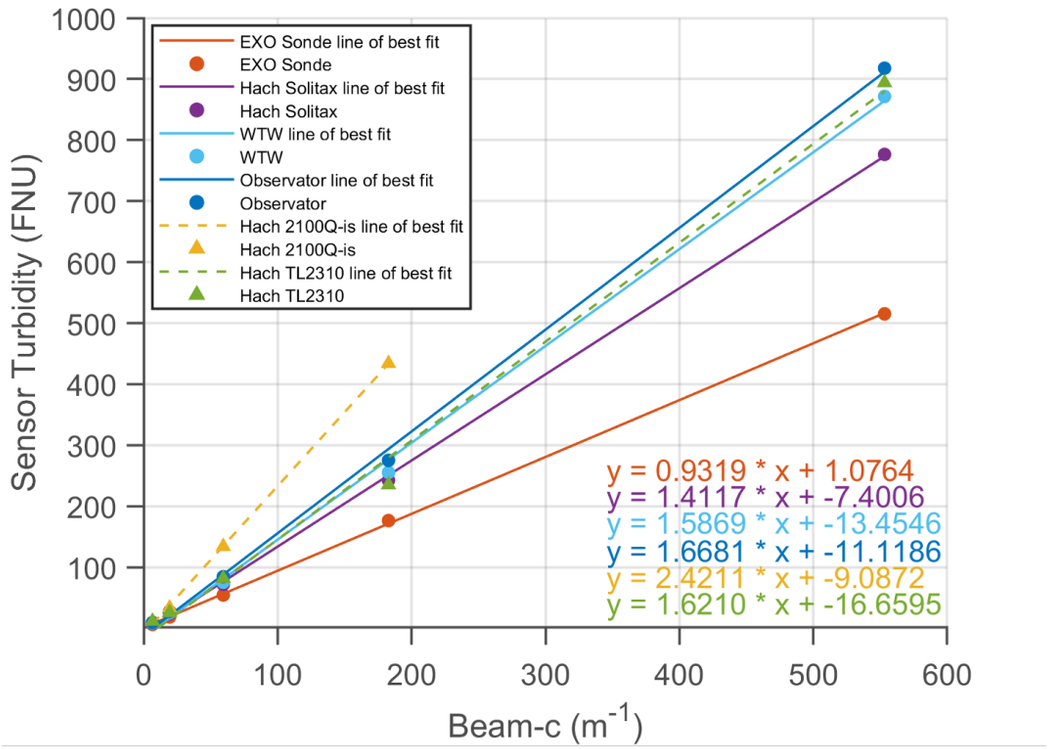


Figure 1. Formazin-standardised response of (ISO 7027-compliant) turbidity sensors in river silt. The beam attenuation coefficient (measured by WET Labs C-Star transmissometer in flow-through mode) is used as the reference optical concentration. (Field in situ instruments – dots with solid lines; cuvette instruments – triangles with dashed lines.)

Discussion and Ramifications

The weak numerical comparability of different turbidity sensors, even those compliant with the ISO 7027 design standard, suggests that turbidity should not be treated as an absolute quantity. Instead, turbidity should be recognized as a relative measure of light side-scattering that usefully indicates SPM concentration or water clarity *with suitable local calibration*. Therefore, reporting turbidity in informal units such as FNU should be avoided.

Since turbidity is poorly comparable on different instruments, it follows that laboratory turbidity measurement is of dubious value. Indeed, NZ's national turbidity dataset, measured with different laboratory nephelometers at different times in different laboratories, is probably compromised to some (undefined) extent. Fortunately, laboratory turbidity measurement can be replaced by absolute measurement of the light beam attenuation coefficient (beam-c = total light scattering plus light absorption) – the reference quantity in our experiments (Figure 1). Beam-c, measured by beam transmissometry in SI units (m^{-1}), is accurately convertible to visual clarity which gives the metric immediate meaning for lay people and policy-makers.

Both the arbitrary nature of turbidity calibrated to formazin, and its instrument-specificity, suggests that removing field sensors for lab recalibration to formazin should be abandoned. Instead effort should go to *locally* calibrating field turbidity sensors to the variables of real interest – usually SPM or visual clarity, or, some other particle-related water quality variable such as total phosphorus (e.g., Davies-Colley & Hughes 2019). The resulting 'rating curves' permit continuous turbidity records to be converted to the variable of interest – in much the same way that a stage-discharge rating permits continuous stage records in rivers to be converted to discharge. Turbidity sensor drift can be checked on-site by fairly precise (coefficient of variation of replicates ~5%) measurement of visual clarity alongside the continuous sensor.

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WHAT ARE THE BENEFITS OF GIVING A RIVER MORE ROOM?

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Since the beginning of civilisation, humans have been living on, using, and modifying floodplains. Over the last 100 years urbanisation and increase in population size have led to a desire to 'control' or 'tame' rivers to help protect people and their property from the impacts of flooding. Changes in community values are seeking a shift from this traditional style of river management to one which takes account of the geomorphology and other natural river processes.

One way to adapt river management is to allow the river more space in which to move and undergo its natural flooding and erosion processes. This reduces the amount of time and money that needs to be spent on river engineering, decreases the potential for adverse environmental effects and can reduce public concern over seeing bulldozers in rivers too often. The dilemma is to know how much room to give the river to allow these natural processes but still prevent damage to people and infrastructure. With many people living next to rivers do the benefits of giving the river room outweigh the need for engineered defenses?

This study critically examines the benefits and risks of giving the rivers more opportunity to function naturally. We will develop this process as a precursor to a tool that can be incorporated into a policy allowing river managers the opportunity to expand and utilise floodplains when it is appropriate. Giving the river space includes allowing flooding onto surrounding land and eroding sections of the river bank. It also means limiting development alongside the river, as this provides the river with an area for flooding and erosion and provides areas for wetland development. Giving the river room is a multi-purpose approach, as it not only provides benefits for flood protection, but natural floodplains also provide a wide range of other ecosystem services (people obtaining benefits from an ecosystem). This can include aquifer water storage in the floodplain, increased habitat diversity for riverine species and increased recreational benefits.

INTEGRATING FLORA AND FAUNA HABITAT INTO RIVER ENGINEERING PROJECTS

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River engineering projects are undertaken to protect, life, property, and to ensure the sustainability of human economic activities. In some cases, biodiversity and the creation of habitat for fauna and flora are either ignored or poorly designed and may be considered as an afterthought or even a constraint on the project. Consequently, the integrity and resilience of aquatic ecosystems may be reduced. In New Zealand, for example, the percentage of native freshwater fish species classified as threatened or at risk has increased dramatically from around 20% in 1992 to 74% in 2013 (M. K. Joy, 2015). Numerous projects we have observed since 2014 suggest there is an opportunity for innovation and better practices to preserve and enhance habitat for different species. Although it is possible to mitigate habitat loss after a project has been constructed, post-project mitigation is ecologically less effective, significantly more costly, and does not address ecological impacts within the time period between project completion and the implementation of mitigative measures. We present several examples how civil engineers and river restoration specialists have successfully integrated habitat into river engineering projects.

TRACE METAL LIMITATION ON PHYTOPLANKTON GROWTH: A LABORATORY EXPERIMENT WITH THREE FRESHWATER PHYTOPLANKTON SPECIES

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[2] NIWA/Centre for Oceanography, Department of Chemistry, University of Otago
[3] National Institute of Water and Atmospheric Research (NIWA) Hamilton
[4] Cawthron Institute, Nelson, New Zealand

The Taupo Volcanic Zone (TVZ) in the North Island of New Zealand was formed and shaped by the last eruption of the Taupo super-volcano, 2000 years ago. This covered large parts of the region in rhyolithic tephra, sealing off surface soils and today's lakebeds, and leaving the region low in trace metals. Therefore, lake waters of the TVZ are very low in trace metals such as, cobalt, zinc and copper, which are important for phytoplankton growth. These low concentrations (mostly below the parts-per-trillion level) are possibly constraining phytoplankton growth and limiting the formation of cyanobacterial blooms. Current fertilising regimes in the region may result in increased trace metals in lake waters and greater knowledge on the risks this poses is paramount.

Growth experiments with two diatom species (*Aulacoseira* sp. and *Fragilaria crotonensis*) and a cyanobacteria species, (*Dolichospermum lemmermannii*), all abundant in Lake Taupo, were performed under low trace metal concentrations similar to those of Lake Taupo. A total of 15 different treatments, including natural as well as two and ten times trace metal concentrations were assessed for six trace metals (manganese, iron, cobalt, copper, zinc and molybdenum) and a combination of these.

Here we present results, indicating that elevation of specific trace metal concentrations differentially enhances growth of the species tested. These results will help guide current lake management strategies in the TVZ.

INVESTIGATING SHIFTS IN THE BACTERIAL COMMUNITY OF DECOMPOSING COWPATS AND THEIR IMPACTS ON WATER QUALITY MONITORING

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[1] Institute of Environmental Science and Research Ltd. (ESR)
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The intensification of dairy farming on the agricultural landscape in NZ has raised concerns about pollution sources from dairy faecal runoff into waterways. An important step for mitigation of pollution is the identification of the sources of faecal contamination.

This study describes amplicon-based metagenomic assays of the bacterial community in ageing cowpats. The research revealed shifts in the bacterial community composition of the cowpats over five and a half months of decomposition under field conditions. Mobilised fractions from the cowpat, which simulated flood conditions, showed major bacterial community shifts from the anaerobic bacteria that dominate the cow rumen and fresh cowpat, to environmental bacterial groups such as the Actinomycetales, Sphingobacteriales and Flavobacteriales. Over the same time period and field conditions, the bacterial community composition of rainfall runoff from the cowpats was analysed and compared with the communities from the simulated flood conditions. The impacts of the bacterial shifts in the cowpats are discussed in terms of their effects on the faecal bacterial indicators (FIB) used for water quality monitoring and the faecal source tracking (FST) markers (host-associated molecular markers).

The hypothesis that these bacterial community shifts would impact on faecal indicators of aged pollution sources was upheld as there were temporal changes in abundance of the bacterial groups targeted by the faecal indicators. In addition, the results from these bacterial community analyses will be incorporated into emerging tools that use computational programmes to track sources of faecal contamination such as the Bayesian classifier, SourceTracker.

WHAT DO RURAL COMMUNITIES HAVE ON THEIR MINDS WHEN DISCUSSING LAND MANAGEMENT ACTIONS THAT HELP IMPROVE WATER QUALITY?

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[3] Happen Consulting
[4] SCION
[5] Effect

Communication between scientists and land managers often occurs in one direction - from scientist to land manager. However, recent models of science communication include more interactive ways to communicate which foster mutual engagement between scientific and rural communities.

This project is part of the design of an online tool to raise awareness about land management actions that improve water quality in New Zealand. Part of this process involves listening to various target audiences, including members of rural communities and national sector representatives (DoC, MPI, MfE, regional councils, NGOs) to find out what is important to them when managing land and people for improving water quality. Social norms, storytelling, future generations, and privacy issues were important themes that emerged from the conversations. In this ongoing process, we will discuss what else needs to be considered when providing information for people that manage water quality.

STYGOFAUNA – A PRACTICAL INDICATOR FOR ASSESSING THE MAURI AND WAIRUA OF GROUNDWATER AND DEPENDENT ECOSYSTEMS

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[1] Stantec
[2] Mauri Protection Agency
[3] KM Water
[4] Department of Conservation

Aims

The Mauri Protection Agency (MPA) wishes to develop a practical methodology for assessing and monitoring the mauri (life force) and wairua (spirit) of groundwater and dependent environments. The proposed change to the Hawke's Bay Regional Resource Management Plan (RRMP) in the Tūtaekurī, Ahuriri, Ngaruroro and Karamū (TANK) catchments provides an opportunity to develop and trial the required method in the rohe of Heretaunga hapū, Ngāti Kahungunu. Mātauranga Māori frameworks and tools are being revitalised and developed to bring together knowledge systems and recognise the interconnectedness of people, particularly indigenous people, and the ecology and environment (e.g. Black et al., 2018). Major outcomes of such work will be the acknowledgment of Te Mana o te Wai, providing recognition and respect for the wairua of groundwater, and to maintain, enhance, and restore the mauri.

Historically, groundwater has been assessed by monitoring water quantity and quality parameters, with little attention given to the mauri, wairua, or what is living in the water. Stygofauna are invertebrates that only live in groundwater and combined with microbiological organisms, they account for everything that lives there. We believe that by including stygofauna in the assessment of groundwater, an indication of the state of mauri can be gained. This will provide a framework for the cultural and spiritual values of tāngata whenua to be monitored and assessed in parallel with western determinants. At the same time, we envisage this approach as providing assistance towards preserving and enhancing stygofauna communities, to create a greater awareness of their contributions to the ecosystem health of groundwater, the country's indigenous biodiversity and the ecological wellbeing of the country overall.

Method

The key goals of the proposed methodology are:

1) preserving stygofauna and preventing the degradation of their ecological systems

2) phased restoration of impacted ecosystems to better conditions

3) utilising mātauranga Māori and cultural processes to enhance groundwater management to reflect Te Mana o te Wai

The flowchart presented in Figure 1 provides a methodological framework for achieving the above objectives. The proposed methodology is **SMART** — **S**imple, **S**pecific (local context), **S**calable, based on **M**easurable indicators, **A**pplicable, **R**elevant, **R**eplicable, and **T**ime-bound. Most importantly, it **utilises life (stygofauna) to measure life, namely, mauri (life force) and wairua (spirit).** Once developed, we hope that the methodology can be applied throughout Aotearoa New Zealand.

The methodology uses feedback and review looping to ensure continued monitoring, assessment of changes, preservation, enhancement, and restoration of the ecological and cultural values of groundwaters and associated ecosystems. Monitoring and assessment will help identify improvement pathways for groundwater management and can be used to inform management responses to degradation over time. The work will be undertaken as a three-step process.

Step 1: MPA and local hapū will lead a literature review and desktop assessment with input from various technical experts in the fields of stygofauna, ecology, mātauranga Māori me ōna tikanga, hydrology, geomorphology, hydrogeology and other sciences.

Step 2: Field surveying of groundwater dependent ecosystems, selected bores, and connected surface water bodies. MPA and local hapū will be actively involved with project planning and will be trained in field work and data analysis techniques.

Step 3: Grouping local ecosystem into categories based on their physical, chemical, biological, and cultural attributes using suitable statistical or machine learning techniques, e.g. hierarchical cluster analysis. Ecosystems within each category will be ranked from good to poor based on stygofauna species richness and abundance. For each category,

experts will use available information to determine pristine conditions which will be used to define ultimate targets for that category. The best ecosystem in each category will be used as an interim target for other ecosystems in that category. Analysis of stressors (environmental variables) and state (mauri and stygofauna community status) will inform the development of management interventions.

Results

With the method still in the initial stages of development there are no results to report. However, we hope that over the coming years, the findings will be made available for the benefit of all.

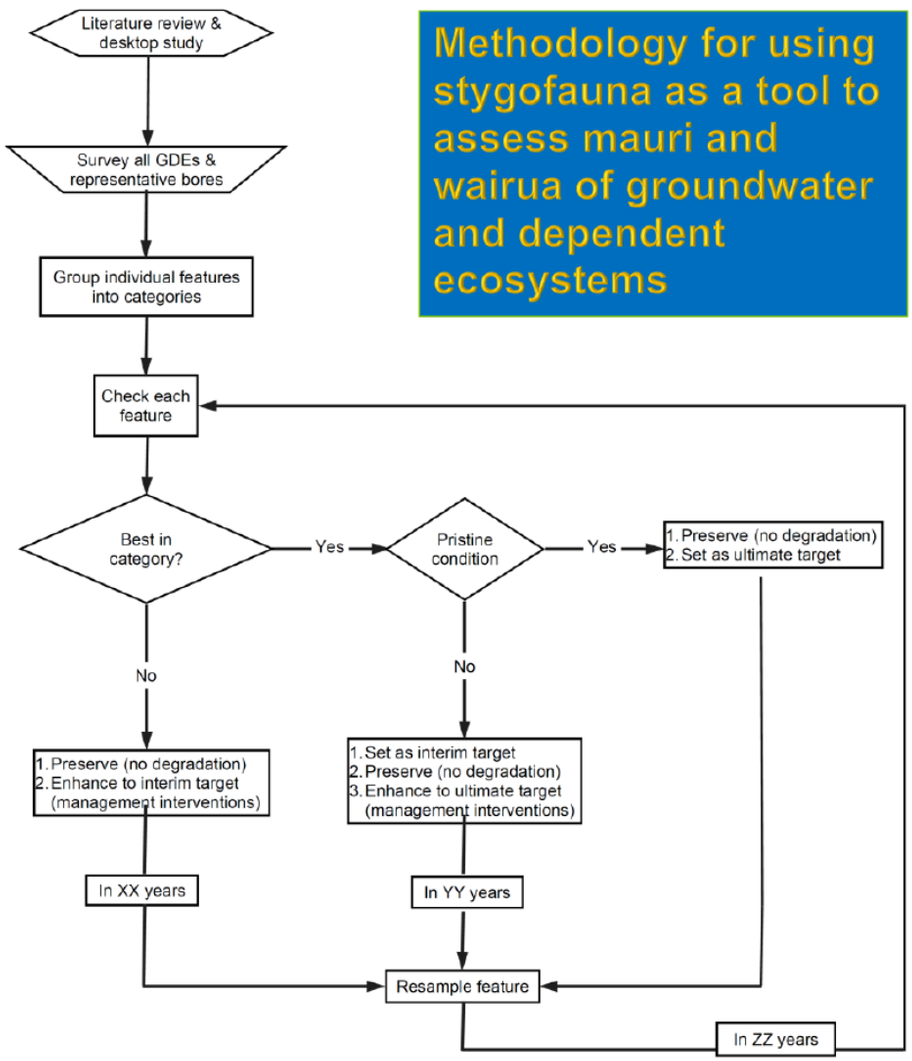


Figure 1. Proposed methodology for the use of stygofauna as an indirect measure to assess the status and changes in groundwater mauri, mana and wairua and to preserve (maintain) and enhance groundwater and dependent ecosystems over time. XX, YY and ZZ years refer to different timeframes for repeated assessment depending on the status of the individual ecosystem. These timeframes will be scientifically informed and determined by stakeholders.

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IMPACTS OF EL NINO SOUTHERN OSCILLATION ON FLOOD RISK IN NEW ZEALAND

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[1] Risk Management Solutions Inc.

Aims

Global warming is expected to enhance El Niño Southern Oscillation (ENSO), with potential impacts on rainfall and flood risk in numerous countries of the Asia-Pacific region. Modeling studies have suggested that positive and negative ENSO phases may intensify by as much as 25% under extreme climate projections (Cai et al., 2015). However, the influence of ENSO variability on flood risk in Asia-Pacific countries is still largely unexplored. Here, we aim to shed light into the link between ENSO and flood risk in New Zealand by combining rainfall observations and state-of-the-art flood risk models.

Method

We draw on 60 years of daily precipitation maps by NIWA (Cichota et al., 2008) to quantify the statistical correlations between the rainfall principal components and the ENSO historical time series. This allows us to generate a stochastic set of daily rainfall maps (Thober et al., 2014) correlated with a long-term, synthetic ENSO time series. The stochastic precipitation maps are then used to drive streamflow and flood simulations at 20 m spatial resolution across New Zealand. The performance of the flood risk model is validated against historical catalogues of flood events and insurance claims in New Zealand.

Results

Our results indicate that positive and negative ENSO phases are associated with higher flood risk in different regions of New Zealand, and that extreme ENSO events tend to cause more severe flood events. We finally investigate the potential differences in economic losses during positive and negative ENSO phases by combining modeled flood footprints with exposure and vulnerability data. These results may guide the implementation of effective adaptation and mitigation strategies against the increasing risk of flood events in warming climate.

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GROUND-BASED ELECTROMAGNETIC SURVEYS TO ESTIMATE DEPTH OF WATER TABLE AND GEOLOGICAL CONTACTS

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Aims

The utilisation of geophysical data for hydrogeology is largely a frontier research field in New Zealand. As part of the MBIE funded "Subsurface Processes in Braided Rivers" programme, Lincoln Agritech has undertaken reconnaissance electromagnetic (EM) surveys of the Selwyn (near Scotts Road, Canterbury) and Wairau (near Jeffries Rd, Marlborough) rivers to collect subsurface electrical resistivity data. These data have the potential to advance our understanding in two areas: Firstly, EM data can reveal a site's lithology by identifying geological contacts. Secondly, EM data can help to elucidate the spatial relationship between the river and the underlying groundwater system by identifying the position of the water table.

Method

Two methods of mobile ground-based EM survey were undertaken using equipment on loan from our collaborators at the Hydrogeophysics Group, Aarhus University (HGG), Denmark. Transect surveys were carried out in Feb 2020 by towing a transmitter/receiver system held on a sled behind a quad-bike. The first method, tTEM, used a transmitter loop, which provides for measurements at variable depths to approximately 70 m below the ground surface. The second method, ground conductivity (GCM), used a DUALEM-421 system, which consists of fixed transmitter positions along a horizontal tube. Because of its fixed receiver spacing, the GCM surveys only capture data up to 17 m below surface. However, the high electrical resistivity of braided river gravels meant that the tTEM data were extremely difficult to resolve, and the GCM data provided the better dataset for subsequent modelling and interpretation.

The resistivity data were inverted by HGG. Modelling of the data relied on four primary sources of data: the inverted resistivity values, borehole logs (and water level elevations), LiDAR and ortho-corrected aerial photography. Logging of boreholes drilled at the study site was undertaken to identify the contact between the recent river gravels and those of the Burnham Formation (at the Selwyn River). Drone LiDAR and bathymetry data were collected concurrently with orthophotography of the study areas. These data were used to correct the elevation of the GCM survey data for the study areas and identify the wetted surface extent of the rivers.

The basis for identification of the water table position is the large change in resistivity values as the alluvium transitions from being unsaturated to being saturated. The resistivity of the unsaturated alluvium is in the range of 850 to 16,000 Ωm, while the saturated material has a resistivity generally less than 650 Ωm. The exact identification of the water table position or contact relies on locating the transition between the unsaturated and saturated alluvium. This transition may be encountered at two positions in the inverted GCM data; at the contact between sounding intervals, or within sounding intervals. If the transition occurs at the contact between sounding intervals, locating the water table is straightforward. A simple categorical approach with bounds between the units can be applied, relying on a simple conditional statement such as if resistivity < 650 Ωm then the unit is saturated, if >850 Ωm the unit is unsaturated.

Estimation of the water table depth in soundings where the contact occurs within a sounding interval is more difficult to resolve. In this instance, we know that the water table contact lies at some position within the sounding depth range, but its exact position is unknown. Thus for the deeper layers, the water table may be encountered anywhere within a two to four metre interval. An approach to predict the position of the water table is the use of Markov Chain Monte Carlo (MCMC) mixing models.

For modelling, the resistivities of the various contributing populations were broken into two categories (three for Selwyn where the Burnham Formation is also present) and then the distributions of the populations assessed in R. The contributing populations were identified in the data, which all showed a large skew and kurtosis. First, the total resistivity dataset was broken into the easily identifiable categories, one representing unsaturated recent alluvium, two representing saturated recent alluvium and three the Burnham Formation (for the Selwyn).

Rather than attempting to implement several different distributions in the MCMC mixing model, we chose to attempt to normalise the total data set. Several transformations were tested, and a Box-Cox transformation was found to sufficiently capture the distributions. Once normalised, the distributions were assessed to distinguish the saturated and unsaturated populations and determine their mean and standard deviation resistivity values.

Next, the sounding interval where the water table contacts occurred was identified. All intervals where the sounding was easily classified as being saturated or unsaturated, were identified and set aside. The remaining data (where the

resistivity lies somewhere within a sounding interval) were assessed using the MCMC model. To do this, the normalised sounding data and associated population distributions were passed to a mixing model, which assumes a "consumer" (target value) is made up of a proportion of some contributing "diet" (e.g. mixed populations). The proportional contribution of one contributing population (e.g. unsaturated) was then used to calculate the contact depth.

Finally, the contact depths were converted to elevations and kriged. The elevation values came from two sources, either the interface between saturated and unsaturated soundings or the elevation estimated from the MCMC model. The kriging variograms were tuned before the prediction of the water table or lithology surface.

Results

We have successfully used the near-surface geophysics to produce piezometric surfaces for both the Wairau and Selwyn Rivers using reconnaissance-quality data. Analysis of the piezometric surfaces shows that the predicted water levels generally fall within half a metre of observed groundwater levels. Additional surveys are underway using significantly more ground truth points to verify the approach and results will be presented if complete by the time of the conference. So far, two key findings have been suggested by the data. Firstly for the Wairau River, it appears that the groundwater levels alternate spatially between being perched and in direct hydraulic connection to the river. In the Selwyn River study, the results suggest that at the time of the survey the river was entirely perched above the groundwater table.

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CLIMATE CHANGE VULNERABILITY ASSESSMENT OF SELECTED FRESHWATER TAONGA SPECIES

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Iwi and hapū throughout Aotearoa are concerned about the innumerable anthropogenic and environmental pressures on our taonga species, including climate change. There is an increasing desire to understand more about how climate change will likely affect Māori and their traditional relationships with freshwater species.

To assist with this understanding, Te Wai Māori Trust approached NIWA to assess the vulnerability of selected taonga freshwater species to a changing climate using a Climate Change Vulnerability Assessment (CCVA) methodology. For the CCVA, available published literature, species-specific sensitivity attributes, future projections of exposure variables (i.e., mean annual precipitation) for two representative concentration pathway scenarios (4.5 and 8.5) and two timeframes (2046–2065 and 2081–2100), together with expert elicitation were used.

The CCVA results revealed there are emerging climate-related threats to Aotearoa-New Zealand freshwater taonga species. Two species ranked as being 'very highly' vulnerable (longfin tuna, piharau/kanakana), five species as highly vulnerable (shortfin tuna, banded kōkopu, īnanga, kōaro, kākahi/kāeo), two species as moderately vulnerable (giant kōkopu, kōura/kēwai), and one was ranked as having low vulnerability (yellow-eye mullet). CCVAs' could not be completed for seven freshwater taonga species due to a lack of basic life history and ecological information (shortjaw kōkopu, grey mullet, common smelt, black flounder, one kōura species, and two freshwater mussel species).

These findings are crucial to guide targeted research and long-term datasets required by decision makers to inform the strategies and actions we need to implement now in order to help our freshwater taonga species/populations prepare for a changing climate.

NUTRIENT REMOVAL AND HYDRAULIC PERFORMANCE OF A FLOATING WETLAND TREATING AGRICULTURAL POLLUTANTS IN THE LAKE AREARE CATCHMENT

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Diffuse pollution from agricultural catchments has led to widespread degradation of lakes, wetlands, rivers and estuaries in New Zealand and worldwide. Numerous and varied mitigation measures have been developed in attempts to alleviate the negative impacts of intensive agriculture on aquatic environments, aimed at reducing nutrient and sediment loads to reverse water quality decline. Constructed treatment wetlands as agricultural management tools have become increasingly popular in the dairy sector, and recent innovations have led to design and trials of floating treatment wetlands (FTWs).

A FTW raft (20 m x 4 m), planted with three species of indigenous sedge, *Carex secta, C. virgata, Cyperus ustulatus*, was placed in a watercourse draining a 148 ha subcatchment of Lake Areare, Waikato, with predominantly intensive dairy-farming land use.

Surface water concentrations of nitrogen, phosphorus and suspended solids were monitored upstream and downstream of the wetland raft monthly, from June 2019 - June 2020, with flow velocities and discharge measured concurrently. Water levels were recorded continuously using an in situ logger.

The water quality treatment efficiency, specifically nutrient and sediment attenuation, varied over the monitoring period, driven by influent pollutant loads and suboptimal flows due to ongoing drought conditions in the Waikato. Overall, nitrate-N was significantly reduced by the FTW, showing promise for FTWs as a mitigation tool in dairy-farmed landscapes. FTWs in agricultural watercourses have the potential to provide inexpensive and effective water quality treatment whilst fitting practically within the productive farming landscape, requiring little maintenance and no loss of productive land.



MAKING THE LINK: STREAM BANK EROSION ANS SOCIO-ECONOMIC DRIVERS IN SOUTHLAND

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Excess stream bank erosion is a problem in developed parts of the Southland region. The process of stream bank erosion removes areas of productive farmland and undermines roads, bridges and flood banks. In addition, excess sediment in the region's freshwater and estuarine environments compromise ecosystem health. This has long-term environmental and socio-economic impacts on the region.

River managers often want to know where to apply mitigation practices to reduce stream bank erosion. Common practice is to employ stream bank erosion models to suggest river reaches at-risk of erosion and to use the results to prioritise the allocation of remediations. However, these models don't predict how a river will respond to changes in shape due to erosion or protective structures. Further, on-site stream bank erosion mitigation measures address *symptoms* not *causes* and may ultimately fail, or make matters worse, unless the main, socio-economic drivers are simultaneously addressed.

We make the case that the primary, overall drivers of excess stream bank erosion are socio-economic and are typically omitted or inadequately considered in river management decision-making processes. It is suggested that a paradigm shift in thinking may be needed.

We propose a shift in thinking from a purely conventional science world view towards a systems view and one that is closer to that incorporated within Mātauranga Māori and Te Mana o te Wai. Combining these knowledge systems with an appreciation of our cultural and human histories is an essential step towards long-term mitigation of problem stream bank erosion, and sediment problems in general.

ARE WE UNDERESTIMATING STREAM DEPLETION IN THICK ALLUVIAL AQUIFERS?

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[2] Environment Canterbury

Regional Council plan rules in some New Zealand regions require consent applicants to evaluate the stream depletion rate associated with their proposed groundwater abstraction. The outcomes of these assessments are used to determine whether a groundwater take is subject to water take restrictions under low stream flow conditions and to determine the split of the groundwater abstraction across the surface water and groundwater allocation blocks for to determine whether water allocation is available.

This paper explores the potential for significant underestimation of the stream depletion when transmissivity values derived from partially-penetrating well aquifer tests are applied to the standard analytical solutions used in stream depletion assessments and to a numerical stream depletion model.

Our study implements the Scientific Method by testing the following null hypothesis:

> "Failure to account for partial penetration leads to significant underestimation of stream depletion rates."

Our approach, which focuses on a Canterbury Plains aquifer system case study, comprises three main components: 1) analysis of pumping test data from partially-penetrating wells; 2) comparison of pumping test-derived transmissivity estimates to water budget and Darcy's Law-derived values; and 3) application of these transmissivity estimates to numerical and analytical models, to test our null hypothesis.

Our pumping test analysis results highlight the non-uniqueness of derived aquifer parameters and show that inclusion of partial penetration effects in the analysis can lead to order of magnitude increases in the derived transmissivity value. These higher values are consistent with those derived from water budget and Darcy's Law calculations. Applying these transmissivity values to stream depletion assessments leads to a much higher stream depletion estimate. The implications of this for water resource management are significant.

UNDERSTANDING THE STREAM DEPLETION EFFECTS FROM DEEP GROUNDWATER ABSTRACTION

Regional plan rules and implementation practice in some parts of Aotearoa New Zealand have favoured installation of deep wells for new water takes and transfer of surface water and shallow groundwater consents to deep wells for existing takes to mitigate the effects of abstraction on stream flows. Although this is likely to reduce stream depletion rates to some extent, we hypothesise that these benefits have been overestimated in many instances.

Robust calculation of the stream depleting effects of deeper abstraction in unconfined/leaky alluvial groundwater systems is challenged by several factors. Foremost among these is the reliance on simple analytical models such as Theis (1935) (Jenkins) or Hunt (2003) solutions. The practical application of these models often requires simplifying assumptions to be made, particularly of aquifer depth and structure. One such simplification involves definition of a cut-off depth below which the stream depleting effects of abstraction are assumed to be minor, and hence are not assessed. Streamflow-based water take restrictions are therefore not included in consent conditions for wells screened below the cut-off depth, and stream depletion is not accounted for in the surface water allocation.

A better understanding the stream depletion effects of deep abstraction is essential to improve freshwater management. We investigate the stream depletion effects of groundwater abstraction across a range of well depths and stream-well separation distances in a suite of synthetic aquifer systems constructed in FEFLOW. The synthetic systems are conceptualised as a homogeneous planar aquifer with bulk conductivity values populated from key quantiles (e.g. 25th, 50th, and 75th) of hydraulic parameters calculated from Canterbury Plains pumping tests.

Our initial modelling results found that the stream depletion effects of deep wells (e.g. > 50m) can be greater than 50% of the abstracted volume after 150 days of continuous pumping. This has significant implications for surface water allocation and for management of the effects of groundwater abstraction. To further understand the impact of deep abstraction we developed a series of meta-models to provide an efficient preliminary estimate of the total stream depletion effects of all wells abstracting from below 50 m on the Canterbury Plains. The results show that these deep wells have the potential to deplete stream flows significantly and highlight the need for a more rigorous investigation of this matter.

SUSTAINABLE USE AND PROTECTION OF FRESHWATER THROUGH STRENGTHENING NATIONAL AND REGIONAL WATER GOVERNANCE

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Aim

The national climate risk assessment (NCCRA, 2020) identified several water related risk for future climate change in New Zealand. Risk to potable water supplies (availability and quality) is identified as an extreme future risk. Regulation and policy related to water management in New Zealand are spread over several Acts and policies. The most recent policy update – National Policy Statement for Freshwater Management 2020 (Mfe, 2020). According to the Resource Management Act of 1991 (RMA) the responsibility for delivering on the integrated objectives of natural and physical resources is devolved to Regional Authorities (RAs). It is known that RAs use modelling tools (either through consultants or in-house) for management of specific water related issues (e.g. water quality, water availability, etc.), but how this management is done in an integrated way is not always obvious. There is no apparent integrated approach to the management of water resources in Aotearoa. Tthere is a strong desire to have healthy waterways that are fairly allocated amongst competing demands. This, however, is a difficult task since decision-making that promotes sustainability must consider environmental, human, cultural and economic attributes in addition to equitable allocation of the water resource. To complicate matters even further, these decisions must be made in an uncertain environment of climate change, economic growth/decline and population change – it is likely that changing how one attribute is managed will affect other attribute responses: potentially in a non-linear manner.

To date, successful implementation of an integrated water management plan (IWMP) has not been well reported, which means that the idea of IWMP in the conceptual sense leads to better outcomes, but it hasn't necessarily shown that this is the case. According to the NZ Institute of Economic Research (NZIER, 2014), the main issues of water in Aotearoa is over allocation in certain areas and deteriorating water quality due to reduced assimilative capacity, especially focusing on increased nitrate leaching. The report also notes a broad consensus across New Zealand that the current water management regime is ill-equipped to mitigate the problems arising from these multiple pressures. The consensus spans:

- cooperatives (e.g. Land and Water Forum, 2012)
- lawyers implementing the RMA (e.g. McGregor, 2007)
- industry and industry representatives (e.g. New Zealand Business Council for Sustainable Development, 2008)
- stakeholder groups (e.g. Deans, 2008)
- regional councils (e.g. Bay of Plenty Regional Council, 2013)
- national agencies (e.g. Hawke, 2006)
- academics, universities and research institutes (e.g. Makgill, 2010; NZIER, 2009).

Methods

Considering the opportunities and challenges above, it is unlikely that the panacea of water resources management in NZ can be developed in one project. It is therefore proposed that proof of concept deployment of an analytical framework to assist in integrated water management should be undertaken on a small scale and only considering a few of the pressures that may be present when undertaking integrated planning in a real situation. The IWMP framework can provide information to planning agencies, enabling them to assess and compare alternative courses of action in preparation for decision-making.

An important feature of the IWMP framework is to provide a structured approach based on consensus on the required information. The framework connects three important parties or stakeholders in the planning process: resources analysts, planners and decision makers. This framework will determine the changes in the utilization and availability of the water resources and in the water resources system itself. The IWMP analytical framework will able to predict the relevant impacts on ecosystems and on the social and economic conditions of the different resource users and society as a whole.

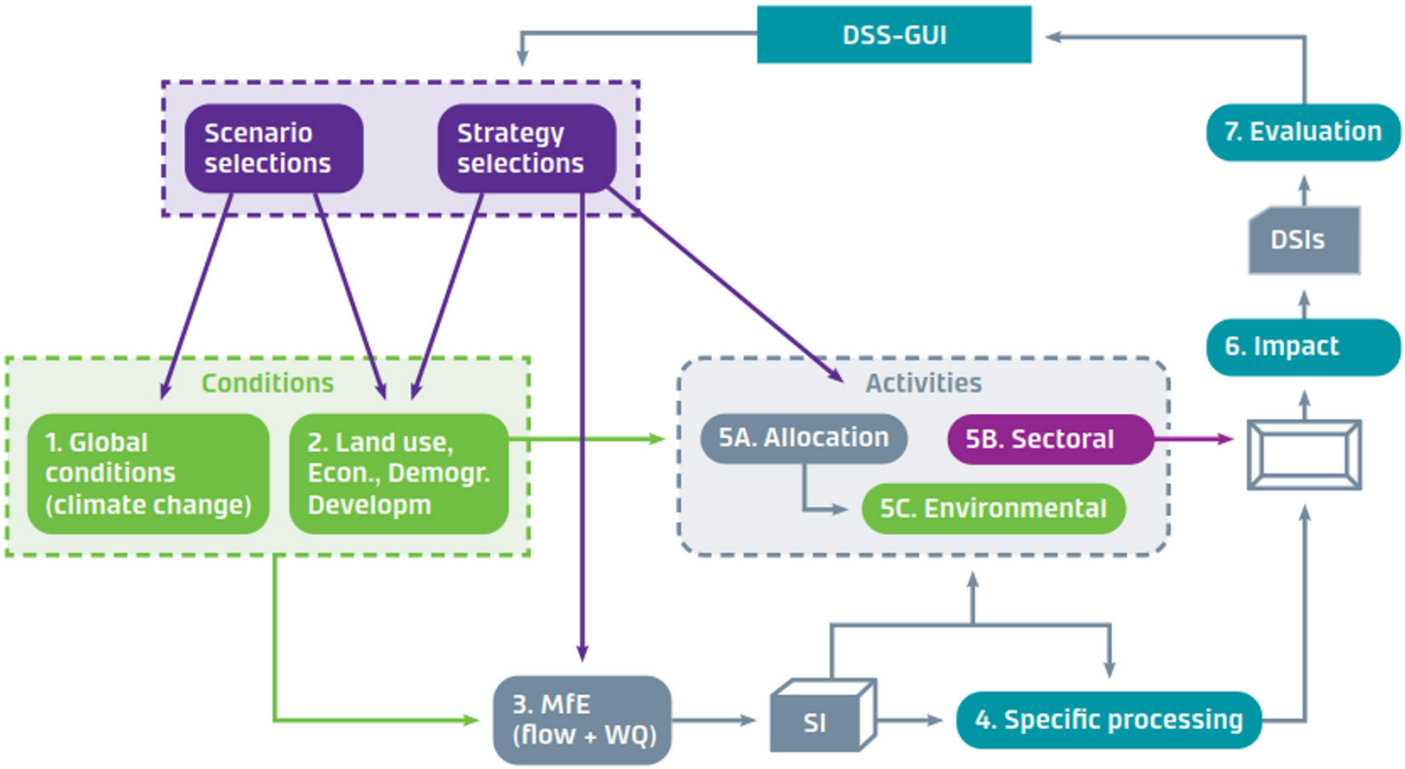


Figure. Analytical framework for IWMP

Results

The framework concept and its computational assumptions will be shared with other agencies involved in water management. This may ultimately result in regional guidelines for water resources system planning and cooperation with river basin management. Such guidelines would also specify the criteria to be used for planning decisions, and could identify the use of multi criteria analysis techniques to compare alternative options or strategies. The framework represents not only a structured set of components and their interrelations, but when visualized through a systems diagram it also provides a structured process for its continued development and implementation.

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FORESEEABLE FUTURE: SEAMLESS INTEGRATION OF WEATHER AND CLIMATE INFORMATION FOR LONG RANGE EARLY WARNING SYSTEM

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As the effects of climate change and extreme weather become more apparent, the need for improved water-induced hazards prediction and forecasting is increasing. Understanding a foreseeable different time scale future climate would enable more informed decision making, allowing users the opportunity to put appropriate prevention in place. The potential increase in occurrence and intensity of extreme weather events as a result of climate change, coupled with an increasing population in vulnerable areas reinforces the need for foreseeable future information systems.

When developing and implementing an early warning system, we need to consider that a more widespread application of early warning systems equates to a more widely experienced uncertainty. Even when there is warning information available, especially for sector and strategy decision-making, it doesn't immediately translate into successful application, because there is a time horizon to turn strategic decisions into tactical decisions.

Long-range warning provides whether it will be hotter or colder, or wetter or drier, than normal over the next three to six months. These broad-brush perspectives on how regional climate is expected to vary are based on slowly evolving planetary patterns that drive weather over the scale of months. However, these long range warnings have proven potential benefits for society. The enhancement of forecasts skills are increasing and scientists are progressing much faster to increase the accuracy of these forecasts. This work has demonstrated the power of information to inform risk-based decision making, and proven the potential use of understanding future risks.

THE EVIDENCE BASE FOR RIPARIAN SETBACK DISTANCES – THE WIDER THE BETTER

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Aims

The Government's 2020 Essential Freshwater reforms have put in place national directions, which include stock exclusion from certain wetlands, lakes and rivers, and a minimum setback of 3 m from the edge of defined water bodies. This Envirolink project for Tasman District Council reviewed and summarised the scientific evidence for deciding effective setback distances from water bodies.

Method

A literature review was completed, focusing on New Zealand research, guidelines and papers, but including key international literature on the effectiveness of riparian setbacks. The review adopts a catchment-scale approach whereby priority riparian functional objectives must first be defined. The report reviews riparian setback widths from water bodies that would achieve each of the following six functional objectives:

1. reduce nutrient and other contaminant inputs via overland and subsurface flow
2. improve the light climate and water-body temperature regimes of water bodies
3. increase freshwater ecosystem health and terrestrial and aquatic habitat diversity, and improve inputs of terrestrial carbon to water bodies
4. improve channel and bank stability
5. pass and attenuate flood flows
6. provide for recreational, cultural, aesthetic and landscape values.

Results

We have (Table 1) devised the following conceptual approach to specific decisions about riparian setbacks, based on principles of integrated catchment management.

Table 1. A catchment-scale process for deciding riparian setbacks

1 Desired outcomes: define the desired outcomes (i.e. functional objectives 1-6 above) for riparian management at the catchment scale.
2 Compliance: identify reaches/water bodies where mandatory riparian exclusion is required under the NPSFM, regional plans and other relevant guidance, initially assuming minimum mandatory riparian setback.
3 Preferred locations: establish or identify reaches/water bodies where existing land management incentives (including avoided costs) would favour riparian buffers, assuming a minimum setback.
4 Long-term riparian programme: for the remaining reaches/water bodies, assume riparian management occurs stochastically within a defined time (10 years may be appropriate).
5 Setbacks that achieve catchment outcomes: define setbacks by assuming some standard for fence placement and type, riparian plantings and/or natural regeneration, with pre-establishment vegetation management.

In reality, riparian setback distances should vary across a catchment in response to land cover, and geographical, climatic and hydrological factors, alongside policy objectives and land-user preferences and priorities.

Based on the literature review, in Table 2 we present suggested long-term minimum setbacks for each of the six functional objectives, taking into account the opportunity costs for intensive land uses in Tasman District and other regions. For more extensive land uses such as forestry, and on steeplands, wider setbacks would be justified.

Table 2. Riparian setback recommendations for the six functional objectives

Riparian functional objective	Minimum setback recommendations	Applicability
Reduce nutrient and other contaminant inputs	10 m 20 m	For land with slope <10o. Aim is to filter out >80% sediment and pesticide, >70% nitrogen and phosphorus in overland flow, and remove c90% groundwater nitrate in fine shallow riparian sediments For steeper land than 10°
Improve light exposure and water body temperature	10 m	Mature trees needed for shading; buffer width should exceed mature tree height and channel width. Even a single line of trees is beneficial.
Freshwater ecosystem health, terrestrial and aquatic habitat diversity	15 m	To sustain macroinvertebrates, fish, terrestrial biodiversity using a range of riparian vegetation. Riparian biodiversity is easier to sustain with a 15 m setback; smaller setbacks and weedy buffers require more management
Improve channel and bank stability	10 m	Equivalent to the root-mass diameter of a mature riparian tree
Pass and attenuate flood flows	None	Base the riparian setback on the flood characteristics of specific catchment and river reach
Recreational, cultural, aesthetic and landscape values	20 m	A balance of ecosystem service benefits achieved in the longer term

Given the wide range of setbacks revealed in the literature review as effective (or not), we do not recommend prescribing minimum setbacks in regional rules, but as guidelines for property-scale achievement of functional objectives. Our suggestion is that a decision support tool, such as an enhancement of Dairy NZ's Riparian Planner developed by Manaaki Whenua (https://www.dairynz.co.nz/environment/waterways/riparian-planner/), would assist in delivering the recommended catchment-based approach.

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RIVER FRAGMENTATION IN NEW ZEALAND

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Many of New Zealand's most widely distributed and valued freshwater fishes (e.g. eels and whitebait) migrate between the sea and freshwater environments during their life. These migrations are critical to the on-going survival of these populations. Structures built in waterways can restrict, delay or completely obstruct these movements, putting fish populations at risk. While barriers to migration have long been recognized as contributing to observed declines in fish populations, the scale of the problem has never been described.

Here we present the results of an attempt to capture available information on the location of instream structures and the state of river fragmentation in New Zealand. We show that despite large regional variations in available information on instream structures and the severity of barriers that a large proportion of the national river network is highly fragmented. We also demonstrate that significant gaps remain in our knowledge of the location and severity of instream barriers, particularly on private land. The results highlight that actions to improve river connectivity could have a significant positive benefit for freshwater biodiversity.

RIVERS AND CLIMATE CHANGE: RESILIENCE, FLOODS AND TIPPING POINTS

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In their natural form, rivers are resilient, and as 'messy' rivers usually able to absorb and respond dynamically to a natural range of floods without changing form. However, this resilience is arguably under threat. Firstly, managed channels are often designed to resist change, which renders them potentially more vulnerable to disturbance by large floods that exceed design capacity. Secondly, predicted climate change is likely to see a phase-shift (upwards) in flood magnitude and frequency. Do New Zealand's rivers have the capacity to adjust to forecast changes in flood magnitude and frequency: are they resilient in the face of predicted rapid global change? To answer this question this paper follows two threads. Firstly we need to understand the scale of modification that has taken place in our river systems in recent decades, which we can achieve using an index of change (Natural Character Index), comparing what is observed today (post-management) with what might be expected (pre-management). Secondly, we need to understand the potential phase-shift in flood magnitude and frequency: how big will floods become? A palaeoflood archive is presented from the Whanganui River, which reveals a connection between very large floods and the El Nino Southern Oscillation signal in New Zealand. The potential impact of large storms on river channels can be devastating, exceeding even the natural capacity to adjust without changing form when tipping points are crossed. The prospect for significant future change in New Zealand's riverscapes must be taken seriously by society. This paper argues there is a pressing need to make room for the river and manage for (much) bigger floods.

BACTERIAL COMMUNITY VARIANTS OF SPATIAL, TEMPORAL AND ENVIRONMENTAL GRADIENTS IN STREAM ECOSYSTEM

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Freshwater stream bacterial communities are deeply diverse and highly variable across space and time. We expanded on previous studies by determining patterns of variability in bacterial community dynamics at taxonomy level across regional environmental gradients. We used 16s rRNA gene amplicon sequencing from 892 stream biofilm samples collected from 6 different streams from 2013 to 2016 to explore relationships between stream bacterial communities and environmental attributes. The results revealed differences in stream bacterial composition with a differential distribution of Proteobacteria, Cyanobacteria, Firmicutes, Planctomycetes, Bacteriodetes, Verrucomicrobia, Chloroflexi, Acidobacteria, Actinobacteria across all the streams. The bacterial richness and diversity were significantly higher in native streams than moderate and high impacted streams; exhibited spatial and temporal variability. These results were consistent with our previous study where we observed differences in bacterial communities by season and year as well as between streams. Conditional Inference tree analysis suggested that the bacterial communities were most influenced by DO, light, pH, temperature ($p < 0.005$). We identified 17 Indicator taxa that were indicative of environmental change. Among them, we found strong correlations between increase in relative abundance of indicator taxa Orders Enterobacteriales, Pseudomonadales, Bacillales (Indicator Value all<0.5) associated with the influence of high light and high dissolved oxygen in all the streams. This group was also found to take over all streams during late 2015 and 2016 summer. Overall, our findings suggest that bacterial communities in stream biofilms follow trends in accordance to changing environmental conditions and may provide a better understanding to assess community variations over time.

METHODS NOT CRITICAL – INANGA SWIMMING PERFORMANCE IS NOT AFFECTED BY CHOICE OF CRITICAL SWIMMING PROTOCOL

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Efforts to improve fish passage in New Zealand are hampered by a paucity of knowledge about the swimming performance of native freshwater fishes. Swimming performance can be measured in different ways, but critical swimming speed is commonly used to compare the steady-state swimming performance of different species. Critical swimming speed trials involve gradually incrementing the water speed at fixed time intervals until the fish fatigues. In a review of 27 critical swimming speed studies we found that the time interval was not standardised, varied widely, and that authors rarely provided a rationale for the interval used in a study. In this talk we discuss the results of our review and a study into the effect of time interval on the critical swimming speed of inanga (*Galaxias maculatus*). Using a repeated measures design, we compared time intervals of 5 minutes and 30 minutes. The critical swimming speed determined using 5 minute time intervals did not vary significantly from that determined using 30 minute intervals. Our findings have implications for the logistics of conducting critical swimming speed experiments as a shorter time interval reduces the overall duration of each experiment. This may increase the number of individuals that can be tested, improving the precision of estimates of critical swimming speed of a species without compromising the accuracy.

LOOKING AT HOW LANDSCAPE ASSESSMENT, PLANNING AND DESIGN CAN CONTRIBUTE TO CATCHMENT MANAGEMENT FOR COMMUNITIES

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Catchments are immensely complex. Not only do they require management of streams, rivers, aquifers and springs, lakes, swamps, estuaries, and lagoons, they require management of land-use and activity, nutrient cycles, and sediment flows from the headwaters to the coastline. How we design and build infrastructure (especially in-river), and design and manage our different landuse such as forestry and agricultural regimes and built environment will have interconnecting and downstream effects. The resulting and cumulative effects of the physical, ecological, and cultural systems, processes and features in catchments are expressed as the landscape we see and experience. One of the most dramatic change to a catchment landscape is through the construction of an in-river Large Dam. By using the example of the past Ruataniwha Dam and Water Storage Scheme proposal in Tukituki catchment, Hawkes Bay, the author will explain the potential complexity of inter-connecting and cumulative effects, and how these would be expressed in that catchment's landscape. The Regional Council's role as the resource consent regulator and applicant and the effects on the community will also be touched on. The author explores the role of multi-disciplinary teams and the need for the synthesis of the different fields and expertise to acquire analytical, systematic, and intuitive thinking for integrated catchment management solutions.

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Sara Gerard was a submitter and Landscape Architect Expert Witness in the 2013-2014 EPA Hearing for the Ruataniwha Water Storage Scheme Resource Consent, and submitted to the BOI on Proposed RWSS Conditions relating to 2015 High Court's directions regarding Rule TTI (j), Hawkes Bay Council 2014 and 2016 Amendments to Long term Plan, 2017 RWSS review, and the 2016 Government Havelock North Drinking Water Inquiry.

INDICATORS AND PATHOGENS IN NEW ZEALAND RIVERS – A PILOT STUDY

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Aims

The aim of this pilot study was to explore relationships between pathogens and indicators in New Zealand rivers, and appropriate methodology for examining these relationships.

Method

Between February and March 2020, 52 water samples from 16 rivers (initially characterised as six urban, five dairy and five Sheep & Beef) from around New Zealand were analysed for the levels of *Escherichia coli, enterococci, Campylobacter, Salmonella*, Shiga toxin-producing *E. coli* (STEC), Cryptosporidium, Giardia, norovirus, enterovirus, adenovirus and a set of faecal source tracking (FST) markers (human, ruminant and wildfowl). Rivers were selected to represent sites more likely to be contaminated.

Results

All six urban rivers contained human faecal markers, in all the samples tested. Four of the Sheep & Beef river samples contained significant levels of ruminant faecal marker in all samples, while four of the dairy river samples contained ruminant faecal marker in most, but not all samples. All the rivers contained wildfowl markers, and were the only source identified in 11 of the samples, and two of the rivers. Four of the rivers had evidence of significant levels of both human and ruminant markers in at least some of the samples from those rivers (two urban sites, one dairy and one Sheep & Beef site).

E. coli were detected in all samples with 17 samples from eight different rivers with >1,000 *E. coli* MPN/100 mL, another six samples with >540 *E. coli* MPN/100 mL, 12 samples with between 260 and 540 *E. coli* MPN/100 mL, and 16 samples <260 *E. coli* MPN/100 mL.

Pathogens were measured in all but two three samples. *Campylobacter jejuni* or *C. coli* were detected in 40 of the samples by either culture and/or quantitative PCR. A potentially new species of *Campylobacter* was found in five of the rivers including those only impacted by wildfowl sources. The maximum level of *Campylobacter* was 92 MPN/100 mL with an median of 0.25 MPN/100 mL.

Salmonella were recovered from seven of the rivers with isolates identified as *Salmonella enterica*, and serovars Enteritidis, Typhimurium, Saintpaul or Emek. The maximum level of Salmonella was 0.25 MPN/100 mL. Shiga-toxin producing *E. coli* was only detected in one sample by MPN enrichment and at a level of 0.14 MPN/100mL. This stx2 positive isolate was confirmed as an STEC, with serotype O177:H25. Quantitative PCR for genes associated with *Salmonella* or STEC detected potential *Salmonella* in five samples, and STEC stx1 or stx2 genes in 13 samples. All were very low levels (maximum of 172 gene copies/100 mL). By culture or qPCR, *Salmonella* and STEC were detected in seven rivers with human or ruminant contamination and two in rivers with dominant wildfowl FST markers.

Protozoa were analysed starting with an in the field filtration of an average of 73 L of river water. Cryptosporidium was detected in 22 (42%) of samples at concentrations from 1 to 30 oocysts/100 L (0.001 to 0.03 oocysts/100 mL). Giardia were detected in 42 samples (81%) with 40 samples between 2 and 24 cysts/100 L (0.002 and 0.024 cysts/100 mL), and the other two at 86 and 250 cysts/100 L (0.09 and 0.25 cysts per 100 mL). Quantitative PCR of a separate sample of a maximum of 2 L, failed to detect *C. parvum* or *C. hominis*, in any sample, while Giardia was only detected in only one sample by qPCR (75 copies/100 mL) – this was the sample with 0.09 cysts/100 mL.

Ten litres of water samples were analysed for enteric viruses using qPCR or RT-qPCR methods. Human adenovirus (HAdV) was not detected in any sample. Overall, 11 samples were positive for at least one human enteric virus. Norovirus GI was detected in six samples, norovirus GII in seven samples, and enterovirus in two samples. However, the concentration of viruses in the water samples were low and could not be quantified. While five of the samples with viruses detected were from two of the human impacted rivers, the other six samples with viruses detected were from rivers with dominant ruminant or wildfowl sources.

Potentially pathogenic micro-organisms were detected in 94% of the samples, but generally at very low levels, with *Campylobacter* in 68% of samples. The pilot dataset is limited, but while it confirms that high levels of faecal indicator bacteria were associated with higher concentrations, and an increased number of the types of pathogens present in river water, direct relationships between indicators and pathogens are likely to be only weakly associated in most New Zealand rivers.

MIND THE (RIPARIAN) GAP: EVALUATING TARGETED BUFFER DESIGNS TO INTERCEPT AGRICULTURAL RUNOFF

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Precision (variable-width) riparian buffers can provide superior targeting of diffuse agricultural pollution as compared to the status quo of fixed width buffers. Variable-width buffers need to intercept the key contaminant delivery pathways at the hillslope scale and match the local soil and pasture conditions. But, existing design tools for farm advisors or landowners are not well-suited to pastoral farming practices or applicable across the diversity of terrain, soils, and rainfall in New Zealand. We reviewed the published GIS-based and field-based precision buffer tools to identify critical design features for targeting variable-width buffers for nutrient and sediment attenuation along 2nd order and smaller agricultural waterways. Emphasis was placed on delineating hillslope-scale network connectivity of the hydrological contaminant delivery pathways that can be intercepted upslope or within riparian buffers.

The majority of precision buffer tools were underpinned by terrain analysis and sizing of buffer widths along stream segments according to hillslope-scale topographical variation in slope lengths, contributing areas, or slope steepness. Surface topography-based designs therefore focused on attenuation of particulate contaminants and often assumed that subsurface flowpaths were governed by variation in surface topography. Very few approaches evaluated surface and subsurface flow as well as soil conditions, which is important for attenuating nitrate. Recent advances in precision buffer design leverage the network structure (disconnectivity) of runoff pathways from hydrologically sensitive areas to infiltrate or store runoff at points between field or riparian margins. Overall, we identified several ways to improve on existing variable-width buffer design tools to intercept and attenuate agricultural runoff.

WHAT MAKES A RIPARIAN BUFFER MOST EFFECTIVE FOR IMPROVING ECOLOGICAL OUTCOMES?

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Riparian planting is one of the most-commonly practiced mitigation interventions to buffer streams from surrounding land use and restore stream health in New Zealand. However, very few riparian planting projects have been adequately assessed after implementation, limiting both our knowledge of their efficacy and our ability to predict the ecological outcomes of riparian restoration.

We are conducting a space-for-time study to investigate relationships between riparian buffer characteristics, stream morphology, water quality, and biota at 25 sites across the Waikato, Taranaki, and Canterbury regions. All sites contain at least 500 m of continuous planted riparian vegetation on both banks, planted 5-20+ years prior to sampling. We are interested in several riparian buffer characteristics, including age, width, length, canopy cover, planting density, and species composition. At each site, riparian vegetation, stream morphology, bank condition, macrophytes, and periphyton are assessed at 100 m intervals within the top 500 m of the planted reach and at the top and bottom of the reach. Continuous temperature measurements, water chemistry, and macroinvertebrate samples are collected at the top, bottom and midpoint of the planted reach.

Relationships between riparian buffer characteristics and in-stream variables will form the basis for guidance on riparian buffer design to maximise instream ecological outcomes, thereby enabling targeted future efforts which can lead to the greatest improvements. We anticipate this study will also generate improved methods for monitoring and reporting the effectiveness of riparian restoration, a measure which is currently exceedingly difficult to quantify. This will in turn support more efficient implementation of national and regional legislation and facilitate adaptive management.

UNDERSTANDING THE IMPACT OF LED STREETLIGHT CONVERSIONS ON FLYING FRESHWATER INSECTS

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Artificial light at night is thought to negatively affect terrestrial and aquatic ecosystems and reduce night sky visibility globally. Across New Zealand, 370,000 streetlights (predominantly yellow high-pressure sodium lamps) are currently being replaced by energy-efficient, blue-white light-emitting diodes (LEDs). While the economic benefits of conversion are significant (~$10 million/year operational costs), the potential cultural and environmental impacts of the increased blue light emitted by LEDs are unclear. Healthy urban waterways provide important ecosystem services and contribute to cultural wellbeing, but their health is declining globally. Ecological light pollution likely alters the behaviour of emerging adult aquatic insects and may contribute to poor ecosystem functioning in urban waterways. We aim to investigate the potential ecological impacts of LED conversions on the adult flying stage of urban aquatic insects and develop recommendations to minimise the ecological impacts of large-scale streetlight conversions on urban waterways.

Using data from preliminary experimental field trials along urban waterways, we will discuss how flying freshwater insects are attracted to different streetlight types. Understanding potential changes in the behaviour of adult insects under different lighting types will help planners prioritise critical areas for alternative lighting solutions and aid in the design of ecologically-sensitive streetlighting.

VARIATION OF SUSPENDED SEDIMENT LOAD ALONG THE ORETI RIVER, SOUTHLAND

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Aims

Knowledge of the spatiotemporal variability of suspended sediment transport down river networks provides information useful for managing catchment sediment exports by informing on sediment source areas and their phasing during runoff events (Rinaldi, et al. 2013, Haddadchi and Hicks 2020). The aim of this study is to understand how different catchment sediment sources induce variation in the timing and load of fine sediments at the hydrograph scale. We pursued this by establishing a network of stations along the Oreti River, Southland, to monitor sediment loads over multiple events.

Method

Four monitoring sites were established in the Oreti River, permitting isolation of sediment eroded from upland hill country, sediment eroded from lowland plains/downland, sediment re-suspended from and settled into the gravel substrate in braided reaches, and the net result of sediment eroded from and deposited on river banks.

Two of these sites (Oreti at Lumsden, Oreti at Benmore) straddle a 34 km span of braided channel that has no significant tributaries. The second pair of sites (Oreti at Wallacetown, Oreti at Taramoa) straddle a 5 km reach that has substantial bank erosion. At all four sites, a continuous record of stage provided by pressure transducers was transformed to flow records using stage-discharge rating curves. Turbidity sensors (WTW sensor at the Lumsden site; Observator Analite NEP5000 sensors at the three other sites) were used to collect continuous records of turbidity. Auto-samplers were used to collect calibration samples for relating turbidity to at-a-point suspended sediment concentration (SSC), while a series of depth-integrated sediment gaugings during five flood events provided relationships between auto-sampled suspended sediment concentration and discharge-weighted cross-section average concentration.

Results

Two consecutive flood events of different sizes were compared to evaluate the variation of sediment load through the Oreti River network (Fig. 1). The February 2020 event, with a flow peak of 1070 m3/s, was one of the highest recorded events in the Oreti River (and had a return period of ~ 20 years, based on Oreti flow records collected by Environment Southland). The December 2019 event was smaller, with a flow peak of 215 m3/s at the Wallacetown site (return period <1 yr). During the February 2020 major flood event, ~ 75000 tonnes of suspended sediment were delivered to the New River Estuary from the Oreti River. Of this total, 42860 tonnes were generated from upland hill country erosion, 6250 tonnes were released from the lowland pastoral areas, while bank erosion along the 5 km Wallacetown-Taramoa reach was responsible for 13% of the total load (9930 tonnes).

The December event had 1765 tonnes of fine sediment transported from the upland hills and 4821 tonnes (77% of the total export) was contributed from the lowland plains. 6232 tonnes were transported to the New River Estuary. While channel bank erosion was one of the main contributors to total event load during the major February flood event, in the December event the bank erosion-prone Wallacetown-Taramoa reach had a small net gain of sediment (355 tonnes, Fig. 2). Comparing these two events indicates how the Oreti catchment sediment budget responds to different flood sizes in terms of sediment generation: an almost six times increase in the size of flood resulted in a 12 times increase in the generated sediment load.

To investigate the effect of flood size on the sediment delivery during the rising and recession of the flow through the river network, the proportion of the event load delivered before and after the flow peaks of these two events were compared (Fig. 3). In the small event, at all sites down the network the majority of the event load was transported before the flood peak (ranging from 73% at Lumsden to 64% at Taramoa). In contrast, in the larger event a higher proportion of the event load was carried after the flow peak (ranging from 62% at Lumsden to 75% at Wallacetown).

These results stress the importance of flood size in the timing and yield of suspended sediments transported through the river network.

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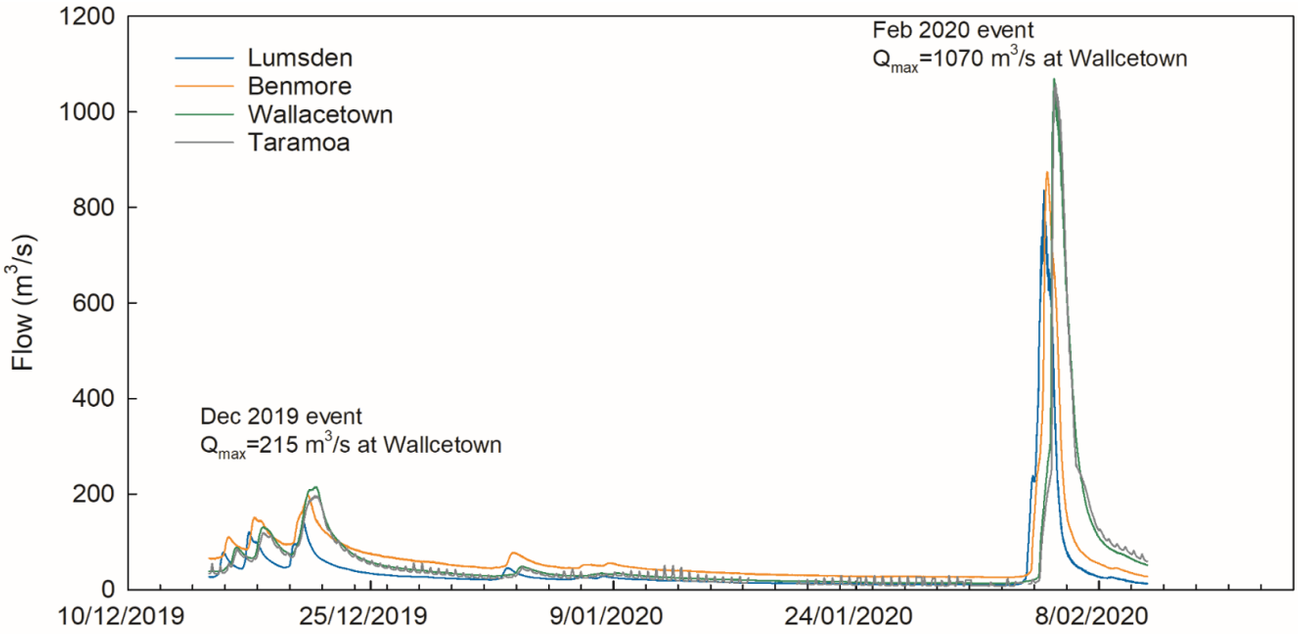


Figure 1. Hydrograph of December 2019 and February 2020 flood events on 4 sites at the Oreti River.

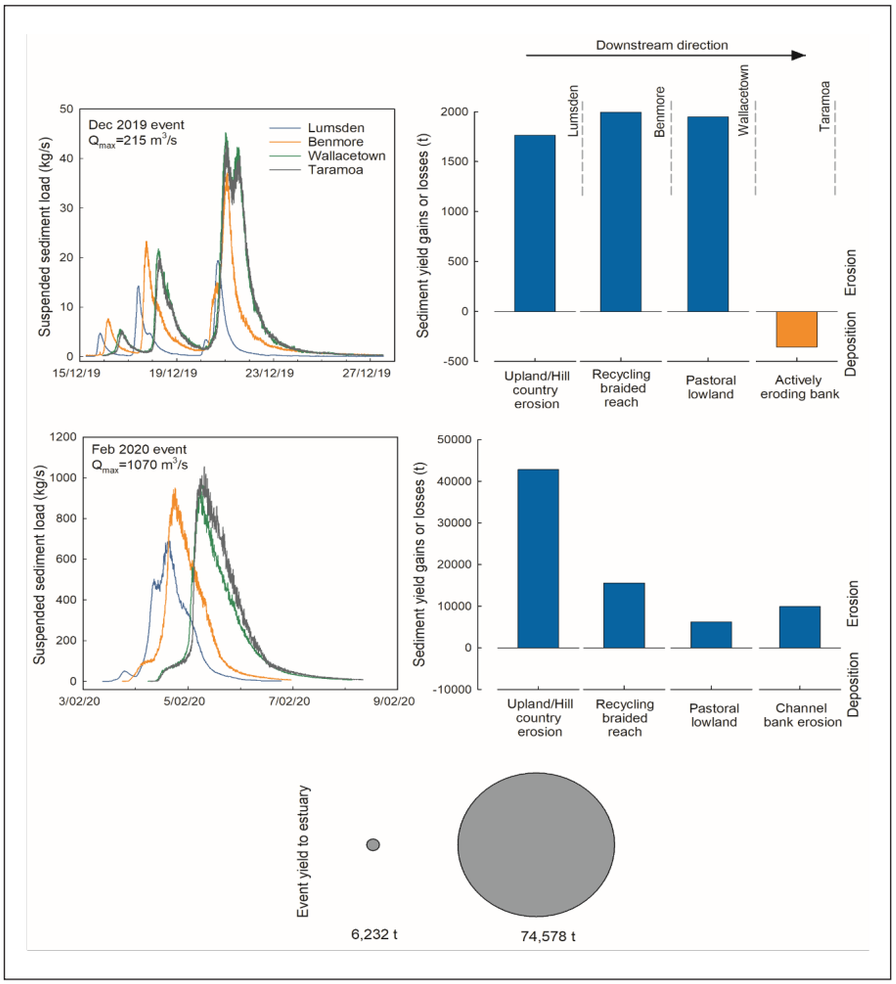


Figure 2. Suspended sediment load (left plots) and sediment yield gains or losses through the Oreti river (right plots) during two flood events.

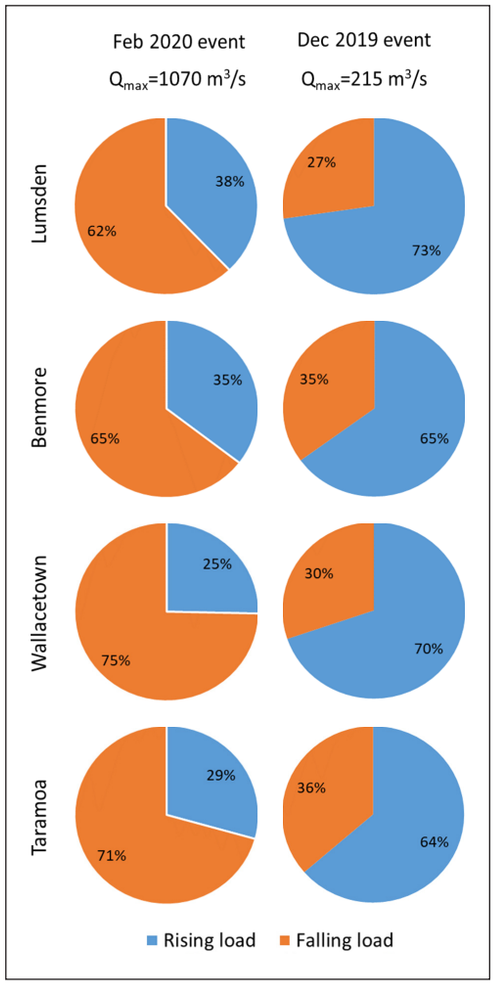


Figure 3. Suspended sediment load through rising and falling stages of the hydrograph for two events

INVESTIGATING COASTAL GROUNDWATER RESOURCES AT HAHEI

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[1] Waikato Regional Council

Background

Hahei is a coastal settlement approximately mid-way along the east coast of the Coromandel Peninsula. Its resident population of about 300 increases about ten-fold during peak holiday periods. Water supply is reliant on four community groundwater supplies. Water use at Hahei over the last summer was severely restricted as supplies effectively reached their capacity. There are concerns about the sustainability of the current community supplies, particularly with respect to saltwater intrusion potential, and the capacity of these supplies to meet current and future needs for increasing users.

Aim

The aim of this work is to provide information for the sustainable management of groundwater resources at Hahei and consideration of community groundwater supply augmentation.

Method

Ongoing investigation includes piezometric surveying and groundwater quality sampling and analysis, as well as sentinel well monitoring involving conductivity depth profiling. Relevant groundwater related information from previous investigation is also collated and summarised.

Results

Hahei derives its water supply from fractured, rhyolitic aquifers. The geology of the Hahei area comprises three main components. Most notable are the dome forming Ruahine rhyolites which are typically sparsely fractured and hence poorly permeable with low yields. The other components are the unwelded to poorly welded, Hot Water Beach Ignimbrite and some localised quaternary sediments within the Hahei valley (Skinner, 1995).

Investigation of the hydraulic characteristics of the rhyolitic aquifer at Hahei includes flow testing at the Pa Rd wellfield and the holiday park. Transmissivity is typically low with a median of 11.2 $m^2 d^{-1}$. Transmissivity estimated from flow testing and drillers' yield tests range from 1.5 $m^2 d^{-1}$ to 370 $m^2 d^{-1}$ with 90 percent being less than about 30 $m^2 d^{-1}$. Storativity estimates range from 5.9 x 10^{-4} to 1 x 10^{-3} with a median of 9 x 10^{-4}. Anecdotal evidence corroborates the confined nature of the aquifer with historic low level free flowing artesian conditions reported in the Pa Rd area.

Although total annual groundwater abstraction from the four community supplies is only some 82,000 m3 (daily maximum ~700 $m^3 d^{-1}$), it results in substantial drawdown below sea level (up to about 30 m). A piezometric surface for the rhyolitic aquifer based on a late January 2020 groundwater level survey is shown in Figure 1. Substantial vertical head gradients may be observed between hydraulic units. For example, at the beachfront sentinel wells, the shallow (4.6 m) piezometer (72_3831) had a water level about 1.1 m above mean sea level (msl) compared to the deeper (104.2 m) piezometer (72_3830) which had a water level 4.7 m below msl. This indicates that flow at that point is still toward the sea in the surficial sediments. The sentinel monitoring wells were established by Waikato Regional Council in 2008 to provide early warning of potential saltwater ingress.

Piezometric contour patterns vary seasonally but have been largely consistent over the last 15 years, reflecting similar and constrained pumping regimes. There remain, however, concerns regarding the long-term sustainability of the current abstraction. These relate to: substantial drawdown below msl in the rhyolitic aquifer at the shoreline; higher salinity groundwater in the Wigmore Crescent area; apparent slight (but not significant) salinity increases at depth in the sentinel well and conductivity increases with pumping in Thames Coromandel District Council's community supply well (60_20). Conductivity triggers of 50 mS m^{-1} are set in consent conditions at the community supplies.

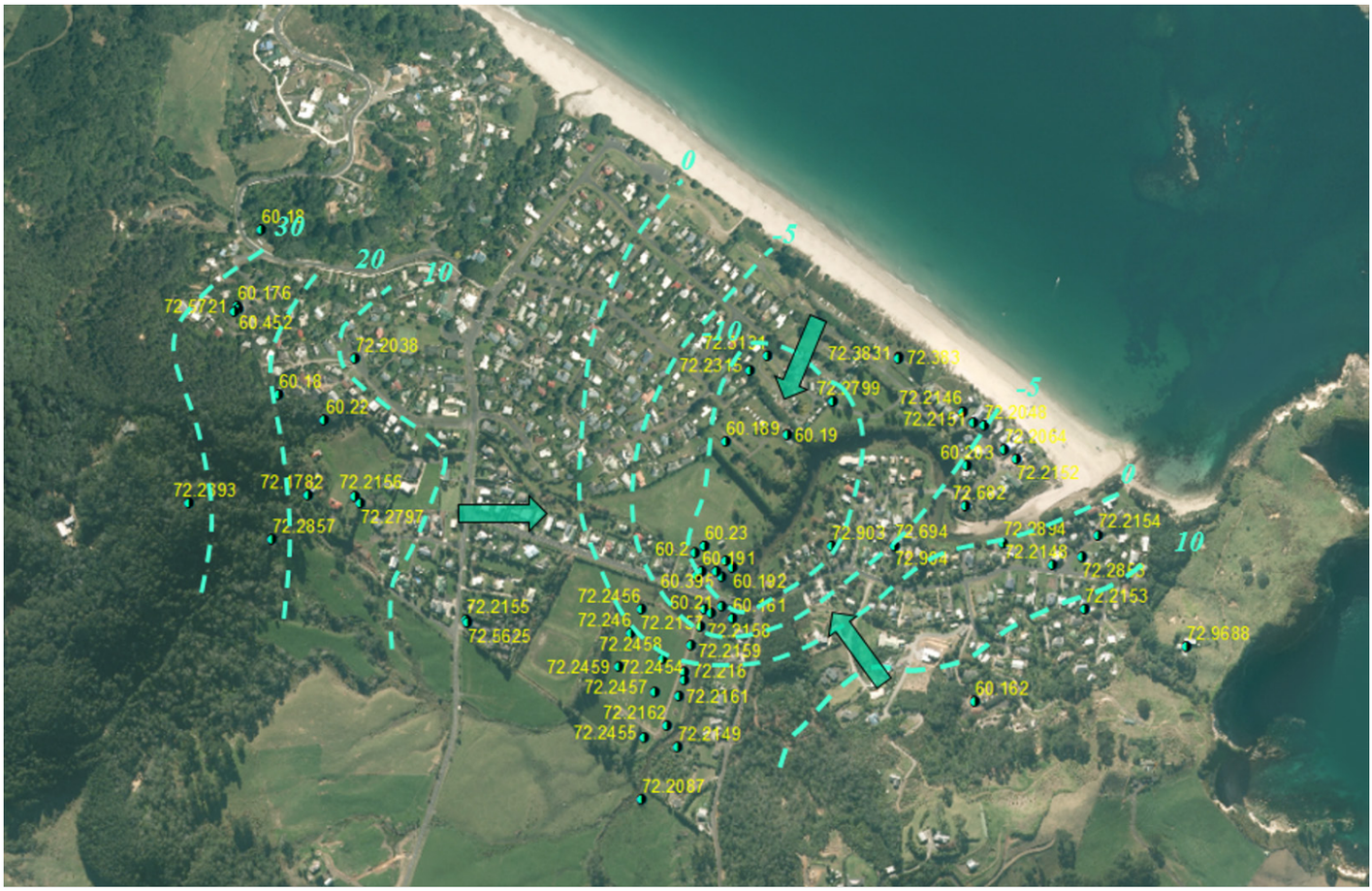


Figure 1. Hahei rhyolitic aquifer piezometric surface January 2020 (contours are in m msl, well numbers are in yellow and arrows indicated approximate flow directions, the black horizontal scale bar is 500 m).

Wigmore Stream (mean flow ~35 to 64 l s^{-1}) is the only significant surface water and is tidally affected and intermittently saline above the Pa Rd wellfield. This is another potential mechanism of saltwater ingress. The aquifer is reliant on the weathered, confining, aquitard for water quality protection from this and other land surface contamination, including discharge from the nearby up-gradient wastewater treatment plant. Groundwater age dating at well 60_20 indicates the occurrence of water older than 100 years mean residence time suggesting limited leakage. Given uncertainties inherent in predicting the fractured aquifer dynamic behaviour and potential for saltwater ingress, numerical modelling is being undertaken to improve the estimation of aquifer sustainable yield.

Groundwater quality analysis from 28 wells shows chloride concentrations range from about 24 mg l^{-1} to 370 mg l^{-1} (median ~ 45 mg l^{-1}) with higher concentrations near the mouth of the Wigmore Stream. Ionic ratios suggest a seawater origin despite the occurrence of local hydrothermal influences. Heavy metals associated with the latter have precluded supply development at Grierson Close, where antimony was encountered at a concentration considerably in excess of the drinking water guideline at well 72_2038. Arsenic also exceeds guidelines at two of 22 wells sampled for its analysis. The unpredictable, although low probability, of such occurrence, is a consideration for imminent drilling for prospective groundwater supply augmentation. Another obvious challenge is the limited and variable nature of aquifer fracturing.

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NEW DRAFT NATIONAL ENVIRONMENTAL MONITORING STANDARDS (NEMS) FOR FRESHWATER PERIPHYTON AND MACROINVERTEBRATES

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[2] Environment Canterbury
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[4] Waikato Regional Council
[5] Greater Wellington Regional Council
[6] Horizons Regional Council
[7] Northland Regional Council
[8] Environment Southland

The need for nationally consistent monitoring of our freshwater resources has never been stronger, a point hammered home with the Parliamentary Commissioner for the Environment's release of *Focusing Aotearoa New Zealand's environmental reporting system* in November 2019. The National Environmental Monitoring Standards (NEMS) is one initiative that is helping to improve the consistency and robustness of environmental monitoring. After an initial focus on hydrological and water quality monitoring standards, new draft standards on the collection and processing of periphyton and macroinvertebrate samples have been released for comment. These standards focus primarily on long-term State of the Environment monitoring in wadeable reaches of rivers but also provide guidance on sampling under the National Policy Statement for Freshwater Management (NPS-FM) and in relation to resource consents. Both standards were prepared by a multi-agency team comprising experienced science and monitoring staff across regional councils, crown research institutes and commercial laboratories. The standards revisit and will supersede existing sampling periphyton and macroinvertebrate protocols prepared by Biggs and Kilroy (2000) and Stark et al. (2001), respectively. They present protocols for: sample point selection, visit metadata, sampling equipment, on-site measurements, sample collection and handling, laboratory processing, and data quality assurance (QA) and archiving. A matrix-style scoring system is included to enable a quality code to be assigned to individual periphyton sample measurements and macroinvertebrate metrics taking into account key aspects of sample measurement/collection and laboratory processing that have the potential to influence data quality. This presentation will highlight the key requirements of the two draft standards.

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WATER, WATER EVERYWHERE: MUSINGS OF A BACKYARD HYDROGEOLOGIST

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1 Aqualinc Research Limited

While working on my 5 acre property on the outskirts of Christchurch, it occurred to me that I know next to nothing about the hydrological processes that impact the area, and also very little about any contaminants of concern, that might be problematic to my family.

Through the use of a number of known and accepted hydrological/hydrogeological methods, educated guesses and some rather sketchy back of the envelope calculations, I investigated the various components of the hydrological cycle within the boundaries of my property.

Some of the results, including an apparent reduction in groundwater nitrate concentration over time, an upward hydraulic gradient where groundwater levels were above stream level, and a thick clay pan below the soils, were pleasing. However, some aspects, including the possibility of stream contribution to our drinking water supply, the low level of aquatic life in the stream, and property development up-gradient, were more concerning.



NOW YOU CAN DO UQ TOO: IMPROVING ACCESS TO UNCERTAINTY QUANTIFICATION AND DECISION SUPPORT MODELLING TECHNIQUES

Hemmings, B.,[1] White, J.[2]
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[2] USGS

Aims

Numerical models are regularly used to inform management decision making. For such modelling applications uncertainty quantification and subsequent efforts to reduce uncertainty through assimilation of historical system observations are critical. Unfortunately, the uptake and use of uncertainty quantification approaches is often restricted by the complexity associated with applying these methods. This work aims to simplify the application of uncertainty quantification and data assimilation in numerical modelling for decision support, through the development of script-based, model-independent, semi-automated, python routines that facilitate the construction of PEST (Doherty, 2015) and PEST++ (Welter et al., 2015) model interfaces for a robust, rapid and repeatable decision support workflow.

Method

We have developed python-based routines, within the pyEMU (White et al., 2016) module to support model-independent PEST interface construction from native model input and output files. These routines work with array-type and list-type (tabular) ascii input files and automate the setup of model "parameters" and system data "observations" for PEST. The routines also construct the necessary directory and file structure (e.g. PEST template and input files) to undertake PEST-based parameter estimation and uncertainty quantification, including supporting definition of high-dimensional geostatistical parameter covariances, realisation sampling, and the application of ensemble-based history matching and uncertainty quantifications methodologies of PESTPP-IES (White et al., 2018).

Results

We present a worked example of the workflow required to construct and run a rapid uncertainty analysis that benefits from the traceability and reproducibility of the script-based approach. We show that these tools can be applied with minimal effort to a model with varied temporal and spatial discretization. The time and cost saving, and the reduction in cognitive load on the modeller, afforded by these methods means that uncertainty quantification can be undertaken earlier, more frequently, and more easily during the modelling workflow.

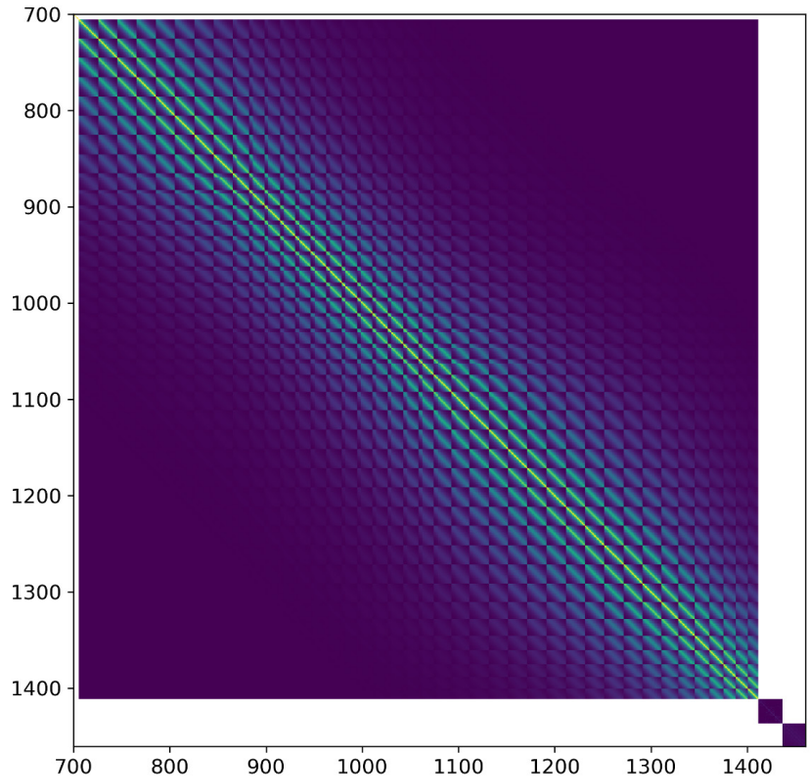


Figure 1. Example block-diagonal parameter covariance matrix constructed using pyEMU PEST interface construction methods.

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SHADING AND TEMPERATURE CONTROL FISH BIOMASS IN TARANAKI STREAMS

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[1] University of Waikato

Land use can control freshwater fish biomass in streams, with obvious additional driving factors such as barriers to migratory fish and distance from the sea. We compared paired sites in six streams on the Taranaki ring plain with one site in forest and one site in pasture for each pair. The sites were 1.7-3.5 km apart and all were within 19-46 km from the sea and 256-475 m elevation above sea level. Catchment areas upstream ranged from 2.48 to 9.15 km^2. A wide range of fish species was found, including brown trout, redfin and bluegill bullies, koaro, shortjaw kokopu, and lamprey, but the longfin eels that were found at all sites dominated the biomass (0.7 and 52.6 g m-2) Total fish biomass in pasture sites (mean 26.7 g m^{-2}) was four times greater than in forest sites (mean 6.2 g m^{-2}). Shortfin eels occurred at 3/6 forest sites and 4/6 pasture sites, and crayfish (0.1-26.6 g m^{-2}) were abundant at all sites.

Total fish biomass was most closely related to mean summer water temperature (r = 0.81), percentage dissolved oxygen (r = 0.75) and mean bank light intensity (r = 0.69), suggesting that primary production drove ecosystem productivity. Crayfish biomass, conversely, was most closely related to total nitrogen (r = 0.95). These results have implications for stream restoration that involves planting dense tree cover in riparian margins. Shading from established trees can be expected to reduce stream water temperature and light availability, which we predict will reduce fish production.

THE ROLE OF GEOMORPHOLOGY IN SUSPENDED SEDIMENT BUDGETS AND HOW CONTINUOUS SEDIMENT MONITORING CAN HELP US TELL THE STORY

Conn, S.,[1] Hitchcock, M.[2]
[1] Tonkin & Taylor
[2] Trustpower Ltd

Aims

Understanding suspended sediment loads in a data sparse catchment sees us often resorting to using small or inconsistent data sets to come up with a sediment budget.

In this study, we aimed to test the validity of a sediment budget developed in 2012 for a small reservoir which was developed from 22 grab samples from a source river over a 15 year period. We compared the 2012 sediment budget to continuous suspended sediment concentration data collected via an acoustic back scatter sediment sensor located in the source river in 2020.

We aimed to assess differences in sediment load calculations using continuous suspended sediment concentration monitoring sensors paired with grab samples, compared to only using grab samples.

Method

The sediment budget for a small reservoir was created in 2012 using grab samples taken over a 15 year period (1990-2005). Initially, a data set of 180 grab samples was collated to be used in the analysis, however 155 of these samples ended up being excluded as they were below a 2 g/m^2 threshold. The resulting relationship had wide scatter between the suspended sediment concentrations and flow adding significant uncertainty in the relationship

During a review of the geomorphology of the catchment, some inconsistencies in the understanding of the sediment regime over the period of 1990-2005 were identified, which called into question the validity of the sediment budget developed in 2012. As such, continuous sediment monitoring was established in 2020 to build a data set of sediment concentration entering the small reservoir over time. The focus was on fine sediments – sands and silts - carried in suspension under a range of flows and so an LISST acoustic backscatter sediment sensor was installed.

To explore the differences between the two data sets, the two sediment rating curves developed from both data sets were compared. The annual sediment loads developed through the sediment duration curve developed in 2012, and from the extrapolation of the continuous sediment concentration collected in 2020, were also compared.

Results

Sediment loads estimated from the two data sources were different, with the continuous suspended sediment monitoring producing a lower sediment yield than grab samples from the 2012 work.

The differences in the sediment loads could be driven by a number of factors, including climatic changes influencing sediment loads, geomorphic processes, differences in data set sizes, and differences in the temporal extents of the data sets.

From the 2012 sediment rating curve, it was estimated that the source river was contributing up to 75% of the suspended sediment into the small reservoir (1,182 t/yr), while the preliminary results from the continuous monitoring suggest it may be as low as 37% (618 t/yr). However, it should be noted that the continuous sediment monitoring only covers a five month period.

The results of the 2012 suspended sediment concentration (SSC) data set, when compared to the 2020 continuous results, suggest that both the small sample size used in 2012, and possibly elevated sediment levels in the river due to headwater landslides, may have skewed the rating curve, and consequently be over-estimating the annual sediment load entering the small reservoir. For example, based on the rating curves in Figure 1, a flow of 80 m3/s would equate to an estimated 90 mg/l of sediment based off the 2012 rating curve, and 40 mg/l based on the rating curve developed using the continuous monitoring data.

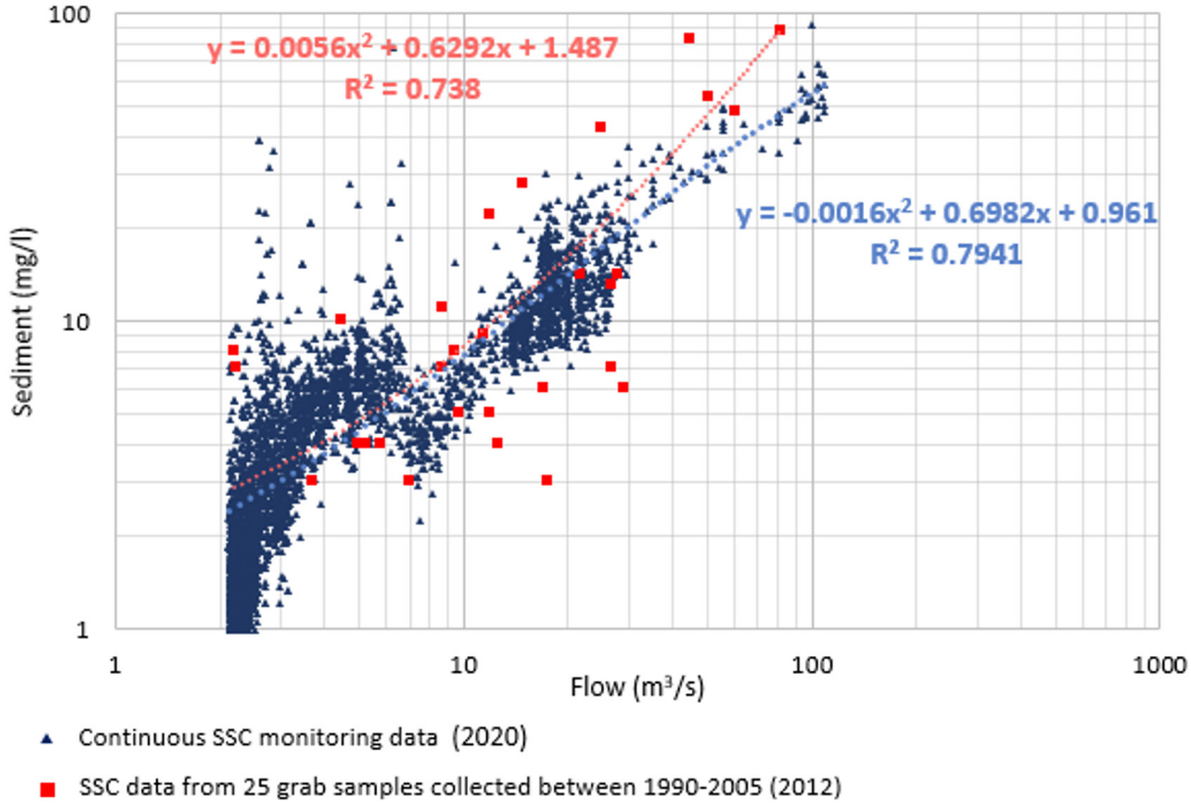


Figure 1. Comparison of SSC data analysed in 2012 but collected between 1990 and 2005 (red), and the continuous SSC data collected and analysed January to May 2020 (blue).

DYNAMIC CATCHMENT MODELLING (SWAT) WITHIN STEEP NORTH ISLAND HILL-COUNTRY CATCHMENTS

Hoang, L.,[1] Hughes, A.[1]
[1] National Institute of Water and Atmospheric Research (NIWA), Hamilton, New Zealand

Dynamic catchment models have capabilities of representing the dynamic behaviours of complex processes and help to gain insights about the complex catchment system where direct measurement are not always feasible at large scales. The Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998) is a multi-scale dynamic catchment model used to simulate catchment hydrology and water quality and predict the impact of implementing land use management practices. SWAT is widely used internationally but has seldomly been applied to New Zealand (NZ) catchments. Previously, SWAT has been successfully applied in the Toenepi catchment, a NZ typical dairy farming catchment and proved to be a potentially suitable model for intensively agricultural catchments in New Zealand (Hoang, 2019). Here we apply SWAT to three steep hill-country headwater catchments under differing land uses at the Whatawhata research Station. Availability of a 25 year water quality and hydrology record from the site makes this a ideal site for testing the model within a typical North Island hill-country farm environment.

Aims

In this study, we applied the SWAT model in three steep-hill country catchments with differing land use: (i) Whakakai, fully forested, (ii) Kiripaka, dominated by forest and pasture, and (iii) Mangaotama, dominated by pine plantation and pasture (Figure 1). The aim of this study is to assess the effect of land use change on streamflow and stream water quality of these steep hill-country catchment.

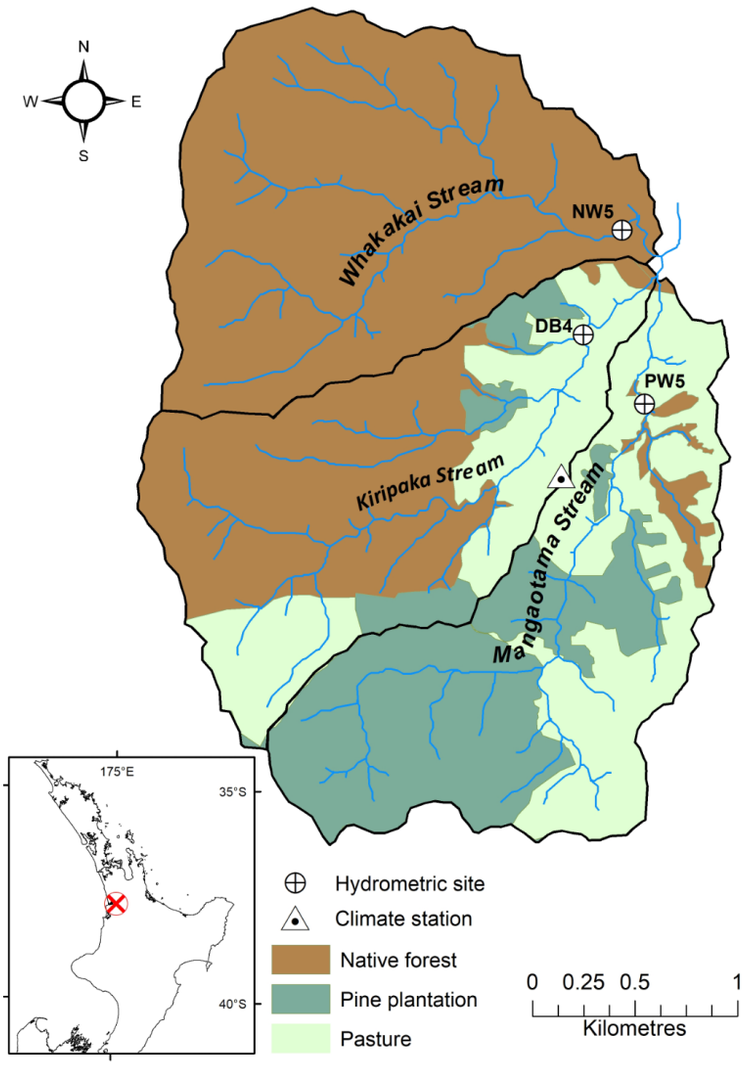


Figure 1. Three catchments with differing land use types at Whatawhata research station

Results

Preliminary results indicate that the SWAT model simulates catchment hydrology well at all three catchments (Figure 2). The daily Nash Sutcliffe Efficiencies (NSE) ranges from 0.71 – 0.79, and monthly NSE from 0.75 – 0.84 (NSE = 1 means "perfect fit"). The flow variation was very well captured, however, flow at some storm events were underestimated. The good water quantity prediction means that SWAT adequately represents hydrological processes in the study catchment and is likely to provide a sound basis for water quality modelling. Water quality calibration will be carried out and the effect of land use change on water quantity and water quality will be assessed.

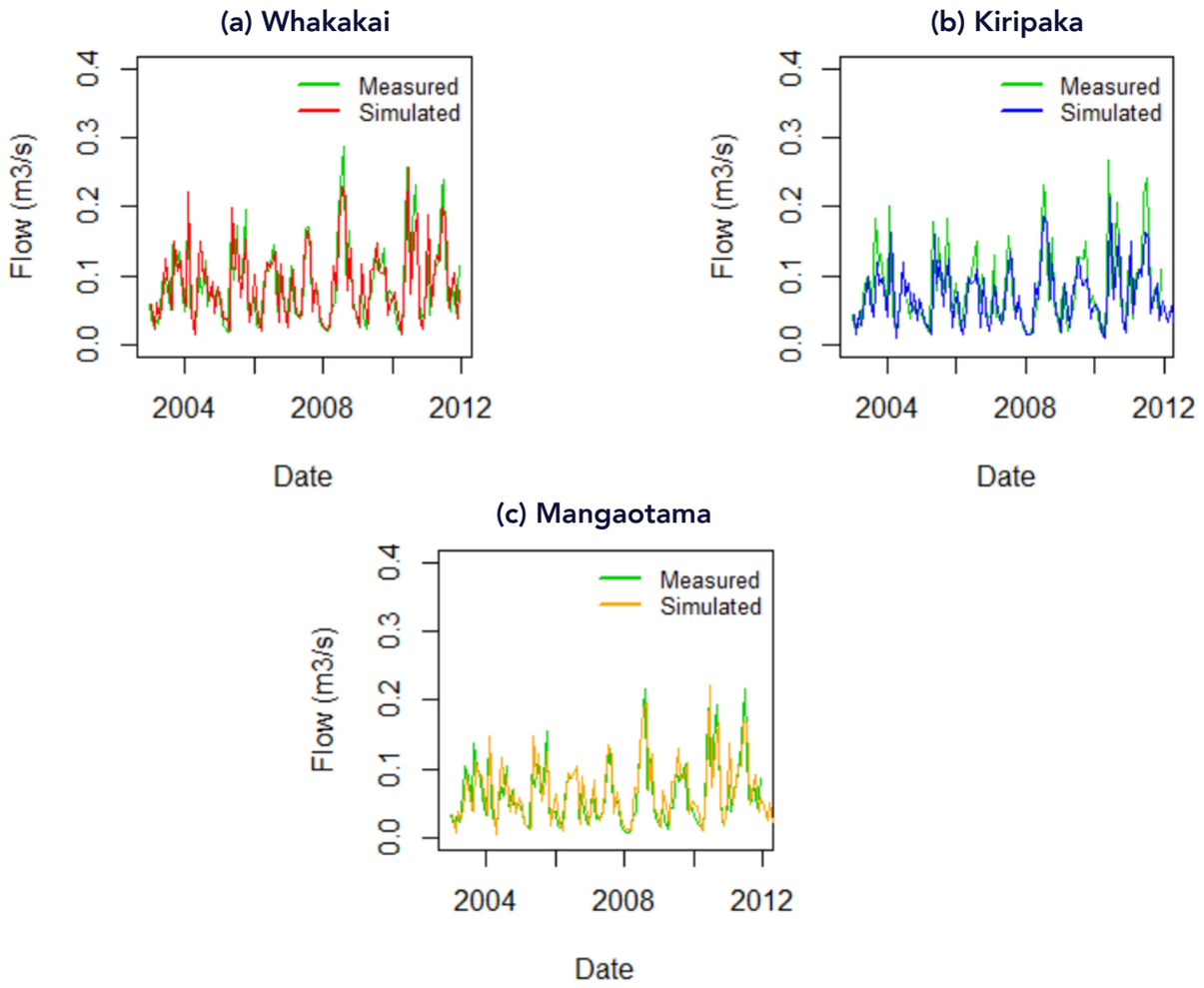


Figure 2. Comparison of monthly simulated and measured flow in the calibration period at three catchment outlets in the Whatawhata Research station

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EVALUATING THE PERFORMANCE OF A CONSTRUCTED WETLAND ON NITROGEN REMOVAL USING A LINKED CATCHMENT-WETLAND MODEL

Hoang, L.,[1] Sukias, J.,[1] Montemmezzani, V.,[1] Tanner, C.[1]
[1] National Institute of Water and Atmospheric Research (NIWA)

Nitrogen loading from diffuse agricultural source is a major worldwide problem. Constructed wetlands have been increasingly used to treat runoff and drainage from agricultural lands. The effectiveness of constructed wetlands is usually estimated based on measured flow and water quality concentration at the inlets and outlets of wetlands. However, where nitrogen loads coming from diffuse sources, it may be difficult to trace flow pathways and measure the direct input loading to wetlands. Modelling may be a useful technique to fill in this gap, which is demonstrated in the Owl Farm constructed wetland, Cambridge, New Zealand which receives drainage from dairy pastures.

Aims

This study aims at evaluating the effectiveness of the Owl Farm wetland in removing nitrogen loading from the upland dairy pasture using a modeling approach.

Method

Contaminant concentrations were measured at two inlet locations: a groundwater well, and a subsurface tile drain, and at the wetland outlet. The diffuse wetland inflow was not able to be directly measured, so it was estimated using a catchment model.

The modelling approach used in this study is a linkage between a catchment model and a wetland model (Figure 1). The catchment model estimates flow from the upland catchment area which is fed to the wetland model. The wetland model simulates movement of water through wetland cells and estimates the wetland outflow. The Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998) was chosen as the catchment model in this study. The wetland model was developed based on a simple water balance approach similar to that used by Tanner and Kadlec (2013). The simulated flow predictions were combined with measured nitrogen concentrations to estimate the nitrogen load removed by the wetland.

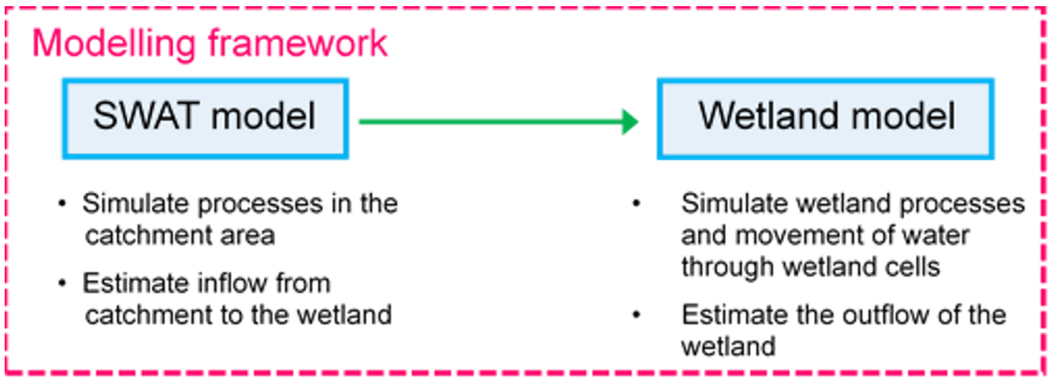


Figure 1. Modelling framework linking the catchment model (SWAT) and the wetland model.

Results

The linked catchment-wetland model can simulate the wetland outflow reasonably well, as shown by a good fit between simulated and observed flow (Figure 2) suggesting it provides a good representation of hydrological processes in the upland catchment and the constructed wetland. It proved useful for filling data gaps where there were gaps in field measurements.

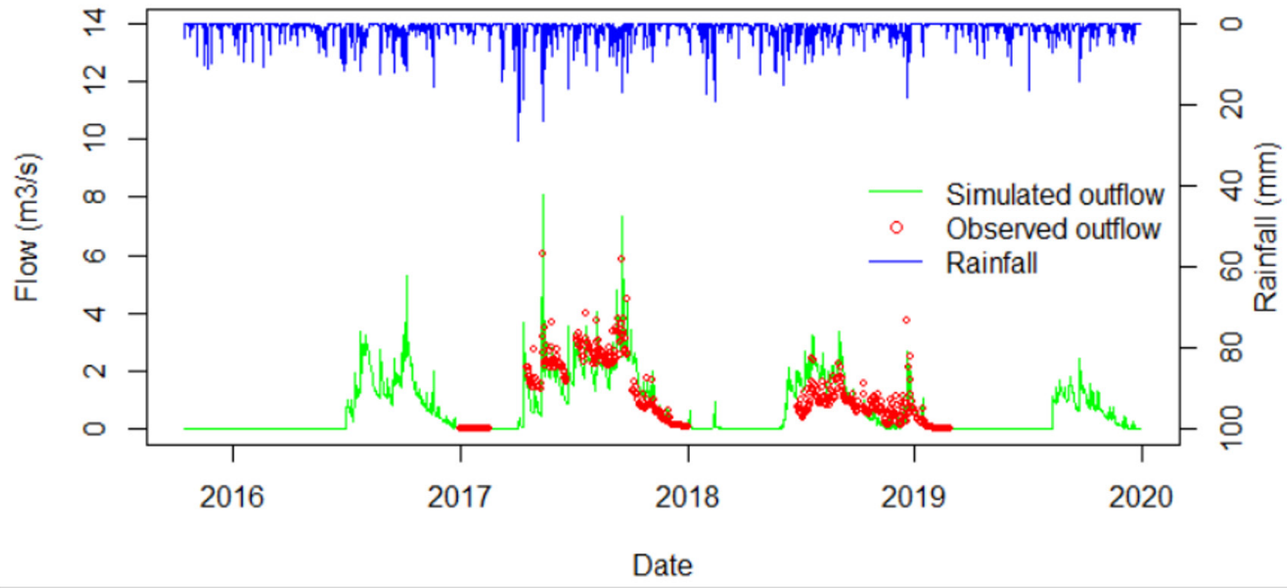


Figure 2. Comparison of simulated and observed outflow of the Owl farm constructed wetland.

We found that the percentage load removal for nitrate and total nitrogen (TN) were related exponentially to the wetland outflow rate with R^2 of 0.80 and 0.88, respectively (Figure 3). Based on the model estimates, the Owl farm constructed wetland is very effective in removing nitrate and TN with average estimates of 62% and 61% respectively. However, this capacity is very dynamic depending on the inflow from the catchment. The removal is very high at low flow, reduces when flow increases, but is still maintained at around 20% during higher-flow storm events.

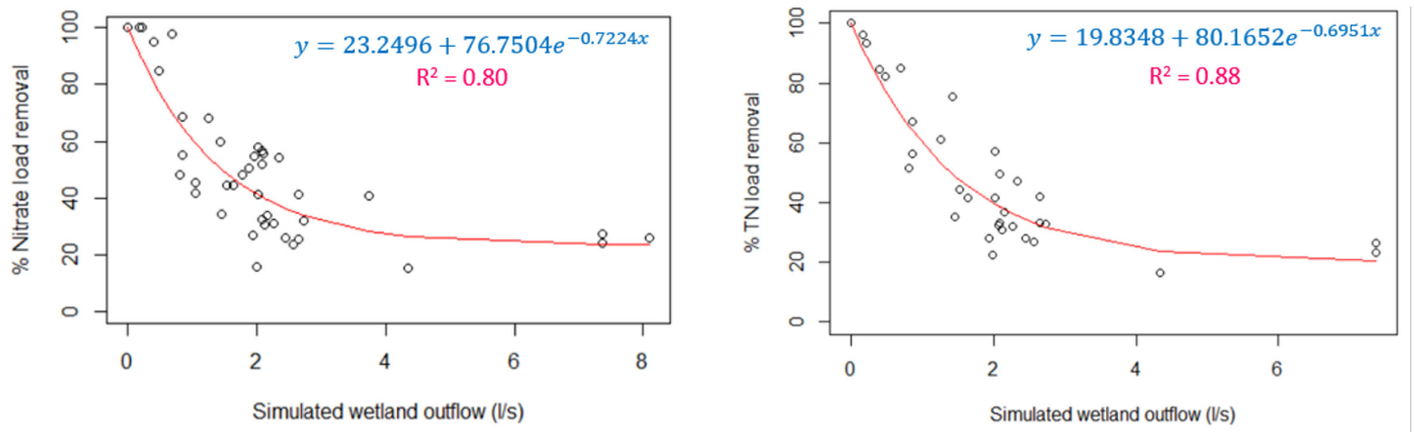


Figure 3. Relationship between percentage of nitrate and TN load removal and simulated wetland outflow.

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SCIENCE COMMUNICATION MATTERS: LESSON LEARNT FROM A NATIONWIDE LAKES RESEARCH PROGRAMME

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[1] Cawthron Institute
[2] GNS Science
[3] Victoria University of Wellington

Effective science communication is essential to ensure the full impact of research is realised. Successful science communication is challenging; it takes considerable time, effort and energy. Investment in science communication at the outset of a research programme will enrich science outcomes. This is achieved through enhancing meaningful interactions that allow the public, iwi and stakeholders to fully appreciate the research and its outcomes, and to learn from and trust one another.

This presentation highlights the science communication approaches utilised by 'Our lakes health: past, present and future' (also known as Lakes380), a 5-year MIBE funded programme. This presentation will reflect upon the challenges and triumphs of maintaining a high level of public engagement in conjunction with running a nation-wide field sampling programme and progressing a suite of research objectives.

FRESHWATER RESTORATION TRIALS (AND TRIBULATIONS): CREATING NATIVE FISH HABITAT IN A WAITUNA LAGOON TRIBUTARY

Holmes, R.[1]
[1]Cawthron Institute

Physical stream habitat restoration is commonplace overseas. Yet in New Zealand, stock exclusion fencing and riparian planting largely represent the extent of our attempts at restoring physical / structural habitat within waterbodies.

In this talk I describe an eight-year stream restoration trial in the main tributary of Waituna Lagoon, an internationally recognised RAMSAR wetland. The restoration trial involved creating a two-stage channel, planting low-stature riparian vegetation as well as the installation of large logs and compacted branch structures onto the stream bed. A 2-D hydraulic model was used to ensure the design channel and habitat structures did not impact the surrounding dairy farm. The ecological outcomes of the project are being followed annually with quantitative electric fishing using a Before-After-Control-Impact study design.

The response of the native fish population to-date has been promising, with at-risk and threatened species including longfin eels, lamprey and giant kokopu all increasing in abundance in the restored reaches relative to the control site. However, gaining consent for the trial was a protracted five-year process and numerous changes to the design were required. Despite this process the trial has been criticised by agencies responsible for bank erosion control and macrophyte removal. The perceived tensions between biodiversity values and land drainage need to be addressed in New Zealand before freshwater restoration projects, that include habitat manipulation, can become more commonplace.

ACOUSTIC DOPPLER DEVICES AND DATA NUANCES

Hook, P.,[1]
[1] Pattle Delamore Partners

Do you have hydrometric stations with complex hydrology? Issues with reverse flow and tidal water levels affecting your stage/discharge relationships? PDP may have the solution for you!

Acoustic Doppler Profilers (ADPs) are becoming increasingly utilised in remote environmental monitoring situations to enable stakeholders to understand complex flow relationships in real time. Pattle Delamore Partners (PDP) have installed and operated ADPs in a large monitoring network (covering a catchment area of 48,900ha) which include sites with complicated stage-flow relationships.

These monitoring locations, where loop ratings (Hysteresis) would have previously been used to understand the stage-discharge relationship, are now able to be accurately measured using ADP technology.

Hysteresis is complex and requires large amounts of time and therefore expense to determine an accurate stage/discharge rating,

Advantages of using ADPs include:

- Flow ratings can be used for other determining other relationships such as sediment flux;
- ADP automatically calculates the flow rate, which can be telemetered back to user providing near real time data;
- Reduced amount of time needed to develop a rating for the monitoring location;
- Can be a more cost-effective solution; and,
- If calibrated to gaugings and operated correctly, velocity indexing can be accurate to within 1%.

There are also a few disadvantages which show that this technology is not always fit for purpose i.e. in particularly weedy rivers.

This presentation will discuss in more detail a Whangamarino case study, detailing the advantages and disadvantages of using this technology and how this technology was used to provide real time sediment flux movement.

A REVIEW OF THE FLOW GAUGE NETWORK IN THE WELLINGTON REIGON

Hopkirk, C.L.,[1] Lockyer, C.L.[1]
[1] Cardno (NZ) Ltd

Aims

River flow data collected by regional councils and other agencies throughout New Zealand is used in a number of applications, including calibration and validation of flood hazard models (which in turn inform district planning and emergency management); state of the environment monitoring (which informs development of regional policy); scientific research; and compliance monitoring for resource consents, among other uses. The suitability of the application of these data across such a wide range of uses varies depending on the characteristics of each particular river flow station and the range of gauged flows over which the station's rating curve is developed.

A review of the flow gauge network in the Wellington Region has been undertaken on behalf of Greater Wellington Regional Council in order to improve understanding of the relative level of confidence in recorded high flow data for use in flood management studies, and to prioritise the allocation of resources for future high flow gauging.

The aims of this review were to:

- Determine the relative level of confidence in the high flow data collected at stations within the network.
- Determine the relative priority for collection of additional high flow gauging data at stations within the network to improve confidence in flows at the upper end of the rating curve.
- Identify constraints to high flow gauging and prepare a priority list for infrastructure improvements to facilitate future high flow gauging.

Method

A multi-criteria analysis approach has been used to determine the relative confidence in high flow data across the 59 rated stations within the network. Criteria used in this analysis included the ratio between the highest gauged flow and the mean annual flood as an indicator of whether the upper end of the rating curve is supported by data; and the stability of the control at the gauging station as a high-level indicator of the likelihood of major shifts in the rating curve. An equal weighting was applied to these criteria.

A further multi-criteria analysis was undertaken to determine the relative priority for the collection of additional high flow gaugings at stations within the network in order to improve confidence in high flow data. The development of a priority list will allow high flow gauging resources to be focused on key flood management stations where high flow gauging has been historically limited by available resourcing, mobilisation time, available infrastructure and the flashiness of many of the rivers in the region. Criteria used to determine relative gauging priority include the relative confidence in high flow data (where sites with low confidence have higher priority); known flood risk; upcoming flood hazard modelling in the catchment, and the of size downstream population centres.

A high-level audit of the available infrastructure for high flow gauging at each station has also been undertaken to identify where infrastructure improvements are required to facilitate priority gauging.

Results

The results of this review indicate that confidence in the high flow portion of the rating curve is low at a number of key flood management stations within the Wellington Region. Additional gauging during events greater than the mean annual flood is required to increase confidence. Relative confidence is generally higher at sites with good access and gauging infrastructure, stable controls, and in less flashy streams. Addressing access and infrastructure issues have been identified as key actions for facilitating future high flow gauging.

Priorities for future gauging and infrastructure improvements are centred around watercourses that have a known flood risk to populations and where upcoming flood studies that are informed by gauged flow data are programmed.

The finding that confidence in high flow data is low at a number of sites in the region highlights the importance of reviewing data used in the development of the rating curve when using rated flow data in flood management studies.

DEVELOPMENT OF A FLOOD HAZARD MODELLING STANDARD FOR THE WELLINGTON REGION

Borrer, S.,[1] Hopkirk, C.L.[2]
[1] Greater Wellington Regional Council
[2] Cardno (NZ) Ltd

Flood hazard models are a key tool used by the Greater Wellington Regional Council to investigate likely flood extents and hazard across a range of storm magnitudes at major watercourses within the Wellington Region. Outputs from flood hazard models are used to inform emergency planning and management, development of floodplain management plans and district planning.

A Flood Hazard Modelling Standard has been developed in order to provide a robust and consistent approach to all flood hazard modelling undertaken by or for the Greater Wellington Regional Council. The standard is a living document that is intended to evolve over time with changes in technology and industry accepted practice.

The Flood Hazard Modelling Standard is an end-to-end standard that covers the entire flood hazard modelling process from project planning and initiation to the delivery of model outputs. The standard is made up of seven procedures that address (1) project initiation and planning; (2) collection and review of all input data including hydrometric, catchment land use, topographical and historical flood data; (3) hydrological modelling; (4) hydraulic modelling; (5) peer review of hydrological and hydraulic models; (6) preparation of model outputs; and (7) independent audit of the project in its entirety.

The standard is intended to assist to improve community buy-in to the flood hazard modelling process by providing transparency of approach, enforcing a requirement for a technical peer review of hydrological and hydraulic modelling to be undertaken, and by requiring an independent audit to be undertaken at the end of a project to ensure that the standard has been followed appropriately. The standard also includes a minimum requirement for community consultation to be undertaken at three stages throughout the project.

HOW MANY SNAILS ARE TOO MANY? SUSTAINED HIGH DENSITIES OF TOLERANT TAXA IN POST-RESTORATION WATERWAYS MAY HINDER RECOVERY THROUGH PRIORTY EFFECTS

Hornblow, K.,[1] McIntosh, A.,[1] Warburton, H.[1]
[1] School of Biological Sciences, University of Canterbury

More successful restoration methods are needed for degraded waterways following declines in ecological diversity and ecosystem functioning associated with agricultural intensification. Many restoration projects improve physical conditions, but are unsuccessful in regaining sensitive macroinvertebrates. Failure to account for biotic interactions hindering recolonization could explain why some of these physical restoration methods (e.g. riparian planting, addition of in-stream habitat and channel reconfiguration) don't meet expectations. Tolerant taxa established in degraded systems may possess traits that allow them to persist at high densities even in post-restoration streams, thereby preventing recolonization of desired Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa. To investigate if sustained presence of a tolerant species could drive such priority effects, we manipulated densities of *Potamopyrgus antipodarum* in artificial stream mesocosms and measured effectiveness of EPT colonization over time. *P. antipodarum*, a native mudsnail, is tolerant of eutrophication and dominates agricultural waterways in Canterbury (typically, 1000 to 30000 per m^2). P. antipodarum density had a significant effect on EPT drift and cumulative colonization, whereby higher snail densities resulted in higher EPT drift rates and lower cumulative EPT colonization. We found a linear negative relationship between *P. antipodarum* density and final EPT colonization, where EPT colonization was significantly reduced from *P. antipodarum* densities of 2000 per m^2 upwards. Biomass of EPT started replacing *P. antipodarum* biomass in our three lowest density treatments, indicating a density threshold around 4500 *P. antipodarum* per m2, below which EPT colonization and establishment was more successful. This suggests an ecological baseline could be used for future restoration projects if methods to reduce densities of tolerant taxa can be devised. Overall, our results highlight that ignoring biotic interactions like priority effects could lead to restoration failure.

EFFECTS OF ARTIFICIAL SWEETENERS ON GROUNDWATER MICROBES

Houghton, K.,[1] Tschritter, C.[1]
[1] GNS Science

Emerging Organic Contaminants (EOC) are a range of chemicals which may be naturally occurring or derive from human activities, including pesticides, pharmaceuticals, artificial sweeteners and industrial compounds. They are often not monitored in the environment but there is growing global concern that these chemicals may have adverse effects on ecosystems and /or human health. Very little work has been done to determine the effects of these contaminants on microbes (or other wildlife), despite the importance of microorganisms in carbon and nitrogen cycles, bioremediation and the synthesis of useful products.

The aim of this preliminary study was to determine the effect of specific organic contaminants on groundwater microbes. Groundwater samples were collected and inoculated into culture media to promote the growth of either generalist or denitrifying bacteria. The cultures were then incubated with environmentally relevant concentrations of artificial sweeteners to discover adverse or beneficial effects of the chemicals.

The results show that some artificial sweeteners are toxic to certain groundwater bacteria but enhance the growth of other microbes, which means that the contaminants change the balance of the microbial community. This may affect food webs in an ecosystem, nutrient cycling or important chemical reactions carried out by bacteria, such as removal of nitrate. Further work needs to be done to improve our understanding of the environmental burden of EOC, and to establish methods to mitigate the predicted adverse effects on ecosystems and processes such as denitrification carried out by bacteria.

MANAGED AQUIFER RECHARGE PRE-FEASIBILITY FOR CENTRAL HAWKES BAY

Sinclair, B.,[1] Houlbrooke, C.,[1] Bower, B.,[1] Dench, W.,[1] Howell, C.[1]
[1] Wallbridge Gilbert Aztec

The Central Hawke's Bay (CHB) encompasses the Upper and Middle Tukituki and Waipawa River catchments and covers the geology and topographic features of the Ruataniwha Basin. Hawke's Bay Regional Council (HBRC) is working in the CHB to address challenges with respect to seasonally low surface water flows, protecting aquatic habitat, enhancing the security of surface water and groundwater supplies, maintaining and improving surface and groundwater quality and providing for increasing water demand.

HBRC is considering a wider integrated approach to the water management issues of the CHB. As part of this approach, Wallbridge Gilbert Aztec was commissioned by HBRC to conduct a pre-feasibility assessment for the application of Managed Aquifer Recharge (MAR) in the area.

Aims

The objective of the MAR assessment was to determine if a Groundwater Replenishment Scheme (GRS) could be an appropriate tool to help stabilize, restore and then help sustainability manage groundwater across the CHB for the primary purposes of:

- Improving groundwater storage levels and proactively managing aquifer sustainable yields, thereby providing potential economic opportunities.
- Increasing groundwater flows and thereby enhancing baseflows in rivers and spring-fed waterbodies and protecting aquatic habitats that are sensitive to low summer flows.
- Enhancing groundwater quality by introducing high quality water while managing risks to community and rural drinking water supplies.

Method

The pre-feasibility assessment was primarily performed as a desk-top review of information provided by HBRC.

Surface water monitoring data including hydrographic and water quality records were reviewed to evaluate seasonal water availability for use as source water for MAR sites. The layout of historical water supply races was reviewed to evaluate potential source water offtake points and gravity-flow distribution areas. Surface water quality data were then reviewed to confirm potential MAR source water obtained seasonally could meet nutrient criteria applicable to the CHB under the current Regional Plan, primarily linked to the management of nitrogen. Water quality parameters, including total suspended solids (TSS) and *E. coli* loads, were reviewed to confirm that operational measures incorporated in site designs could manage the risk of recharge system clogging and potential risks to water supply bores.

A lot of work has been done on the geology of the alluvial deposits in the Ruataniwha Basin, together with conceptual and numerical modelling of the associated aquifers, with extensive documentation of this work extending back over 20 years being publicly available. Drillhole geological, construction and hydraulic testing records together with groundwater level monitoring records and an assessment of groundwater age in the basin were reviewed to update past assessments of aquifer characteristics, groundwater level trends, potential water acceptance capacity and groundwater travel times within the aquifers. Groundwater quality data provided by HBRC were reviewed to assess the hydrogeochemical receiving environment for recharged water, together with the risks of chemical reactions leading to declines in groundwater quality or aquifer clogging.

Results

Two surface water allocation zones have been defined in the CHB catchment. Allocations limits for both zones include both a core allocation that is managed via the minimum flows, and a high-flow allocation (flow sharing) which is managed relative via high-flow minimum flows. The core allocations are fully allocated. At the time of the assessment a MAR trial ranging from 40 L/s (passive injection) to 200 L/s (including infiltration basins) could potentially be consented under the current high flow allocation regime. Further source water could potentially become available through other existing consents. The presence of extensive historical stockwater race networks across the basin demonstrates that source water delivery to MAR sites by gravity flow is achievable. Although these races have been decommissioned, some may still offer opportunities for water delivery to MAR sites.

River water quality at the upstream edge of the basin is generally good. Nitrate concentrations and *E. coli* counts generally increase in surface waters as the distance across the basin from the headwaters increases. NNN concentrations in most of the potential source waters are suitable for use in MAR. The *E. coli* counts in potential source waters are

generally within the ranges successfully managed by MAR projects elsewhere in New Zealand to avoid any risk to water supply systems. Observed TSS concentrations and loads are manageable through the appropriate design and operation of MAR systems. Overall, the quality of winter (non-irrigation) season water sourced from the rivers and streams in the western (headwaters) parts of the CHB does not represent a limiting factor with respect to the establishment of a GRS.

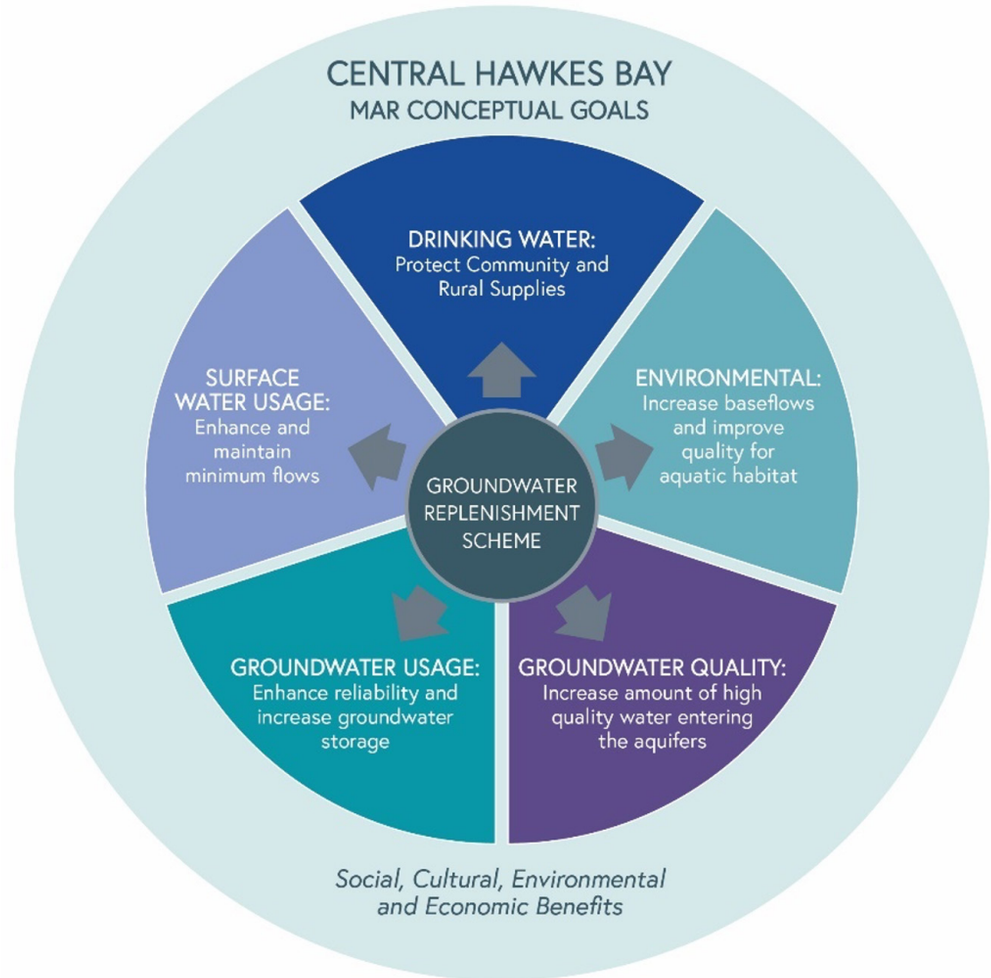
There are two alluvial aquifers recognised within the core of the basin; the shallower unconfined Young Gravels and the deeper semi-confined Salisbury Gravel. The Young Gravels Aquifer plays a key role in providing baseflows (quantity and quality) to spring-fed streams and rivers in the eastern portion of the catchment. The Salisbury Gravel Aquifer is the primary target for groundwater abstraction in the basin. Some monitoring wells in this aquifer are showing long-term pressure declines.

The recharge acceptance capacity of the Young Gravels Aquifer, which is linked to the depth to the groundwater table, decreases from west to east across the basin and approaching watercourses. However, give the unconfined nature of the Young Gravels Aquifer, the potential water storage capacity may be higher than in the deeper, more confined aquifer.

The Salisbury Gravel Aquifer recharge acceptance and storage capacity is locally limited by the confined nature of the aquifer and natural groundwater pressures that approach flowing artesian conditions. However, seasonal pumping for irrigation lowers the groundwater pressure and therefore presents targeted opportunities for enhanced recharge in the central area of the basin.

As the groundwater in the deeper semi-confined Salisbury Gravel is of high quality, the MAR water needs to be sourced and managed to ensure the groundwater is not degraded. This is most easily achievable using source water offtakes appropriately sited at the western edge of the basin.

Overall, the CHB contains a well-defined alluvial basin with a range of water management issues that are amenable to being addressed through enhanced recharge using good quality water. The outcomes of the pre-feasibility study indicate MAR can be applied in the basin as part of a wider integrated water management programme to help resolve many of the identified issues.



SUBSURFACE PROCESSES IN BRAIDED RIVERS – HYPORHEIC EXCHANGE AND LEAKAGE TO GROUNDWATER

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Aims

Braided Rivers contribute a major component of the groundwater in NZ's east coast plains. Despite their hydrological importance, little is known about how river-groundwater exchange processes actually occur. This lack of conceptual knowledge hampers our ability to predict rates of hyporheic exchange or recharge to groundwater.

Our new five-year MBIE-funded research programme aims to fill this knowledge gap by understanding subsurface saturation associated with braided rivers, and the physical processes of how they interact with their bed sediments. To achieve this aim, we have gathered a multidisciplinary research team with a wide range of NZ and international expertise.

The new conceptual knowledge gained from our research will enable the reliable quantification of hyporheic and parafluvial exchange fluxes and leakage rates to groundwater. Once this is achieved, we intend to understand the influence of river management interventions on different aspects of the river water balance.

Method

Three rivers for investigation have been chosen in conjunction with our respective regional council partners; Environment Canterbury (Selwyn), Marlborough District Council (Wairau), and Hawkes Bay Regional Council (Ngaruroro). The complex nature of the river morphology and hydrogeology requires that a combination of field methods be applied. Field installations consist of river stage/flow and piezometer installations, and horizontal direct drilling beneath the rivers. The horizontal drill holes are instrumented with passive and active fibre optic cable for passive and active distributed temperature sensing (DTS), and electrical resistivity tomography (ERT) cables. Field survey methods consist of capture of LiDAR and aerial imagery using a UAV, surveyed bathymetry, concurrent flow gauging runs, ground-based electromagnetic and ERT surveys, tracer studies (radon, temperature, salt), and substrate investigations (grain size and porosity analysis, trenching, sonic drilling).

Numerical quantification and hypothesis testing will be carried out using Hydrogeosphere, a modelling package to simulate fully coupled surface water-groundwater interaction, in variably saturated conditions. This will involve an interdisciplinary approach to modelling by both surface and sub-surface modellers.

Results

Work so far has focussed on establishing baseline data and field instrumentation in the Selwyn and Wairau rivers. We have established a stage/flow recorder in the Selwyn, three stage recorder sites in the Wairau, and piezometer networks in the riparian gravels of both rivers. UAV surveys have been carried out to collect aerial imagery and a full digital elevation model has been generated for both sites. Ground-based reconnaissance electromagnetic surveys have been carried out in collaboration with Aarhus University to map subsurface saturation in detail. A new approach to modelling resistivity data has been applied to generate preliminary surfaces of the water table for the Selwyn and Wairau rivers. Trial modelling of 2D profiles across the Selwyn and Wairau rivers with Hydrogeosphere has already begun. We hope to start reporting the results of our field investigations and preliminary modelling next year.

Key collaborators

In addition to the authors, New Zealand collaborators include Gu Stecca and Murray Hicks (NIWA), Patrick Durney and Antoine Di Ciacca (Lincoln Agritech), Leanne Morgan (Waterways Centre for Freshwater Management, University of Canterbury), Ngaio Tiuka (Ngati Kahungunu), Peter Tait and John Saunders (Agribusiness and Economics Research Unit, Lincoln University), Rosa Kirkham (Hawkes Bay Regional Council). International collaborators are Thomas Woehling and Moritz Gosses (Chair of Hydrology, TU Dresden), Eddie Banks (School of the Environment, Flinders University), Jesper Pedersen and Denys Grombacher (Hydrogeophysics group, Aarhus University).

CASE STUDY: STEAMFLOW DEPLETION EFFECTS OF RECORDED WATER ABSTRACTIONS IN THE WELLINGTON AND MANAWATU-WANGANUI REGIONS FOR THE PERIOD JULY 2015 TO JULY 2018

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This case study for two regions aims to establish a proof of concept for estimating the streamflow depletion effects of recorded water abstractions on streams at the regional level, and highlight the opportunities and existing barriers to wider implementation of the employed methodologies. It uses regional council daily time-series abstraction data and aquifer modelling to estimate the combined flow depletion effects of surface and groundwater abstractions on stream and river segments. For the subset of rivers and streams where river flow was measured by regional councils during the same period, regional council flow data was used to model the post-depletion flow volume in each segment. Summing the estimated flow depletion and the modelled post-depletion flow volumes for any point in time provides an estimate of what the river flow would be without the influence of the upstream abstractions. The estimated depletion volumes corresponding to these summed river flows were compared to determine the proportional flow reduction experienced by each segment. The results of these pending analyses will demonstrate the potential depletion effects of abstractions as a proportion of the total flow in rivers and streams, providing greater insight into the effects of individual and combined water abstractions on river networks. We will conclude with an assessment of the opportunities and barriers to developing this methodology for use by regional councils as an effective freshwater accounting tool to help satisfy the requirements of the National Policy Statement for Freshwater Management 2020.

ON-SITE WASTEWATER: OUT OF SHITE, OUT OF MIND

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There are more than 270,000 domestic on-site wastewater management systems (OWMSs) in operation throughout New Zealand (NZ), all discharging effluent that has undergone various levels of treatment, to the land. Such discharges present a hazard to groundwater quality. Whilst individual technical components of OWMSs have been systematically tested through controlled experiments at the On-Site Effluent Testing (OSET) facility in Rotorua, there remains little direct evaluation of the performance and environmental impact of OWMSs in uncontrolled operational settings in NZ.

Alluvial gravel outwash typifies much of the low-lying surficial geology on the South Island, NZ. We know the efficacy of such material to rank lowly at pathogen removal. Also, gravel aquifers tend to be poor at attenuating nitrate pollution. To evaluate the impact an operational OSWM has on the environment, we are undertaking a practical case study of a domestic OWMS sited over a shallow gravel aquifer in the Canterbury region. The objective is to monitor the treatment efficacy of pathogens and nutrients offered through the separate engineered components of the system, as well as the capacity of the natural undisturbed sediments to assimilate effluent. We are employing hydrogeophysical methods to map discharges from OWMS effluent drainage fields through the subsurface, and to determine residence times in the unsaturated zone, where most pathogen removal is assumed to occur. Results from the hydrogeophysical work are being used to guide the design of a groundwater monitoring network at the study site, as well as inform environmental risk assessment.

EFFECT OF HEAVY METALS ON PHENANTHRENE DEGRADATION IN STORMWATER USING LIGHTWEIGHT FILTRATION MEDIA

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Aims

This study investigated phenanthrene's removal in the presence of six different combinations of three heavy metals (Copper, Zinc, and Lead) in the lightweight filtration media mix. This filtration media mix is intended for low footprint applications such as suspended structures on buildings or under bridges for stormwater management.

Method

The media mix was spiked with phenanthrene aliquoted into 24x50 ml tubes and dosed with synthetic stormwater (11.2 mL) containing heavy metals (Zn, Cu & Pb) three times a week for four weeks. Seven heavy metals combinations were used (Table 1), and three columns were dosed with each combination. The effluent samples were collected weekly and analysed for phenanthrene and heavy metals. Media samples were evaluated weekly for phenanthrene levels.

Table 1: Combinations of heavy metals present in synthetic stormwater

Type	Phe (30 mg/kg)	Cu (100 µg/L)	Zn (1000 µg/L)	Pb (100 µg/L)
Control	+	-	-	-
1	+	+	-	-
2	+	-	+	-
3	+	-	-	+
4	+	+	+	-
5	+	-	+	+
6	+	+	-	+
7	+	+	+	+

Phe – Phenanthrene, Cu – Copper, Zn – Zinc, Pb – Lead

Results

The overall phenanthrene degradation for different combinations calculating the mass balance ranged from 71.7(± 9.6) to 90.4(± 8.4)%, with control with 87.5(±11.4)%. The mix with Pb (3) alone showed phenanthrene degradation up to 78.9(± 7.5)%. This may be because Pb, unlike other metals, does not play a significant biological role, and is considered toxic to microorganisms (Sobolev and Begonia, 2008). It is also reported that the presence of Pb significantly reduces the decomposition of complex hydrocarbons (Jensen,1977). Moreover, Pb, when present in combination with other metals ZnPb (5) and CuPb (6), also reduces phenanthrene degradation with reduction percentage as 78.9(± 8.5)% and 71.7(± 9.6)%, respectively.

The mix with a combination of CuZn (4) also showed a lower degradation rate of 77.7(±3.8)%. This can be accounted for the fact that a mixture of PAHs and metals depending on their nature and concentration, can show synergistic or antagonistic effects on enzyme activity and toxicity (Baltrons et al.,2018). Similarly, Zn alone (2) showed degradation of 71.0(±10.6)% which is also less than control, indicating it has a negative impact the phenanthrene degradation.

This maybe is because the presence of Zn leads to increase in detoxification of phenanthrene (Moreau et al.,1999). However, Cu alone (1) showed a positive impact on Phenanthrene degradation (89.0± 9.8)%), which is in line with the study performed by Zukauskaite et al. (2008), demonstrating that small concentrations of Cu can positively affect hydrocarbon-degrading population growth. Similarly, Sokhn et al. (2001) also showed microbial phenanthrene degradation in the soil in Cu's presence.

Furthermore, mix with CuZnPb (7) combination showed phenanthrene degradation of 90.4(± 8.4)%, which is slightly higher than the control. This is explained by Saison et al. (2004) who reported that the adsorption of phenanthrene on soil increases by adding metals (Cu, Zn, Pb), which is related to change in structural conformation of organic molecules in the soil. These interactions also have consequences on the mineralization of PAHs and their bioavailability.

Overall, Pb alone (3) and its combination mix (5,6), Zn alone (2) and CuZn (4) showed a negative impact on phenanthrene degradation. However, Cu alone (1) and CuZnPb (7) showed a positive effect on phenanthrene in our mix. There was significant evidence ($p<0.05$) that there is a difference for mix 1,5,6,7 from control in phenanthrene degradation.

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FISH SCREENING: HOW DO THE REGIONS COMPARE AND WHAT ARE THE IMPLICATIONS FROM NEW RESEARCH?

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During the last decade there has been increasing interest in issues relating to water quality and quantity and this has also resulted in increased recognition around environmental issues relating to water infrastructure. This recognition has seen a resurgence in interest at a national scale to improve the outcomes for fish that interact with water infrastructure (e.g., intakes and fish screens associated with irrigation schemes). To gain an understanding of what requirements regional councils have on new and existing water abstractors around New Zealand we examined regional plans to identify fish screening requirements. This highlighted variability between regions as well as questions and knowledge gaps around what constitutes an effective fish screen. The effectiveness of novel fish screens, screening materials and aperture has now been examined in a series of experiments on both native fish species and sports fish. The results of these experiments will be synthesized in this presentation which has implications for future fish screening guidance and regulation.

PRODUCTIVE RIPARIAN BUFFERS

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[2] NIWA

The Productive Riparian Buffers (Sustainable Farming Fund) project is exploring which plant species can be usefully grown along waterways for productive as well as environmental benefits. Stock-excluded riparian buffer zones are not usually considered a productive part of the farming system. However, we have identified a wide range of riparian planting options that can potentially contribute to environmental gains for adjacent waterways while also delivering a productive return, for example as an on-farm input or as the basis for novel business ventures. Some examples include: herbaceous feed and silage crops; fuel and bioenergy; tree fodder; timber; fibre (e.g., flax); honey production; fruits or nuts; essential oils or medicinal products.

Under the guidance of two farmer groups in Northland and Waikato and a number of experts in the fields of silviculture, agroforestry, agronomy and land management, we have further explored some of the potential challenges as well as beneficial uses of particular plant species. We will share the results of our harvesting trials showing the potential for species such as Tōtara to provide multiple products - from essential oil to high quality timber - at different stages of their life cycle, and discuss the challenges for mechanical harvesting in riparian buffer zones. We will share the early results of our investigations into the potential fodder value of a range of species; and for ensiling tree fodder from coppiced willows. We will also provide insights into the costs and benefits of some of the species we have explored in more depth.

ADVANTAGES OF FLEXIBLE MESH SUB-GRID SAMPLING 2D MODELS IN ASSESSING FLOOD HAZARDS DUE TO DIKE BREACHES

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Flood hazard assessments for dike protected communities require comprehensive understanding of both hydraulic and geomorphological hazards caused by dike breaches. The 2-Dimensional (2D) flexible mesh hydraulic models with sub-grid sampling features are well-suited for such assessments, especially for highly braided rivers and streams of complex morphology. The flexible mesh enables refined delineation of important bathymetry and terrain features such as channel anabranches, river training structures, dike crests and alignments, and secondary flood barriers; the sub-grid sampling feature allows larger cells to be used for floodplains to considerably reduce run time yet retain the higher resolutions of input digital elevation models (DEMs).

This study comprises two case studies. The first case discusses the application of a calibrated hydraulic model developed with HEC RAS (V 5.0.7) in determining designated flood construction levels (FCLs) and assessing flood hazards due to twelve (12) dike breaches in a western Canadian city. In the Canadian city application, the 2D domain comprises an approximately 70 km long river reach and nearly 900 km^2 of floodplain; for such extended modelling domain, deliberate model mesh construction techniques such as adopting refinement regions and extensive use of breaklines are vital for optimizing model accuracy and efficiency. The same modelling approach is applicable for the flood assessments of many New Zealand cities sheltered by floodbanks. In the second demonstration case, the same mesh construction techniques will be applied to an uncalibrated hydraulic model of the Clutha River from Balclutha to Molyneus Bay based on the publicly available digital surface model (DSM) without bathymetry. This proof-of-concept model of Clutha River serves as a local example to corroborate the benefits of the flexible mesh with sub-grid sampling modelling approach.

ASSESSING EFFECTIVE PASTURE ROOT DEPTH FOR IRRIGATION SCHEDULING BY WATER BALANCE MODELLING

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Aims

The root depth of pasture that is used for irrigation scheduling has substantial implications in estimating irrigation requirements. Field experiments were undertaken at the Lincoln University Dairy Farm (LUDF), Christchurch, New Zealand to improve estimates of the effective root depth of ryegrass pasture (Lolium perenne) based on a water budget study in non-weighing percolation lysimeters.

Method: Twenty non-weighing lysimeters and Aquaflex soil moisture sensors installed at the LUDF were utilized for the study. The lysimeters used for the study were installed in two groups, with 10 lysimeters in each group (Figure 1). The distance between adjacent lysimeters was 1 m, and the distance between the two groups of lysimeters was 50 m. The Aquaflex was 100 m away from the first lysimeter in the second group. The Aquaflex consisted of two sensors, one was installed at an inclination from the soil surface to 200 mm soil depth and the other was installed horizontally at 500 mm.

Actual evapotranspiration (ETa) was calculated by applying the following standard water balance equation to the lysimeter data:

$$ET_a = P + I - DP - \Delta SM \quad (1)$$

Where, ET_a = actual evapotranspiration, P = precipitation, I = irrigation supply, D = deep percolation, and ΔSM = change in soil moisture content during the time interval (one day in this case). Units of all variables are in mm.

A rain gauge was installed near the lysimeters to measure precipitation (P) and irrigation (I). Deep percolation (D) was measured by an individual container connected to each lysimeter. The weighted mean of the Aquaflex top and bottom sensor readings (Equation 2) were utilized to estimate soil moisture of the soil mass considered in the water budget equation for the lysimeters data.

$$\theta_D = \theta_1 \times \frac{d_1}{D} + \theta_2 \times \frac{d_2}{D} \quad (2)$$

Where Θ_D = soil moisture of D mm soil column based on Aquaflex top and bottom sensor readings, d_1 = top soil depth covered by the top sensor reading (Θ_1), and d_2 = bottom soil depth covered by the bottom sensor reading (Θ_2).

ET_a was calculated by considering 500, 600 and 700 mm vertical soil depths in the mass balance equation. To estimate the soil moisture of a 500 mm soil column, d_1 = 350 mm and d_2 = 150 mm were applied in Equation 2. Likewise, for the soil moisture of a 600 mm soil column, d_1 = 350 mm and d_2 = 250 mm, and for the soil moisture of 700 mm soil column, d_1 = 350 mm and d_2 = 350 mm were used, respectively. Reference evapotranspiration (ET_r) was estimated using CropWat 8, a soil-plant-atmosphere model (Smith, 1992), based on climate data collected from Broadfield weather station, 3 km NE from the LUDF. The single crop coefficient approach was used to develop relationships between crop coefficient (K_c), actual evapotranspiration (ET_a) and reference evapotranspiration (ET_r). Since crop coefficient varies with crop growth stages (Allen et al., 1998), K_c was estimated at different grazing stages. Pasture height (in cm), as a representation of crop growth, was measured for each of the 20 lysimeters on a daily basis. This produced a relationship between K_c and pasture height for different grazing stages.

Results:

Individual lysimeter measurements are point measurements, representing measurements of ET_a at only one location in the farm from 0.2 m^2 surface areas. It might not be justifiable to extrapolate the result from one lysimeter to large areas. Results from one group of 10 lysimeters represent one particular field's characteristics. Therefore, to represent wider field conditions all the data measured for the 20 lysimeters were lumped together as one group. To identify the relationship between K_c and pasture height 'h' (in cm) we tested linear, power and exponential curve fittings, where the linear relation was the preferred option. Figure 2 (a) represents the linear relation between K_c and h developed based on 500 mm soil depth with regression coefficient (R^2 = 0.43). Figure 2 (b) demonstrates the linear relation between K_c

and h developed for soil depth of 600 mm with regression coefficient (R^2 = 0.35). Figure 2 (c) shows the linear relation between K_c and h developed for 700 mm soil depth with regression coefficient (R^2 = 0.24). The low R^2 is attributed to the effect of soil moisture in the water budget equation. For all 20 lysimeters the same Aquaflex soil moisture information was applied as it was the only available option. In fact, such constraints are obvious upon many irrigated farms. The result clearly showed that the 500 mm soil depth considered in the water budget equation improved the R^2 for the K_c - h relationship. This indicates that in this farm the pasture root depth that plays major role in the water budget occurs predominantly in the top 500 mm soil. Thus, irrigation needs for this farm should be calculated based on 500 mm depth, which has the potential to reduce applied irrigation, improve irrigation efficiency and reduce leaching of nutrients to our water bodies.

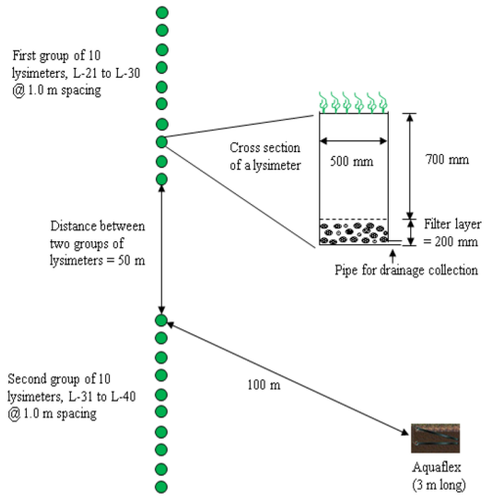


Figure 1: Equipment set-up in the field with cross-section view of a lysimeter. Source: (KC,2016)

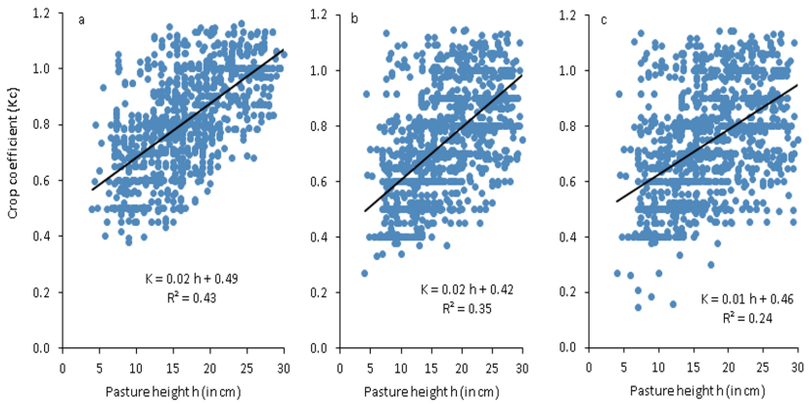


Figure 2: Linear relation between crop coefficient and pasture height, under 500 600 and 700 mm soil depth, respectively. Source: (KC,2016)

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SNOW STORAGE ESTIMATION SYSTEM FOR THE UPPER RAKAIA RIVER

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Background

River water is harvested from two tributaries of the Rakaia River to augment Lake Coleridge. This water is used for hydro-electric generation and for irrigation storage. Unlike most other large hydro-electric reservoirs in the country, high flows are not harvested. This constraint increases the importance of the contribution of baseflow to its operation. A significant contributor to baseflow for several months of the year is snow melt. Snow melt is restricted by the size of the snowpack, so there is a seasonal forecasting opportunity if the magnitude of the snowpack can be determined. Direct measurement of the snowpack is problematic, but an index of its size is possible from measurements of rain and temperature.

Aims

To provide a daily estimate of the snow in two Rakaia River sub-catchments.

Method

A computer model was prepared (in the R scripting language) that kept a daily account of the snow in each of the catchments. Each day the snow storage was adjusted based on the amount of snow fall and snow melt that was estimated to have occurred. Daily snow was accumulated everywhere that precipitation occurred in sub-zero temperatures. Snow melt occurred at a rate proportional to the temperature above zero (a degree-day approach).

Spatial precipitation and temperature data were required for the model operation. The spatial temperature data were prepared by applying an elevation lapse rate to observed temperature. Similarly, spatial precipitation was prepared by scaling a mean annual precipitation map to daily precipitation observations. A new precipitation map was prepared for this purpose from all available rainfall records, particularly those in Griffiths and McSaveney (1983) which reported on the findings of the Rakaia precipitation measurement transect of the 1970's.

The calculated snow indices were considered most valuable as a relative measure that may be compared to previous years. To enable a long record of the index to be prepared, 30-year daily time series of precipitation and temperature data were created for each of the observation sites. This time series extension was carried out through correlation with nearby sites.

Forecasts of the snow indices were provided by running the model forward in time using the last 30 years of weather data. This provided a spread of 30 possible futures.

The snow storage estimates and forecasts were provided via a Shiny® web application.

Results

As implemented, the system is simple, efficient, and is automatically updating each morning by 6:30 am. If required, it could be applied relatively quickly to any region.

The system was commissioned prior to the start of the 2020 snow season. The snow estimates were lower this year than for any of the previous 30 years. Anecdotally, natural snow fall has been very low this year with many ski fields not opening (as of 23rd August).

The median of the range of the forecast snow melt for November 2020 is (as of August 23rd) well below the long-term median.

The system has provided an objective, evidence-based estimate that the contribution of snow melt to the baseflow of the tributary catchments is likely to be well below average this year. This has provided advance notice for water managers to plan accordingly.

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PERCH (PERCA FLUVIATILIS) INDUCED TROPHIC CASCADE IN TWO EUTROPHIC NEW ZEALAND LAKES – A BIOMANIPULATION PERSPECTIVE

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Abstract

In many eutrophic lakes, nutrient control has been undertaken, but restoration success clearly requires additional measures. Biomanipulation is a complex restoration technique requiring detailed assessments of key species phenology and specific trophic linkages.

We studied two monomictic and relatively small but deep and eutrophic lakes. Lake Hayes exhibited clear water state in some recent summers indicating recovery after decades of nutrient control and accidental establishment of a non-indigenous *Daphnia pulicaria*. Therefore, we hypothesize that in Lake Hayes, high water clarity in occasional summers was achieved due to *D. pulicaria* persistence but in other summers which exhibited more typical phytoplankton blooms, the clear water state could not be achieved due to high recruitment of juvenile perch, which potentially control *D. pulicaria* populations in the lake.

To test this hypothesis, we sampled littoral and pelagic phytoplankton, zooplankton and fish communities alongside physico-chemical parameters. We aimed to ascertain intra-annual variation in the communities and at which time of the year perch were potentially able to induce a trophic cascade. We combined classical techniques of community abundance and gut contents, stable isotope analysis and fatty acid methyl esters analysis. Significant ontogenic shifts in perch feeding niche widths were observed. Larval perch in late spring and summer are exclusively pelagic and zooplanktivorous, precipitating a shift from *Daphnia* dominance to dominance by smaller *Bosmina* and *Copepods* zooplankters. Our results show that biomanipulation has great potential to alleviate phytoplankton blooms, but must be targeted either at perch spawning or at larval populations during spring.

WORKSHOP: TE MANA O TE WAI IMPLEMENTATION IN THE SOUTHLAND FRESHWATER OBJECTIVES PROCESSES

Cain, A.,[1] Kitson, J.,[2] Bartlett, M.,[3] Norton, N.,[4] Wilson, K.[5]
[1] Kauati Ltd, Tāhuna/Queenstown, Waitaha, Kati Mamoe, Ngāi Tahu
[2] Kitson Consulting Ltd, Waihōpai/Invercargill, Ngai Tahu ki Murihiku
[3] Te Ao Marama Incorporated, Waihōpai/Invercargill
[4] Land Water People, Ōtautahi/Christchurch
[5] Environment Southland/Te Taiao Tonga, Waihōpai/Invercargill

The term Te Mana o te Wai was instigated in the NPS-FM 2011 and has evolved to be the foundation of freshwater management in New Zealand. While this term is not specifically used by Ngai Tahu ki Murihiku, the paradigm of providing for mauri and health of the waterbody is embedded in mātauranga ki Murihiku and echoed in the iwi management plans, policy and expressions passed down from past generations.

Environment Southland in partnership with Ngai Tahu ki Murihiku have embedded ki uta ki tai and Te Mana o te Wai in the proposed Southland Water and Land Plan (pSWLP). Te Mana o te Wai puts the spotlight on water and land rather than human use and consumption, and it is ki uta ki tai that holistically binds and integrates all elements. The pSWLP "embodies ki uta ki tai and upholds Te Mana o Te Wai and they are at the forefront of all discussions and decisions about water and land." pSWLP-Second interim decision of the Environment Court.

In the pSWLP, ki uta ki tai is designed as the overarching prinicple in which Te Mana o te Wai, including hauora (health), is enabled. Ki uta ki Tai reflects the mātauranga that all environmental elements are connected and must be managed as such.

Ongoing Treaty Partnership is required to meaningfully work within this bicultural framework based on ki uta ki tai to realise Te Mana o te Wai in Southland's freshwater management. This requires the respectful melding of science and mātauranga (including Ngai Tahu indicators of health), community and Ngai Tahu values in all freshwater management processes.

The presenters have worked together to combine these elements, for the draft Southland Murihiku freshwater objectives and they will share the evolution of this process. The workshop will consist of 3 talks and a panel discussion

- **Ki Uta ki Tai, Te Mana o te Wai, Mauri and Hauora –Ngai Tahu ki Murihiku and Southland context.**
  What do these concepts mean, their hierarchy and how these concepts are implemented in the pSWLP, Alisa Cain lead presenter. 15 mins presentation with 5 min questions
- **Application of Hauora in developing the draft Southland Murihiku Freshwater**
  Objectives – the hauora principles used, incorporation of Ngāi Tahu indicators of health and the process for the team to attain a common understanding. Jane Kitson and Maria Bartlett lead presenters. 15 mins presentation with 5 min questions
- **Incorporating mātauranga and science to inform the freshwater objective process.**
  The development of narrative and numeric attributes and an envelope approach for defining science and hauora-based options for numeric objectives. Ned Norton and Karen Wilson lead presenters. 15 mins presentation with 5 min questions
- **Facilitated panel discussion:** Panel includes: Ned Norton, Jane Kitson, Maria Bartlett, Karen Wilson and Ailsa Cain. Facilitator: Joanne Clapcott. 20 mins.

References:

National Policy Statement for Freshwater Management 2011
[2020] NZEnvC 93 Aratiatia Livestock Limited vs Southland Regional Council

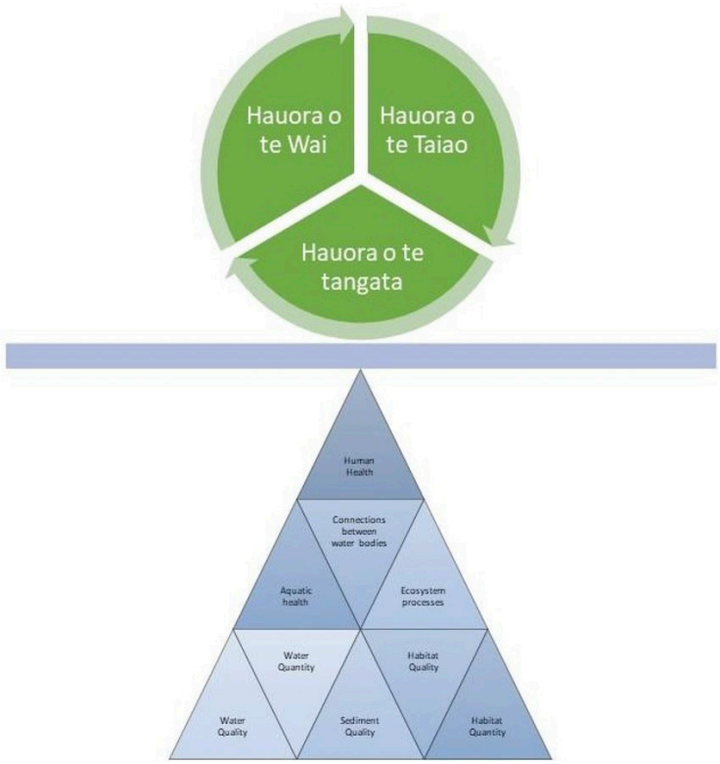


Figure 1: Holistic balance of components upholding Te Mana o te Wai [Murihiku Southland]. Ki uta ki tai holistically binds all the components.

Speaker Bios:

Maria Bartlett: Senior Advisor at Te Ao Marama Inc with a background in strategy, policy and planning within regional council and as part of the Ngāi Tahu tribal structure over two decades, particularly focussed on local government relationships with manawhenua, freshwater management and planning for climate change response.

Ailsa Cain: Waitaha, Kati Mamoe, Ngāi Tahu (Murihiku). Cultural heritage professional with research interests in at-risk heritage, and the continuation of cultural practices and associations/connections with place. Director of Kauati Ltd, a consultancy that uses historical sources to inform environmental planning and policy, strategies and decision making.

Dr Jane Kitson: Ngāi Tahu ki Murihiku. Ecologist and environmental scientist with research interests in freshwater, mahinga kai and cultural monitoring. Director of Kitson Consulting Ltd, that links values and science to support mana whenua in their environmental management aspirations and needs.

Ned Norton: Environmental scientist and resource management consultant specialising in water and land multidiscipline science-informed policy development process. Director of LWP Ltd, a consultancy providing technical science, economic, policy interface and process advice to assist sustainable management of New Zealand's natural resources.

Karen Wilson: Team Leader – Science, Strategy & Design, Environment Southland. Environmental scientist with research interests in freshwater, resource management and social sciences.

Facilitator Bio:

Dr Joanne Clapcott: Ngāti Porou. Freshwater ecologist with research interests in integrated freshwater assessment frameworks and indicators. Team leader at Cawthron Institute and co- lead within the BioHeritage National Science Challenge with a focus on strengthening the relationship between people and te taioa to regenerate thriving and sustainable ecosystems.

HE PUNA WHAKAATA O MĀTAURANGA: A VISUALISATION TOOL FOR THE MURIHIKU CULTURAL WATER CLASSIFICATION SYSTEM TO ENABLE ARTICULATION OF REQUIRED STATES FOR CULTURAL USES

Kitson, J.,[1] Cain, A.,[2] Williams, E.,[3] Young, R.,[4] Blair, S.,[5] Whaanga, D.,[5] Johnstone, M.,[6] Skerrett, M.,[6] Murihiku Runaka Advisory Group[7]

[1] Kitson Consulting Ltd, Waihōpai/Invercargill, Ngai Tahu ki Murihiku
[2] Kauati Ltd, Tāhuna/Queenstown, Waitaha, Kati Mamoe, Ngāi Tahu
[3] NIWA/Taihoro Nukurangi
[4] Cawthron Institute
[5] Te Ao Marama Incorporated, Ngai Tahu ki Murihiku
[6] Ngāi Tahu ki Murihiku kaumātua
[7] Representatives of Hokonui Rūnaka, Te Rūnanga o Ōraka-Aparima, Waihōpai Rūnaka and Te Rūnanga o Awarua.

Rivers, lakes, estuaries, wetlands and other waterbodies continue to be a critical element in the way of life and identity for Ngāi Tahu. Historically, there was a direct correlation for Ngāi Tahu between the state of the water, what it was used for, and peoples' associations and values with that water. For generations, concerns have been raised by rūnanga about the changing shape and quality of the waterways. As the mauri and wairua of Murihiku waterbodies have declined, there has become a disjunct between state, use, association and value. Various legislative mechanisms require that tāngata whenua values are protected by freshwater management processes occurring at national, regional and local levels, including in the NPSFM 2020. However, in general, Aotearoa-NZ freshwater management approaches are struggling to recognise and protect cultural values/uses in a climate of multiple conflicting demands.

The Murihiku Cultural Water Classification System (MCWCS) was developed to strengthen cross- cultural understandings about Murihiku cultural values, and their water-related dependencies – as defined by the Murihiku Rūnanga Advisory Group – in a robust, respectful, and meaningful way. In this framework, Kitson et al. (2018) bring knowledge together from various disciplines (including mātauranga Māori, social science, science and cultural heritage) around different cultural value/use thematics that are of importance to Murihiku whānau, beginning with Wai Pounamu, Wai Nohoanga and Wai Tuna. This has never been done before across all the thematics currently included in the MCWCS.

The MCWCS was able to bring together the knowledge generated by a variety of qualitative and quantitative tools to more accurately reflect the current state of cultural uses. Murihiku whānau were also able to define the targets (what is good and what is bad) that the monitoring data was assessed against and ground-truth the resulting aggregated scores for each thematic.

Most of the data remains with the kaitiaki whānau and has not been published. The exclusion of certain knowledge is a deliberate decision by the research team to ensure kaitiaki whānau retain control over how the information is interpreted and reused when shared in the public domain.

He Puna Whakaata o Mātauranga is the "outward facing" visualisation tool to help communicate the site-specific impacts of the current environmental state on Murihiku cultural uses to external parties. Its structure varies for each cultural use and the colours relate to the site assessment scores. This tool can communicate the site-specific impacts of the current environmental state on cultural uses to external parties and internal management processes, across a range of management applications, including restoration, policy and planning, monitoring and research, consents, non-regulatory tools and conservation management.

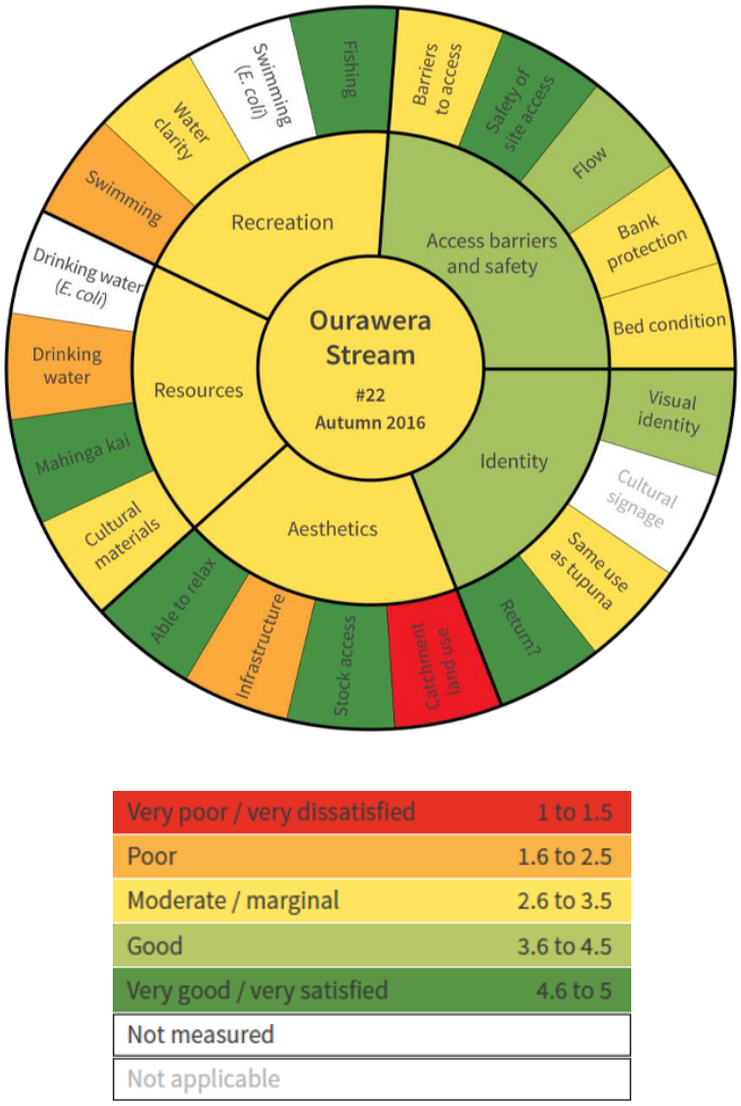


Figure1: He Puna Whakaata for Wai Noho at Ourawera Stream (Site 22, Autumn 2016).

References:

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Speaker Bios:

Dr Jane Kitson: Ngāi Tahu ki Murihiku. Ecologist and environmental scientist with research interests in freshwater, mahinga kai and cultural monitoring. Director of Kitson Consulting Ltd, that links values and science to support mana whenua in their environmental management aspirations and needs

Stevie Blair: Ngai Tahu ki Waikawa me Wairewa. Iwi environmental advisor at Te Ao Marama Inc [the resource management agency for Southland Murihkiu rūnaka]. Stevie has strong interests in mahinga kai and supporting whānau in the management of their taonga to continue their links to cultural practice.

A CANTERBURY FLOOD FORECAST MODEL USING GRADIENT BOOSTING MACHINE LEARNING

Kittridge, M.,[1] Martin, A.[1]
[1] Environment Canterbury

Aims

Floods in New Zealand cost tens of millions of dollars property loss and these costs can grow significantly when major cities are impacted (MfE, 2004). To help alleviate the impact and prepare for these events, flood forecast models are used to estimate the magnitude and timing days before the flood events occur.

In Canterbury, Christchurch has been flooded in the past by the Waimakariri River. This has happened several times from the mid-1800s to the early 1900s. Consequently, major flood protection measures were undertaken which included stop banks along the river and monitoring of both flows and rainfall. Once advanced computing was available, flood forecasting became another valuable tool to add to the existing flood forecasting measures. The original flood forecasting model for the Waimakariri River was built in 1990 (reference) and had been upgraded through the years until late 2018 when it was decommissioned. Now with further advances in statistical algorithms in the form of machine learning, new flood forecasting models can be built and run more easily than ever. The aim of this project was to build an accurate flood forecasting model using a Gradient Boosting machine learning algorithm for the Waimakariri River that could be applied to other major rivers in Canterbury.

Method

The model forecasts high flows at the Old Highway Bridge (OHB) on the Waimakariri River and water level upstream at the gorge. The model was built in Python using a Gradient Boosting algorithm from the Scikit-Learn toolset. The model was trained and tested using hourly precipitation from three upstream stations using data from 12-36 hours in the past as input. The training used the full range of flows (and water levels) and were not transformed as this combination was found to produce the most accurate results. Approximately 80% of the data was used for training and 20% for testing. In operation, the model uses telemetered precipitation if available and forecasted precipitation from the New Zealand MetService and the Norwegian Met Institute (YR.no) for three days following the model run time. Precipitation was only used as input to the model to reduce dependencies like that of a functional telemetry network during a major flooding event.

Results

From the model testing, the top 20% highest flows at OHB has a mean absolute normalized error (MANE) of 29% and the top 20% of the water levels at the gorge has a MANE of 10%. This model type is relatively easy to set up and run in many existing catchments providing accurate results requiring only precipitation as input. The main limitations to this modeling type are that it does not extrapolate beyond the input data and it would only be applicable for datasets with long records that have captured many high flow events. This flood modeling method could be applied to any river in Canterbury with a sufficiently long record of flow (or water level) with a similarly long record (or estimate) of precipitation for training the model.

References

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CONSTRUCTED WETLANDS AT A LANDSCAPE SCALE: EXPERIENCE FROM TE AHURIRI

Farrant, S.,[1] Ko, S.[2]
[1] Morphum Environmental Ltd
[2] Environment Canterbury

Whakaora Te Ahuriri wetland is an ambitious project to restore ecological, cultural and social values through the construction of a large wetland system on land previously drained to support agriculture. The site is located where the margins of Te Waihora/Lake Ellesmere once met the freshwater input of the Huritini/Halswell River within the large flat gradient catchment in the Canterbury Plains. With an intent to improve water quality from upstream agricultural inputs, support mahinga kai uses and reinstate 'lost' biodiversity values, the design and construction followed a collaborative process to reflect the vision of the Te Waihora Co-Governance Group to work closely as iwi, central and local government, industry and the wider community, to restore the mauri of Te Waihora/Lake Ellesmere.

The project includes the re-connection and restoration of 550m of the remnant Huritini/Halswell River channel (cut off since 1913) and the conversion of a 4-hectare grazed paddock to a constructed wetland where over 130,000 aquatic and terrestrial eco-sourced indigenous plant species help filter nutrients from the water and return biodiversity to complement other catchment-wide initiatives. Flow controls installed at the inlet and outlets enable manipulation of flowrates through the wetland to support the complex mix of physical, chemical and biological processes which will deliver the long-term water quality improvements.

The design and construction of a large-scale wetland on a flat gradient catchment presented a number of challenges which needed to be worked through. These included a careful balance of cut and fill to manage potential impacts on flooding, design of hydraulic controls and wetland bathymetry to pass a controlled flowrate through the system and a well-considered earthworks and construction strategy to avoid too much disturbance of the soil which was highly responsive of the river and groundwater levels and quickly became unworkable with too much vibration. Long-term, Te Ahuriri wetland will support a study of the effectiveness of constructed wetlands in terms of both Matauranga Maori and 'western' science to contribute to the progressive improvement of New Zealand's freshwater lakes and estuaries.

This project, which was completed in May 2020, serves as an example with shared understanding for iwi, scientists and engineers on the role of constructed wetlands in our future landscape and how through integrated design we can return wetlands to the landscape in a manner which mitigates landuse impacts on receiving environments.

Note
There are two other abstracts on this project – regarding the project's collaboration and relationships management, and the project's Mātauranga Māori monitoring programme – which, if all were accepted, we thought would be of interest for the audience if they all could be back-to-back in the same session.

THE FRESHWATER FORWARD POLICY PROGRAMME MOVING INTO 2021 AND BEYOND

Buckle, S.,[1] King, J.[1]
[1] Ministry for the Environment

The regulation of freshwater reformed substantially in 2020, with the enactment of the new National Policy Statement on Freshwater Management (NPS-FM), National Environmental Standards for Freshwater (NES-FW), stock exclusion regulations, and updated regulations on the measurement and reporting of water takes. These reforms set the base for the freshwater forward policy work programme as we move into 2021. Sam Buckle (Deputy Secretary, Water Policy and Resource Efficiency) will provide an overview of this work programme as it stands at early December 2020, and then give a strategic overview of the wider policy environment. James King (Senior Analyst, Fair Allocation) will then provide further detail on the work programme, and provide some insights on how to best to engage with the Ministry for the Environment over the next term of government.

LUXURY NUTRIENT UPTAKE BY PERIPHYTON EXPLAINS DIEL VARIATION IN DISSOLVED OXYGEN AND INSTREAM NUTRIENT CONCENTRATIONS

Kuczynski, A.,[1] Chapra, S.C.,[2] Lewis, C.,[3] Rutherford, J.C.[1]
[1] National Institute of Water and Atmospheric Research
[2] Tufts University
[3] The University of Birmingham

Nuisance and toxic periphyton growth pose great threats to human and ecosystem health, with *Microcoleus* making headlines by causing dog deaths. Predictive attached algae models are developed to synthesize science and provide credible advice to ecosystem managers. However, the predictive capacity of those models is often poor when growth is simulated solely as a function of extracellular nutrient concentrations. The objective of this work is to demonstrate that observed diel variations in instream nutrient and dissolved oxygen concentrations can be represented by a simple model when luxury nutrient uptake, i.e., excess internal nutrient storage, is included as a model mechanism. Droop kinetics consider the effect of internal nutrient stores (the cell quota) on nutrient uptake rates, where high stores suppress uptake and low stores enhance uptake rates. The Droop formulation was applied to enhance the Delta method (Chapra et al. 1991), a simple approach for estimating primary production, respiration, and reaeration in streams, to now also simulate instream nutrient concentrations. The model was calibrated and confirmed using hourly measurements of dissolved nutrient concentrations, conductivity, pH, temperature, and dissolved oxygen in New Zealand rivers. This work supports the need for inclusion of a luxury nutrient storage mechanism in primary production models of streams.

NEW ZEALAND RIVER FLOW FORECAST: BIAS-CORRECTION USING FLOW DURATION CURVES

Lagrava Sandoval, D.,[1] Cattoën, C.,[1] Conway, J.[1]
[1] NIWA, Christchurch

Aims

The New Zealand river flow forecast research project produces categorical flow forecasts at national scale, with 48-hour lead time, for approximately 60,000 river reaches including gauged and ungauged catchments (Cattoën et al., 2016). The categorical forecasts (e.g. above normal, well-above normal) are determined from uncalibrated raw streamflow simulations that are converted into relative values (e.g. 0-100%) using Flow Duration Curves (FDC), generated from long-term flow simulations at each river location. While the categorical information is useful to stakeholders, producing unbiased absolute flow forecasts (e.g. flow in m^3/s), remains a grand challenge. The objective of the current work is to prototype a system to generate absolute flow forecasts by adapting an FDC bias-correction procedure (Farmer et al. 2018).

Preliminary forecast verification statistics indicate that this FDC bias-correction improves predictions of absolute flow at gauged sites (Conway et al., 2020). To extend and generalise this approach, we have curated data for ~400 sites around the country, including Regional Council sites. In addition to analysing the performance of our approach at these sites, Machine Learning (ML) is applied to generalize the FDC correction methodology to produce bias-corrected absolute flow forecasts for ungauged catchments.

Method

The New Zealand river flow forecasting system is based primarily on the surface hydrology component of the New Zealand Water Model (Cattoën et al., 2018), NIWA's framework for national river flow modelling. River flow forecasts are produced by coupling NZWaM's hydrology model to NIWA's high-resolution (1.5km) convection-permitting numerical weather prediction model, NZCSM. The hydrological model is semi-distributed (Clark et al., 2008), and is based on TOPMODEL processes (Beven et al., 1995) to model the physical processes at a sub-catchment scale. To be consistent for gauged and ungauged catchments, the model is not calibrated.

To create bias-corrected absolute timeseries, the exceedance probability (relative to a 'simulated' FDC created from a 40-year simulation) of each point in a simulated timeseries was matched to that absolute flow of the same exceedance probability in an 'observed' flow FDC (Figure 1). These 'observed' FDC can be generated from historical timeseries at gauged sites or estimated using ML techniques.

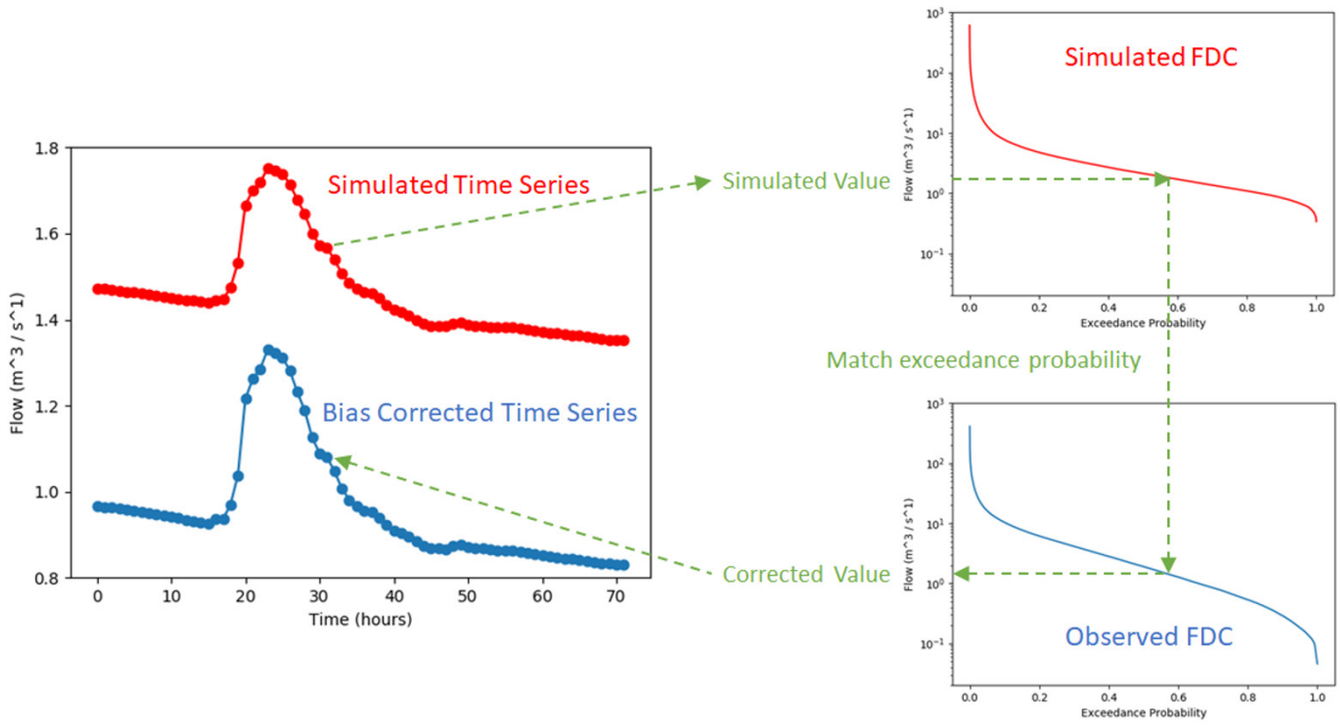


Figure 1: Bias correction of simulated time-series by using an observed FDC

In the first part of the study (forecasting at gauged sites), we created estimated 'observed' FDC from observed flow time-series for a set of ~400 selected sites. We tested and produced several types of FDC from the time-series:

- all-time: using all the data available to estimate the probability of exceedance
- per-decade: dividing the data on periods of 10 years and provide a different FDC for each period
- per-month: dividing the data by month. For each month produce a different FDC.
- Seasonal: dividing the time-series data by season. Generate an FDC for each season

We investigated the impact of each type of FDC on the absolute forecast values generated by comparing them to the observations available. The bias-correction routine was applied automatically as part of the generation of our results so absolute values can be conveyed to users.

For the second part of the study (forecasting at ungauged sites), we generated synthetic estimated 'observed' FDC for ungauged sites using ML techniques. We compared two techniques for the generalization: 1) Random Forest based generalization (Booker et al., 2012) and 2) Multioutput Neural Networks (Worland et al., 2019). The ML synthetic estimated FDC were validated on the observed set. Finally, we generated synthetic FDC for each of our test sites and studied the performance of the absolute values with respect to the observed flows and of using the real estimated FDC.

We will present results of this FDC bias-correction approach, its application to national-scale river flow forecasts, and discuss future steps and directions.

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CO-CREATION OF FRESHWATER MANAGEMENT PLANS: THE CASE STUDY OF LAKE WANAKA

Langhans, S.D.,[1,2] Schallenberg, M.[2]
[1] BC3 – Basque Centre for Climate Change, Leioa, Spain
[2] University of Otago, Dunedin, New Zealand

Public participation is an effective way to resolve the tensions between contested values and objectives, while maintaining ecological integrity. New Zealand is one of the few countries that takes a collaborative approach to environmental management, mandating that management plans for catchments are co-created with local communities. The National Policy Statement for Freshwater Management (NPS-FM), and more specifically the National Objectives Framework, give guidelines on objectives and attributes that must be considered to safeguard freshwater values. They also specify minimum quality standards, but allow communities to set higher standards and to add more objectives. A critical challenge in this process is to successfully account for potentially conflicting objectives in a framework that supports decision-making. Little guidance on this is provided in the NPS-FM, which leaves the challenge to the Regional Councils to overcome. We present a participatory decision support approach based on multi-criteria decision analysis (MCDA) that allows the weaving together of different values, objectives and, therefore, different ways of knowing. The strengths of the MCDA-approach are that it i) is transparent, ii) allows for the whole range of community values to be quantified and accounted for, and that it iii) can ultimately be used to prioritise cost-effective management actions with collective buy in. We illustrate how we implemented the MCDA-approach to develop a catchment management plan for the Upper Clutha catchment (Central Otago). This implementation of the MCDA-approach provides valuable insights to help foster its successful use in other catchments across New Zealand.

CLIMATE CHANGE ADJUSTMENT OF LONG TIME SERIES RAINFALL

Law, M.[1]
[1] Beca Ltd

Aims

With varying degrees of uptake over the last twenty years, flood modellers, river engineers and others have been taking account of climate change in our assessments, modelling and designs. We have been building climate resilience before it became a buzz word in the media.

Whether it be a blanket 20% increase in rainfall and (as promoted by the UK's 2001 'Development and Flood Risk' planning policy guideline 25) or more refined recent assessments from NIWA and Ministry for the Environment (MfE) here in New Zealand, our focus has been on extreme events; those severe storms that test the performance of stormwater infrastructure and stopbanks, for example. However, apart from an acknowledgement that we will experience more droughts, we have paid little attention to what effect climate change will have on 'normal rainfall'; those rainy days that do not result in flooding. There seems to have been little effort put into developing pragmatic tools and guidelines that can be used to quantify the effects on normal rainfall. But with the growing recognition of the pressures on water resources and the value of natural and artificial wetlands, we need to understand how climate change will affect long time-series rainfall and flows, not just extreme events.

MfE's ***Climate Change Projections for New Zealand*** (MfE 2018) predicts that while extreme rainfall depths and intensities will increase with climate change, annual rainfall totals are expected to change by only a few percent. This means that simple scaling of long time-series rainfall is not an option. To generate long time-series rainfall for rainfall runoff modelling and continuous stormwater simulation, we need to accommodate those increases in storm depth and intensity, while reducing the frequency and magnitude of low-normal rainfall so that annual rainfall does not change significantly.

This presentation focuses on a pragmatic approach to generating climate adjusted rainfall time-series for use in water resource investigations and continuous simulation for stormwater modelling. The author has developed a simple model to do this that does not require access to climate models and simulation, and so can be used by practitioners with limited time and resources.

Method

The approach developed uses the increases in extreme rainfall predicted in MfE 2018 to adjust recorded rainfall depths for extreme events. A linear relationship (Figure 1) is then used to adjust the rest of the daily rainfall record to account for the predicted effects of climate change. The slope and intercept of the linear relationship is informed by the requirements to ensure that the adjusted rainfall record meet the annual or seasonal changes in mean precipitation reported in section 3.6.1 of MfE 2018.

A spreadsheet model has been developed to generate the daily climate adjusted rainfall time-series, with the model interface allowing the user to choose which residual concentration pathway (RCP) to use.

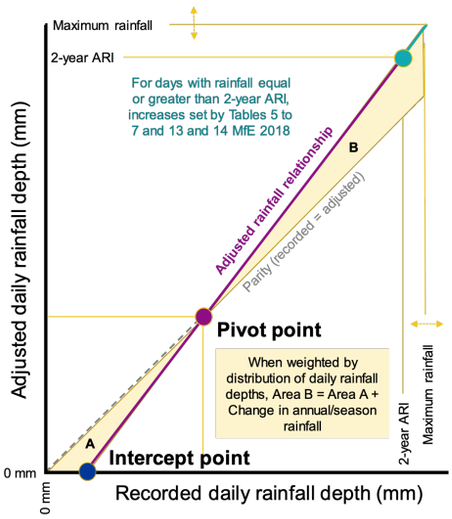


Figure 1. Approach to rainfall adjustment

The model uses recorded or simulated rainfall data over a minimum period of one-year, though longer time-series would improve the robustness of the results. As well as the adjusted time-series (Figure 2), the model results include rainfall duration tables and curves. The results presented show that for the dataset tested days with more than about 10 mm of rain will see an increase in rainfall in the future, while days with less than 10 mm of rain currently will see a reduction in rainfall depth. This 'Pivot' (Figure 1) rainfall depth varies depending on the change on mean precipitation, as does the 'Intercept', which is the current daily rainfall depth below which there will be no rainfall in the adjusted rainfall series.

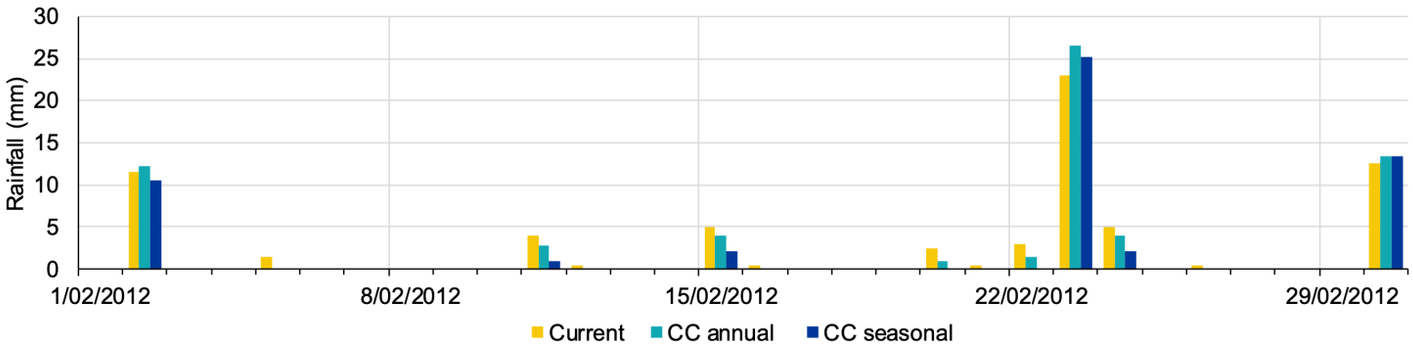


Figure 2. Recorded and adjusted rainfall time-series

As shown in Figure 3, there will be an overall reduction in the number of rainy days and the contribution of rainfall from days with heavy rainfall (>20 mm for this dataset) will increase.

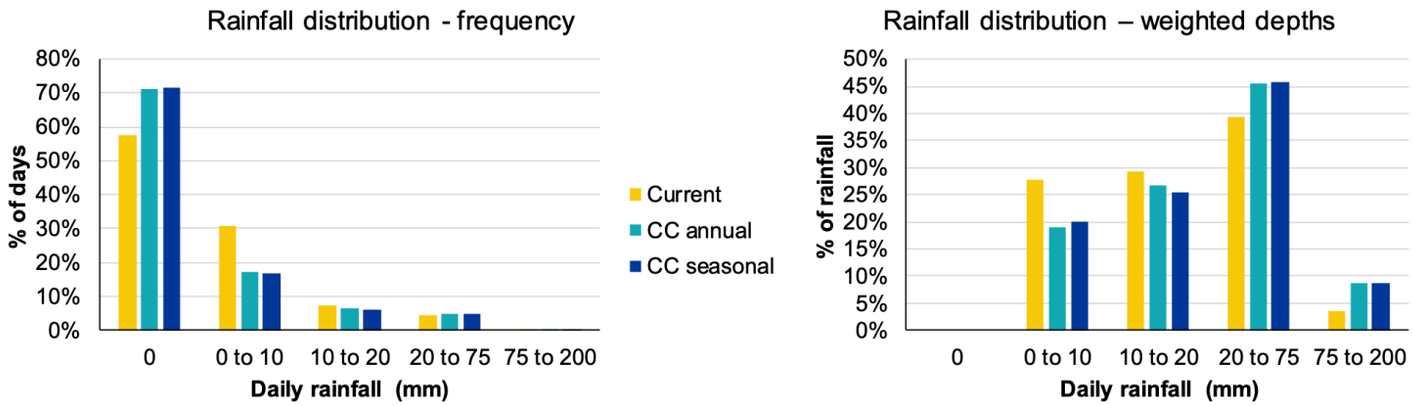


Figure 3. Recorded and adjusted rainfall distributions

Using the adjusted rainfall time-series as inputs to a rainfall-runoff model indicates that:

- Peak flows will increase.
- Mean flows will increase by about the same amount as the mean precipitation change in annual rainfall.
- Median flows decrease, while there is little change in FRE3 (three times median flow) flows and frequency.
- Mean Annual Low Flow (MALF decreases as the reduction in low-normal rainfall and fewer rainfall days results in longer, and deeper flow recessions.

The approach and model is a new development, and the author is keen to receive feedback on its applicability and perceived robustness in parallel to science based approaches, as well as whether there is an appetite for using/adjusting sub-daily data in the model, and on other initiatives in this space.

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STATE OF THE ENVIRONMENT GROUNDWATER QUALITY DATA FOR OTAGO

Levy, A.,[1] Ettema, M.,[1] Lu, X.[1]
[1] Otago Regional Council

Groundwater has various uses across Otago. However, in contrast to the extensive aquifers in other regions, Otago only contains several regional aquifers. This paper summarises results from Otago Regional Council (ORC)'s groundwater quality State of Environment (SoE) monitoring. The data spans between the start of monitoring of each SoE bore and 31/12/2019. The results were evaluated against drinking water (E. coli, arsenic, nitrates) and ecosystem health standards, where nitrate, DRP, and ammonia concentrations from bores <20m deep were assessed against the NPS-FM and the Regional Plan limits for receiving water bodies.

The results show that, similar to surface water, groundwater quality in Otago is highly variable, with good groundwater quality measured in some FMU/rohe (e.g. the Upper Clutha Lakes) and degraded water quality in others (e.g. Lower Clutha, North Otago). E. coli, high nutrient concentrations, and elevated dissolved arsenic concentrations in some bores were the main issues reported. Poor groundwater quality results can be attributed to land use (e.g. intensive farming, septic tanks) and local factors (shallow, poorly-secured monitoring bores). Elevated arsenic concentrations were attributed to the prevalent schist lithology in the Upper Clutha/Wakatipu area.

Nutrient concentrations commonly exceed Otago's Regional Plan limits/NPS-FM standards, particularly in areas of intensive farming (e.g. North Otago) and rapid development (e.g. Glenorchy, Kingston). Elevated groundwater nutrient concentrations can adversely impact surface water quality, particularly in catchments dominated by groundwater-surface water interaction. Potential mitigation measures include increased education activities and regulatory policies to improve bore security, reviewing land use policies, and augmentation/replacement of unsuitable monitoring bores.

REFORM OF VOCATIONAL EDUCATION AS AN OPPORTUNITY TO REFORM THE STATE OF MICROPLASTICS QUANTIFICATION IN NEW ZEALAND

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Aims

Microplastics are plastic particles smaller than 5 mm and have been found in our food, water, and even in the most remote places on Earth (i.e. Antarctica). The majority of literature on plastic pollution is focused on the marine environment and only one study in New Zealand has quantified microplastics present in waterways despite evidence suggesting that rivers contain the highest concentrations of plastic pollution. A further complication is the variation in the methodologies of sample collection, quantification, and identification, which are not yet standardised, making it difficult to compare findings. Using tested methodologies from existing literature (e.g. Liedermann et al., 2018; Masura et al., 2015), our project adapts and employs a straightforward, inexpensive, and accessible standard operating procedure (SOP), which has successfully been used to quantify microplastics in Invercargill waterways (Edginton et al., in press). The SOP involves quick and easy sampling techniques, as well as equipment and chemicals that are generally available in a tertiary level chemistry laboratory. The goal is to present a simple and standardised approach that can be easily applied by other schools or tertiary students, empowering communities through environmental education and addressing the paucity of nationwide data on microplastics in waterways through citizen science. By first quantifying the state of microplastic concentrations in New Zealand waterways, measurable efforts can be implemented to reduce microplastic pollution and inform mitigation strategies. The Reform of Vocational Education (RoVE) in 2020 and subsequent merger of all ITPs into one institute (NZIST, or New Zealand Institute of Skills & Technology) is a unique and timely opportunity to operate the methodology across all of New Zealand using NZIST institutes as hubs for coordination of sampling by local school and community groups.

Method

We have developed an SOP for quantifying microplastics in waterways by adapting and collating existing literature on measuring river flow, collecting microplastics samples from waterways, and laboratory procedures for separation and visual examination (Figure 1).

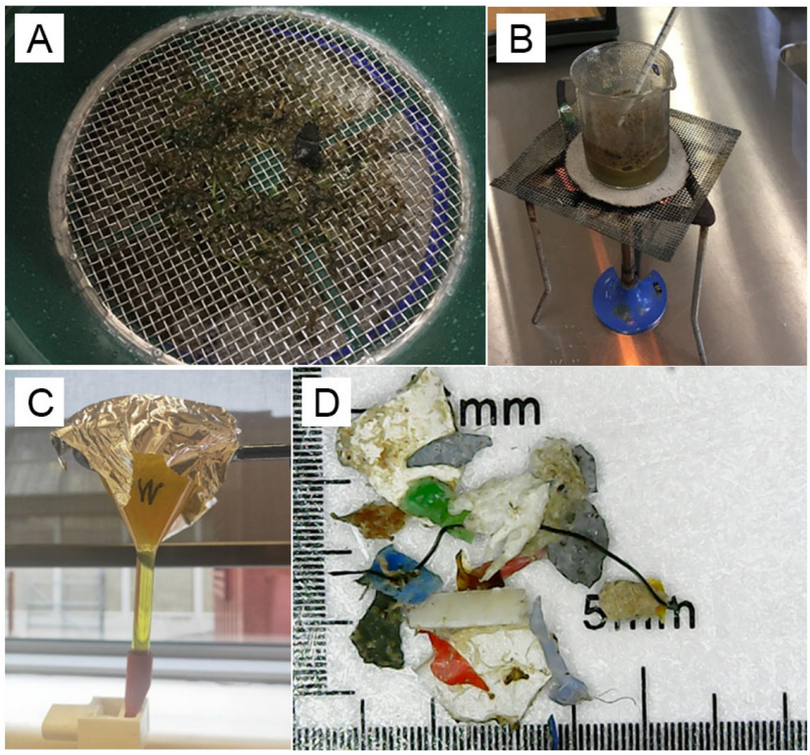


Figure 1. Water samples collected from rivers using a plankton net are filtered through an arrangement of 5 mm and 0.3 mm mesh sieves (A). Any organic matter in the sample is broken down using a solution containing hydrogen peroxide (B) and sodium chloride (salt) is added to increase the density of the solution and allow the microplastics particles to float to the top (C). The separated microplastics can then be counted and categorised (by type and colour) using an inexpensive USB microscope (D).

We employ this SOP with secondary and tertiary students in Invercargill as part of class exercises, field trips and student research, using the SIT chemistry laboratory as the hub for analysis of samples. The next steps involve expanding the citizen science coordination and programme components to beyond SIT, across other NZIST institutes – establishing partnerships between schools, community groups, and institutions to share resources and volunteer efforts towards quantifying and monitoring microplastics concentrations across New Zealand.

Results

This project has currently been selected as one of three pilot projects sponsored by NZIST Research Directors. The project began in early 2019 when there were no published findings on microplastics in NZ waterways and it was clear that there was a paucity of knowledge around the existence and extent of microplastics pollution in the country. Since then, a study quantifying microplastics in Auckland region waterways was released, as well as a handful of information on government initiatives, including an Environment Southland commissioned report by the Cawthron Institute on the risks of microplastics in Southland (Tremblay et al., 2019). This shows that New Zealand is at the forefront of microplastics research with academic projects and government initiatives (e.g. Scion, ESR, MPI, NIWA, MBIE) coordinating efforts towards quantifying and characterising microplastics pollution. This is an opportunity for New Zealand to be a leading example in the widespread effort to quantify, monitor, and subsequently mitigate the spread of microplastics in the environment.

We believe that the best approach towards an immense effort like this is to engage and enlist the community through citizen science – to develop a simple quantification method for use by citizen scientists that can help to identify 'hotspots' that warrant more focus and extensive characterisation to better understand the source and inform mitigation strategies. The merger of polytechnics and institutes of technology into NZIST is not only an opportunity for collaboration of expertise on this project, but also to explore expanding the methodology nationally through the different NZIST hubs. This partnership approach enables the possibility of schools sharing resources with more equipped institutions for the lab component of the SOP and also facilitates the dialogue around microplastics pollution while fostering a heightened sense of community. An added benefit of the programme is that the partnership between schools and NZIST institutes may also help in the recruitment of future students, as well as promoting interest in STEM related courses.

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AN IMPROVED PEDOTRANSFER FUNCTION FOR SOIL WATER RESPONSE

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Aims

Regression functions are needed to estimate the soil water content (cm^3/cm^3) for pre-defined tensions (0, 5, 10, 20, 40, 100, and 1500 kPa) for soil polygons defined by S-map. The estimates must be physically plausible, conforming to the range [0,100%], monotonically non-increasing with increasing tension, and computed such that derived properties formed from the response difference at different tensions (e.g. the total available water) are also within the range [0,100%]. The complexity of the regression models is limited by the range of explanatory variables available from S-map, as well as the small number of tensions available. A previous S-map soil water content model (McNeill et al 2018) used logistic regression, producing satisfactory estimates for most soil types, but poor results for Granular and Pumice soils. Predictions from this model were not released on S-map Online. An even earlier model is available within S-map using logistic regression, but without estimates of uncertainty.

More recently, the store of field and laboratory measurements has been drastically improved by incorporation of historical data from the National Soils Data Repository (NSDR). Using the increased size and representativeness of the data, an improved regression model was sought to better represent the soil water response over a wider range of soil types and regions of New Zealand, using the wider range of explanatory variables now available within S-map.

Method

Explanatory factors were derived from the S-map functional horizon description, soil type (NZSC soil order and soil group), rock class of the fines, estimated texture of sand, silt, and clay, and the soil depth. Anthropic, Organic, and Raw soils were specifically excluded. Several different approaches were tested to ensure that the soil water response was bounded and non-increasing with increasing tension, including constrained GAMLSS, and constrained machine learning methods. The final model used Beta regression for the response at 1500 kPa, as well as Beta regression for the difference in response at 1500 and 100 kPa (the next lowest tension), repeating this approach to a tension of 0 kPa (total porosity). The regression functions were then applied to all S-map polygons to find cases where predictions were problematic, or where the expert-assessed predictions were not satisfactory.

Results

Including NSDR data has increased the number of samples for incorporation in regression development from 1439 (on 313 sites) to 4366 (on 652 sites), which is a three-fold increase in the number of samples and over twice the number of sites from the previous version of the regression model (McNeill et al 2018). While development of a single regression model to cover all tensions was sought, using constrained GAMLSS and machine learning methods, in the end Beta regression for the marginal response at each tension yields the most accurate result, especially for small-population soil orders. A notable improvement for predictions using the new model compared with the previous S-map predictions is the ability to produce estimates of uncertainty. Moreover, these estimates proved to be more stable at low values of response and total available water when compared with versions from McNeill et al (2018).

A comparison between predictions made by the new regression functions and an expert assessment suggested poor results for Pallic soils outside the training data. One possible reason for this is poor representativeness of the training data with respect to the high sand content of the Pallic soils in S-map (Figure 1). For S-map, the soil water response for the very sandy Pallic soils is now derived from Recent soils, which is the most closely related soil type. The predictions provide improved coverage of soils, with satisfactory results for Granular and Limestone derived soils. More importantly, predictions are also associated with the uncertainty, for both direct response (e.g. 1500 kPa response) as well as derived responses (e.g. total available water) (Figure 3).

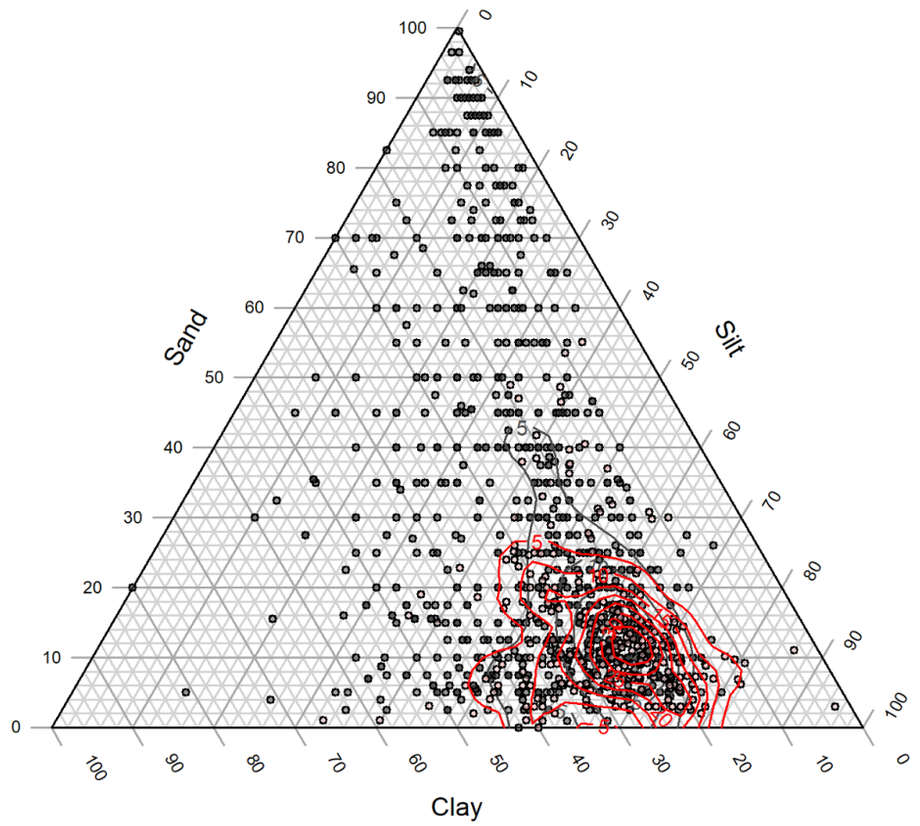


Figure 1. Ternary plot of texture for Pallic soils for the training dataset (red contours of data density) and S-map (markers and gray contours of data density).

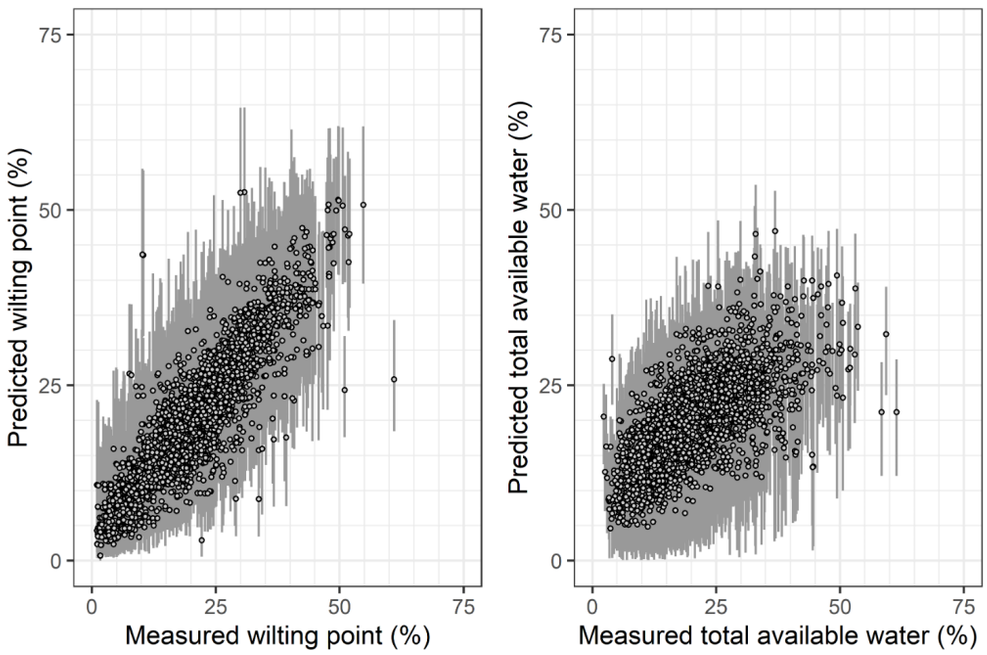


Figure 3. Plot of the predicted versus measured response for the 1500 kPa tension (wilting point) and total available water. The intervals correspond to the 95% confidence intervals of the mean estimate.

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PROVIDING SOIL HYDROLOGICAL DATA TO NEW ZEALAND WATER MODEL (NZWAM)

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Aims

Catchment hydrological models including NZWAM require soil hydrological characterization (usually in the form of *characteristic curve, Θ(ψ), and unsaturated hydraulic conductivity, K(ψ)* or associated parameters) to simulate a range of surface and ground water fluxes and predict the environmental impact of land use, land management practices, and climate change. A process was developed to provide this information to NZWAM that takes advantage of the best available soil data. The advantages of using the new soil hydrological information are tested in a case study area.

Methods

There are currently three digital soil spatial databases covering parts of New Zealand: *S-map* (MWLR 2020), *Fundamental Soil Layers (FSL)* and a hybrid layer called *CanterburyLRI (FSL polygons linked to S-map siblings)*. The limited set of soil properties for the Fundamental Soil layers are described in Newsome et al (2008). The S-map and CanterburyLRI layers can access the S-map inference engine (Lilburne et al. 2012) and its set of pedotransfer functions developed from statistical analysis of laboratory measurements of soil data from the National Soil Data Repository (NSDR). McNeill et al. (2018) describe their beta regression approach to predicting points on the soil characteristic curve. The seven points (at 0, 5,10, 20, 40, 100 and 1500 kPa) are fitted to Kosugi (1994) *Θ(ψ)* curves. K*(ψ)* is derived from *Θ(ψ)* by using a process-based model derived by Pollacco et al., (2017). The S-map polygon data are also rasterized to a spatial resolution of 150 m x 150 m and discretized at the following 14 depths: 2.5, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, 100 cm. This high-resolution soil property database is known as *Smap-Hydro*. It contains values for the *van Genuchten, Brooks and Corey* curve, *Green Ampt* infiltration parameters, *Clapp and Hornberger* conductivity parameters.

The soil hydrological information for each watershed from the River Environmental Classification version 2, is derived from the three soil layers in the following order of precedence: S-map, CanterburyLRI and Fundamental Soil Layer (FSL). S-map is only available for 36.6% of New Zealand, and CanterburyLRI is 10%. The Smap-Hydro properties are provided for the first two soil layer options (where available) and simple FSL properties (rooting depth, profile available water to 90cm, macroporosity to 90cm) where Smap-Hydro is not available. This ensemble of soil information is used as part of the NZWaM-HydrogeoFabric module to provide catchment average soil parameters for use in the NZWaM modelling framework.

Results

A workflow has now been in place that combines predictions of the soil characteristic curves and unsaturated conductivity from S-map-Hydro with the simpler soil properties from FSL where S-map is not available. These data have been provided for six regions of New Zealand. Testing in Southland showed large differences in the spatial distribution of soil hydrological characteristics. Figure 1 presents the difference in the spatial distribution of the a-priori determined depth of hydrologically active soil across the Mid-Mataura catchment, with the black outline indicating the extent of Smap-Hydro coverage over the catchment. Similar results are found across other hydrological characteristics. The paper will compare hydrological simulations when using the two sets of hydrological characteristics and will discuss the potential implications for hydrological modelling.

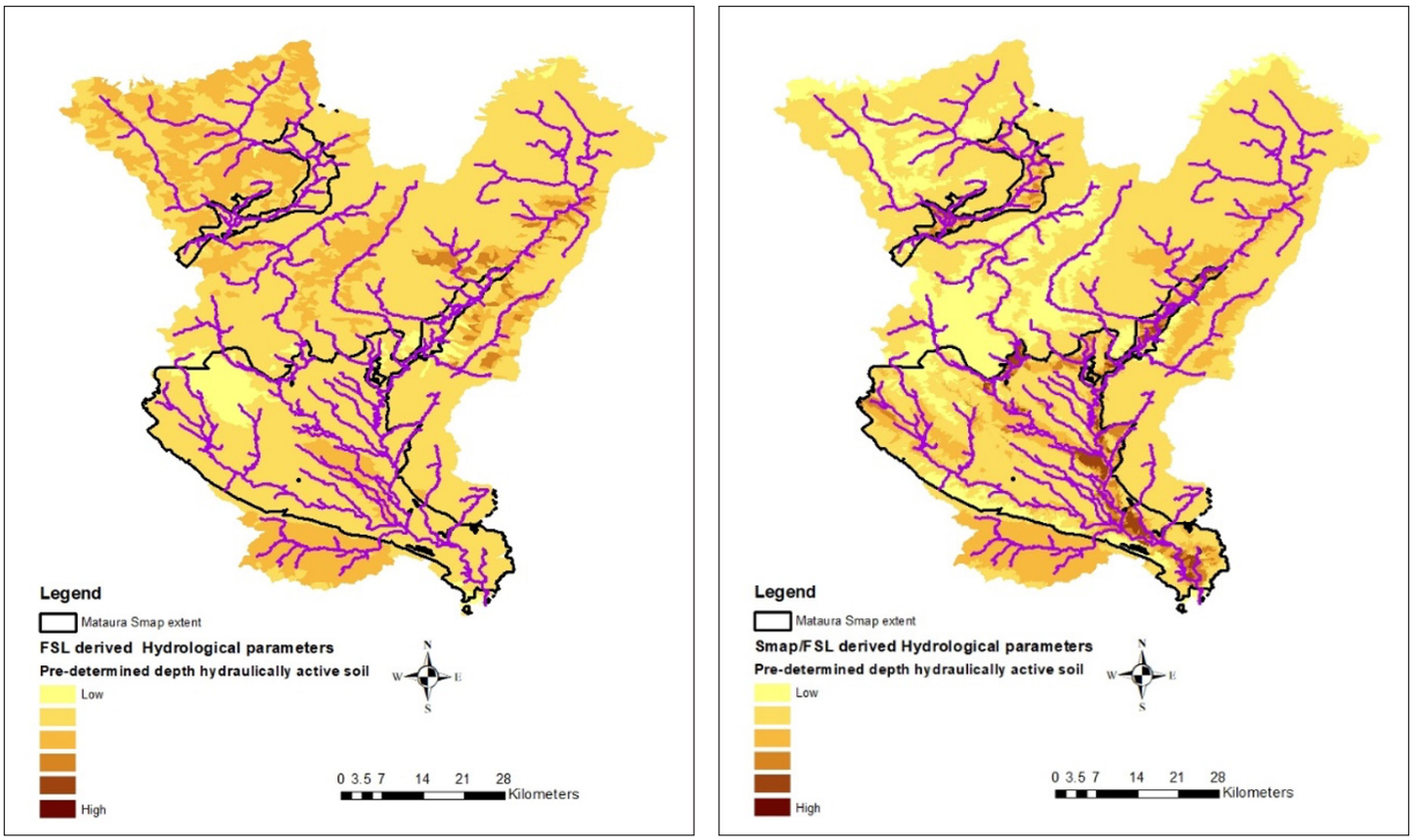


Figure 1. FSL derived (left panel) and Smap/FSL derived (right panel) depth of hydraulically active soil.

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TROPHIC LEVEL BIOACCUMULATION OF CADMIUM IN MAHINGA KAI OF THE TE ARAWA LAKES

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[1] The University of Waikato, Hamilton

Freshwater environments may become enriched with potentially toxic non-essential trace elements through natural or anthropogenic processes, and New Zealand has experienced anthropogenic enrichment with cadmium through the use of phosphate fertilizers. The unique and varied geochemistry of the Te Arawa Lakes serves as an excellent natural system to examine processes associated with bioaccumulation of geothermally derived trace elements. Non-essential heavy elements such as mercury and lead are generally assumed to progressively biomagnify with increasing trophic level. However, cadmium appears to exhibit a much more complex trophic association. Cadmium levels in fish from cadmium-enhanced environments may be significantly elevated in some species and not in others. Analysis of macroinvertebrates (kōura and kākahi) and rainbow trout from the Te Arawa Lakes showed lowest bioaccumulation of cadmium in trout and highest levels in koura, with this pattern being consistent across many lakes with highly variable cadmium concentration. Further understanding of trophic distribution of cadmium and other potentially toxic trace elements in New Zealand freshwater environments is required to fully understand ecological threats and human consumption risks associated with mahinga kai species.

RED-EARED TURTLES ARE WIDESPREAD IN NEW ZEALAND

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[1] The University of Waikato, Hamilton

Red-eared slider (RES) turtles are the most commonly traded turtle worldwide and listed as one of the 100 most invasive animal species by the IUCN. Although the importation of RES was banned in New Zealand in the mid-1960s they are bred locally and distributed through the pet trade with an estimated 2000 juveniles sold annually. They are the cheapest and most commonly traded turtle in New Zealand. Red-eared turtles typically live >30 years and are commonly discarded by their owners or transferred to an outside pond when too large to be accommodated in a home aquarium. Adult turtles are often gifted to rescue organisations such as the SPCA. There are many cases of individuals found wandering in suburban areas having escaped their owners' pond enclosures, however, there are also increasing records of animals becoming established in the wild. Wild turtles have been observed in wetlands, lakes, streams and rivers from Kaitaia to Invercargill. At least four populations in New Zealand have bred in their natural environment and produced viable offspring. Red-eared turtles have temperature dependent sex determination. Temperatures above 20°C are required for eggs to develop and below 28°C all offspring will be male. Above 32°C all offspring will be female. Given the longevity of the species, regular reproduction, albeit male dominated, along with occasional release of female individuals is of concern because of the potential for population increase and spread especially in the context of a warming climate and the possibility of producing natural female offspring. The opportunistic and omnivorous diet of these turtles poses a threat to macroinvertebrates, small-bodied fishes and juveniles of waterfowl but their ecological risk has not been adequately examined.

UNDERSTANDING LOW FLOW BEHAVIOUR IN CHRISTCHURCH CITY'S SPRING-FED RIVERS

Lintott, C.[1]
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Aims

Four spring-fed rivers run through Christchurch city: Heathcote River/Ōpāwaho, Avon River/Ōtākaro, Styx River/Pūharakekenui, and Ōtukaikino/Waimakariri South Branch. Figure 1 indicates the catchments and recharge sources for these rivers. With more than 25 years of continuous flow recorder data now available for the Avon, Heathcote and Styx rivers, combined with a large network of gauged tributary sites for each catchment (150+ gaugings for many sites), we had the opportunity to further our understanding of these spring-fed rivers and their low flow behavior, in order to inform future hydrological investigations for these catchments.

Method

In order to understand the current low flow behavior of the four catchments, we analyzed flow data and assessed relationships between gauged tributary sites and recorder sites, as well as with local shallow groundwater levels. We then put this information into context with past studies and available climate and groundwater data in order to understand any long-term trends evident, and made recommendations for future hydrological investigation for these high aesthetic, cultural and ecological value rivers, particularly in the Styx and Ōtukaikino catchments which had much more sporadic data available.

Results

Anecdotally baseflows have been declining in the city rivers over the last 100 to 150 years, linked to more efficient drainage, increasing development and abstraction, climate change, and confining of the Waimakariri's flow path. Most recently, the 2015/2016 summer, a period with extreme El Niño conditions, saw public concern about particularly low flows and pronounced dry reaches in the city streams. Figure 2 shows the effect of this dry period on two Avon tributary sites, in the context of the long-term flow record and groundwater levels.

There has previously been little quantitative data available to analyse the perceived decline in stream flow in the spring-fed city rivers. In recent statistical analysis by Alkhaier et al. (2019), analysis of flow data that is now available from the 1990s to present showed little long-term change. Baseflows in the city rivers are driven by groundwater levels, which are in turn driven by winter rainfall recharge of inland aquifers. As such stream flows will fluctuate with seasonal patterns in rainfall as well as year to year climatic variability, and the effect of increasing abstraction in recent years appears to be minor in comparison to this natural variability. The extensive low flows seen in the 2015/2016 period noted earlier can be attributed to the lack of winter rainfall falling in 2015, and thus lower land surface recharge, and Figure 2 shows that these flows recovered through 2017 to 2019. However, as abstraction continues to increase and climate change occurs, the effect of natural fluctuations in climate on groundwater recharge will likely be exacerbated, with more frequent and more severe periods of low flow occurring in the city rivers and their tributaries.

The recommended outcomes of this investigation are to continue monitoring of the Avon and Heathcote catchments at a sufficient frequency to capture future changes and maintain monitoring of key shallow groundwater wells that provide good indicators of spring flow. It is also suggested to extend regular monitoring into the less understood Styx and Ōtukaikino catchments where seepage from the Waimakariri River is a significant driver of spring flow. Ongoing monitoring will be of increasing importance as these city catchments, particularly the Heathcote and Styx, are further developed and as climate continues to change.

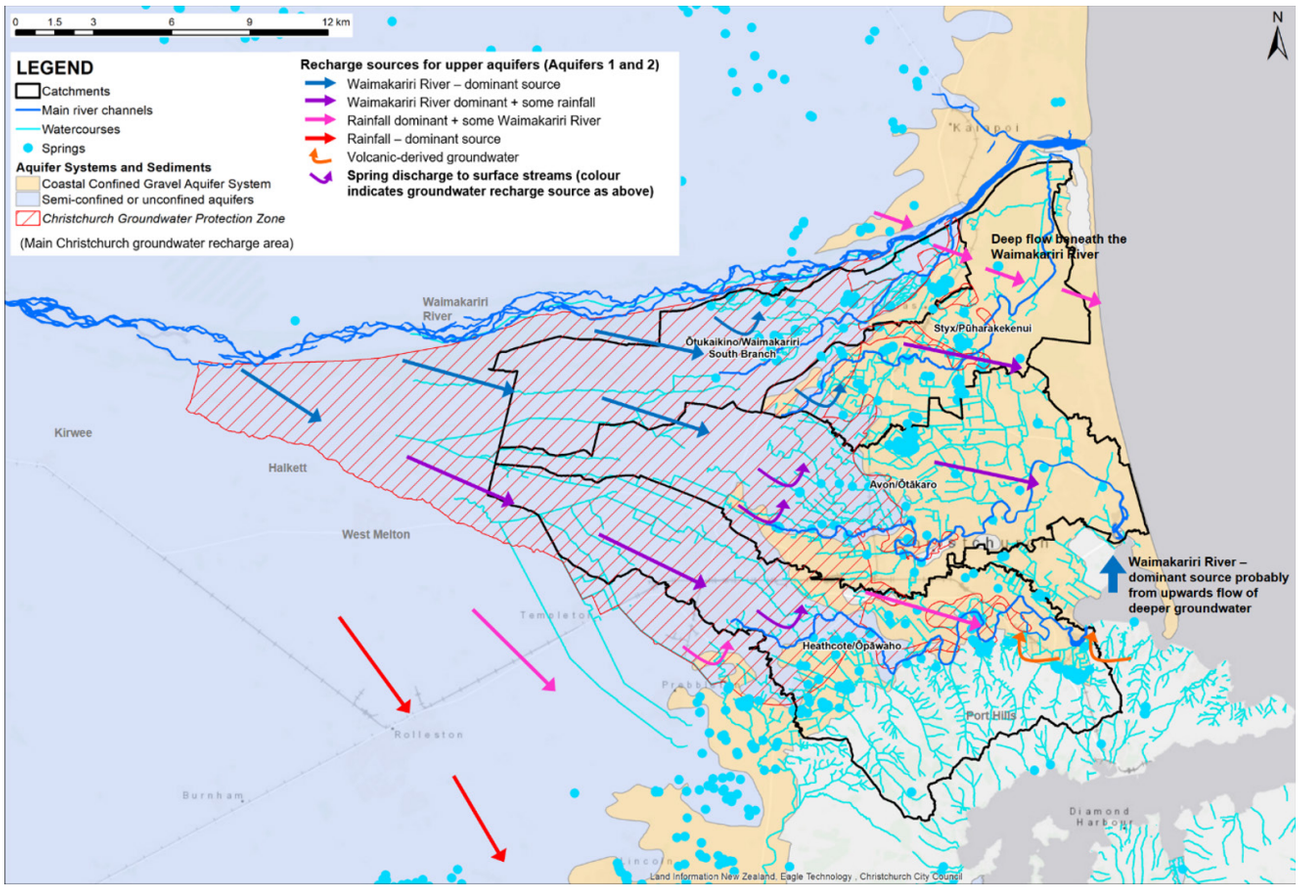


Figure 1. Christchurch city river catchments, spring locations and recharge sources (adapted from Hayward et al. 2002)

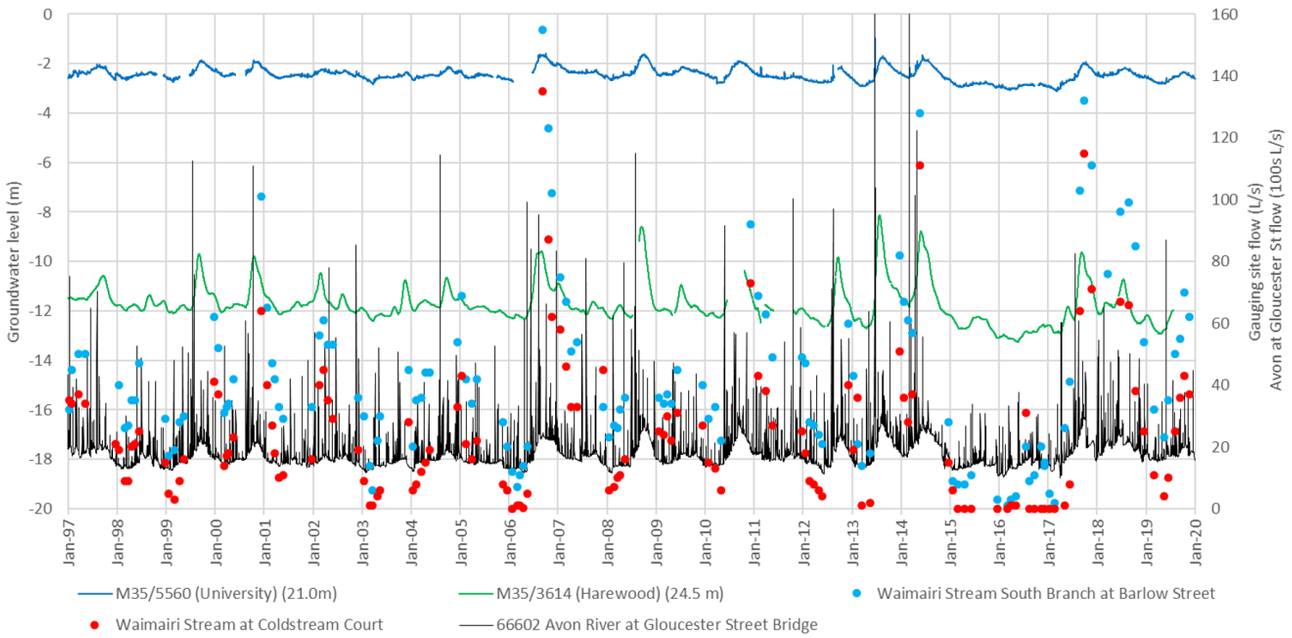


Figure 2. Variation in spring-fed flows at two gauging sites in the Avon catchment due to climate variability, with 2015/2016 low flow period shown. Nearby groundwater levels shown for comparison.

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HYETOGRAPHS FOR FLOOD MODELLING IN NORTHLAND

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[1] Northland Regional Council
[2] Macky Fluvial Consulting Ltd
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Northland's population is well spread across the region, with many people living and working on the valley floors of many mostly small catchments. The role of Northland Regional Council (NRC) in minimizing flooding hazard therefore requires a knowledge of the flood hydrology and hydraulics of all these catchments. NRC has carried out flood modelling of selected catchments as its Priority Rivers programme. Recently, NRC has commissioned flood modelling of the entire region. Such an extensive exercise will be simpler with a single design hyetograph scaled to match the local rainfall design depth.

The Priority Rivers hyetograph shape (MWH 2011) (Figure 1) was developed specifically for the first batch of modelling. For the flood modelling now under way of the remaining catchments, NRC wanted to review this hyetograph shape in the light of two developments. First, rain radar data have been captured in Northland since 2014 and have been calibrated against rain gauges (Sutherland-Stacey et al 2019). Second, an alternative hyetograph shape (HIRDSv4) has been produced by NIWA (2018), who have derived design rainfall depths and hyetograph shapes for all of mainland New Zealand.

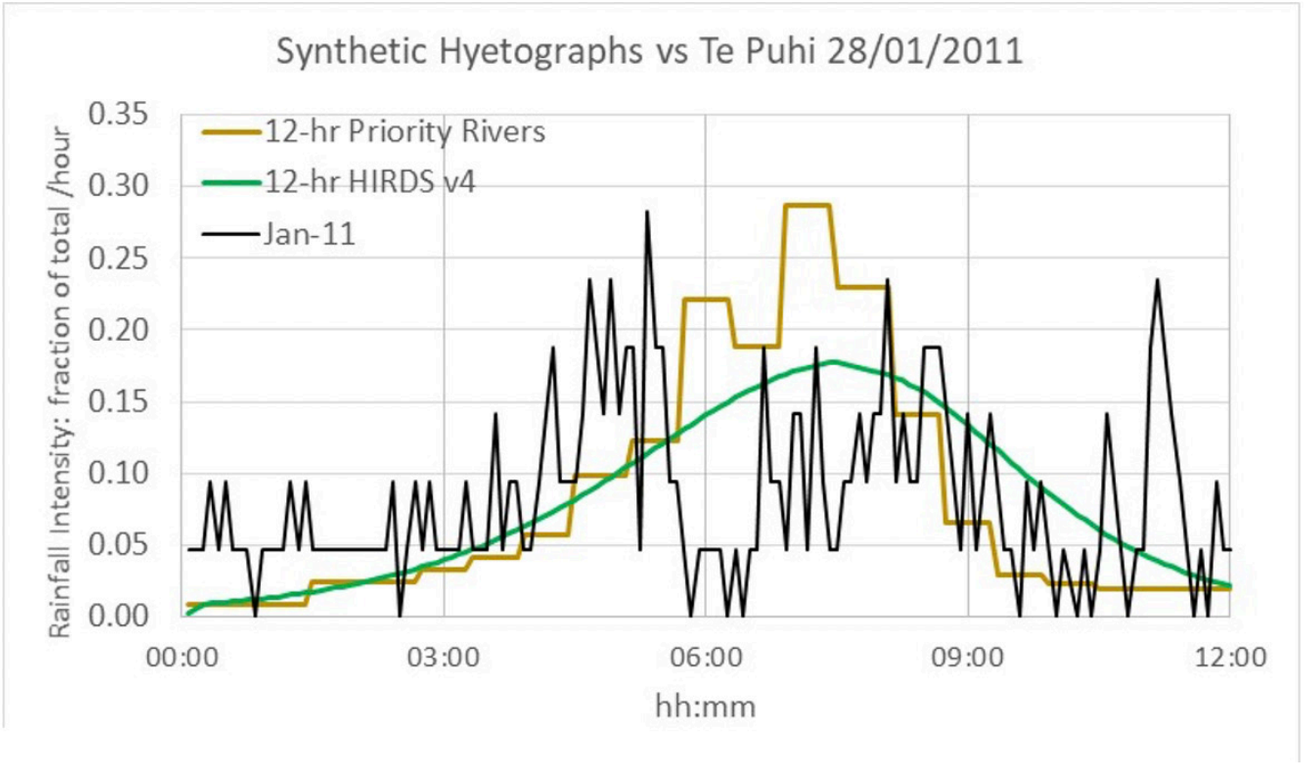


Figure 1. Synthetic design hyetographs compared with January 2011 event, Te Puhi, Kaitaia

A previous study (Shamseldin 2016) illustrated the variable rainfall pattern of recent significant events. This variability is also evident in earlier extreme events such as the 2011 event in Figure 1. The lack of a distinct peak is quite common and is in contrast with both synthetic hyetographs.

Aim

This study aimed to model catchment runoff using synthetic and actual hyetographs, and so identify the best design hyetograph shape for Northland catchments.

Method

Six major rainfall events in four different catchments were modelled. First, a simple catchment model of each catchment was calibrated against a single large event. Catchment hyetographs were derived from rain gauge data using Thiessen polygons. A 12-hour event duration was chosen, because previous modelling has shown that heavy rainfall lasting about 12 hours is the critical event for flooding in many Northland catchments which are very roughly 40 km^2 in area. A 6-hour event might be better for smaller catchments than this.

Each event was modelled three times with the same rainfall depth: first with the rain gauge record intact, and twice with the most intense 12 hours of gauged rainfall replaced by either the Priority Rivers or the HIRDS v4 12-hour hyetograph, scaled to provide the same depth of rainfall. The three resulting runoff hydrographs were compared, to assess how well the two synthetic hyetographs replicated the real record.

Results

Both synthetic hyetographs, especially the Priority Rivers hyetograph, typically gave over-estimates of modelled peak flow compared to the value obtained using the actual rainfall record. This can perhaps be attributed to the pronounced central peak in the synthetic hyetographs.

The HIRDS hyetograph shape has been chosen for the flood modelling now under way, because it over-estimates peak runoff by a relatively small fraction. It is expected that shorter events will also be adequately modelled by the 12-hour HIRDS hyetograph.

As more rain radar data are gathered, NRC intends to further investigate spatial and temporal hyetograph patterns. It is hoped that further runoff modelling will then indicate whether there is a better design hyetograph pattern than the HIRDS one, and whether more than one rainfall event length needs to be modelled to obtain robust design flood levels.

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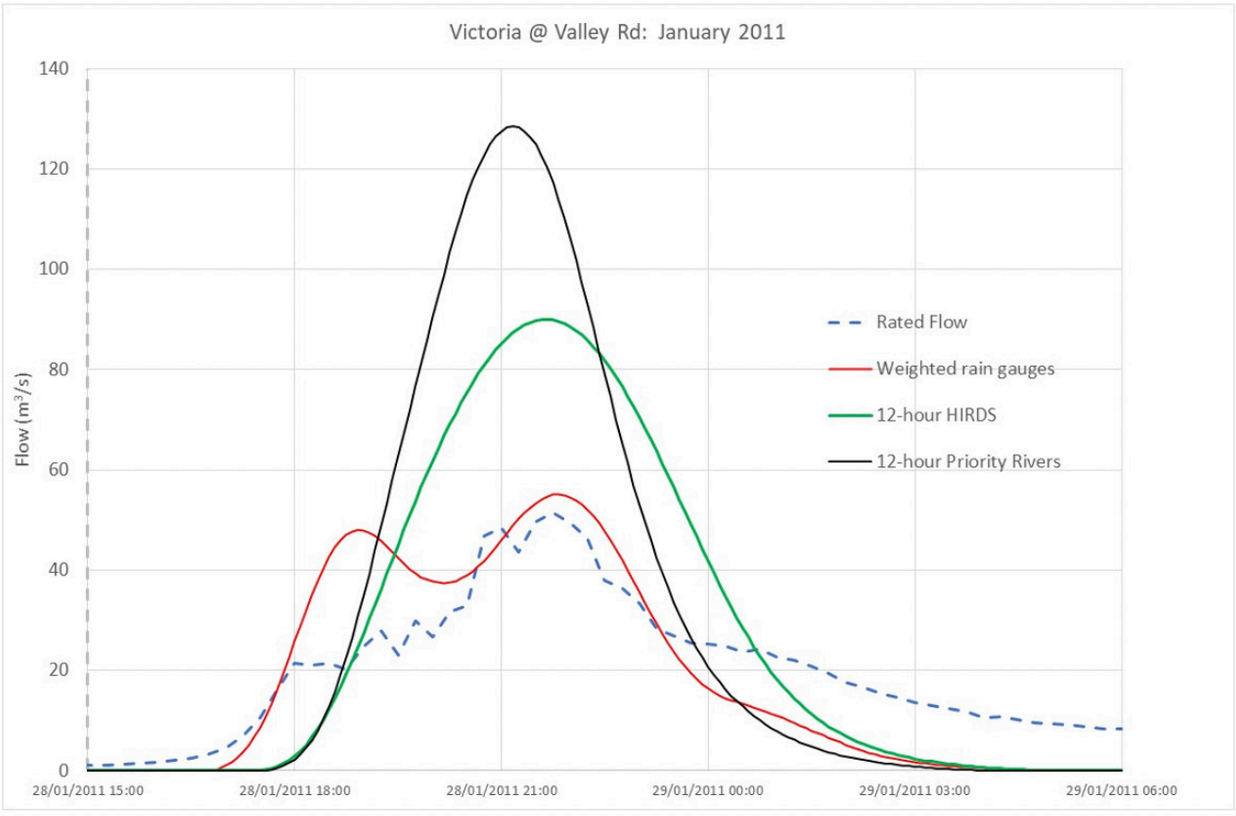


Figure 2. Victoria River, Awanui: Modelled and rated flow hydrographs, 28 January 2011

EXAMPLES OF GEOMORPHIC EFFECTS ON LOWLAND FLOOD REGIME

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Aims

The geomorphic setting of some catchments means that flood flow rates from the headwaters are not the only factors in determining the effects of flooding in the lowlands. Resource management decisions, including where to locate towns and intensive farming operations, can exacerbate or reduce the adverse effects. Catchments the writer has worked on are discussed in relation to two questions:

- How much does the particular geography determine the risks from flood flows?
- Are there locations where intensive development and urbanisation, should be avoided?

Kaituna River, Bay of Plenty

The Kaituna drains Lakes Rotoiti and Rotorua, and formerly drained into the Maketu Estuary (Figure 1), albeit with occasional breakouts directly to the sea, until the Kaituna Cut was made in the 1950s to bypass the estuary and thus lower river levels. In the 1990s the writer was asked to investigate the cause of erosion of land at the rivermouth widened with flood events. The answer lay in the 60km2 of wetland stopbanked in the 1970s and reclaimed for farming. This area had provided detention storage during major flood events, making for much more modest peak flows through Maketu Estuary or (since the 1950s) through the Kaituna Cut. The regional council's works to restore Kaituna flows to the Maketu Estuary have been well publicised. With the detention storage gone, a quasi-natural flow regime entering the estuary has been provided by continuing to pass the highest flows through the Kaituna Cut.



Figure 1. lower Kaituna River and Maketu Estuary (LINZ)

Vu Gia – Thu Bon River Basin, Vietnam

These two significant rivers drain a hilly and largely forested combined catchment of 10,350 km^2, and share the same large rivermouth delta – a flood plain roughly 700km^2 in area. The Thu Bon River flows through the southern half of the delta to its mouth at Hoi An, and the Vu Gia flows through the northern half of the delta to the sea at Da Nang. Several anabranches criss-cross the delta from one major river to the other. The delta has long been intensively farmed but now also has significant areas of urban development.

Widespread flooding of the delta is not uncommon. Modelling of the probable maximum flood shows almost complete inundation of the delta, although the most intensive urban development near the coast generally remains above water.

The particularly "random" anabranches appear to be a feature of flood plains with more than one major river. People are more at risk from extreme flood events because flood flows in these channels would isolate much of the flood plain. With only limited bridge connections, quick evacuation of so many people from the delta would be difficult.

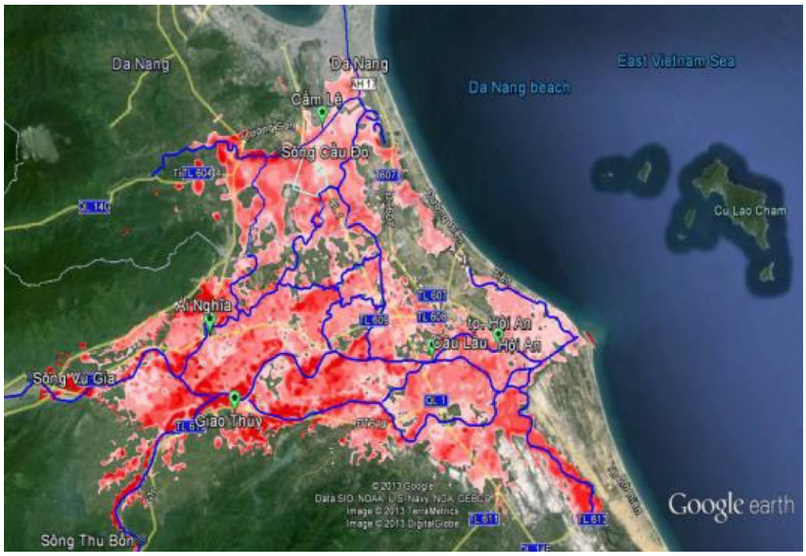


Figure 2. Vu Gia – Thu Bon River Delta: observed flooding 30/09/2009 (Le Song et al. 2014)

Awanui catchment, Kaitaia, Northland

The Awanui catchment also has two waterways sharing the same floodplain, albeit on a much smaller scale. The Awanui River and Tarawhataroa Stream nearly meet at Kaitaia (Figure 3), flowing on either side of the town. Tarawhataroa Stream then veers westward into a wetland (Lake Tangonge) with a gated outlet back to the Awanui River well downstream. The constructed Whangatane Channel diverts Awanui flows just downstream of Kaitaia, reducing the flood risk downstream. Floodplain flow from one waterway to the other is one-way, a breakout from the Awanui across State Highway 1 in high flows about 2km upstream of Kaitaia. Kaitaia is therefore virtually surrounded by more extreme flows. River works are under way to reduce the town's risk.

Was Kaitaia built in the right place? There may well be no better alternatives, as our modelling shows extensive flooding of river flats and former wetland both upstream and downstream. The two waterway channels at Kaitaia appear stable, ensuring reasonably safe ground in between.

Meanwhile, the floodwater storage in Lake Tangonge reduces peak flood flow downstream. However, its slow release afterwards, following flooding of farmland, creates a significant water quality problem downstream due to low dissolved oxygen.



Figure 3. Awanui and Tarawhataroa at Kaitaia (LINZ)

Conclusions

Riverine flood plains often do not fit the "standard" version of enclosed areas either side of a single river channel. Multiple channels and large wetlands and coastal floodplains can then create a more complex hydrological system, with effects on both river flows and the wetland /flood plain environment. Resource management is then more challenging, needing to balance of the sometimes conflicting goals of reducing flood risk and preserving environmental values.

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FRESHWATER BIOLOGICAL INVASION – HOW METAPHORS OF MILITARY POWER, KILLER ALIENS AND BIOCONTAMINATION INFLUENCE PUBLIC AWARENESS, POLICY AND SCIENTIFIC METHODS

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Metaphors are widely used in science to convey messages and information between scientists, government agencies, decisionmakers and the public. Metaphors in freshwater science are commonplace, with rivers and lakes seen as 'healthy' or 'unhealthy', 'pristine' or 'disturbed', often suffering 'pressures' such as 'pollution', 'regulation' and 'invasive' species. The latter are a focus of a wealth of metaphor and hyperbole, which often militarizes and demonizes the process of biological invasion, the protagonists themselves and their impacts. I briefly consider how such metaphors have been used to describe freshwater macroinvertebrate invasions in Europe and North America and provide the example of the 'killer shrimp' *Dikerogammarus villosus*. I show the biology behind the moniker and how the nickname itself has driven policy and public engagement in the UK. Linked to the messages stakeholders receive about the impacts, real or potential, of invasive species are messages about how to monitor and 'manage' them. Rivers and lakes are 'invaded', there are 'incursions', there is 'biopollution' and 'biocontamination'. I show how this metaphorical rhetoric surrounding biological invasion, has translated itself into a practical monitoring approach that seeks to grade macroinvertebrate communities into levels of contamination based on native and invasive taxa richness and relative abundance. Despite its debatable metaphorical origins, I show why this approach is useful for managing freshwater systems in Europe. I also show how it could be translated to ecological assessment and protection of freshwaters in New Zealand.

FISH PATHWAY ASSESSMENT FOR SMALL-BODIED FISH

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Understanding fish behavior in turbulent flows is crucial for planning, designing and optimization of fish passage solutions. Fish pathways are key behavioral guides, consisting of the hydrodynamic characteristics of resting locations and the maximum tolerable values of water velocity and optimal turbulence for selected fish species. Identifying fish pathways is a two-step process. Initially, hydrodynamic characteristics of turbulent flows for possible fish passage solutions are studied, for example, in a laboratory setup. Fish behavior is then analyzed by recording fish movement within such flow fields. In this study, we present results from the hydrodynamic testing of different spoiler baffle sizes and arrangements, all whilst considering the swimming capacity of typical small-bodied fish species of New Zealand, such as Inanga (*Galaxias maculatus*). The quantitative assessment includes comparison of the magnitude and extent of the recirculation zone, low velocity zones and various turbulence parameters. This work is of crucial importance to better understand fish behaviour at various scales. We present the results for the flow around individual spoiler baffles consistent with the present size and spacing recommendations in the New Zealand Fish Passage Guidelines. We discuss how future work will match fish behaviour with the observed hydrodynamic characteristics, ultimately synthesized into a fish passage solution framework that takes behavioral information into account.

BUILT TO POISON?: LEACHING FROM INSTREAM STRUCTURES

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[1] Christchurch City Council
[2] Aquatic Ecology Limited

Temporary and permanent instream structures within waterways (such as bridges, culverts, linings and retaining walls) have the potential to leach contaminants into waterways, negatively affecting both water quality and biota. To understand the potential effects of using instream structures, we carried out a review of the literature on the effects of three commonly used materials: copper-chrome-arsenate (CCA) treated timber, galvanised steel, and concrete. The greatest environmental threat appears to be from CCA treated timber. Several risk factors were identified, such as the use of newly treated timber and the use of timber within poorly flushed waterways. This draws attention to the use of timber lining and retaining walls in waterways, especially in environments with sensitive biota. With respect to galvanized steel, most waterways likely have appropriate water chemistry to prevent accelerated corrosion and therefore leaching. There are some risks with the use of concrete structures. However, as with CCA treated timber, it is possible to reduce these risks by following design standards and considering whether the environment the structure is to be used in is more likely to cause leaching. Recommendations were developed for treatment and management methods to reduce leaching, and to determine where the use of these structures may not be appropriate. Areas for future research were also identified. Investigations were subsequently carried out to determine current practices and whether these recommendations would be difficult to achieve.

CONTAMINANT ATTENUATION BY RIPARIAN BUFFERS REVISITED: A REVIEW AND GUIDELINES DEVELOPMENT

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New Zealand currently faces declining aquatic biodiversity and water quality, resulting in part from inputs of nutrients, sediment and faecal bacteria from agricultural lands. In response, the government's Essential Freshwater package includes new requirements for riparian set-aside. The DairyNZ-NIWA INTERCEPTOR project aims to develop new performance and design guidance for mitigation tools, including riparian buffers, to support uptake and implementation.

To develop new guidance, we conducted a systematic review of published literature for field-scale studies. We considered factors affecting performance, including contributing area (e.g., land use, slope, soil type and texture, hydrological flowpaths) and buffer characteristics (e.g., vegetation, width, soil texture).

We found that performance efficacy varied widely. For surface runoff, soil clay content was an important determinant of performance. We also found:

- strong relationships between efficacy of sediment removal, and TP and TN removal in surface runoff;
- consistently high (>40%) removal efficacy for nitrate-N from subsurface flow when the buffer was underlain by a shallow impermeable layer, and;
- higher removal of nitrate-N from subsurface flow in finer textured soils compared with sandy/gravelly soils.

The review enabled us to generate preliminary guidance for sediment removal by riparian filter strips for soils with <28.5% clay on uniform flat to rolling slopes, with performance related to buffer width to hillslope length ratio. However, the review and guideline development process has highlighted a paucity of NZ data. Additional studies are recommended to develop a more robust model and guidelines, suited to NZ landscapes, including situations where farming occurs on high clay content soils.

WHAT MAKES AN 'OUTSTANDING' INDIGENOUS FISH HABITAT?

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Aims

The high proportion of indigenous fish species threatened with, or at risk of extinction in Aotearoa New Zealand indicates protection of their habitats is urgent. 'Outstanding' waterbodies and their values can be protected by Water Conservation Orders (WCO) (Part 9, RMA 1991) and the National Policy Statement for Freshwater Management (NPSFM 2011, 2014, 2020) requires the protection of the significant values of outstanding freshwater bodies. However, a small number of waterbodies (Nevis River, Kawarau WCO; Lake Ellesmere/Te Waihora WCO) currently contain protection of indigenous fish habitat under law. Despite several attempts at protecting indigenous fish through legal mechanisms (e.g., Buller River, Rangitata River, Ngaruroro River), protection remains low. Ironically, WCOs to protect introduced trout habitat and fisheries have been more successful.

WCO processes to date have set an almost impossibly high bar to prove waterbodies have outstanding indigenous fish habitat. Several factors confound proving 'outstandingness' for indigenous fish, including:

a) a lack of national ecological criteria to assess 'outstandingness',
b) low national species richness,
c) the influence of diadromy and ubiquitous distribution of much of the fauna,
d) biogeographically driven differences between fish communities in the 'north' and 'south',
e) inconsistent sampling methods and national data, and
f) the high cost associated with WCO applications and hearings.

We aim to identify at least one criterion which overcomes many of these limitations, to determine outstanding indigenous fish habitat for protection that includes waterbodies from North and South Islands using reach-scale fish species richness.

Method

The New Zealand Freshwater Fish Database (NZFFD) is maintained by New Zealand's National Institute of Water and Atmospheric Research (NIWA). The NZFFD, by early 2020, contained 48,341 records.

We examined 32,171 records, for 41 indigenous freshwater fish species from 2000 to 2020. Data were converted to presence/absence of indigenous fish to enable consistent analyses. Nine records for the Ngaruroro River not in the NZFFD were included from Jellyman and Sinton (2018) to support evidence to the Environment Court for specific protection of that river.

The number of indigenous fish species recorded from individual surveys at a site were summed to determine 'reach-scale' species richness.

Results

Highest reach-scale species richness was ten indigenous fish taxa and was found at five rivers in the South Island (Table 1). Reaches with nine indigenous fish species were also relatively rare. Of the 32,171 NZFFD records examined, 26 records from 21 reaches (some surveyed more than once) in 17 rivers had nine or ten taxa. The dataset included six rivers from the North Island and thus met our requirement to establish a criterion that included rivers across the two main islands. Eight of New Zealand's 16 regions had rivers with nine or ten species at the reach-scale. Determining regionally outstanding indigenous fish habitat may require more refined criteria than national scale anlysis.

No lentic records (apart from the coastal lagoon of the Waitaki River mouth with ten taxa) had fish species richness of 7 or more taxa. We note this method is unlikely to be adequate in comparing across lentic and lotic waterbodies and other criteria are needed for lentic environments.

Table 1. River reaches with high indigenous fish species richness, data from 2000 to 2020.

Year	Locality	Taxa count	Locality description	Region	Island
2014	Wigmore Stream	9	Small coastal stream – Coromandel Peninsula	Waikato	North
2002	Waitaki River Lagoon	10	Coastal Lagoon – large braided river	Canterbury	South
2001	Waipara River	10	Mainstem river reach – small semi braided	Canterbury	South
2000	Waipara River	9	Mainstem river reach – small semi braided	Canterbury	South
2003	Waikato River tributary	9	Tributary (inland) Waikato River	Waikato	North
2003	Waikato River tributary	9	Tributary (inland) Waikato River	Waikato	North
2005	Waikato River tributary	9	Tributary (inland) Waikato River	Waikato	North
2006	Waianakarua River	9	Mainstem river reach - braided (small area)	Otago	South
2001	Unnamed stream Flea Bay	10	Small coastal stream - Banks Peninsula	Canterbury	South
2001	Unnamed stream Flea Bay	9	Small coastal stream - Banks Peninsula	Canterbury	South
2001	Unnamed stream Flea Bay	9	Small coastal stream - Banks Peninsula	Canterbury	South
2012	Poorman Valley Stream	9	Small coastal stream - Waimea Inlet	Nelson	South
2012	Poorman Valley Stream	9	Small coastal stream - Waimea Inlet	Nelson	South
2009	Pigeon Bay Stream	10	Small coastal stream - Banks Peninsula	Canterbury	South
2012	Paparahia Stream	9	Small coastal stream	Waikato	North
2002	Pakuratahi Stream	9	Small coastal stream	Hawke's Bay	North
2017	Ngaruroro River	9	Mainstem river reach - braided	Hawke's Bay	North
2010	Mokihinui River	10	Mainstem river reach - single channel	West Coast	South
2001	Maraetai Stream	9	Tributary (coastal) - Port Waikato	Waikato	North
2014	Maitai River	9	Mainstem river reach – single channel	Nelson	South
2014	Maitai River	9	Mainstem river reach – single channel	Nelson	South
2012	Maitai River	9	Mainstem river reach – single channel	Nelson	South
2014	Koturetawhenua Stream	9	Tributary (coastal) Awapoko River	Northland	North
2013	Kakanui River	9	Mainstem river reach - single channel	Otago	South
2008	Kakanui River	9	Mainstem river reach - single channel	Otago	South
2001	Anaweka River	9	Mainstem river reach - single channel	Tasman	South

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FRESHWATER SEDIMENT ATTRIBUTES AND URBAN DEVELOPEMENT

McCord, J.,[1] Smith, J.,[1] Rossaak, A.,[1] Clarke, C.,[1] Bambic, D.[2]
[1] Morphum Environmental
[2] Paradigm Environmental

Urbanisation is well known to result in an increase in sediment generation and potential subsequent increase in turbidity of our streams and rivers for phases of the development cycle. As part of the development of the National Policy Statement: Freshwater Management, The Ministry for the Environment investigated the inclusion of the sediment attributes for streams and the classification of the stream state based on the long-term medium of turbidity and total suspended solids. The Ministry wanted to understand if development adversely impacts current attribute states and what the effect an inclusion in the National Policy Statement: Freshwater Management could have on development.

Best practice erosion and sediment controls can be up to 90% effective at reducing sediment yields at development sites. Using contextual and monitoring data from current development projects in New Zealand, the instream indicators were assessed to determine long-term trends and if this could lead to a change in the sediment attribute state. What this data revealed is that monitoring requirements outlined in consents generally only require event-based monitoring when a threshold condition is reached, and data from baseflow conditions, which determines the sediment attribute state, is severely limited.

The data also revealed the impact that storm events, beyond the design of sediment and erosion control structures, can have on short term stream quality. This led to modelling of various development scenarios using a 15 year rainfall dataset to assess relative sediment generation potential for different land use types under five development staging scenarios. This modelling highlighted the variability in risk from temporal and spatial distribution of bare earth during land development processes. Number of rainfall days per year, site slope and catchment proportion of exposed earth were confirmed as key factors in sediment generation.

SPACE TIME IMAGE VELOCIMETRY (STIV) USE IN SOUTHLAND

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Space Time Image Velocimetry (STIV) is a relatively new method in New Zealand, providing the opportunity to process surface velocity results from video. Cameras stationed in the field allow the remote capture of video. A large benefit of STIV is the ability to remotely capture video at any time without sending staff out into the field. Recent times with covid19 and a Southland flooding event in February 2020 have demonstrated the potential of STIV to complement the hydrology program. Environment Southland has trialed two sites and since installed a number of fixed cameras. The intention is to use STIV methods to assist developing a rating for two recently installed sites, as well as capturing high flow events.

Video is captured either from fixed cameras, handheld cameras or drones. A number of image velocimetry videos are collected alongside conventional gauging techniques. Image velocimetry video is then processed in software to give a discharge result when the cross sectional data is applied. Cross sectional data is collected when collecting routine gaugings to update any changes to the channel and cross section that may have occurred.

Sites where STIV results have been collected are compared with conventional gauging methods on the same section. These comparisons have resulted in similar flow calculations to date...

THE IMPACT OF SHALLOW GROUNDWATER ON IRRIGATION REQUIREMENTS

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Aim

Shallow groundwater can move from a water table into crop root zones via capillary action, contributing to crop water needs. The standard soil water balance models that are routinely used to determine irrigation allocations in New Zealand do not account for upward movement of water from shallow groundwater and may overstate irrigation requirements.

Given the pressure on groundwater resources, there is a need to understand the contribution that shallow groundwater can make to meeting crop water needs and to refine irrigation allocations accordingly.

Method

Irrigation water requirements were assessed for grazed pasture on shallow silt loam over gravel and for mature avocados on deep silt loam using Hydrus 1D (Šimůnek *et al,* 2013). Modelling was completed for a range of shallow groundwater depths below the crop root zones and under typical fluctuating groundwater levels, as would be expected to occur in practice.

Results

Shallow groundwater can significantly reduce irrigation needs of deep rooted crops on fine-grained soils. In some situations, where the water table is close to the root zone, irrigation may not be required at all. For shallow rooted crops on coarser-grained soils, there is little benefit unless the groundwater table is very close to the bottom of the crop root zone.

With fluctuating groundwater levels, the impact varies, depending on the range of groundwater levels experienced. Groundwater can significantly reduce or even eliminate the need for irrigation at times. At other times, it could provide virtually no benefit. Irrigation then become an issue of managing the risk of shortfalls.

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EXPLAINING TROPHIC STRUCTURE OF MUDFISH-DOMINATED RAINFOREST POOLS: INVERTED BIOMASS PYRAMIDS, METHANOTROPHS AND SIZE-STRUCTURED FOOD WEBS

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Food-web interactions in extreme environments provide useful insights into processes structuring communities because of the intense pressures at play. The brown water pools formed by tree tip-ups in South Westland (NZ) rainforest have low pH, low dissolved oxygen, can dry for weeks at a time, and have low primary production. Despite these severe conditions, predators, including Odonata and mudfish (Neochanna apoda), can be super abundant (e.g., 200 mudfish/m3) even to the point that pools appear to have very top-heavy (i.e., inverted) biomass pyramids when classified taxonomically. Such trophic arrangement, despite being potentially unstable, is usually associated with allochthonous energy subsidies. Indeed, we found mudfish abundance was related to pool surface area to volume ratios, such that pools with more surface area contained more mudfish, suggesting terrestrial energy subsidies (e.g., insects falling in) fuel the trophic webs. However, size-spectra of aquatic organisms binned by body size revealed highly size-structured communities that fitted expectations from metabolic theory and were not particularly top-heavy. Cannibalism and reciprocal intraguild predation, including odonates feeding on small mudfish as well as mudfish feeding on odonates, could offer a simple explanation for this trophic structure. Stable isotopes (δ13C and δ15N) supported this proposition, but also raised another possibility; that food webs were additionally fuelled by methanogenic microbes. Thus, although allochthonous energy might make inverted biomass pyramids possible, extreme environmental conditions driving strong biotic interactions likely force food webs towards a more stable structure, aided by additional and unforeseen energy sources like those accessed by methanotrophs.

AUCKLAND FLOOD FREQUENCY

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The study provides estimates of extreme floods in Auckland streams. These are termed "design floods" that typically have annual exceedance probabilities of ranging from 10% to 0.5%, in other words return periods from 10 years to 200 years. The design flood magnitudes are key parameters for designing bridges, determining culvert sizes, defining flood hazard zones and planning flood protection measures.

The study used all the available flood peak records for Auckland streams. It covered 65 records with lengths ranging from less than one year to 53 years. A key result is, that of the candidate distributions for flood frequency analysis of annual maxima, the two-parameter Extreme Value type 1 or Gumbel distribution is recommended for prediction of design floods. Where only short records for a site are available, a regional dimensionless frequency curve is provided to assist with estimates.

The study identified one extremely large event recorded on the Waiwhiu Stream on 20 January 2011 which is notable for its severity and rarity. (The catchment area is 8.0 km^2 and the peak discharge was 186 m^3/s.) This event is significant in the context of maximum floods because it is close to a New Zealand maximum for a catchment of that size.

The study compared pre-2000 data with post-2000 data. It found that in some cases there was a tendency for larger floods to have occurred in the earlier interval. This apparent difference is worth further investigation using longer Auckland rainfall series.

The results provide essential design parameters for infrastructure projects in the ongoing developments in Auckland.

THE MANGAKŌTUKUTUKU URBAN RESEARCH HUB - WATER SENSITIVE URBAN DESIGN

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[2] Hamilton City Council
[3] NIWA Auckland

Hamilton City's population is projected to grow rapidly over the next 20 years and many of these new residents will live in identified greenfield growth cells. The community's expectations, set out in plans and supported by legislation, require us to work toward the "restoration and protection of the health and wellbeing of the Waikato River". Water sensitive urban design (WSUD) will therefore be required for stormwater management as part of the greenfield Peacocke development. The Integrated Catchment Management Plan for the Mangakōtukutuku catchment, which includes the Peacocke development, will include wetlands, rain gardens and rain tanks. HCC and NIWA have established the Mangakōtukutuku Urban Research Hub to combine our resources, capabilities and knowledge to assess the impact and potential of WSUD. We have adopted a before and after paired catchment experimental design. The main infrastructure (bridge, main roads and pipes) in the Peacocke catchment will completed in 2023, allowing for several years of "before" monitoring. The adjacent Rukuhia catchment will serve as a control catchment. We are operating a network of five water quantity and quality monitoring stations in the 2300 ha Mangakōtukutuku catchment. We will report on the first year of "before" data and the growing research programme.

HIGH FREQUENCY NITRATE IN THE LOWER MATAURA RIVER

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High frequency data can assist in identifying water quality drivers. Seasonal, diel, event and within-event, finer time scale patterns may be interpreted in terms of contaminant mobilisation, delivery and availability. In March 2016 NIWA installed two UV spectrophotometric nitrate sensors on the lower Mataura River to deliver real-time nitrate concentrations, develop best practice, and compare in-river and pumped systems. Discrete grab samples were collected adjacent to the in-river sensor for data verification. The sensors have consistently performed well when compared to lab nitrate, operating within the stated accuracy (±5%+0.01 mg/l) to deliver high quality data across the range of sampled concentrations. The relationship between the in-river sensor and pumped sensor is consistently good ($r^2 > 0.95$) and operating two sensors has allowed us to fill gaps in the sensor record. Technical staff found the pumped system easy to operate, but the pump was replaced several times during the four years. A longer observation interval would reduce the pump's workload and extend its lifespan. Considerable effort is required to maintain a long sensor deployment that produces high quality data. Analysis of the time series record reveals that for general resource management purposes on large rivers such as the Mataura, there is little benefit in collecting data at higher than daily frequency. For other purposes and more dynamic catchments, shorter observation intervals are desirable to capture rapidly changing nitrate concentrations.

COUNCIL REFLECTIONS ON THE COMMUNITY ENGAGEMENT APPROACH TO FRESHWATER LIMIT-SETTING IN SOUTHLAND

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Environment Southland has embarked on a community-involved process to further develop our approach to managing land and water in the region. Through the People, Water and Land Programme, this has included formation of a Regional Forum to help us explore, amongst other things; community values; freshwater objectives, limits, and both regulatory and non-regulatory methods to achieve them. When reflecting on the community engagement element of this work programme, there are a number of key learnings that can be drawn from our experiences. Building from internal drafted values reports and evaluation processes, this paper will highlight some of the key challenges and successes that eventuated through an engagement approach that was centred around the delivery of two key social research methods; questionnaires and focus group interviews.

In particular, this paper aims to highlight how the mandatory requirements of community consultation, and subsequently the use of social research methods to help set freshwater limits, can introduce diverse techniques within traditional council engagement approaches. This is evident principally in terms of scale, resourcing, and the reflexivity and objectivity that is required when engaging with community members, necessitating internal adjustment and preparation. An evaluation into these processes helps prepare council for future engagement endeavours, at the same time providing external parties an opportunity to support their own engagement requirements for limit-setting.

ESTIMATING SEDIMENT TRANSPORT IN A LOWLAND RIVER CATCHMENT AND THE IMPLICATIONS FOR RESTORATION

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Lowland landscapes have been subjected to marked changes due to anthropogenic intensification. These have often left little room for the waterways, which have been co-opted for management issues, such as drainage. This has created networks of highly-altered waterways sandwiched into confined spaces in modified landscapes. The Canterbury Waterway Rehabilitation Experiment (CAREX) have been working in agricultural waterways of the Ararira/L II River catchment near Christchurch, New Zealand. This modified drainage network is characterised by deeply incised, steep-banked waterways and high levels of sedimentation. Using a combination of sediment collectors, tiles and stage height loggers, we mapped the movement of sediment throughout this catchment, particularly during multiple flood events. All floods exhibited a 'first flush' of sediment, probably driven by the increasing flows re-suspending benthic sediment. However, most had greater sediment movements occurring later, particularly during the highest water levels, which we suggest is indicative of externally-derived sediment entering the water, likely from inundation of steep streambanks as well as sediment washed from the surrounding agricultural lands. Consequentially, we suggest that better management and design of the riparian zones could result in drastic reductions in total sediment entering the waterways during floods. Thus, reducing the need for mechanical clearing of deposited sediment, and allowing the use of other restorative tools previously prevented by this practice.

EFFECTIVENESS OF AQUATIC HABITAT RESTORATION IN HINDS DRAINS

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The Hinds Drains are an array of drainage channels channeling groundwater and land drainage water from an extensive historically drained wetland complex south of Ashburton (Mid Canterbury). Some drains previously flowed freely over gravel beds and supported abundant fish populations including trout and native fish populations. Extensive land use development and irrigation development across the plains over recent decades has reduced flows and increased contaminant (particularly nitrate nitrogen) concentrations. The Hinds Drains Working Party, a community initiative, examined ways to enhance or reinstate some of the natural values of the drains.

The Eiffleton Irrigation Scheme has enhanced flows in some drains by augmenting flows with groundwater abstractions to deliver water to downstream irrigators. This results in both increased flows during summer low flow periods and seasonal dilution of high nitrate concentrations. Community initiatives also examined improvement of the habitat of the straight and uniform drains by installing boulder weirs in reaches of two free flowing drains to generate greater habitat diversity and enhance waterway habitats for fish.

We collected quantitative macroinvertebrate samples from upstream control sites, from the boulder weirs, from gravel run sites between the weirs, and from drift nets set five metres below the weirs. These were designed to examine whether these initiatives improved the productiveness and diversity of these drains beyond the improved water quality and flow initiatives. We report on the various effectiveness of these habitat initiatives in highly modified drainage networks.

NGĀ AWA: DOC'S PRIORITY RIVER RESTORATION PROGRAMME

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DOC's priority rivers programme, Ngā Awa aims to collaboratively improve the ecological integrity and climate change resilience of 14 river catchments. The intention is to co-manage with Treaty Partners and work collaboratively with other agencies and communities at a catchment-scale, providing restoration coordination where required, operational delivery, and science and technical support.

In this presentation we will describe how the 14 priority catchments were identified through a social process informed by technical analysis that aimed to bring together existing freshwater protection, distribution of threatened species and where there was a range of freshwater ecosystem types. Opportunities to align with national and regional initiatives were also considered.

River Restoration Coordinators (RRCs) are beginning to work in each catchment to establish the co-management foundation with Treaty Partners, and then with councils and community. Catchment restoration teams are starting to identify restoration objectives and actions through facilitated workshops captured as a riverine conceptual model. This process will identify and complement community initiatives and council processes under the NPS-FM but with an added biodiversity focus. Collating information on the existing state of knowledge within the catchments has been a valuable first step.

Ngā Awa is seeking to collaborate and learn from other river restoration initiatives, councils and research providers to trial innovative approaches to collaborative riverine restoration and monitoring across socio-ecological, cultural and technical aspects.

REGULATORY CHALLENGES FOR IMPLEMENTATION OF FARM-SCALE DIFFUSE SOURCE POLLUTION MITIGATION MEASURES

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[1] NIWA

Constructed wetlands, detention bunds, woodchip denitrification filters and planted riparian buffers are examples of a growing suite of edge-of-field and farm-scale mitigation initiatives that are being trialled across rural New Zealand to reduce the impact of intensive land use on fresh water quality. While the evidence base for the technological efficacy of these mitigation initiatives continues to grow, a wide range of social/behavioural, cultural, economic and regulatory barriers may limit their potential adoption by landowners. We will summarise a desk-top review of Regional Plan requirements relevant to the construction, operation and maintenance of these mitigation measures, particularly when sited close to or within waterways and drains. Many essential activities – such as earthworks, stream diversions, stream bed disturbance and discharges to land or water – may trigger the need for resource consents in accordance with Regional Plans prepared under the Resource Management Act (RMA) 1991. Although permitted activity rules do exist for many of these activities, the rules vary from region to region and are typically accompanied by lengthy lists of conditions. Failure to meet one or more of these conditions will trigger the need for resource consent. It would be beneficial for researchers and practitioners to engage directly with policymakers to improve awareness and understanding of the various diffuse pollution mitigation measures and develop guidance on how these should be constructed, operated and maintained to minimise any potential adverse environmental effects. This could inform the subsequent development of specific rules in Regional Plans that facilitate more efficient consenting and – in turn – implementation of diffuse pollution mitigation measures.

FLOOD FORECASTING OF THE CLUTHA RIVER AT BALCLUTHA

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Aims

To present a rainfall-runoff flood forecasting model developed using HEC-HMS for the lower Clutha River catchment downstream of the Roxburgh Dam (5,000km2 approximately). The purpose of the model is to provide flood warning for Balclutha township and the Clutha Delta.

The outflows from the Roxburgh Dam are input to this model in addition to forecast and observed rainfalls. The model is used to forecast the hourly Clutha River hydrograph at Balclutha.

Method

Rainfall variability over the lower Clutha sub-catchments is high but the rainfall recording network is scarce, not necessarily in adequation with the rainfall variability. In order to prepare the modelling, a rainfall-runoff analysis of available telemetry rainfall and flow sites in this lower Clutha catchment have been carried out, using multiple regression, to first identify the rainfall sites which best represent rainfall over each gauged sub-catchment, and then to estimate the effective rainfall and the weights for these rainfall sites. Significantly 24 independent high flow events of the lower Clutha have been identified for this rainfall-runoff analysis.

HEC-HMS model's parameters were then estimated based on the rainfall-runoff analysis, the analysis of available gauging at flow sites in the catchment, the analysis of historical events, topographical information and the analysis of the recession part of high flow hydrographs. Further optimization of these parameters was achieved within HEC-HMS to minimize the difference between observed and simulated flows.

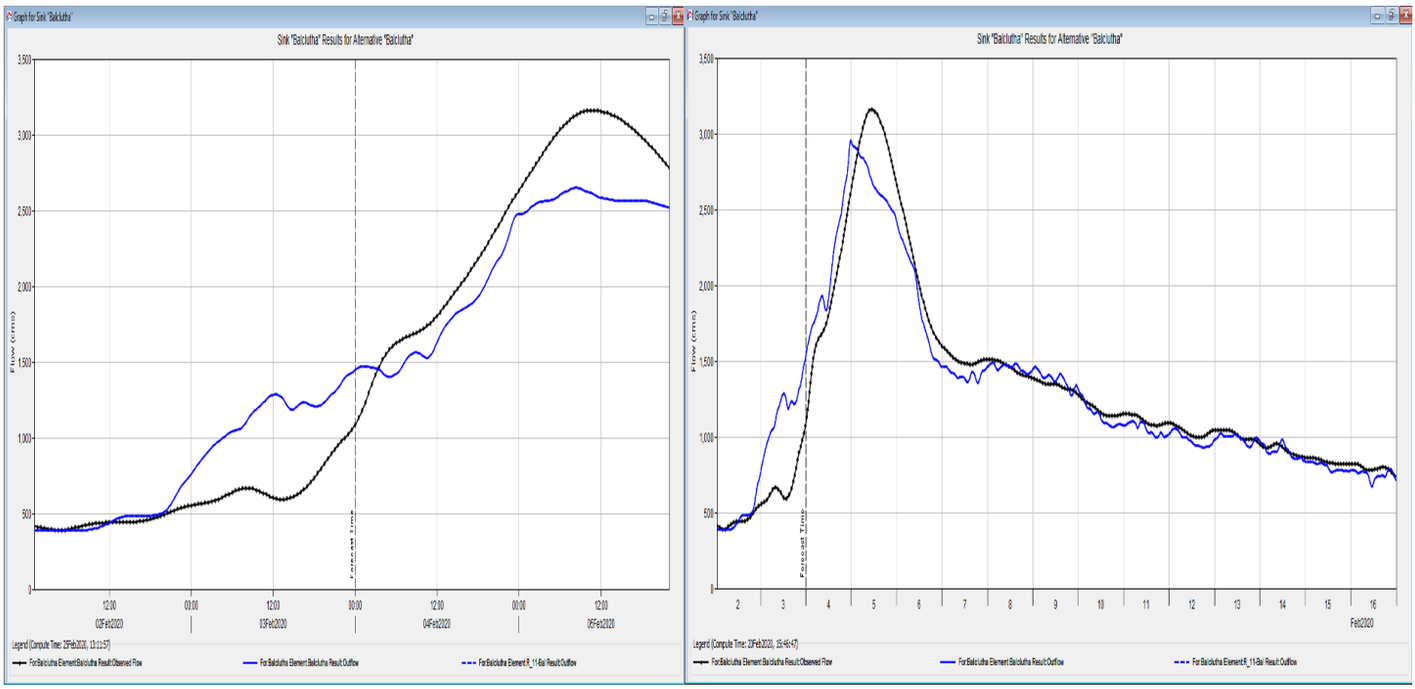
Results

The model consists of 16 sub-catchments between the Roxburgh Dam and Balclutha, one flow input (Roxburgh Dam outflows), 16 river reaches, 13 junctions and one sink for the river outlet at Balclutha.

The model was used to forecast the flows of the February 2020 flood event and it was capable of suitably giving a warning of flows exceeding the warning level about 36 hours before the event. The model was consistent in giving this warning of high flows exceeding 2500 m^3/s all the time starting from 36 hours before the event up to the occurrence of the event.

Figure 1 (a) shows application of the model to forecast the Clutha River flows at Balclutha 36 hours before the event based on absolutely forecasted rainfall, while Figure 1 (b) presents the application of the model with actual observed rainfalls due to this event after the event occurred. Figure 1 (b) shows how the model would forecast the Clutha River flows at Balclutha if the forecasted rainfalls really happened.

Despite the "satisfactory" performance of the model to forecast the February 2020 flood event at Balclutha, further improvement can be achieved by adding more rainfall and flow sites in the lower Clutha catchment.



(a) *(b)*

Figure 1 Flood Forecast of Event February 2020 (a) 36 hours before the event based on forecasted rainfall, (b) using observed rainfall after the event occurred

RIVER CONFINEMENT AND AGGRADATION IN THE WAIHO, A MODELLING PERSPECTIVE

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Flooding of the Waiho river in Franz Josef is a well-known problem. Several highly publicized flood events have occurred in recent years including the Waiho river bridge damage in March 2019 stranding ~450 tourists and damage to the Mueller hotel in 2016. The river is currently confined with stop banks in an attempt to protect local infrastructure from the damaging effects of river flooding. However, increases in riverbed elevation, estimated at ~30cm per year, necessitates frequent increases in stop bank heights to maintain protection.

Traditional river engineering theory suggests that narrowing a river between stop banks should increase gravel transport efficiency and therefore result in riverbed downcutting. However, confinement of the Waiho (and other naturally braided rivers around New Zealand) has resulted in increased aggradation. We hypothesize that failure of traditional river engineering is due to lack of realism in the underlying sediment transport theory. While classical sediment transport theory quantifies bedload yield through cross-sections by applying one-dimensional hydraulics over static riverbed elevation profiles, we postulate that the two-dimensional morphological evolution of river planforms is the key driver of sediment transport at the reach scale. Planform evolution happens in braided rivers as a series of transient morphological events (such as channel avulsions) which rapidly mobilize sediment and result in bedload pulses. Our aim is to quantify the average contribution of these events to overall sediment transport and understand how these processes are controlled by the imposed river width

To this end, we use a two-dimensional morphodynamic model to describe the behavior of the Waiho river. Model parameters are tuned to duplicate riverbed aggradation between two LiDAR surveys, performed in 2016 and 2019. The relative importance of avulsions and traditional sediment transport in the Waiho is explored with the model. The impact of river confinement on sediment transport and gravel aggradation is discussed.

HOW UPSCALING HYDRAULIC PROPERTIES UNDERMINES THE RELIABILITY OF OUR DECISION-SUPPORT PREDICTIONS

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Most model representations of the subsurface use upscaled parameters to represent smaller-scale heterogeneous hydraulic properties. Many different methods for deriving these upscaled parameters exist, which may lead to very different model parameter values, and different simulated outputs. Numerous studies in the petroleum industry literature demonstrate that correctly upscaled parameters are stress dependant; where 'correct' can be defined as upscaled parameters which provide the same prediction as a model which represents the 'true' prediction-salient small-scale heterogeneous properties. Other studies in the inversion literature demonstrate that when using a 'de facto' upscaling methodology, aka 'model calibration' or 'history matching', parameter values will also be dependent on the data that is available.

When assessing the uncertainty of predictions made with upscaled properties, this stress and data dependency of upscaled parameters presents a challenge. The stochastic nature of these upscaled parameter values must be defined either implicitly or explicitly e.g. parameter covariance matrices or credible parameter bounds. These parameter values will be very different to those hydraulic property values measured in laboratory or field tests.

We present worked examples that demonstrate the nature of this important issue, in the context of contaminant transport. We focus both on a pathogen contaminant, in which the first arrival time of the pathogenic contaminant represents our prediction. We contrast this with the upscaled parameters derived for a conservative contaminant, where the peak concentration represents our prediction.

DEALING WITH INCOMPLETE DATASETS AND IMPACTED SITES TO DEFINE NATURAL TREND BASELINES IN GROUNDWATER QUALITY FOR ENVIRONMENTAL REPORTING.

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[3] Ministry for the Environment, Wellington

Aims

It is essential to establish what the naturally occurring ranges of chemical concentrations in groundwaters are and how they change over time to effectively manage sustainably groundwater bodies. In this study, we defined baseline trends for New Zealand groundwaters combining pattern recognition techniques to deal with inconsistent monitoring suites between the national (110 sites) and the denser regional network (> 1,000 sites), with multivariate statistics to identify and remove impacted sites from the enhanced dataset.

Method

Rates of changes were calculated for 13 parameters between January 2005 and December 2014 at more than 1,000 groundwater quality monitoring sites. The resulting dataset included 262 complete cases (CC), which was enhanced using Machine-Learning (ML) techniques to a total of 607 sites. Hierarchical cluster analysis was used to identify trend clusters that were consistent between the CC, ML-enhanced datasets and a 2006 study based on solely on the national network. Trend clusters were subsequently refined using groundwater quality state information, enabling the identification of impacted sites. Parameter-specific trend baselines were subsequently derived from unimpacted sites using univariate quantile distribution (5th and 95th percentile thresholds).

Results

The largest trend cluster (WR) consisted of low magnitude changes across all parameters and was attributed to water-rock interaction processes. The second largest cluster (I) exhibited fast changes particularly for parameters linked to human-induced impact. The third largest cluster (D) comprised decreases of all parameters and was associated with dilution processes. Integrating groundwater quality state information enabled identification of impacted sites outside of Cluster I in the ML-enhanced and CC datasets.

To demonstrate the use of baselines for environmental reporting, we developed classifications combining baselines (state and trend) and natural variability (Figure 1). This allowed the new identification of deteriorating trends at sites where groundwater quality state is not yet affected in addition to trend reversals. These classifications can be adapted to incorporate new knowledge or align with surface water quality reporting.

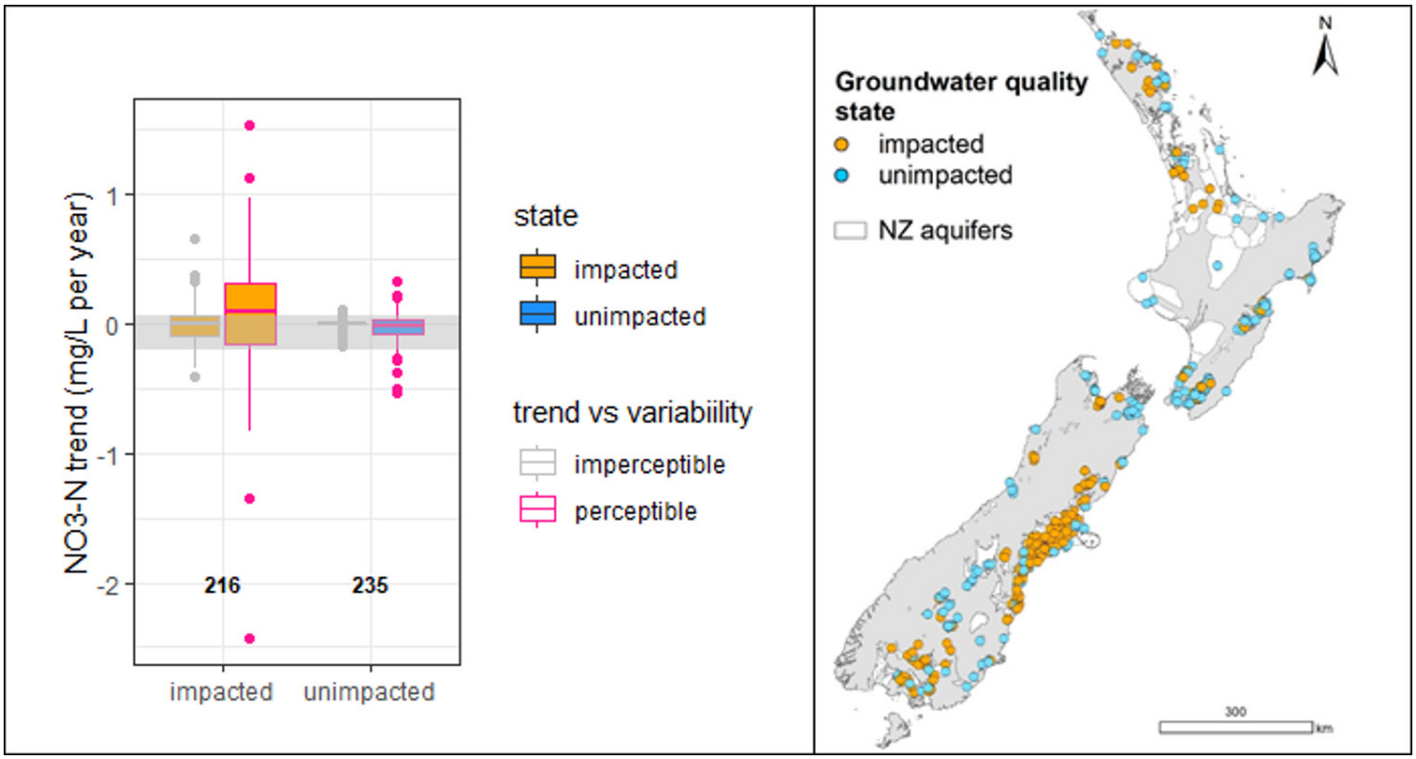


Figure 1. Nitrate-nitrogen concentration in groundwater trends over the period 2008-2014 (left) at 451 State of the Environment monitoring sites across New Zealand (right). Sites are classed using a tiered approach. The first tier is based on nitrate-nitrogen concentrations using a state baseline ("unimpacted" and "impacted" classes). The second tier compares the amount of change over the trend time period to natural variability defined by four times the median absolute deviation ("perceptible" and "imperceptible" classes). On the boxplot, the shaded area displays the trend baseline range and the bold numbers indicate the number of sites.

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HERETAUNGA PLAINS 3D GROUNDWATER AGE: WHAT IT CAN TELL ABOUT THE AQUIFERS

Morgenstern, U., Brown, L., Harper, S., Rawlinson, Z., Lee, J.

The aquifers underlying the Heretaunga Plains, Hawkes Bay, are one of New Zealand's most important groundwater systems providing about 85% of the Heretaunga Plains water demand. The aquifers are a result of geological processes responding to climate change cycles from cold glacial when sea level was more than 100m below present sea level, to warm interglacial periods with sea level similar to present day. Glacial climate strata are river gravel, sand and silt deposits and include the artesian aquifers. The interglacial strata form the aquicludes and are marine sand, silt, and clay deposits with interbedded estuarine, swamp and coastal fluvial silt, clay, peat and gravel deposits. These alternating strata of permeable river gravel beds and fine impermeable beds form an interconnected unconfined–confined aquifer system with complex groundwater flow processes.

To improve understanding and enable sustainable management of this valuable groundwater resource, several large investigations of the Heretaunga Plains aquifers and their groundwater were carried out:

- 5-year (1991–96) investigation including drilling of three deep test bores with subsequent multi-level observation well set up (Dravid and Brown, 1997);
- Airborne transient electromagnetic (SkyTEM) geophysical survey early 2020.

In addition, the Heretaunga Plains groundwater system is also subject to detailed investigations using environmental tracers of the water, including groundwater dating, within GNS' MBIE Endeavor programme *Te Whakaheke o Te Wai* – The Pathways of the Water.

We have re-visited tracer data sampled during the drilling of the bores and are collecting new samples from these multi-level bores in order to understand in 3D the groundwater recharge sources, groundwater recharge and flow rates, connection to the rivers, and potential groundwater discharge out to sea. Consistently young water (c. 25 years) at depth greater than 100m indicates preferential flow paths, likely related to paleo-river channels. Broadly the flow pattern obtained from the water tracer data seems to fit with the geologic information from the drill-holes, and with the initial SkyTem information.

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THE ONE BILLION TREES PROGRAMME & POTENTIAL IMPACTS ON GROUNDWATER QUANTITY ALLOCATION LIMITS

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[2] Northland Regional Council
[3] Waikato Regional Council

Aims

The number of afforestation programmes under development is growing worldwide with the intention to mitigate climate change through carbon sequestration. In New Zealand (NZ), the One Billion Trees (1BT) Programme, launched early 2018 by Te Uru Rākau / Forestry NZ, intends to mitigate NZ carbon emissions as well as providing employment, and improving land productivity, water quality, biodiversity, and habitat provisioning. Considering that (i) large afforestation programme, if not carefully planned, can lead to unintended consequences on the aquatic ecosystem services (e.g., Schwärzel et al. 2019); (ii) the limited understanding of the potential impact of forest cover expansion on the water resources in NZ (e.g., Meason et al. 2019); and the scarcity of groundwater-related studies, our research aims to inform resource managers (i.e., regional councils) on the potential impacts of afforestation on groundwater quantity allocation limits.

Method

Our approach used remote-sensed imagery and cloud-computing processes to develop a series of groundwater recharge scenarios under different afforestation conditions. First, the 2018 forest cover and the cover changes that occurred between 2000 or 2001 and 2018 were assessed, using both global (Hansen et al. 2013) and national datasets (LCDB.v5 2019). We then calculated groundwater recharge ratios under various afforestation scenarios based on this forest cover data set, characteristics of the 1BT Programme, and the National Groundwater Recharge Model (Westerhoff et al 2018). Lastly, we ground-truthed the modelled outputs against local observational datasets in two case studies areas in Northland and Waikato.

Results

National forest cover* was estimated at c. 108,300 km^2 in 2000 decreasing to c. 103,300 km^2 in 2018 (Hansen dataset), and at c. 106,200 km^2 in 2001 decreasing to 105,700 km^2 in 2018 (LCDB.v5 dataset). The full implementation of the 1BT Programme would require approximately 8,500 km^2 of additional land, based on a 1000 trees/hectare density.

Increased evapotranspiration (ET) rates of trees compared to grassland were quantified, using global satellite products, with nationwide average ET being 120–140 mm/year and 210–230mm/year greater for tree cover than for high and low producing grasslands, respectively. The higher water demand of trees compared to grass was inferred to reduce groundwater recharge, especially in low recharge areas. Figure 1 illustrates this reduction in recharge, expressed as "lost recharge ratio". The outcome of this "demand side" approach would suggest recommending the lowering of current allocation limits for catchments where afforestation takes place. However, an emerging alternative or "supply side" approach considers processes such as soil infiltration enhancement and rainfall recycling, which would reduce the negative recharge effects, and in some cases lead to increased groundwater recharge.

* NZ total area ≈ 268,021 km^2, Chatham Islands were excluded from forest cover calculation.

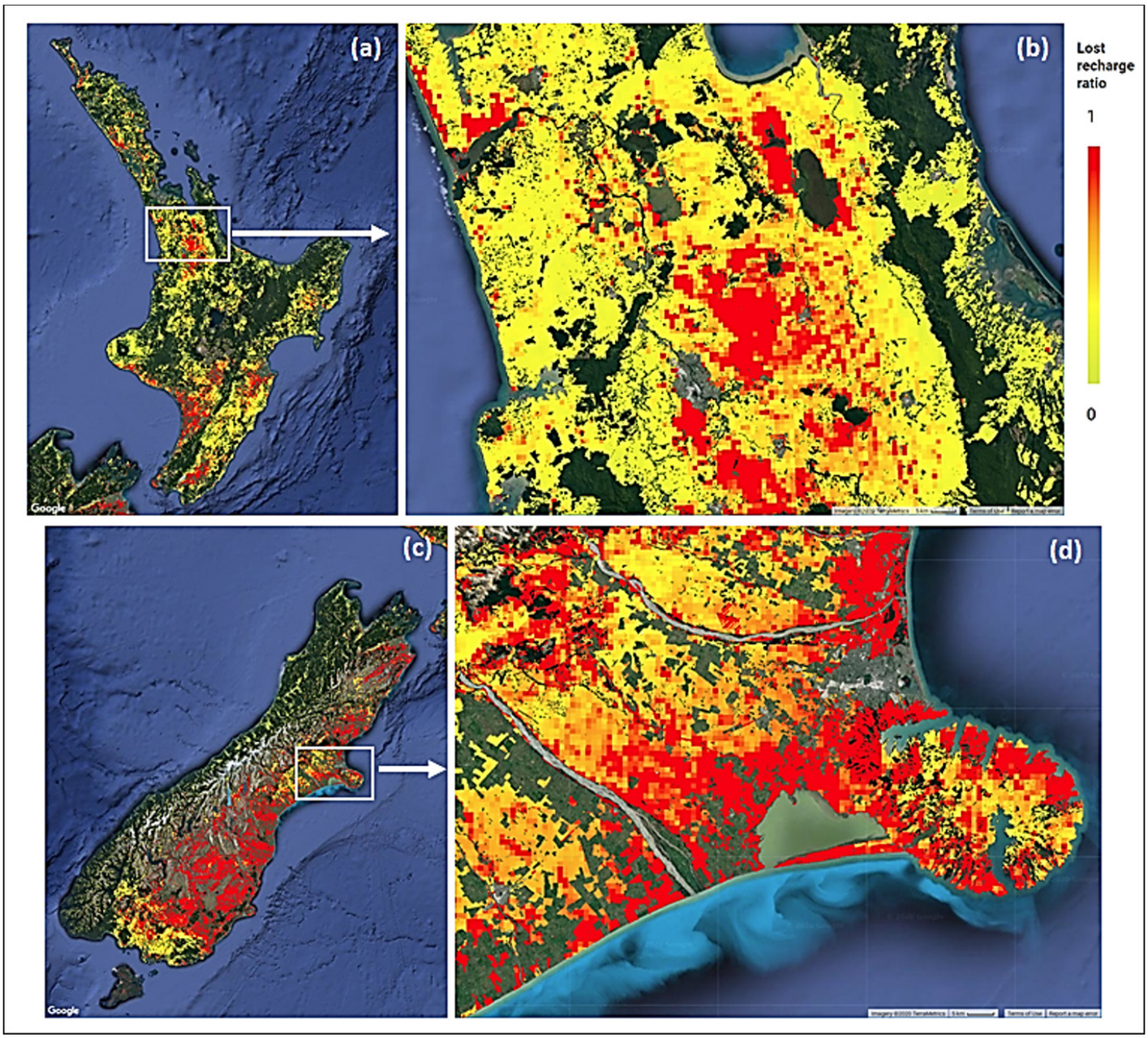


Figure 1. Afforestation related lost recharge ratio maps for (a) NZ North Island; (b) Northwest Waikato/Hauraki Plains; (c) NZ South Island; and (d) Canterbury Plains/ Banks Peninsula.

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THE CHALLENGES OF INTEGRATING MULTIPLE SENSOR TECHNOLGIES INTO A LIVE WATER QUALITY DASHBOARD

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[1] AgResearch Invermay
[2] AgResearch Ruakura

Environmental sensor technology holds a lot of promise for capturing high frequency data and streaming this into live dashboards to support decision making by a wide range of stakeholders. These stakeholders can be farmers wanting to understand and improve their environmental performance, regulators wanting proof of compliance or the public wanting to know if the water is good for a swim or to gather mahinga kai. Different sensors are available from a range of manufactures and most are supported with proprietary dashboards to view the data as it is generated by the specific technologies. However, to gain a full picture of water quality we will need to integrate the data from sensors supplied by multiple different manufacturers. Furthermore, with digital systems we can also incorporate publicly available data from other sources and as a scientist I would also like to incorporate manual grab sample data or record management events. At AgResearch we have developed a live dashboard targeted at the farmer wanting to monitor water quality in a small stream on their property. During this project we have encountered the challenges of dealing with small stream channels, solar power, cell phone coverage, sample collection and Covid-19. Through this we have created a proof of concept system that collects data from multiple sources, quality control checks the data and stores this in a cloud server. The data can then be viewed through a dashboard that integrates and models the data to provide a snapshot of the current conditions as well as a historical period of data for context. The dashboard also provides an overlay of rainfall and grab sample data to help interpret the individual digital data sources. This proof of concept dashboard in now ready for testing with farmers.

THE WHAKAORA TE AHURIRI CONSTRUCTED WETLAND: AN EXAMPLE OF COLLABORATION AND CONSENSUS

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[1] Environment Canterbury

Ahuriri Lagoon, which drains into Te Waihora/Lake Ellesmere, was once a significant mahinga kai resource to Ngāi Tahu. However, with European settlement, the Lagoon was completely drained and the mahinga kai values had been all but lost. To improve water quality, mahinga kai, and biodiversity values, the Whakaora Te Ahuriri project was initiated to develop a constructed wetland at the site. The project has been a model of collaboration and consensus, with: the constructed wetland co-designed by consultants, staff, and representatives of rūnanga and neighbouring farmers; the delivery of the project by a multi-disciplinary project team; and the project's governance by the Te Waihora Co-Governance Group. With the completion of engineering and earthworks over the four-hectare site, and the installation of 124,000 plants, the wetland is now operational. The outcomes of the project will be measured via the complementary approaches of a Mātauranga Māori monitoring programme and an applied research methodology. Time invested in project relationships resulted in a design that met the aspirations and expectations of all partners, and the ability to overcome challenges during the design and construction phases.

Note

There are two other abstracts on this project – regarding the project's design and engineering, and the project's Mātauranga Māori monitoring programme – which, if all were accepted, we thought would be of interest for the audience if they all could be back-to-back in the same session (starting with this presentation, then followed by the design and engineering presentation, and then ending with a presentation on the Mātauranga Māori monitoring programme).

MODELLING SUSPENDED SEDIMENT BASELINES AND REDUCTIONS REQUIRED TO ACHIEVE FRESHWATER OBJECTIVES FOR SOUTHLAND USING SEDNETNZ

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[1] Manaaki Whenua – Landcare Research
[2] Environment Southland
[3] Land Water People

MfE have announced changes to the National Policy Statement for Freshwater Management (NPS-FM 2020), including the addition of a suspended sediment attribute (visual clarity). Environment Southland has begun the process of setting freshwater objectives for the Southland region under the People, Water and Land programme, including objectives for suspended fine sediment. To assess the feasibility of achieving draft objectives, estimates of the reduction in average annual suspended sediment loads needed to achieve target visual clarity were required. SedNetNZ was identified as a suitable model for this process.

A regional application of the SedNetNZ model was developed for Southland, with the inclusion of the sediment trapping effect of lakes, impact of winter forage cropping, and spatially variable soil erodibility. Baseline average annual suspended sediment loads were modelled using SedNetNZ for the Wairau, Ōreti, Aparima, and Matāura Freshwater Management Units (FMUs). Sensitivity to the extent and spatial distribution of winter forage cropping was tested using remotely sensed data from 2014 and 2017. Baseline average annual suspended sediment loads were calculated using landcover and existing mitigations representative of 2017, including the spatial distribution of winter forage cropping and extent of existing stock exclusion fencing. From modelled baseline visual clarity, the reduction in load required to meet draft visual clarity objectives was estimated at selected sites across Southland using empirical models of the relationship between SSC and visual clarity. Suspended sediment loads from the SedNetNZ model will be presented along with load reductions required to meet visual clarity objectives.

ASSESSMENT OF THE POTENTIAL OF LUCI TO ESTIMATE HEAVY METAL LOADS IN URBAN CATCHMENTS

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Contaminants entering waterways, particularly heavy metals, are a human and environmental health concern in particular in urban areas due to the large fraction of impermeable surfaces such as roofs, car parks and roads. The current work aims at assisting with planning of sustainable urban stormwater systems to address water quality issues. For this purpose a process-based pollutant load model 'Modelled Estimates of Discharges for Urban Stormwater Assessments' (MEDUSA) (Charters et al.,2020) has been implemented in the Land Utilisation and Capability Indicator (LUCI). LUCI is an ecosystem services modelling tool, applicable from sub-field to national scales to inform decision making in relation to land management and strategic planning of landscape development and the provision of ecosystem services. MEDUSA can be utilized to simulate event-scale loads of dissolved metal and total suspended solids (TSS). The MEDUSA integration in LUCI was tested for sub-catchments of the Avon river catchment in Christchurch. More specifically, it was parameterised using sampled contaminant loads from key impermeable surfaces and then applied to the Okeover and Addington Brook sub-catchments. An application of MEDUSA to the entire Avon river catchment will be shown, thereby linking sources of contaminant loads to discharge outlets. This can support city planners to better understand how urban planning decisions affect river water quality. This in turn aids in selecting best management options to reduce contaminant load flux from impermeable surfaces and to meet water quality standards.

WHERE THE RUBBER HITS THE ROAD: MANAGEMENT OF URBAN WATERWAYS IN RELATION TO SETBACK CONSENTS

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[1] Christchurch City Council

Urban waterways are constantly under pressure as towns and cities continue to expand. Christchurch City has been subject to increased urban development particularly since the Canterbury Earthquakes, with new subdivisions being developed and pre-existing residential areas being altered. This urbanisation can result in incremental adverse effects on the waterways that flow through these areas. The Christchurch District Plan requires a resource consent when undertaking building, filling or excavating within the defined setbacks of waterways. This is primarily to protect the Christchurch City Council's philosophy of a six-value approach to waterway management: cultural, amenity, landscape, recreational, ecology, and heritage. The number of waterway setback resource consents being applied for have increased dramatically over the years, due to both urbanisation and earthquake recovery (i.e. rebuilding). Consents typically involve intrusions into riparian margins, and piping, realigning and naturalising of waterways. There is often conflict between what the landowner would like to do and what the District Plan is trying to achieve. There are also issues with small cumulative effects combining in a catchment to create significant effects overall. This presentation will focus on the current planning rules, case studies where the rules have resulted in both positive and negative outcomes for waterway ecology, and lessons learned with respect to effective urban waterway management.

RIPARIAN CHARACTERISTICS OF PASTORAL WATERWAYS IN THE WAIKATO REGION, 2002-2017

Norris, M.,[1] Jones, H.,[1] Kimberley, M.,[2] Borman, D.[1]
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[2] Environmental Statistics Limited

The restoration and ongoing management of riparian margins is an important tool to achieve targeted water quality outcomes across New Zealand's farmed landscapes and there have been a number of regional and national initiatives (including policy instruments) to facilitate, and now regulate, riparian restoration efforts. To capture these impacts, the Waikato Regional Council (WRC) has conducted four surveys (2002, 2007, 2012 and 2017) to establish, and track changes in the state of fencing, vegetation, buffer width, crossings and stream-bank erosion at sites on pastoral land across the Waikato region. Prior to 2002, an absence of detailed riparian information made it difficult to benchmark the effects of improved riparian management over the long-term. Thus, the 'regional riparian characteristics survey' was designed to enable the repeatable, quantitative assessment of key riparian characteristics and to provide a region-wide picture of the state of riparian characteristics and the changes in some of these (i.e. fencing, vegetation and stream-bank erosion) over time. Differences in riparian characteristics between land use types, management zones and stream orders (state and trend) are also examined. In this paper, key results from the 2017 survey (undertaken during the summer/autumn of 2017/18), are presented, and changes over the previous 5, 10, and 15-year monitoring periods described. Data from the 2017 survey were collected from 432 waterway sites comprising 244 in dairy and 188 in drystock. An analysis of survey results in relation to regulations outlined in the Action for Healthy Waterways package (2020 'Decisions on the national direction for freshwater' document) and Waikato Regional Council's Plan Change 1 decisions version document (Schedule C) was also undertaken.

UNDERSTANDING LONGFIN AND SHORTFIN GLASS EEL RECRUITMENT VARIATION IN A LARGE REGULATED RIVER

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The marine life stage of New Zealand's longfin (*Anguilla dieffenbachii*) and shortfin (Anguilla australis) tuna/eels is poorly understood. While freshwater habitat degradation, migration barriers and disease are widely known to impact freshwater life stages, less is known about how changing conditions in the marine environment and triggers for inward migration to freshwater (i.e., temperature and discharge) affect glass eel recruitment and migrations.

Currently, there is very little monitoring of glass eel recruitment in Aotearoa. However, the International Eel Review Panel that reviewed New Zealand eel management in 2013 suggested that glass eel recruitment monitoring may help to disentangle trends in eel populations.

Here, we describe temporal variation in the recruitment patterns of longfin and shortfin glass eels in the Rangitāiki River, Bay of Plenty. The Rangitāiki River is the largest river in the Bay of Plenty region with two hydro-electric schemes at Matahina and Āniwaniwa. Together with assistance from mana whenua, we sampled for glass eels bi-monthly using fine-mesh fyke nets between June and November 2020 across a wide range of environmental conditions. We describe temporal patterns in glass eel abundance, catch-per-unit-effort and proportions of longfin and shortfin eels in the catch with respect to environmental conditions. We further describe temporal variation in species-specific phenotypic traits including size and body condition at inward migration. Our results will help to better understand temporal variation in glass eel recruitment and phenotypic traits in a large regulated river.

APPLICATION OF A BAYESIAN CHEMISTRY-ASSISTED HYDROGRAPH SEPARATION (BACH) MODEL TO 48 DIVERSE CATCHMENTS IN WAIKATO, HAWKE'S BAY AND TARANAKI

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To investigate the contributions different pathways make to stream flow and the transfer of nitrate and total phosphorus, we applied a BACH model to flow data and monthly nitrate and phosphorus concentration time series from Waikato, Hawke's Bay and Taranaki regional councils. The BACH model separates the total flow into fast (near-surface), medium (shallow groundwater), and slow flow (deep groundwater) components based on the dynamic changes in stream flow and in the concentrations of two routinely measured water constituents (used as tracers). The BACH method assumes constant pathways discharge concentrations of these tracers during the time period under study (e.g., constant phosphorus and nitrate concentrations in the fast, medium and slow flow path discharges). The time-varying concentrations observed in the stream are interpreted as the flow-weighted combination of the contributions made by the three flow paths (using the end member mixing analysis assumption). The climate and topography of the 48 catchments varied significantly. This is reflected in the flashiness index (the frequency and rapidity of short term changes in streamflow) of the streams, which ranged from 0.09 to 0.68, and the mean slope of the catchments, which varied from 0.24 to 5.9 degrees. The relative contributions of fast, medium, and slow flows to solute transport were somewhat affected by temporarily changing climate condition, but they were dominantly controlled by the characteristics of the catchment. The modelled concentrations of phosphorus generally increased from slow to fast flow and that of nitrate showed the highest concentration in medium flow. Although the contribution of slow flow was significant, fast and medium flow transported in most catchments the majority of nitrate and phosphorus. Overall, fast flow was the largest contributor for phosphorus transport, and the medium flow was the largest one for nitrate. However, the regions and subregions differed in their relationship between average slope, flashiness, and the transport of nitrate and phosphorus, reflecting their varying combinations of landuse, climate, geology and topography. In Waikato, two distinct relationships were observed in terms of flashiness, mean slope, and nitrate transport. While nitrate transport on the Coromandel peninsula was dominated by fast flows, the medium flow component was dominant in all other parts of the Waikato region. We included 6 sets of nested catchments in our dataset to investigate the effect of catchment size on our results.

STUCK IN THE MUD: USING ENVIRONMENTAL DNA TO INVESTIGATE SHIFTS IN LAKE SEDIMENT CORE BACTERIAL COMMUNITIES

Pearman, J., Biessy, L., Thomson-Laing, G., Reyes, L., Shepherd, C., Howarth, J., Rees, A., Li, X., Vandergoes, M., Wood, S.

A continuous record of environmental history is stored in lake sediments providing an avenue to explore current and historical lake communities. Traditionally paleolimnological methods have focussed on microscopic fossils (e.g. pollen, chronomids, diatoms) to investigate environmental changes. The application of environmental DNA techniques has enabled the investigation of microbial communities through time. The 'Our lakes' health; past, present, future (Lakes380)' project aims to combined traditional and molecular methods to explore shifts in biological communities at a national scale over the last millennium, which encompasses pre-human arrival in New Zealand. In this study we sampled sediments cores from across New Zealand and used 16S rRNA gene metabarcoding approaches of both DNA and RNA to reveal microbial community changes across time and especially how the lake communities shift in response to human induced changes. We further investigate the changes in inferred functional potential of the microbial communities as the taxonomic composition of the lake differs over time. These approaches are complemented by the investigation of specific taxa, such as bloom forming *Microcystis*, with droplet digital PCR as indicators of changes in lake health. The analysis of microbial communities, combined with hyperspectral scanning and pollen data will improve the knowledge of historical and current shifts in lake communities and improve the characterisation of the timing of changes in lake health. The inclusion of microbial data will provide a greater understanding of the environmental history of lake systems and will help to inform management decisions relating to the restoration and protection of lake health.

ARSENIC IN CANTERBURY GROUNDWATER: SOURCES, TRIGGERS AND SPATIAL OCCURENCES

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Aims

In some areas of Canterbury, arsenic (As) concentrations in groundwater exceeding the (heath-based) maximum allowable value (MAV; 0.01 mg/L) have been observed. This is problematic because groundwater is a drinking water source, and, if chronically consumed at concentrations of ≥0.01 mg/L, As can increase the risks of human health issues (Hopenhayn, 2006).

This work aimed to increase our understanding of spatial occurrences of elevated concentrations in Canterbury groundwater by identifying the sources (i.e. natural or anthropogenic) and drivers (e.g. water-rock interactions, geochemical triggers) of elevated As. This approach aims to allow earlier identification (and avoidance) of potential As contamination of drinking-water.

Method

This work had two main components. Firstly, we mapped, reviewed, and summarised Environment Canterbury's groundwater quality data collection. Secondly, to help us interpret our data, we also reviewed national and international scientific literature, and internal reports from previous investigations in Canterbury.

Results

In groundwater, As can originate from natural (e.g. geologic/mineralogic/hydrothermal) or anthropogenic (e.g. landfill, sheep dip sites) sources. Across Canterbury, 1,277 wells (including springs) have been sampled for As (1984-2020) (Figure 1 a.). Of these wells, 162 (12.7 %) have contained detectable As at least once, and 49 (3.8 %) wells have a recorded As concentration which exceeds MAV (Figure 1 b). However, the total numbers and percentages of wells with high As concentrations varies between zones (Figure 1 b).

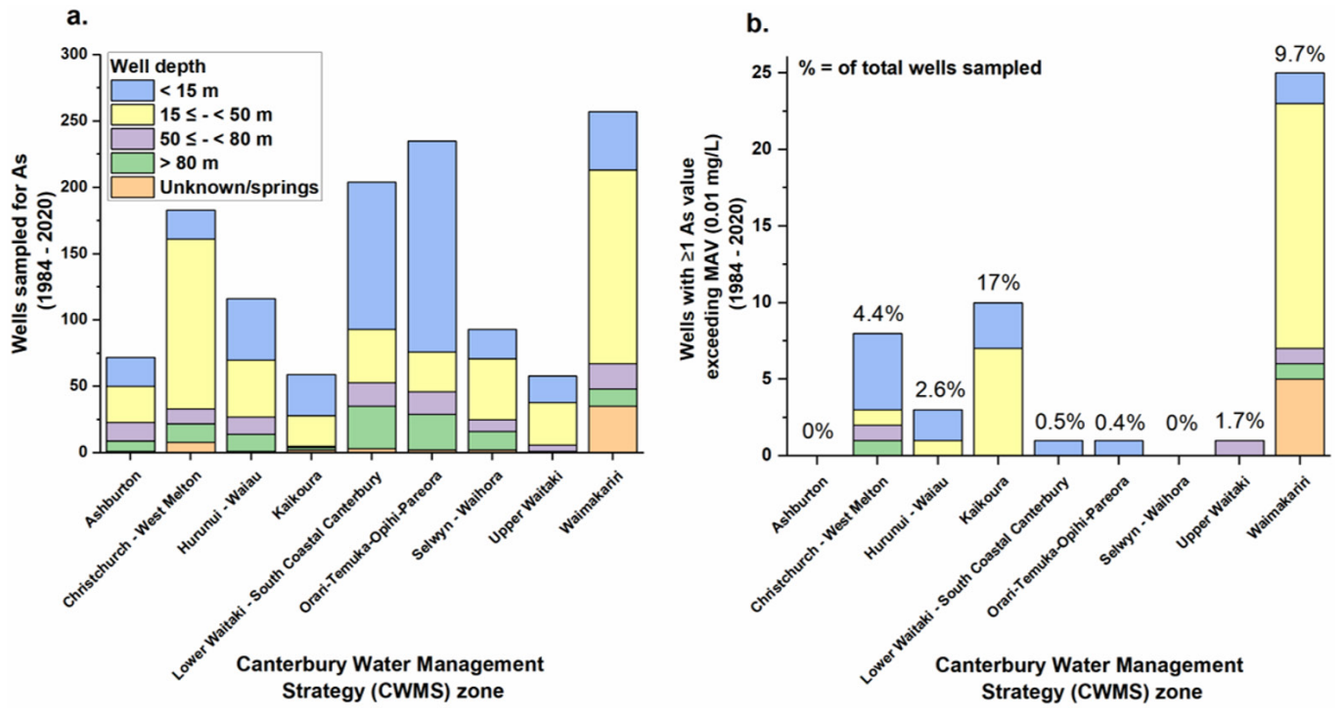


Figure 1: (a.) Total no. of wells sampled for As per zone across Canterbury (b.) Total no. of wells with maximum recorded As values in exceedance of MAV per zone across Canterbury.

Our As map (Figure 2 a.) shows there are some 'hotspot' areas where As values have exceeded MAV, and even twice MAV. Environment Canterbury's more intensive sampling for As has been primarily targeted at the areas known to have elevated As, including west of Kaikoura township (Kaikoura zone) (Figure 2 b.) and patches near the coast in the Waimakariri and Christchurch West-Melton zones.

Across Canterbury, our data showed that As concentrations exceeding MAV are more likely to occur in low-lying, coastal areas. Coastal aquifers are more likely to have reduced groundwater (Wilson et al., 2020), which can 'trigger' elevated As concentrations (Nordstrom, 2002; Smedley & Kinniburgh, 2002) due to reductive dissolution of As bearing minerals (e.g. iron oxides/hydroxides). Our data also revealed evidence for As release from some landfill sites. Notably, in Ashburton and Selwyn-Waihora zones, there is a lower incidence of As detection, indicating that either As is not present, or that it is not being mobilised due to generally oxic groundwater conditions.

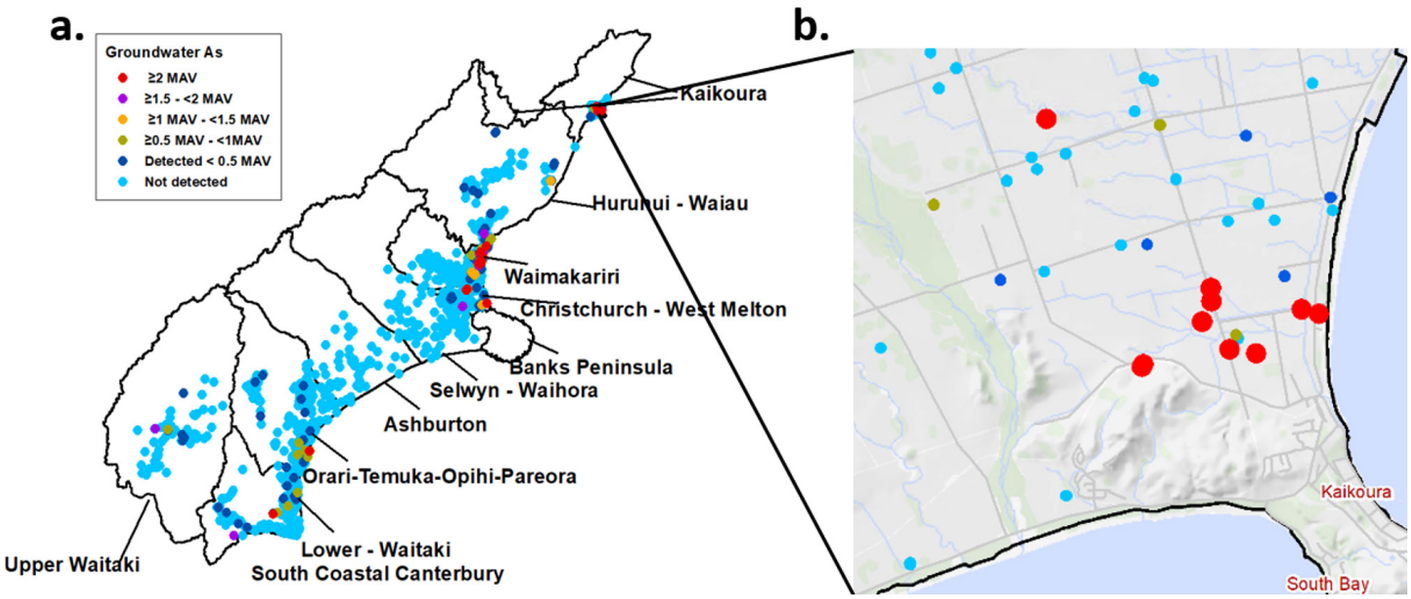


Figure 2: (a.) Maximum As values recorded in individual wells in Canterbury, shown in the context of maximum allowable values (b.) An example of an As 'hotspot', where maximum groundwater As concentrations exceed double MAV in 9 wells Kaikoura.

Our findings have been used to produce two outcomes. Firstly, a technical report for groundwater scientists and secondly, an 'information to well owners' document, which informs on the necessity of As testing for individual zones, hotspot areas, and Canterbury as a whole.

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ETI TOOL 3: ASSESSING ESTUARY TROPHIC STATE USING A BAYESIAN BELIEF NETWORK

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Excessive nutrient and sediment inputs threaten many New Zealand estuaries; these inputs cause ecological problems such as algal blooms and poor physical and chemical conditions for estuarine life. Until recently, guidance on how to assess the extent of eutrophication and sediment impacts in NZ estuaries has been limited. To respond to this challenge, regional councils worked with NIWA to develop the Estuary Trophic Index (ETI) tools. The purpose of the ETI is to provide a nationally consistent approach to the assessment and prediction of estuary eutrophication.

The ETI tools enable users to assess susceptibility of estuaries to eutrophication (Tool 1) and score an estuary along an ecological gradient from minimal to high eutrophication using field observations of indicator states collected from estuary surveys (Tool 2). We will discuss the development of Tool 3, a Bayesian Belief Network (BBN) that predicts estuary responses to eutrophication and sedimentation pressure. Tool 3 uses knowledge of the ecological connections between drivers of estuary trophic condition (e.g., estuary type, nutrient and sediment loads, estuary closure state) and responses of indicators (e.g., muddiness, seagrass cover) to calculate an ETI score. We will describe the overall structure of the BBN and the ecological and geomorphic information underpinning the connections between its nodes. We will demonstrate its utility using case studies of impacted and un-impacted estuaries.

RAIN-ON SNOW IN THE SOUTHERN ALPS: HYDROMETEOROLGY AND IMPACTS

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Rain-on-snow (ROS) events are important hydrometeorological phenomenon in alpine catchments. A combination of snowmelt and heavy rainfall can result in a rapid hydrological response and bring about significant flooding events (Marks *et al.,* 1998). The Southern Alps of New Zealand are influenced by maritime weather conditions with mountainous regions regularly experiencing temperatures above 0 °C in winter months (Fitzharris, Lawson and Owens, 1999). Consequently, seasonal snowpacks are exposed to frequent ROS events over the snowpacks (Moore and Owens, 1984). Despite the frequent occurrence of ROS in the Southern Alps, the hydrometeorological characteristics of these events remain poorly understood. Of particular interest is the characteristics of water vapour transport and its role in providing moisture and warm temperatures during the days leading to ROS events.

Mid-latitude Southern Alps have been found to be largely influenced by frequent landfalling atmospheric rivers (ARs) (Kingston, Lavers and Hannah, 2016; Little *et al.,* 2019). Since atmospheric rivers contain warmer temperatures compared to other winter storms due to the freezing level being at higher altitudes (Guan *et al.,* 2016), there is a greater likelihood that some landfalling ARs result in ROS in maritime mountain regions where ROS events are common phenomena.

Aims

Given the current gap in the knowledge of hydrometeorology of ROS events and their potential significance in snow hydrology of the Southern Alps, the primary objective of this study is to explore the mechanisms of moisture transport during ROS event. More specifically, this study intends to: (1) identify the role of ARs in producing winter- and spring-time ROS events by analysing integrated vapour transport (IVT), and (2) investigate atmospheric conditions and snowpack response of two individual ROS events during early winter (June 2016) and spring (November 2018) in order to provide a better understanding of hydrometeorological characteristics of ROS events in the maritime Southern Alps.

Data and Method

The climate variables from Mueller Hut automatic weather station located near the Main Divide of the Southern Alps were used to identify rain-on-snow events. In order to characterise the general patterns of moisture transport during major ROS events the 10 topmost ROS events with the highest daily accumulated rain were selected during the periods when snow was on the ground and a decrease in snow depth occurred.

In order to quantify the magnitude of moisture flux from the Tasman Sea towards the Southern Alps the integrated vapour transport (IVT) was computed during ROS events using ERA reanalysis data from the Interim European Centre for Medium-Range Weather Forecasts (ECMWF). An AR identification method (Length ≥2000 km, Length/Width ≥2, and IVT ≥ IVT^{85th}) was applied to explore the relationship between ARs and ROS events in the Southern Alps.

Results

Analysis of IVT showed that all ten identified events were associated with strong fluxes of tropical water vapour travelling over Tasman Sea in a north west to south east direction. It was found that out of these 10 ROS events, nine were associated with ARs. An analysis of two individual ROS-producing ARs (Figure 1) which made landfall in winter (June 2016) and spring (November 2018) revealed further details about hydrometeorological characteristics and impacts of such events in the Southern Alps.

The November AR produced the largest ROS during the period of this study with total accumulated rainfall as much as 540 mm recorded in parts of the Southern Alps. The June event was regarded as the largest winter time ROS with a total rainfall of 229.5 mm recorded at Mueller Hut. Interestingly, both ARs had several similar synoptic features while passing the Tasman Sea. The formation of a deep low pressure system which moved from the southwest of South Island towards the Southern Alps, was identified during these events. Both events were associated with strong moisture fluxes (up to 822 kg m^{-1} s^{-1} near the Main Divide) containing anomalously high temperatures at lower levels of the troposphere and high advection of warm airflows. Analysis of the vertical structure of the temperature revealed an increase in freezing level with the 0 °C line located between 725 650 hPa. In the Southern Alps, these conditions brought about a rapid increase in air temperature with values up to 10 °C, and consequently high snowmelt rates (up to 20 cm/day) near the Main Divide.

Observations of alpine river flows during the passage of ARs indicate that a combination of persistent heavy rainfall

and intense snowmelt can generate significantly high peak flows in the upper terrains of the Southern Alps. While the primary focus of this study was the large-scale hydrometeorological characteristics of ROS events, further studies are required to comprehensively investigate flood-generating ROS events which are capable of causing disruptions in alpine catchments of the Southern Alps.

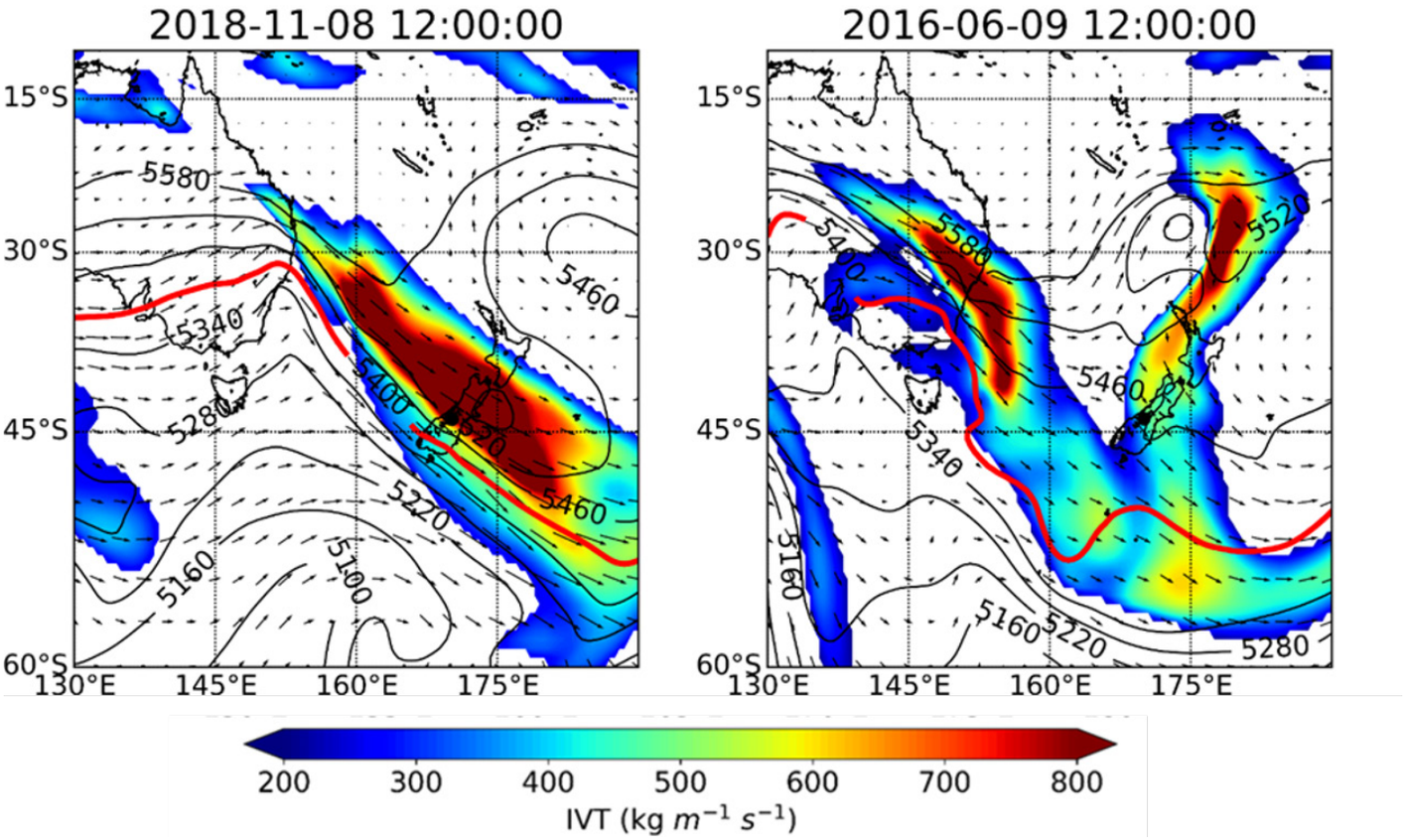


Figure 1: ARs associated with June 2016 and November 2018 ROS events

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EFFECT OF RIPARIAN WIDTHS FOR REDUCING CONTAMINANTS FROM DAIRY-FARM LANEWAYS

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[1] Groundtruth Ltd, Te Awamutu
[2] Dairy NZ, Lincoln
[3] Horizons Regional Council, Palmerston North
[4] Lucy Burkitt, Massey University

Dairy farm laneways adjacent to drains pose a risk as a potential source of contaminants to water. Laneways represent locations with large amounts of effluent loading. Furthermore, cow movement across a laneway of compacted gravels is likely to mobilise fine sediment, increasing the possibility of transport into waterways via runoff during rainfall events. Despite the risk of contaminant losses from laneways to nearby waterways, few studies have quantified the effects of good riparian practices to reduce loading of nutrients, sediment and faecal material from surface runoff.

A trial has been installed on a Pāmu (Landcorp) farm in the Manawatu, Moutua complex where a cow laneway runs adjacent to an open (pumped) drain for 900m+. Six plots of rank grass riparian buffers have been installed at 25, 115, 220, 3445, 715 and 940m from the cowshed to determine the effects of differing riparian widths (0.5 to 3.5m) on laneway run-off. A novel sampling technique to capture surface runoff- and estimate attenuation of contaminants has been installed.

Water quality data from 170 samples of laneway run-off were collected over 9 rainfall events between December 2019 and August 2020. Initial analysis showed that in while increased width of vegetative (grass) buffer generally reduced phosphate (P), nitrogen (N) and E. coli. concentrations in laneway run-off, the effect was not consistent. The effect of distance from the cowshed was also not consistent with a peak in P, N and E.coli. concentrations at 220m. Sites were apparently very similar (slope vegetation, interface with laneway) suggesting closer analysis should focus on aspects like animal behaviour, run-off volume vs rainfall.

THE RELATIONSHIP BETWEEN FLOODING AND ATMOSPHERIC MOISTURE AND ITS VARIABILITY THROUGHOUT NEW ZEALAND

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[1] School of Geography, University of Otago
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[3] National Institute for Water and Atmospheric Research, Christchurch

The occurrence of flooding in New Zealand regularly results in devastating impacts to the local society and environment. The intensity of precipitation is an important factor to consider when exploring flood risk and the potential for damage. The relationship between precipitation intensity and atmospheric moisture is explored in this presentation with a particular focus on the spatial variability in this relationship throughout New Zealand. The strength of this relationship is highly dependent on the topography of the South Island. On the West Coast of the South Island, the intensity of precipitation events (and potential for flooding) is closely linked to the amount of moisture being transported through the atmosphere. Approximately 60% of the variability in precipitation intensity (3-day precipitation) on the West Coast can be explained by variations in atmospheric moisture transport. In other locations around New Zealand, between 6% and 14% of precipitation intensity is explained by atmospheric moisture transport. Along with current warming, the atmosphere is also getting more moist and these established relationships are important to consider when exploring possible changes to flood events into the future. The ability to characterise the governing factors of the most devastating floods in New Zealand will further our ability to envisage and prepare for future extreme hydrological events and maintain livelihoods throughout the county.

USING FOSSILISED PIGMENTS TO UNDERSTAND CYANOBACTERIAL BLOOMS IN NEW ZEALAND LAKES

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Phytoplankton (including cyanobacteria) are a natural component of lake ecosystems and are the base of many food webs. However, changes in the lake catchment, the lake itself and the wider environment (e.g., climate change) can alter the composition of phytoplankton communities. Of recent concern is the increase in the abundance of cyanobacteria and the formation of blooms in many of New Zealand's low-land lakes (>30% of those that are monitored). Because regular monitoring data does not stretch back more than 10-30 years and many lakes are not regularly monitored, it is difficult to ascertain whether the intensity of present-day blooms are a new phenomenon or are part of a pre-existing cycle. The pigments produced by cyanobacteria (and other phytoplankton) are deposited in lake sediment and can be extracted from sediment cores and surface sediment samples. Analysis of these pigments by high-performance liquid chromatography and fluorescence spectroscopy has allowed us to reconstruct the historical phytoplankton community from eight New Zealand lakes and to track the emergence of cyanobacteria in impacted lakes. In this talk we will present data on the performance of different cyanobacteria pigment indicators and the use of phycocyanin and phycoerythrin for such studies. Several case studies will also be presented to demonstrate how fossilised pigment data can be used to understand shifts in lake phytoplankton communities.

REINSTATING ACCESS AFTER A SEISMIC SHIFT IN THE WAIAU TOA/CLARENCE RIVER

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[1] Beca Ltd

The Waiau Toa/Clarence River flows from Lake Tennyson in the Canterbury high country, 230 km to the east coast about 33 km north of Kaikōura. It has a catchment of 3,300 km². The Waiau Toa/Clarence River is one of the great iconic wilderness rivers of New Zealand, set in a rugged and remote landscape, it has 'high naturalness' values.

In the November 2016 Kaikōura Earthquake, the Papatea Fault, which crosses the Waiau Toa/Clarence River twice about 11 km upstream of the river mouth, ruptured with uplift on both sides of the fault but approximately 5 m more uplift on the true right than the true left of the river. This caused the collapse of the Glen Alton Bridge that carries Clarence Valley Road across the Waiau Toa/Clarence River, cutting off access to the community on south side of the river upstream of the Wharekiri Stream.

The earthquake also led to a change in course of the river downstream of the Glen Alton bridge site, with the formation of a new channel to the true left following the lower side of the fault line and cutting though farmland. This was a significant step change in the river morphology in an already dynamic braided river.

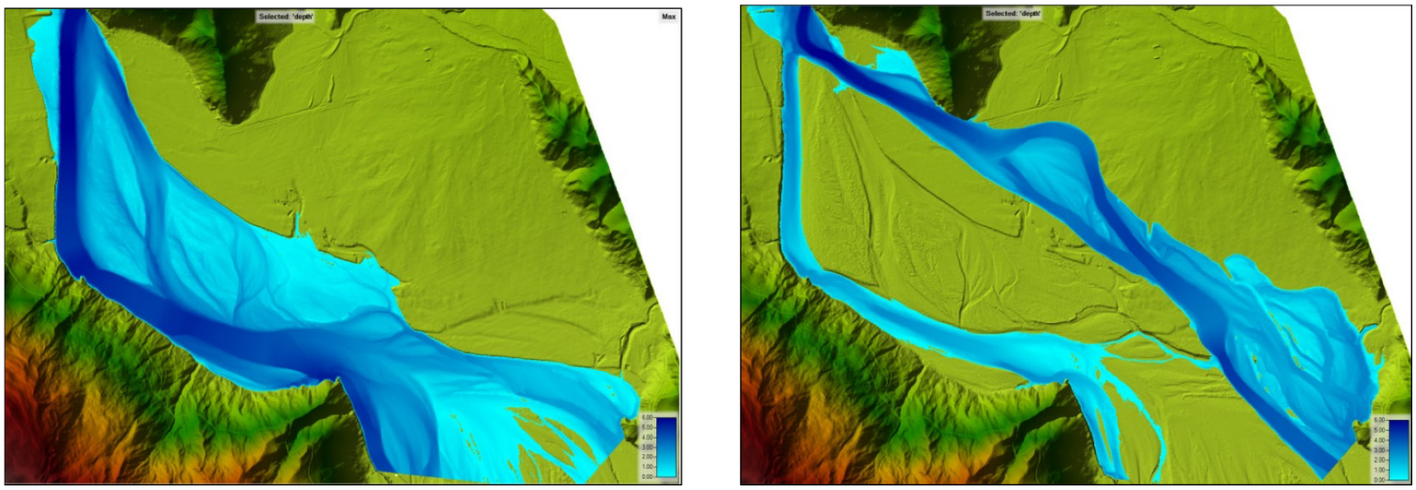


Figure 1. 2D flood modelling of the Waiau Toa/Clarence River downstream of old Glen Alton Bridge, with 2012 and 2019 geometry

In 2018 Beca was engaged to consider options for reinstating vehicular access to the Clarence Valley, including investigating the river morphology and providing river engineering input into access options. This required understanding the new river form and predicting likely changes in the short and long term, to:

- Inform consideration of access options, including road alignments and bridge and ford locations to cross the main channel of the river and overflow channels.
- Provide inputs into bridge design taking account of flood levels, scour and long-term channel bed aggradation/ erosion.
- Design river engineering works to train the river and minimise the risk to the road.

The rapidly evolving river form river and limited data available made this challenging. The investigation and design process included many site visits, meetings with and input from locals, comparison of photos from known vantage points, and drone footage, as well the more usual sources such as aerial photographs, survey, LiDAR, and water level monitoring. The author has also kayaked the river twice since the Kaikōura Earthquake, in December 2017 and again in December 2019, providing another perspective on this stunning and dynamic river.

The preliminary design for a new access across the river was completed in May 2020, for consideration as part of the 2020/2021 Kaikōura District Annual Plan.

This presentation will explore:

- The changes in the Waiau Toa/Clarence River in the Clarence Valley area due to the Kaikōura Earthquake
- The challenges in predicting on-going changes in the river morphology in the short and long term, while working with limited data
- The emergency river engineering works undertaken to protect the existing road
- The long term access options for Clarence Valley and the associated flood modelling and design of river engineering works.



Figure 2. The author kayaking the Waiau Toa/Clarence River in December 2017

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KAUPAPA MAORI METHODOLOGIES – WHAT'S OUT THERE?

Rainforth, H.[1]
[1] Perception Planning

National freshwater direction and legislation requires an increased focus on mātauranga Māori and mana whenua partnerships. Te Mana o Te Wai and meeting compulsory Māori vales will require an increase in the development and support for kaupapa Māori assessments, but where do you start?

Kaupapa Māori assessments are not new and have been in development for some decades. There are now numerous different tools available to assess different values or situations. This talk will provide a starting point and introduce some of the possible tools and considerations that may be useful when starting on this journey.

MODELLING CUMULATIVE CATCHMENT STREAMFLOW DEPLETION DUE TO ABSTRACTIONS

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[3] Horizons Regional Council
[4] Waikato Regional Council

Background and Aims

Water abstraction from rivers and aquifers has considerable potential to alter flow regimes in many countries (Dalin et al., 2017), including across New Zealand (Booker 2018), thereby influencing the physical, chemical and ecological wellbeing of freshwater ecosystems (Poff et al., 2010). The economic and social benefits of abstraction need to be balanced against their potentially detrimental consequences for hydrology dependent ecological functions, ecosystem services, cultural values and recreation (MFE, 2015). Legislative requirements therefore often require river and water resource managers to deploy catchment planning frameworks. These frameworks often aspire to maintain ecological health and life-supporting capacity of rivers, including regulation of water abstractions to limit alteration of river flows. Impacts of an abstraction on flow regimes are often assessed in isolation and thereby fail to understand cumulative impact of many spatially distributed abstractions on the catchment. However, the National Policy Statement for Freshwater Management (NPS-FM) directs regional councils to set limits on the use of water resources for all waterbodies; the limit is intended to enable the council to manage the actual and potential cumulative impacts of abstractions and reduce allocation of the hydrological resource in over-allocated catchments (MFE, 2015). It is also important to have nationally consistent methods for reporting (e.g. State of the Environment reporting). While spatially distributed, high-resolution model(s) (e.g. MODFLOW) can be developed to understand the cumulative impacts of abstractions, it is cost and data (e.g., system properties, hydroclimatic) prohibitive to develop such a model at regional scales and such site specific models cannot be transferred to other spatial locations. Therefore, there is a need to develop an approach, which is inexpensive, defensible, transferable, consistent and repeatable, that can be used to allocate water sustainably, manage waterbodies and assist limit setting. The main aim of this research project was to develop and apply a model to estimate cumulative daily timeseries of streamflow depletion resulting from recorded or estimated abstractions from surface and groundwater across New Zealand.

Method

We have developed a model to estimate cumulative streamflow depletion at given locations of a stream network resulting from both surface and groundwater abstractions at relatively fine spatial and temporal scales. The New Zealand's national river network, as defined in the River Environment Classification (REC; Snelder and Biggs, 2002) was used as the spatial framework for all analysis in this project. The spatial locations of both surface water and groundwater abstractions are based on regional council consent information. The surface water abstractions directly deplete the nearest segment (with which the abstraction is associated) of the REC river network. However, depletion owing to each groundwater take was associated with all segments on the REC which was within a 2 km radius of the coordinates describing the groundwater take point (Figure 1(a)). The proportion of depletion from each river segment owing to a groundwater take is dependent on distance between well and segment, flow (based on the naturalised 7-day mean annual low flow) and length of the segment within 2 km radius of the well.

The rate of stream depletion due to abstracting groundwater may depend on many factors: groundwater pumping rate, horizontal distance, depth, hydraulic properties of the aquifers, hydraulic properties of confining layers between the pumping aquifer and stream, streambed sediments and hydraulic gradient between the two water bodies. Data and information available for estimating stream depletion vary considerably within and between regions. Data gaps in some areas introduce uncertainty into selecting the most suitable model for estimating the streamflow depletion in a regional/national scale study. Therefore, we applied two different approaches to estimate streamflow depletion. The two approaches and the assumptions made under each approach were:

1. A one-layer model - The aquifer from which groundwater is abstracted is essentially a single unconfined aquifer. Therefore, the screen of the well is hydraulically connected (homogeneously through the aquifer material) to the stream(s) that depletes due to groundwater pumping.
2. A two-layer model - A two-model approach is used based on the screen depth of the groundwater well. The approach described in the above (1) is used for the groundwater abstraction (screen depths) within 0-30 m below ground level (i.e., it was assumed that the aquifer system up to 30 m depth is unconfined as that depth is generally used as the average thickness of the unconfined aquifer (e.g., Ministry of Health, 2010). Whereas the takes below 30 m are assumed to be pumped from a semi-confined aquifer overlain by an aquitard and an upper aquifer. The

streamflow depletion due to pumping from the bottom aquifer is estimated using an analytical model developed by Ward and Lough (2011).

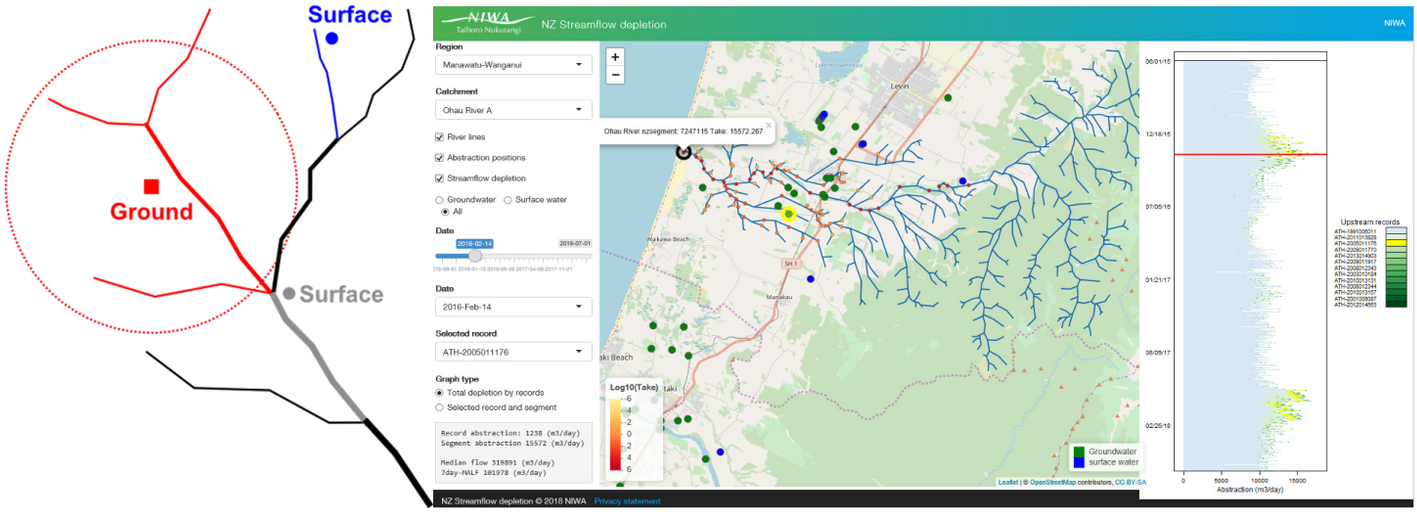


Figure 1. (a) A schematic diagram showing the segment assignment for surface water (blue) and groundwater (red) abstractions, (b) Screen capture showing the streamflow depletion interactive app.

Two aquifer parameters (transmissivity and storativity) are used for calculating the streamflow depletion. Field tests can be used to measure these parameters, but observations are not available for all necessary location. We used Random Forest statistical technique to estimate the aquifer parameters at unmeasured locations.

Results

The model was applied to the Greater Wellington and Horizons regions using their consent, water use data and aquifer parameters. Results are displayed using an interactive app (Figure 1(b)). The model can be used to obtain timeseries of cumulative stream depletion at any location in the river network due to many spatially distributed abstractions. This can be used for scenario testing of different abstraction regimes to assess the impact on stream flows. The model is also currently tested against MODFLOW model results for Hauraki Catchment in collaboration with Waikato Regional Council and GNS, and these results will be demonstrated at the presentation.

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HAWKE'S BAY 3D AQUIFER MAPPING PROJECT USING AIRBORNE TIME-DOMAIN ELECTROMAGNETICS (SKYTEM): OVERVIEW AND UPDATE

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[1] GNS Science
[2] Hawke's Bay Regional Council
[3] Aarhus University HydroGeophysics Group
[4] Project Haus

The Hawke's Bay 3D Aquifer Mapping Project is a three-year project (Sept 2019 – Dec 2022) that is jointly funded by the Provincial Growth Fund, Hawke's Bay Regional Council (HBRC) and GNS Science (GNS).

In early 2020, SkyTEM data for the project was collected by SkyTEM Australia using a specially equipped helicopter flying over Hawke's Bay along flight lines about 200 m apart. Close to 8000 km of data was collected over the Heretaunga Plains, the Ruataniwha Plains, and the Otane and Poukawa Basins.

An overview and update will be provided on progress to-date, including the survey design and objectives, the successful communication approach taken, flight details, preliminary datasets, and advanced data processing and inversion being undertaken. The survey area of Otane and Poukawa Basins has been processed first and key results presented will focus on this area.

SEDIMENT DISCHARGES FROM SMALL SCALE LAND DISTURBING ACTIVITY: SHOULD WE BE CONCERNED?

Redman T.,[1]
[1] Pattle Delamore Partners Ltd

Contribution of sediment from large scale land disturbing activities to adjacent water ways is a known issue. Therefore, consents granted by local government target run-off by making sediment controls and monitoring mandatory. However, what happens once large-scale earth moving contractors move out and developers/builders move in? This part of the development process often goes unmonitored and therefore the quantity of sediment entering receiving environments is mostly unknown.

Pattle Delamore Partners Ltd (PDP) in conjunction with the Auckland Council and with support from the Howick Local Board, identified a newly established subdivision as an appropriate case study to deploy monitoring equipment to understand the impact of small-scale earthworks. This subdivision is made up of several small-scale earthwork or construction sites that are no larger than 500 m2.

Two monitoring stations were installed, one upstream and one downstream of the targeted small-scale earthworks sub-catchment. The telemetered monitoring stations deployed consisted of pressure transducers and ISCO automatic samplers at each monitoring location. The pressure transducers were set to a particular level (trigger level for sampling) which was above base flow levels within the stream. This trigger level was determined to identify a storm event, purely by the water level rising above normal. Once the trigger level was met, the logger connected to the PT signals the ISCO to start sampling.

To enable PDP to calculate sediment flux, a flow relationship was required. Flow was obtained by an indirect flow method carried out in accordance with the National Environmental Monitoring Standards. Thereby, allowing a discharge rating to be established for each of the monitoring locations, in conjunction with water level, to create a continuous flow record. Flow was then combined with sediment concentrations captured by the automatic samplers (spanning large portions of rainfall events) to calculate a theoretical sediment flux.

By having both an upstream and downstream location, a comparison can be drawn between the two sites and the impact of the catchment in question evaluated. The results indicate a first flush sediment discharge from the sub-catchment but an overall limited impact on the receiving environment.

Overall, the use of automated sampling methods proved invaluable during this project. Automatic samplers triggered by water level allowed for samples to be taken during first flush periods and then throughout rainfall events without staff being present. The use of the indirect flow method also proved beneficial. With budget limitations not allowing the development of a traditional stage-discharge relationship, the indirect flow method still allowed for a theoretical sediment flux to be determined.

INVERCARGILL SHELL-BED AQUIFER – MUNICIPAL SUPPLY SOURCE?

Rekker, J.,[1] Rissmann, C.,[1] Rodway, E.,[3]
[1] JH Rekker Consulting Ltd
[2] Land and Water Science Ltd
[3] Environment Southland

Aims

Invercargill has been supplied with ample water from the Oreti River, which after treatment has been entirely adequate for the city's needs since the late 1950s. However, the city has no back-up raw water source and a costing of bringing back-up surface water supplies from the southern Fiordland lakes for emergencies underlined the desirability of seeking a back-up source locally. Accordingly, Invercargill City Council has funded investigation into the accessibility and treatability of deep groundwater within the wider Invercargill area.

Method

Eastern Southland has had little exploration or development of deep groundwater, so initial scoping studies identified the availability of substantial data on subsurface condition obtained during petroleum and mineral investigations in the late 20th Century. These included petroleum geophysical surveys, coal seam gas drilling to 300 m or more, lignite mine feasibility investigations to 240 m and a recently uncovered groundwater supply investigation commissioned by Ocean Beach Freezing Works that wound up before the water source could be developed.

Literature search and data analysis identified Miocene aged shell-bed coquinas lying beneath the thick Gore Lignite Measures as a potential groundwater source with promising quality and capacity. The 1986 Ocean Beach drilling investigations south of Invercargill provided bore logs, geophysical logging, water analyses, but no aquifer testing for a potential bore field drawing on the Chatton Formation shell-beds (Morrison, Cooper and Partners, 1986). Comprehensive aquifer testing was undertaken in the Gore Lignite Measures in the same year at the Ashers-Waituna proposed lignite mine. Significantly, the Ashers-Waituna aquifer testing (Liquid Fuels Trust Board, 1986) provided detailed characterisation of the inter-aquifer leakage characteristics with the expectation of applicability to underlying the shell-bed coquina aquifer. The Chatton Formation shell-bed coquinas are sandy and comprise detrital shell accumulations in a shallow marine to intertidal environmental setting.

Bore logs, down-hole geophysics (particularly resistivity) and grain size analyses from Ocean Beach exploration holes were used to generate probable multi-layer groundwater system properties for the Quaternary sediments, Gore Lignite Measures and Chatton Formation shell-beds. Aquifer and aquitard depth layering alongside coefficients of permeability, storage and inter-aquifer leakage were used to initialise a generic (non-calibrated), transient model within Groundwater Vistas.

Results

The combination of aquifers and aquitards within the saturated sediments beneath Invercargill represents a leaky, multi-aquifer groundwater system of moderate bulk permeability, that is potentially suitable for establishing water supplies from bores tapping shell-bed coquinas from depths as much as 350 m below ground surface.

A significant source of replenishment would be the leakage of groundwater through aquitards from above, replacing groundwater removed from the Chatton Formation by bore-field pumping. However, elastic storage would provide much of the water in the initial phase of pumping. The modelling analysis was premised upon the operation of six bores screened across the Chatton Formation in positions at least 700 m apart, each pumping at 30 L/s for a combined production of 180 L/s. Preliminary modelling of a bore-field operation in the Chatton Formation indicates that bores would have the capacity to absorb combined head losses by using electric submersible pumps housed in the deeper parts of the bore casing. By setting pump units below anticipated bore drawdown, the bore-field would be able to provide groundwater yield sufficient to meet projected demand for an emergency city water supply (see Figure 1).

There was considerable uncertainty inherent in the conceptual model for the Chatton Formation aquifer and the formulation of the model to test the capacity for water supply. It is recommended to advance evaluation of feasibility for alternative water supply potential by undertaking geophysics, deep drilling investigation, test bore construction and careful aquifer testing.

Invercargill City Council voted in July this year to proceed in accordance with further investigations as recommended above.

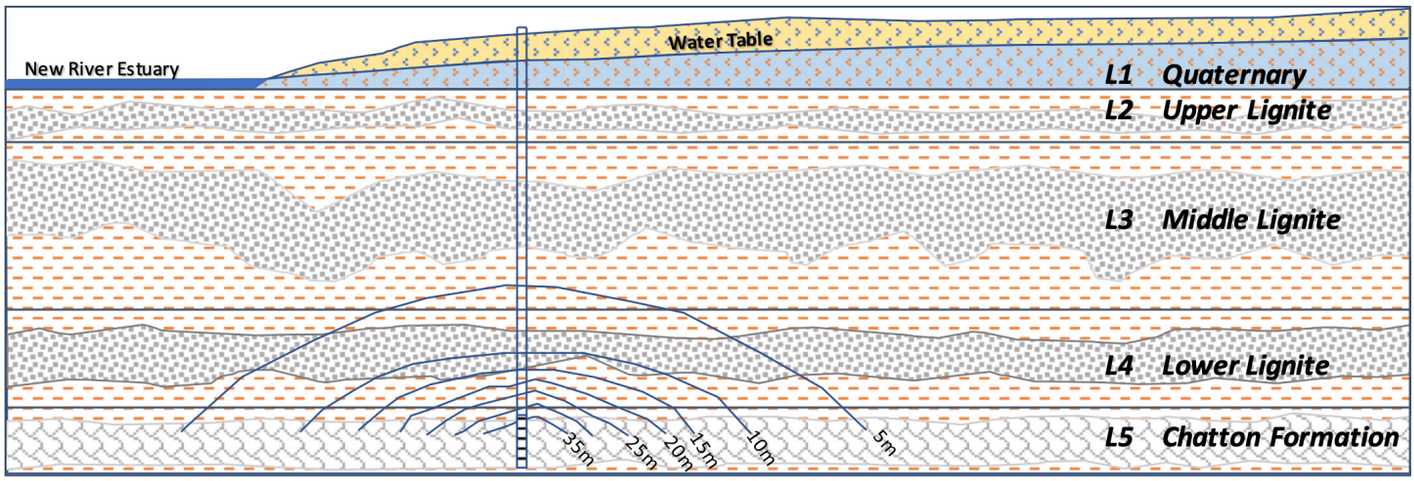


Figure 1. Representative West – East cross-section through the midst of the bore-field showing centrally-located Well-D and modelled (Year 1) drawdown contours.

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A RESEARCH STRATEGY ON MIGRATORY FISH SPECIES

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[1] Department of Conservation

New Zealand is facing a biodiversity crisis across its terrestrial and aquatic ecosystems, coupled with an increase in anthropogenic pressures and threats. To address this major issue, the Department of Conservation has been implementing a new work programme, with substantial funding ($76m over four years) dedicated to support the conservation effort. Part of this funding is allocated to increasing security for three native diadromous fish species presenting concerning trends in their population status: Shortjaw kōkopu (*Galaxias postvectis*) (classified as Threatened—Nationally Vulnerable), Īnanga (*G. maculatus*) and Longfin Eel/Tūna (*Anguilla dieffenbachii*) (At Risk—Declining). Due to their migratory life cycle, these species require a landscape-level strategy to ensure they can live in, and move between, the full range of habitats needed during their lives. However, the current state of knowledge varies across species, their different life stages, and around the pressures they are subjected to. Critical knowledge gaps can impede the development and implementation of species-specific management and effective conservation measures. To address this problem, DOC is developing a four-year research strategy to 1) better understand these species' life history and ecological requirements at different life stages, 2) understand the mechanisms leading to populations decline, 3) identify and evaluate tools and methods to reduce pressure on these populations, and 4) identify potential leverage points that can help increase species security. This talk will outline the Department's research strategy for the coming two years and identify critical needs in science and partnership development to improve current conservation and management methods of these three vulnerable species and inform the strategic deployment of resources on the ground.

INTEGRATION OF RADIOMETRIC SURVEY, SATELLITE IMAGERY, AND TERRAIN MEASURES TO SUPPORT WETLAND IDENTIFICATION

Rissmann, C.,[1] Pearson, L., [1]
[1] Land & Water Science

Wetlands have yet to be comprehensively and accurately mapped at the national level. As part of recent work to support the identification and subsequent classification of wetlands nationally, a data-driven classification of wetness gradients relating to soil bulk density, volumetric moisture content and the seasonality of wetness was developed by integrating airborne gamma-ray spectroscopy (AGRS; 50 m), Sentinel-2 (20 m) satellite imagery, and terrain measures (13 m) across South Island areas of AGRS. AGRS was used to identify areas of low soil bulk density and high gamma-ray attenuation associated with elevated volumetric water content, respectively. From time-series Sentinel-2 imagery, a soil moisture seasonality classification was generated, i.e., perennial, intermittent and ephemeral soil moisture. Machine learning algorithms were applied to identify the natural number of AGRS and seasonality classes. The resultant Relative Wetness Gradient (RWG) classification discriminates between organic and mineral soils and their associated seasonality. Zonal statistics of ancillary datasets, those thought to be useful for classifying wetland type (e.g. elevation, mean annual rainfall, mean annual temperature, water table depth, physiographic setting (e.g. Alpine, sub-alpine, lowland) and soil type) were quantified for every polygon in the classification. The classification was compared against existing inventories of hydric soils (S-map), peat (Q-map) and wetland extent (LCDB v5). A critical outcome of the classification was the identification of areas of likely former wetland now under pasture and areas of previously unidentified, natural state wetland. Ground truthing of potential new wetlands is required.

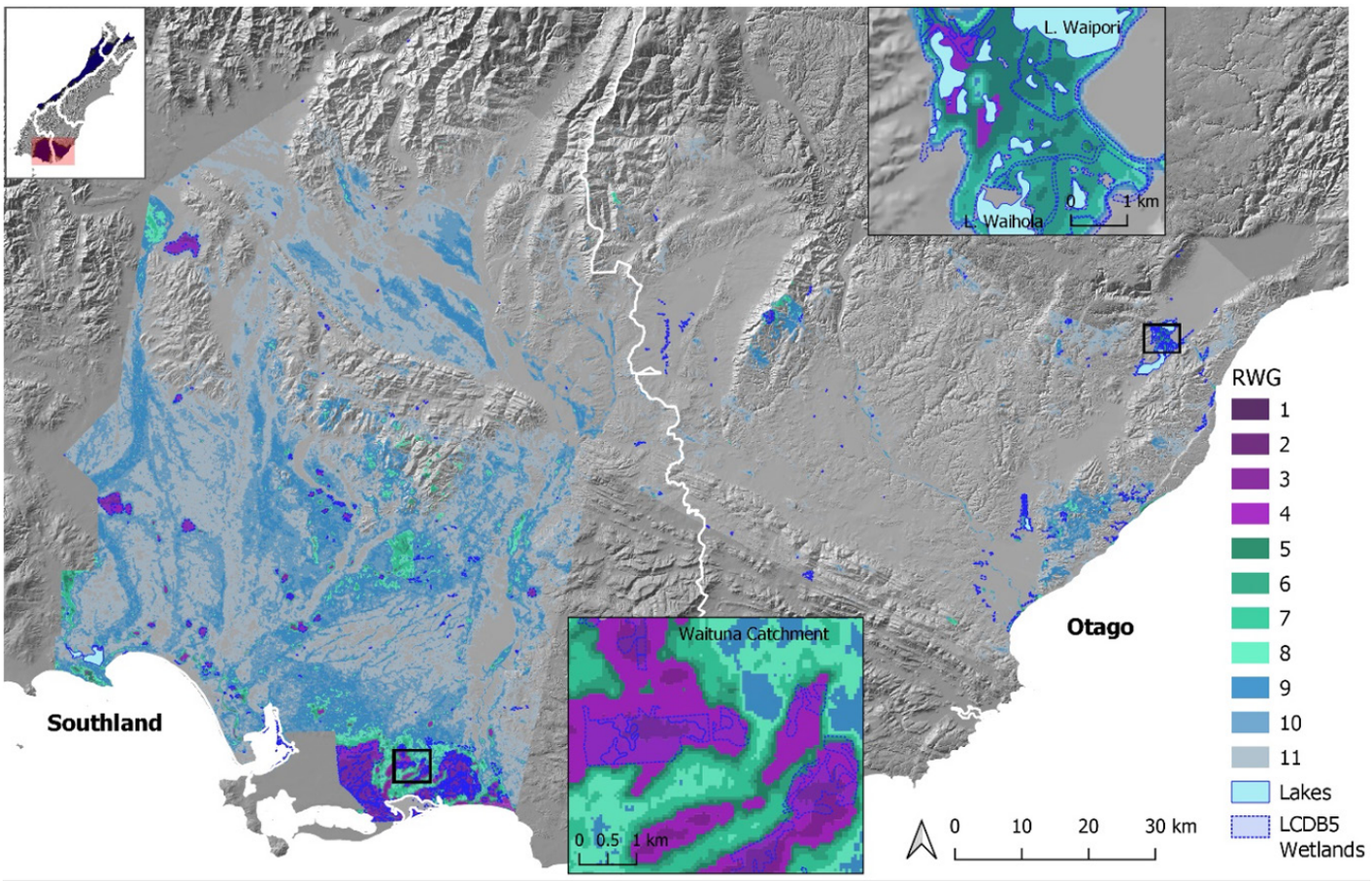


Figure: Relative Wetness Gradient (classes 1 – 11) for Southland and east Otago regions with AGRS (shaded extent). The RWG provides a relative wetness continuum defined by the transition from classes 1 - 4 (Family 1: peat/organic) <-> classes 5 – 8 (Family 2: mixed organic-mineral wetland soil types) <-> classes 9 - 11 (Family 3: imperfectly drained or shallow groundwater table impacted mineral soils). Insets show parts of the Waituna Catchment (Southland) and Lakes Waihola and Waipori (East Otago). Peat deposits (class 1 – 4; Family 1) are flanked by transitional wetland soil types (Family 2, classes 5 – 8). The modern-day floodplain of the Aparima River (blue classes 9 and 11; left arrow), and other floodplains, exhibit imperfectly to poorly drained soils due primarily to the influence of a shallow groundwater table.

A NOVEL METHOD FOR CALCULATING NITRATE REMOVAL RATES IN WOODCHIP BIOREACTORS USING DATA FROM HIGH-FREQUENCY MONITORING

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Woodchip bioreactors have increasingly been used to remove nitrate from subsurface artificial drainage. One method to assess their performance is to calculate the nitrate removal rate (RR), which is the amount of nitrate removed per unit volume of the bioreactor per unit time.

There are currently two widely adopted methods for calculating RR: 1) cumulative RR, in which the amount of nitrate removed is computed from the difference between the cumulative nitrate load (or inflow) and discharge (or outflow) over time; and 2) instantaneous RR, where the amount of nitrate removed is calculated from pairs of synchronously measured concentrations at the inlet and outlet. Both methods have limitations. The cumulative RR provides a single value for a significant time period, such as several months or the whole drainage season. Therefore, it does not offer vital information on the temporal variability of removal rates. On the other hand, the instantaneous RR assumes that ignoring the time lag between inlet and outlet does not affect the accuracy of the calculated RR. However, this may not apply to NZ conditions, where highly variable flows and concentrations are common.

Accordingly, we have utilised high-resolution flow and concentrations data collected in 2018 and 2019 at our Tatuanui bioreactor (Waikato) to develop a new method that explicitly takes the travel time between entrance and exit of a parcel of water through the bioreactor into account. This presentation will discuss the advantages of this novel method and the benefits of high-frequency monitoring in improving our understanding of the performance of bioreactors.

ESTIMATING REFERENCE CONDITIONS IN SOUTHLAND ESTUARIES

Roberts, K.L.,[1] Ward, N.J.,[1] Wilson, K.,[1] Norton, N.[2]
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[2] Land Water People

Environment Southland has embarked on the objective setting process as set out in the National Policy Statement for Freshwater Management (2017), including estuaries as part of the freshwater management units. Regional attributes, broadly using the A to D banding system, have been proposed for Southland estuaries and comprise key ecosystem health indicators including but not limited to muddiness, macroalgae, chlorophyll and metals (Norton et al. 2019a). To set appropriate and achievable objectives for estuaries there needs to be an understanding of current state, historical state and "reference state" for each regional attribute (Norton et al. 2019b). Environment Southland has estimated "reference state" ranges for Southland estuaries, where "reference state" refers to the state of the ecosystem prior to various different anthropogenic (human) impacts. Several approaches were taken to develop a preliminary estimate of "reference state" conditions including the consideration of pre-human condition data (paleolimnological studies), historical data, modelling under historical and pre-human conditions, current state data from pristine estuaries and expert opinion in the absence of other sources. Three key learnings from this work will be discussed; (1) Reference state range varied depending on the attribute, highlighting the underlying complexities of communicating ecosystem health across the gradient of the A to D banding system, (2) Southland estuaries have changed significantly as a result of anthropogenic activities and (3) more research is required to understand whether "reference state" objectives are achievable in Southland estuaries.

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DEFINING APPROPRIATE RESTORATION TARGETS FOR FRESHWATER ECOSYSTEMS: ARAWAI KĀKĀRIKI

Robertson, H.,[1] Pomeroy, E.[1]
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Restoration of freshwater ecosystems in New Zealand is increasing, multiple initiatives at large-scales are being implemented in attempt to improve the ecological integrity of aquatic habitats. These restoration initiatives are multi-faceted, including regulatory mechanisms to achieve minimum water quality standards, interventions that target biotic pressures (e.g. invasive species control, riparian planting), and direct actions that address abiotic pressures (e.g. on-farm mitigation, constructed wetlands, flow enhancement). However, we often lack evidence to evaluate whether meaningful restoration outcomes are being achieved, and in many instances restoration targets are inadequately defined.

Ecosystem health (EH) and Ecological Integrity (EI) frameworks have been developed for New Zealand and provide a basis to define restoration goals at varying scales. The EH and EI frameworks overlap with core components that relate to species persistence, habitat quality (e.g. indigenous dominance), ecological processes and ecosystem representation.

Applying the EH/EI framework we aimed to quantify ecosystem restoration targets for Arawai Kākāriki, a DOC-led programme to restore large-scale (>7,000 ha) freshwater wetlands and lakes. Ecologically relevant targets were derived from interrogation of (1) pressure-response thresholds, (2) pre-disturbance or reference states, (3) biosecurity standards, (4) species population status and (5) ecosystem protection status.

Evidence to underpin target-setting varied between indicators and environment types, highlighting that incomplete knowledge of the status of freshwater ecosystems and lack of information of how pressures affect ecological processes at the site scale, remains a significant barrier. We conclude that returning to pre-disturbance conditions is not always viable, however defining targets for Arawai Kākāriki presents an important benchmark to advocate for wetland conservation.

FRESHWATER BIODIVERSITY IN AOTEAROA – KNOWLEDGE, STATUS AND RESPONSE

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[1] Department of Conservation

Freshwater ecosystems are the most threatened of all global habitats, suffering from widespread and ongoing degradation and biodiversity decline. Also impacted are the ecosystem services that aquatic habitats and species provide to people. Human-induced pressures continue to negatively impact on freshwater biodiversity in Aotearoa New Zealand.

We present findings from *Biodiversity in Aotearoa: an overview of state, trends and pressures*, a 2020 assessment of the state of New Zealand's biodiversity. The report collates knowledge, including mātauranga Māori, of biodiversity state and trend for freshwater lakes, rivers and streams, groundwater and wetlands, and draws attention to critical information gaps that impede conservation efforts. *Biodiversity in Aotearoa* reiterates that freshwater habitats are facing widespread and sustained pressure from invasive species, changes in land use, water abstraction, pollution and the increasing threats posed by climate change.

From this knowledge platform, we then provide a synopsis of the Department of Conservation's (DOC) freshwater conservation and science programmes that respond to this challenge and align with the Aotearoa New Zealand Biodiversity Strategy. Our programmes include new initiatives to restore riverine ecosystems, ensure the long-term persistence of threatened species, target freshwater pests and address ecosystem pressures. Additionally, Te Kaupapa a Te Papa Atawhai, DOC's new organisational strategy means Te Ao Māori and Te Reo Māori have renewed emphasis in our mahi.

Given the state of biodiversity in Aotearoa and our new conservation goals, urgent action is needed to improve our management of freshwater resources. We require transformational tools to achieve freshwater outcomes by closing knowledge-implementation gaps. This waterscape draws attention to the importance of establishing new conservation-science partnerships in Aotearoa.

MAPPING THE SPATIAL DISTRIBUTION OF FINE SEDIMENT IN LARGE BRAIDED RIVERS – METHOD DEVELOPMENT IN THE RANGITATA

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The accumulation of excess fine sediment in gravel-bed rivers may create a cascade of impacts that degrade ecosystem health, recreational value and natural character. Monitoring the quantity and distribution of deposited fine sediment is based typically on a combination of visual assessment and sparse direct sampling. These methods do not scale well to quantify patterns at the catchment scale or for large, braided rivers where the active fairway extends over hundreds of metres. An alternative method to map, reproducibly, the spatially-explicit and longitudinal distribution of fine sediment cover in large rivers is needed urgently to better understand river management actions and help design restoration strategies.

We present a new approach to this problem based on multi-modal remotely sensed data and apply this to map the pattern of sediment cover for the piedmont reach of the Rangitata River, Canterbury, NZ. Our approach involves multisensory fusion of dense airborne LiDAR and RGB orthophotography acquired from a manned helicopter platform. Combining centimeter-scale LiDAR and optical imagery resolution provides opportunities to retrieve the surface roughness of representative surface facies using the local elevation distribution (Brasington et al., 2012) and the structure of optical reflectance at the scale of the microtopography (Buscombe 2013; Carbonneau et al. 2005; Hoyle et al. 2019).

Here, image analysis is combined with ground-truth data to develop and train a machine-learning classification method capable of characterizing longitudinal fine sediment cover over the active bed. The data and classification method will support substrate and geomorphic change mapping after future surveys that include ADCP coverage of channels as well as 2-D sediment transport modelling efforts and ecological effects characterization. Scaling up these methods will increase our understanding of large-scale river health and character over time.

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AUCKLAND PEST FISH DECISION SUPPORT TOOL

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[2] Pullan Environment and Aquatic Consulting Ltd

Exotic freshwater fish have established in most freshwater ecosystems in the Auckland region with pest fish populations being largely unchecked by predators. The impacts of pest fish populations on New Zealand's freshwater ecosystems are broad and include transmitting parasites and diseases, food web impacts, reduced water clarity, reduced macrophyte cover, benthic habitat disturbance and mobilised nutrients.

Auckland Regional Pest Management Strategy (2007) and Auckland Regional Pest Management Plan (2019) set out to manage pest fish to protect ecological values and to prevent adverse effects. A Pest Fish Decision Support Tool (PFDST) was developed for the Auckland region to support the decision-making process on managing pest fish from public and council reports and information in accordance with the pest management plans. Additionally, it sets a benchmark for the management of pest fish, through operational activities, for the wider New Zealand context and has the potential to be modified to meet a broader set of objectives.

The Decision Matrices provide a recommended pest fish management strategy and control method for various scenarios, considering site-specific values and constraints (e.g. environmental, infrastructural and ecological factors). Potential management strategies addressed in the Management Strategy Decision Matrix include:

- Do Nothing
- Site-Led Response
- Sustained Control
- Eradication

For the first time, a decision support tool is available to guide the rapid, effective and consistent response to pest fish reports in Auckland. Our paper will present the collaboratively developed decision support flow diagrams, incorporating the utilisation of emerging technologies such as eDNA. This tool will ultimately contribute to the control and eradication of pest fish in the region.

SOURCE PROTECTION ZONE DELINEATION: USING NUMERICAL AND ANALYTICAL MODELS TO GUIDE DECISION MAKING

Rutter, H.,[1] Weir, J.,[1] Hector, R.[1]
[1] Aqualinc Research Ltd

Increasingly, Regional Councils require the delineation of source protection zones for public supply bores. Within these zones, land use activities may be restricted, or require consent to take place, the aim being to protect water supplies from potential contamination. Source protection "zones" include the well head protection zone, the one year travel time zone, and the total catchment area. From the point of view of potential microbial contamination of water supply sources, the one year travel time is the zone of interest.

In order to delineate this zone, the extent of the one year travel time needs to be predicted. The ways in which this can be done, depend on available data and models. Some example sites will be outlined, and delineation of zones explored, using either numerical or analytical approaches. Some of the methods by which we can impose stresses on models to provide conservative estimates of the zones will be outlined. Sensitivity testing can also be completed to ensure that the results are sufficiently conservative.

ADVANTAGES AND ISSUES WITH THE USE OF GROUND SOURCE HEAT PUNMP TECHNOLOGY IN CHRISTCHURCH

Rutter, H.[1]
[1] Aqualinc Research Ltd

The Christchurch rebuild provided the catalyst for the development of numerous commercial GSHP systems across the city. The city is located on a series of confined aquifers, ranging in depths from 5 m to greater than 200 m. These aquifers contain water that is consistently between 12-13 o C providing a stable consistent source of heat energy. The systems extract heat from this source and also use it as a sink for cooling. Whilst the technology has been well established overseas for many years, the take up in New Zealand has been slower. However, the combined drivers of the rebuild, more straightforward planning rules, and the wish to utilise more sustainable, energy efficient ways of heating and cooling, have resulted in considerable uptake in Christchurch.

The advantages of these systems will be outlined and discussed, using examples from Christchurch. However, open loop GSHPs also come with some issues. I will cover some of the potential factors to be considered when considering the use of this technology, again using examples from Christchurch. Issues include stream/river augmentation or depletion, impacts on shallow groundwater levels, thermal interference between systems, and physical limitations of aquifers.

The technology has significant advantages over other heating/cooling options, but the potential risks need to be fully understood, and allowed for within project planning and implementation.

THE HOLE STORY: WHAT DO DRILLERS' LOGS ACTUALLY TELL US?

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[1] Aqualinc Research Ltd
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Drillers' logs are vital to the understanding of the underlying geology. They are used in numerous ways, including in developing various models, which, in turn are used to support decision making. Therefore, an understanding of how reliable the lithological data obtained from drillers' logs is, is critical to understand.

Christchurch City Council (Canterbury, NZ) wanted to verify the depth to the first confining layer at several sites, in order to retrospectively place grout seals, and drilled sonic bores for this purpose. Sonic-drilled cores provide a much greater level of detail than drillers' logs from rotary or cable-tool drilling (see Figure 1). This sonic core data was compared to nearby original drillers' logs. How closely the logs matched nearby sonic logs was calculated by comparing the lithologies and predominant sediment types.

Analysis of all comparatives showed that only 53.5% of the main sediment types were identified correctly by drillers' logs. Overall, there was an over-identification of clay, where the sediment was silts or sands. Worryingly, gravels were regularly described as sands or silts, and vice versa. However, it was reassuring that clear confining layers, were often identified correctly. Of concern, was the fact that gravels were only correctly identified 70-80% of the time, instead being identified as sands or clays.

The main lithology was correctly identified 57% of the time by cable drilling, but only 38% of the time by rotary drilling, showing, as expected, that cable tool drilling is a more reliable source of lithological data.

In conclusion, the reliance placed on drill logs should be reassessed. When using logs to interpret city-wide aquitards and aquifers, they are probably adequate, especially if no great weight is placed on individual logs. However, detailed local-scale modelling, is likely to be affected by incorrect identification of lithologies in drillers' logs, particularly where these are derived from rotary drilling methods.

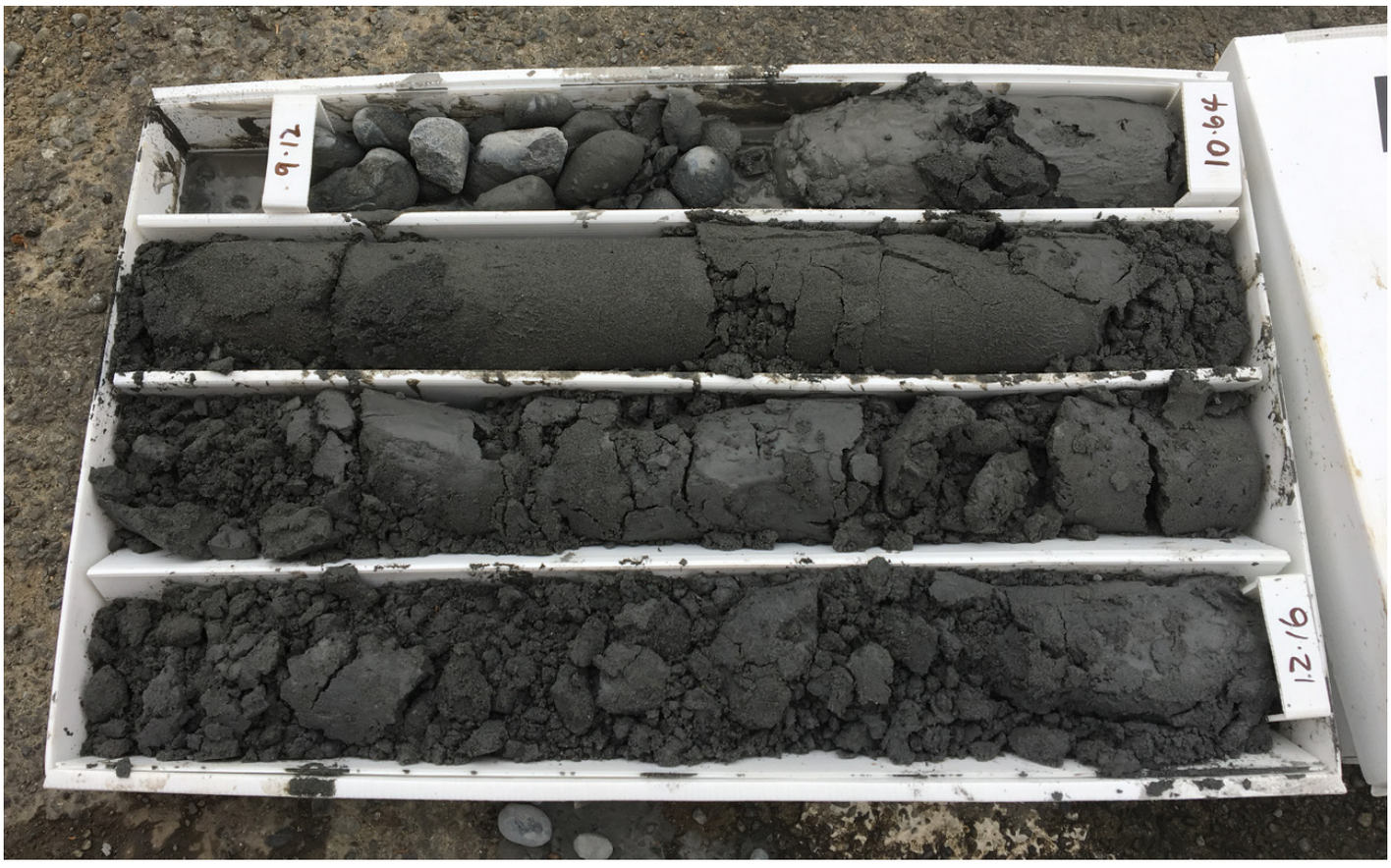


Figure 1. Example of sonic-drilled cores

TRANSITION PROBABILITY ANALYSIS OF LITHOLOGY DATA: IMPLICATIONS FOR NUMERICAL DELINIATION OF WELL CAPTURE ZONES

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[1] ESR (Institute of Environmental Science and Research)
[2] GNS Science

Aims

Capture zone delineation is particularly important for assessing contamination risk and the security of drinking groundwater supplies. Numerous approaches have been reported in the international literature for the calculation of source protection zones (SPZ's). These approaches vary greatly, in terms of problem conceptualization, underlying simplifications, level of detail and the amount of resources that need to be invested. As part of the 'Te Whakaheke o Te Wai' project we aim to develop methodologies that can reasonably accurately and efficiently calculate SPZ's over a range of spatial scales, covering local to large scale supplies. Our numerical study considers the inherent uncertainty associated with this task, relying on Monte Carlo simulations of flow and transport, in selected case study areas. In our first case study area of West Melton in Canterbury's Selwyn District, the aquifer heterogeneity is considered in a stochastic framework and probabilistically described by several three and four categorical variables transition probability models.

Method

More than 3000 bore logs were extracted from the Environment Canterbury's bore log database, all located within a 10km radius from the two existing drinking supply wells in West Melton. Each bore log was discretized to three intervals ranging from 0.25m to 1.0m. The 83 lithology groups in the bore logs were grouped so that transition probability analysis was feasible. Since it is impossible to infer hydrogeological flow and transport properties uniquely from variably sourced and variably accurate lithology descriptions, we opted to undertake several alternative groupings. Each grouping scheme aimed to assign all database lithology descriptors having similar flow and transport characteristics, to a single hydrogeological categorical variable. The transition probability analysis was undertaken using T-PROGS (Carle, 1999) in three steps: i) the bivariate transition probabilities of the observations dataset were calculated using GAMEAS, ii) the three dimensional Markov-Chain model of the spatially structured categorical heterogeneity was generated using MCMOD, and iii) conditional and unconditional simulations of the three dimensional categorical fields were generated using TSIM.

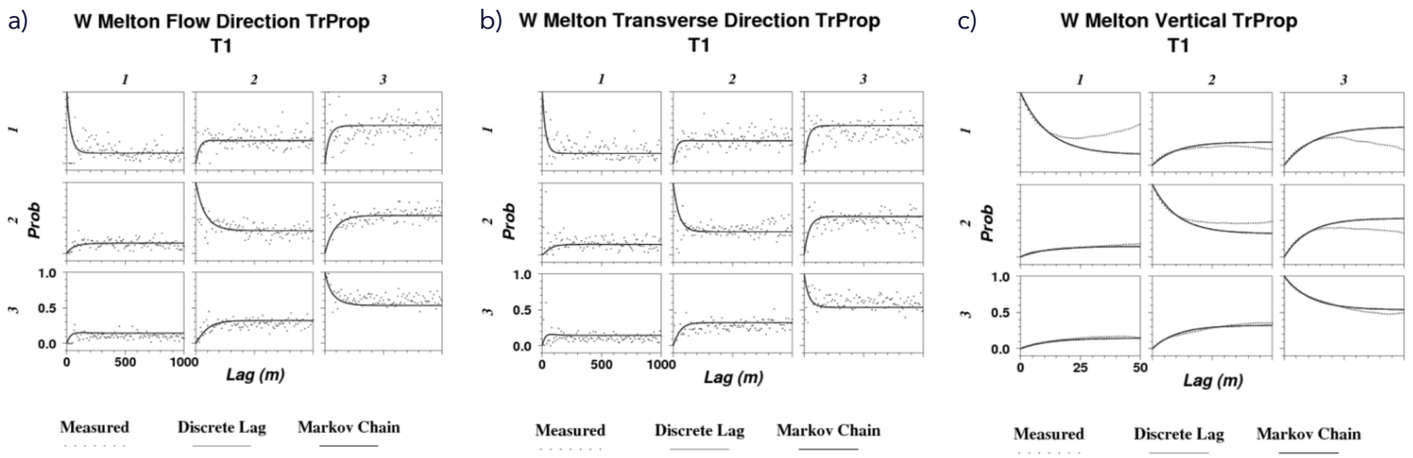


Figure 1. A three variable, three-dimensional transitional probability model for the West Melton lithology data. The calculated bivariate transition probabilities are plotted as points and the fitted Markov-Chain models are plotted as solid lines. The labels 1 to 3 correspond to the three categorical hydrogeological variables. The horizontal axis corresponds to lag (separation distance). All models have been calculated in the three main directions: main flow (a), transverse to flow (b) and vertical (c)

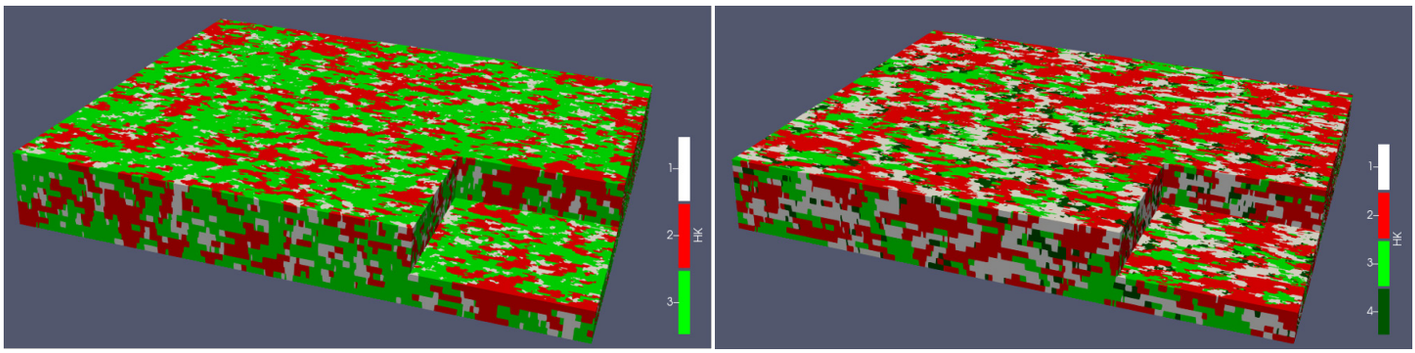


Figure 2. Single conditional realization of a three (left) and a four (right) categorical variables field. Lower variable number corresponds to faster transport conditions.

Results

Overall, 10 three-dimensional transitional probability models were created from the bore log data, covering various bore log grouping and discretization scenarios. For each geostatistical model one hundred unconditional and one hundred conditional (using soft conditioning data) realizations were generated. Forward particle tracking was used to probabilistically delineate the 1-year travel zones to the pumping well. The effect of the geostatistical model, grid dimensions and conditioning data are discussed.

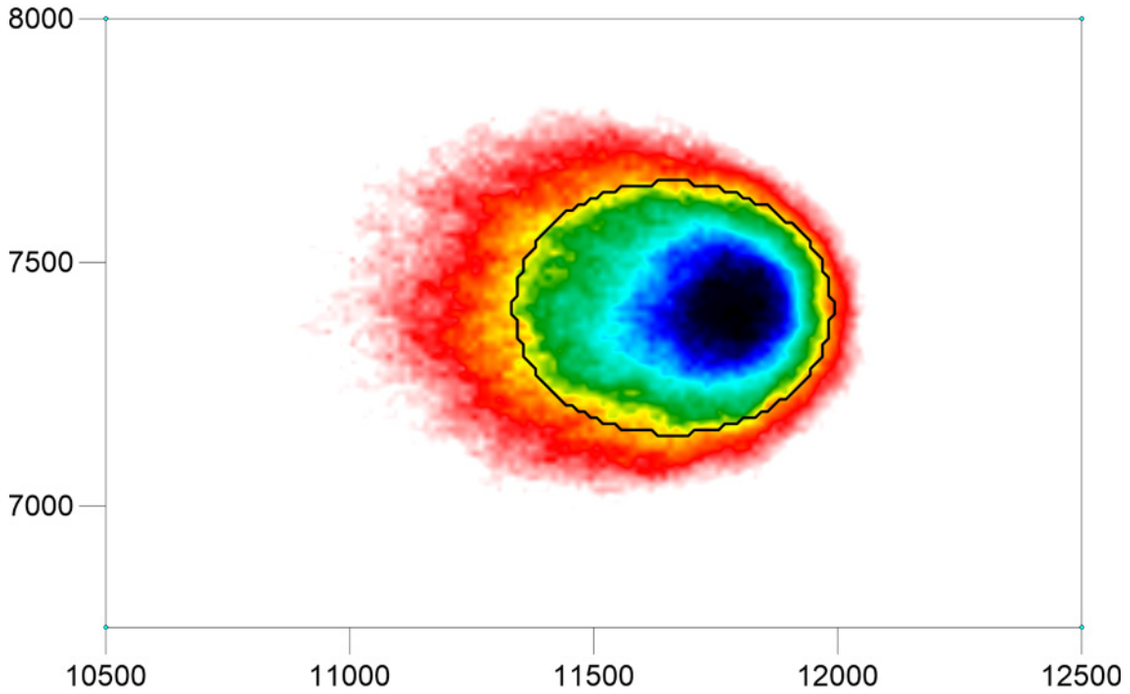


Figure 3. Probabilistic capture zone for a supply well. Colours correspond to the probability that a particular location is within the well source zone. The black line shows the outline of the same zone obtained from a homogeneous simulation.

Acknowledgments

This work is part of the MBIE-funded 'Te Whakaheke o Te Wai (The Pathways of the Waters)' programme led by GNS.

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THE LITTLE PLANKTON THAT COULD: UNDERSTANDING THE SUCCESS OF PICOCYANOBACTERIA ACROSS LAKE TROPHIC STATES.

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Picocyanobacteria (Pcy) are the most abundant photosynthetic organisms on earth, forming the base of the foodweb in many lakes worldwide. Previously thought to inhabit only oligo- and mesotrophic systems, new research is revealing the presence and importance of Pcy (Order: Synechococcales) across a wide range of freshwater environments and trophic states. How does this cyanobacterial group succeed in such contrasting environments? Hypotheses include the ability of some strains to utilize organic nutrient sources, and the potential for horizontally acquired genes to aid adaptation to specific environmental conditions. Modern genomic techniques can now shed light on Pcy function by revealing the functional genes held by different strains. Using Pcy isolated from six New Zealand lakes, I used a comparative genomics approach to investigate the different genes held by Pcy strains from lakes of contrasting trophic state, with a focus on genes relating to nutrient uptake and metabolism. Pcy genomes from eutrophic lakes Ellesmere/Te Waihora, Hayes and Johnson plus oligotrophic lakes Wanaka, Hawea and Wakatipu were compared, with reference to Pcy phenotypic characteristics including pigment content and the natural ecological niches in which the strains were isolated. This study suggests that freshwater picocyanobacteria are highly adaptable, and highlights the need for further study on strain adaptation in response to predicted changes in our freshwater ecosystems, including increased nutrient loading and climate change.

PATTERNS OF PERIODICITY IN PHYTOPLANKTON BIOMASS IN NEW ZEALAND LAKES

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[1] University of Otago

Phytoplankton biomass in lakes varies over time, showing different periodicities, or no apparent periodicity at all. Understanding and predicting the phytoplankton periodicity of lakes provides insights into the drivers of phytoplankton productivity and should facilitiate the monitoring and management of algal blooms. We used long-term chlorophyll a times series, sampled monthly from Regional Council lake monitoring programmes, to analyse the various periodicities of chlorophyll a in 20 lakes, spanning substantial ranges of depth, trophic state, climate and geographical location. We used fast fourier transforms of the logged chlorophyll a data to extract dominant frequencies. Only half the lakes showed dominant annual periodicities. Six-month and 4-month frequencies were also common, with some lakes showing more than one significant periodicity. Some lakes showed distinctly consistent periodicity patterns whereas others were less consistent, but were nevertheless statistically significant. Two of the 20 lakes showed no signficiant periodicity in chlorophyll a concentration at all.

Although our analysis was limited to only 20 lakes, due to the paucity of long-term, regularly monitored datasets, the analysis shows remarkable diversity of periodicities, indicating diverse interesting patterns in temporal drivers of phytoplankton biomass. Clear patterns were observed for lakes undergoing spring/autumn phytoplankton blooms as well as for lakes showing winter or summer blooms. These patterns can be explained by known mechanisms related to the annual cycle of mixing and climate drivers such as runoff patterns. However, the presence in our analysis of lakes with 4-monthly and irregular periodicities, and lakes lacking periodicity altogether indicates the importance of some less-well-understood mechanisms driving phytoplankton production and biomass, potentially related to zooplankton grazing or artificial hydrological alteration.

BLINDED BY THE LIGHT: THE INFLUENCE OF LED LIGHT ON ADULT INSECTS IN CANTERBURY RIVERS

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[2] NIWA

In New Zealand, little is known about the effect of artificial lights, such as street and park lighting, on freshwater organisms. Currently councils are converting streetlights from high-pressure sodium lamps to more energy efficient light emitting diodes (LEDs). Artificial lighting at night can have detrimental effects on freshwater adult insects. Light can attract adult insects from their flight path along rivers and result in a loss of recruitment back into the river.

Shorter wavelengths of light (UV, blue, and green) are more visible to adult insects than longer wavelengths (yellow, orange, and red). Therefore, freshwater adult insects are expected to be more affected by cooler white LEDs (6500 K) that have a greater peak in intensity of blue light than warmer colour temperatures (3000 K).

This study investigated the influence of LED lighting by comparing four colour temperatures: 3000 Kelvin (K), 4000 K, 5650 K and 6500 K LEDs. 20 LED light traps were set up per night at three rivers in Canterbury on warm, calm nights. The differential influence of colour temperature on different taxa was noted. In a separate experiment, 10 lights were set up from 0 - 100 m from the river on multiple nights to observe how distance of LED lights from rivers affects the attraction of adult insects. This study aims to improve knowledge of the ecological effects of LED lights at night and inform urban lighting decisions.

DEVELOPMENT AND UPDATING OF RISK MAPS FOR NITRATE IN CANTERBURY GROUNDWATER

Scott, M.,[1] Scott, L.,[1] Wilkins, B.[1]
[1] Environment Canterbury

The first risk maps for nitrate in Canterbury groundwater were developed in 2013 as part of a joint communication plan between the Canterbury District Health Board and Environment Canterbury. The maps are updated every two years, and we recently published a fourth update. The maps are intended for people drinking water from private supply wells on individual properties and are distributed by midwives and local health professionals.

Canterbury groundwater was divided into three risk categories. High-risk areas are where nitrate concentrations in shallow groundwater are above the Maximum Acceptable Value (MAV) for nitrate-N (of 11.3 mg/L) most or all the time. In low-risk areas, nitrate concentrations in groundwater are always below the MAV. Moderate-risk areas are areas where we are not sure if a sample collected from a well will have nitrate concentrations exceeding the MAV. There are different health messages associated with these different risk categories.

We used Environment Canterbury's water quality data to identify clusters of wells where groundwater is above or below the MAV. We also reviewed reports from previous investigations to help us further refine the clusters based on additional parameters.

A two-year review period gives enough time for new investigations to be completed and to observe if any changes to groundwater quality are permanent. The biggest challenges for our latest update were areas where data are becoming old or where we know that recent land use intensification could affect the current risk category.

These maps are a useful and simple tool in communicating different categories of risk with the general public and a similar mapping approach could be applied to other parameters.

Working with the BC Provincial government, First Nations, and the Oil & Gas Commission, we have developed hydrological statistics (hydro-stats) and water allocation estimates that capture the most sensitive times and conditions for making water related resource decisions. In this study, we generate the necessary geospatial variables for all 4618 FreshWater Atlas (FWA) assessment polygons in the study area (220,132 km²), and generate 27 hydro-stats for all 4618 sites. Beyond the Mean Annual Discharge (MAD) and Mean Monthly Discharge (MMD), we also developed models for the Summer (Jun-Sep) 7 day average Q with a 10 year return period as a fraction of MAD (S-7Q10/MAD), the Annual 7-Q10/MAD (A-7Q10/MAD) and the A-30Q10, along with Monthly Q10/MAD (MmmQ10/MAD) for each month. We then combine water availability and allocation data and make observations such as:

- The low-flow period occurs in winter in 84% of the catchments, summer in 3%, and could occur in winter or summer in 13%.
- From a drought management perspective, an important finding is that 18.8% of the 1074 catchments (with a water license) have more than 100% of their A- 30Q10 allocated without EFN protection.

We understand that Allocation and Water Management decisions are multi-layered, sophisticated, and ever-changing requiring water managers to balance stakeholder interests, human resources, and environmental stewardship. There is always more that we can do, and deciding the most effective way to manage our shared resources is the purpose of this study.

USING THE EXISTING CELLPHONE INFRASTRUCTURE AS A NOVEL TECHNOLOGY PLATFORM FOR HIGH-RESOLUTION, REAL-TIME RAINFALL MONITORING

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[1] University of Waikato

Accurate, real-time rainfall monitoring is critical for water resources management, agriculture, weather prediction, climate research and ground validation of satellite-based precipitation estimates. Heavy rain is responsible for many natural hazards, including floods, erosion and landslides. In spite of significant efforts to mitigate these hazards through automated flood warning systems, these efforts are not successful because of the lack of reliable rainfall data. Rain gauges and rain radars are often the only available options, but inadequate spatial coverage and the coarse national rain-radar observations are insufficient for most hazard modelling applications.

In recent years, the possibility of using the attenuation of electromagnetic waves between telecommunication antennae to monitor rainfall intensity has been suggested by some researches. However, the current method is only applicable to high-frequency electromagnetic waves and has high uncertainty when electromagnetic wave frequencies are below 15 GHz. As many telecommunication towers work in a range below 15 GHz, this method is not reliable for monitoring rainfall.

Our numerical modelling of raindrops in microwaves fields show in lower-frequencies electromagnetic waves only are affected by certain raindrop sizes, depending on the wavelength and the size of the raindrops. A new raindrop size distribution technique is suggested to enable accurate rainfall monitoring using smaller electromagnetic waves in the range at which telecommunication towers function.

The Novel technology leverages the existing cellphone infrastructure to create a real-time rainfall monitoring platform. Using this technology will enable rainfall monitoring in remote, mountainous, and other less-accessible regions, dramatically improving weather forecasts and revolutionising our ability to understand, predict and respond to the threats of rainfall-induced landslides, forestry catchment erosion, flooding and water quality in urban, semi-urban, rural and natural environments.

HYDROGRAPH RECESSION/LOW FLOW PREDICTION BASED ON HINDCAST DATA

Singh, S.K.,[1] Griffiths, G.A.,[1]
[1] National Institute of Water and Atmospheric Research Ltd., Christchurch, New Zealand

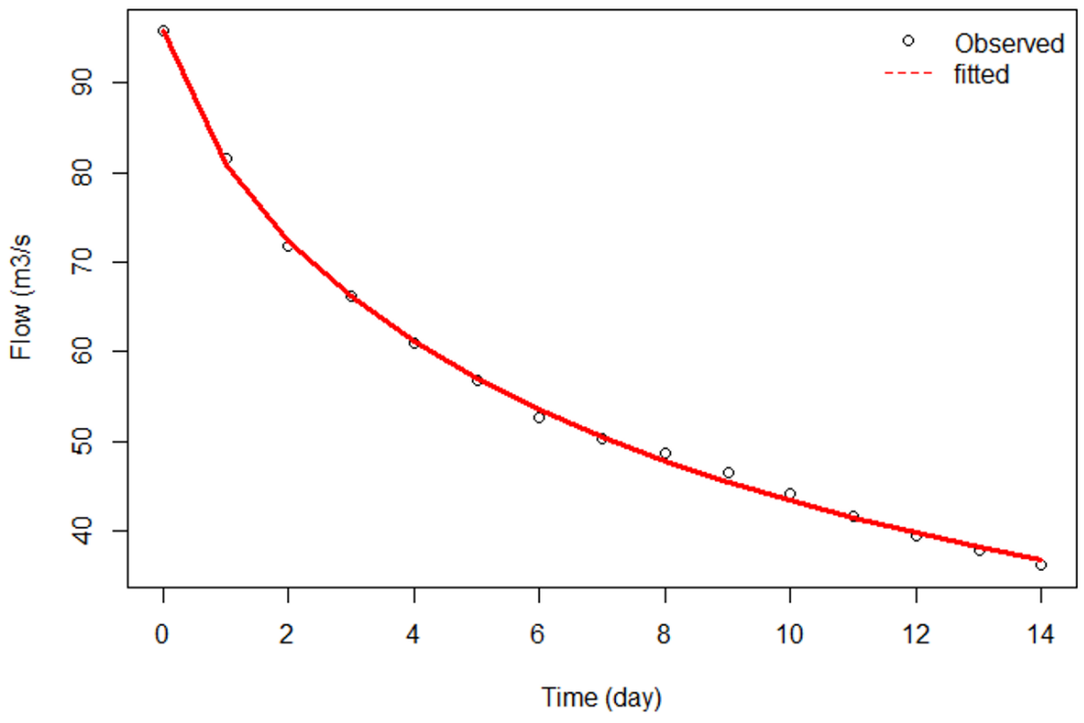
Low flows refer to a randomly occurring phenomenon which is an inherent component of the regime of a river. The low flow/recession component of a hydrograph represents the slow release of water stored in a watershed. Low flows are associated with the storage dynamics of a catchment, particularly aquifer outflows. In fact, these are the composite output of several regulation mechanisms acting through the terrain surface, soil moisture zone and subsoil (Risva et al., 2018). Hall (1968) defines low flows as "the portion of flow that comes from groundwater or other delayed sources". They depend on multiple factors, including geologic and geomorphic characteristics of a catchment, infiltration characteristics of soils, the extent and hydraulic properties of aquifers, rate frequency and amount of recharge and actual evapotranspiration; as well as vegetation, topography and climate (Smakhtin, 2001; Kroll et al., 2004; Risva et al., 2018). Rivers with slow recession rates are typically groundwater or lake dominated whereas fast rates are generally characteristic of flashy rivers draining impermeable catchments with limited storage(WMO, 2008).

Low flow statistics are used for various activities such as planning water supply, hydropower, and irrigation systems; designing cooling plant facilities, treatment plants and sanitary landfills; determining waste-load allocations, and making decisions regarding interbasin transfers of water and allowable basin withdrawals. In addition, low streamflow events are often critical periods for aquatic habitats due to potentially low dissolved oxygen concentrations and/or high pollutant concentrations. Low flows are also important for water quality management where they provide critical dilution of nonpoint source and point source pollution discharges during dry periods; and in water quantity management where low flows greatly influence water use policy (Kroll et al., 2004)

The major objective of the study is to better understand flow recession behaviour at a station and predict recession curves, without precipitation information, based on historical recession records at the site.

Methodology

The methodology adopted was to fit a three parameter, non-linear equation to all the observed recession curves lying between mean annual low flow and mean annual 7-day low flow. Example of fitted and observed recession is given in Figure1. Based on the fitted parameters a library of parameters was generated using optimisation techniques. This library was then used for predicting recession curves.



Results

Figure 2 shows the observed and predicted hydrograph recession/low flow for 2 recession events. Observed recession curve (green) and predicted recessions (blue). From figure we can see that observed and model recession curve are in good agreement and these preliminary results are promising.

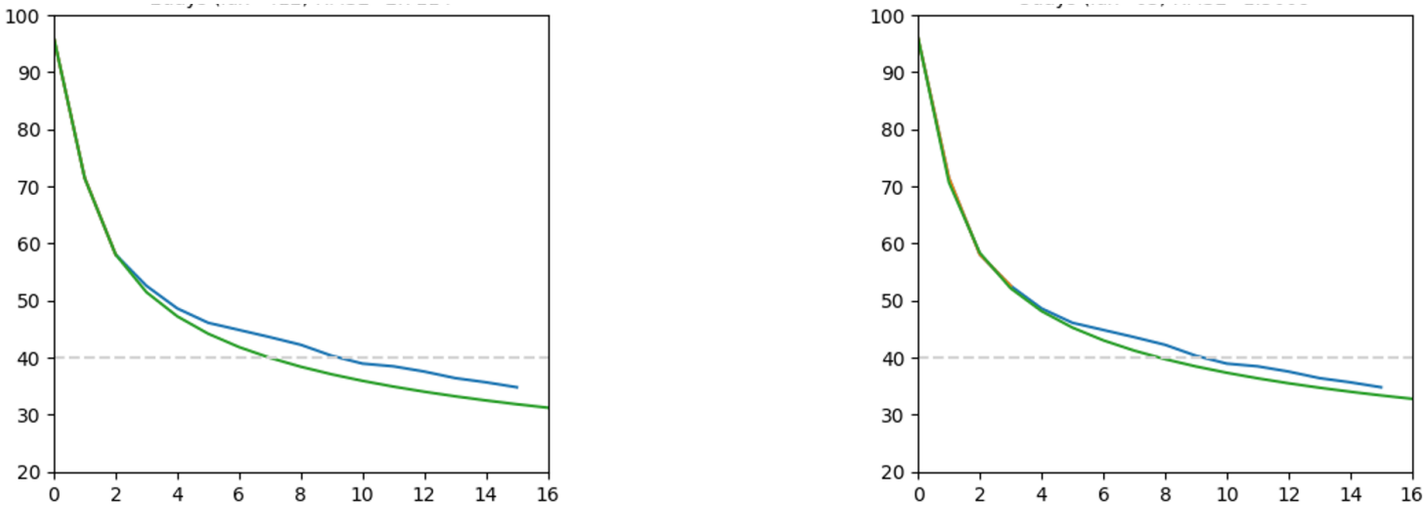


Figure 2. Observed recession curve (green) and predicted recessions (blue). X axis is in number of day and y axis is in m3/s. The dash grey line is 7 day mean annual low flow.

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EFFECTS OF SHALLOW FLOWS ON THE RATIO OF DEPTH AVERAGED VELOCITY TO WATER SURFACE VELOCITY

Smart, G.M.,[1] Biggs, H.J.[1]
[1] NIWA, Christchurch.

Aims

Urbanisation, climate change, water allocation, pollution and recreational activities are putting increasing demands on water management. Because good management relies on measurement, river monitoring presents an ongoing challenge for local government, environmental agencies and hydrologists. Streamflow measurement is crucial for flood risk evaluation, water allocation, hydropower generation, ecosystem health monitoring, pollution control and hydraulic/hydrologic modelling. As spatially dense monitoring networks are expensive to install and maintain, innovative remote sensing solutions are being developed. Also, at conventional river monitoring sites, discharge is not routinely measured directly: rather stage is converted to discharge using a stage-discharge relationship fitted from direct discharge measurements. However, direct discharge measurements (using mechanical or acoustic current meters) are dangerous or impossible in severe flood conditions. To overcome these limitations discharge measurements from Surface Velocity Radar (Welber *et al.*, 2016) and photogrammetric techniques from river banks (Le Coz *et al.*, 2010; Fujita *et al.*, 2018) or drones (Detert *et al.*, 2017) are increasingly being used. For these non-intrusive methods, a technique to convert water surface velocity to depth-averaged velocity is required. Typically a coefficient (α) relates depth-average velocity to surface velocity. We herein study the effects of shallow flows on the α ratio.

Method

Following current best practices α can be estimated empirically or theoretically (Le Coz *et al.*, 2010) with a default value of around 0.857 (Rantz, 1982). It is also possible to relate α to physical parameters such as bed shear stress or fluctuations in the surface velocity (Smart & Biggs, 2020). These later derivations assume that there is an underlying log law velocity profile. Close to the bed and in shallow flows, a log law profile does not apply. This is often unrecognised or ignored in many model applications. Laboratory measurements reveal a near linear velocity profile in the vicinity of the tops of roughness elements (e.g. Aberle, 2006; Smart *et al.*, 2010). This is shown in Fig. 1 along with an overlying log profile.

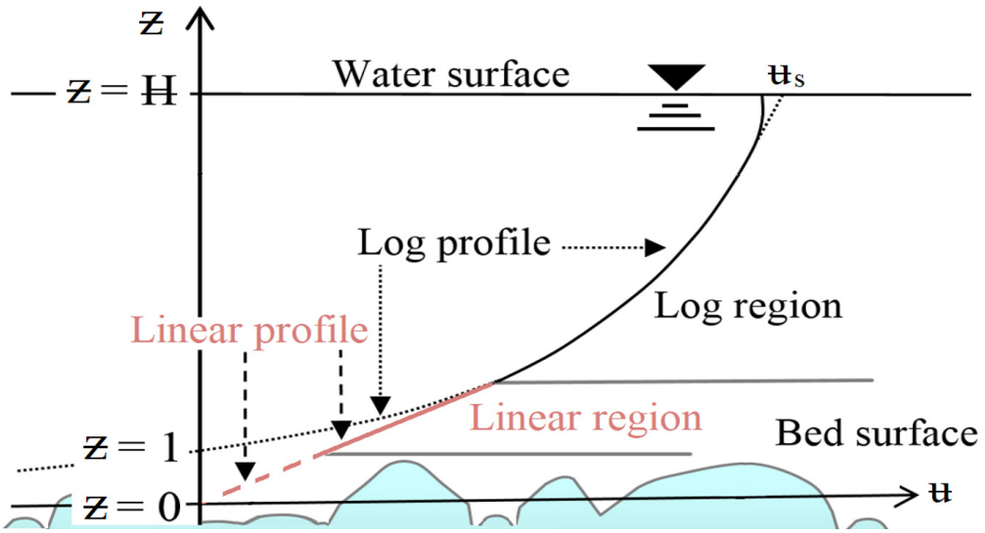


Figure 1. Vertical profile of dimensionless streamwise velocity and relative depth showing a log-law region and a linear region.

Adopting dimensionless notation: height above datum ƶ = z/Z_0, downstream velocity ʉ = κu/U*, u = time averaged streamwise velocity, κ ≈ 0.4, relative depth Ħ = H/Z_0, U* = shear velocity and Z_0 = roughness height. The velocity profile equation for the log region is ʉ = ln(ƶ). Assuming the log law and linear profile have the same z origin and the junction between the two profiles is continuous (the linear section is tangential to the overlying log profile), the equation for the linear region is ʉ = ƶ/e. Integrating the linear and logarithmic equations over their respective regions up to the flow depth then averaging gives the following mean flow equations: U/U*= Ħ/(2κe) ≈ 0.46Ħ for 0<Ħ<=e; U/U*= (1/κ)(ln(Ħ)+e/(2Ħ) – 1) for Ħ>e. At the water surface, $ʉ_s$= Ħ/e for 0<Ħ<=e; $ʉ_s$= ln(Ħ) for Ħ>e.

These equations result in the following α ratios:

$$\text{for } 0 < Ħ <= e \quad \alpha = U/u_s = U/(U^*ʁ_s/\kappa) = \kappa(U/U^*)/ʁs = [Ħ/(2e)]\,/[\,Ħ/e] = 0.5 \tag{1a}$$

$$\text{for } Ħ > e \qquad \alpha = \kappa(U/U^*)/ʁ_s = [\ln(Ħ)+e/(2Ħ) -1]/\ln(Ħ) = 1+ e/(2Ħ\ln(Ħ)) -1/\ln(Ħ) \tag{1b}$$

When the linear region is ignored and mean velocity is derived from the integral of a logarithmic profile from Z_0 to H the equation is (Smart & Biggs, 2020):

$$\alpha = U/u_s = Ħ/(Ħ - 1) - 1/\ln(Ħ) \tag{2}$$

With further simplification for high relative depth, Ħ >>1:

$$\alpha = 1 - 1/\ln(Ħ) \tag{3}$$

Results

A comparison of the formulae is provided in Fig. 2.

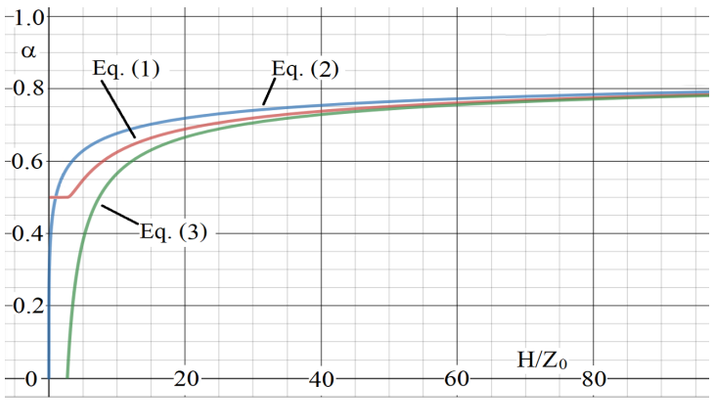


Figure 2. Effect of linear flow region on alpha ratio at changing relative depths.

Allowing for a linear region in the velocity profile Eq. (1) results in α values which lie between those predicted by Eq. (2) and Eq. (3). This provides a better match to field data (e.g. Hauet *et al.,* 2018). Further improvements are also likely when the physics of deviations from a log-law profile at the air-water interface (Fig. 1) are accounted for. For low relative depths, defining flow depth is problematic. In the above Ħ is measured from the ƶ = 0 origin of the velocity profiles. By assuming this lies at mean bed level, reasonable results can be achieved (Smart *et al.,* 2002).

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TAKING STEPS TO IMPROVE FISH PASSAGE MANAGEMENT IN THE WELLINGTON REGION

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[1] Greater Wellington Regional Council

New Zealand's indigenous freshwater fish species require the ability to move freely through waterways and in some cases out to sea in order to access suitable habitat, resources and to complete their lifecycles. Instream structures (such as culverts, fords and weirs) that are inadequately designed or maintained can present a barrier to fish passage. The consequence of this is a reduction in the distribution and abundance of some of our iconic and threatened indigenous freshwater fish species. In the Wellington region, we have records of approximately 20 indigenous freshwater fish species, the majority of which are threatened or at risk.

With the recent release of the New Zealand Fish Passage Guidelines and Fish Passage Assessment Tool coupled with the strong legislative drive regionally and nationally, Greater Wellington Regional Council (GWRC) has initiated a project to identify the ways in which we can use these resources to aid us in improving fish passage management in the Wellington region.

In June 2019, a project team was established to develop a programme plan to assist GWRC in improving its management of fish passage across the Wellington region. A series of workshops were held between July and December 2019 during which the project team used a logic model approach to build up the basis for this Plan.

Over the last two years, the council has been working in partnership with other territorial local authorities to employ summer students to undertake fish passage assessments in parts of the Wellington region using the New Zealand Fish Passage Assessment Tool. The data captured on this tool is being used to inform decision making on where to target fish passage remediation as and when funding becomes available.

This presentation will give an overview of the key learning's GWRC has obtained from the project and fish passage assessment work.

FINGERPRINTING SEDIMENT SOURCE CONTRIBUTIONS TO THE FEBRUARY 2020 FLOOD EVENT IN THE ŌRETI RIVER, SOUTHLAND

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[1] Manaaki Whenua – Landcare Research
[2] NIWA

Aims

Fine sediment has significant impacts on water quality, ecosystem health and recreational amenity (MfE & Stats NZ, 2019). To reduce these impacts, we require information on the catchment sources contributing fine sediment to river networks to enable better targeting of erosion control. Geochemical sediment source fingerprinting is a technique that allows direct measurement of the proportional contributions of sediment from sources to downstream locations. It involves selecting geochemical properties to use as tracers that discriminate sediment sources and un-mixing contributions from those sources. The basis for source discrimination with geochemical tracers relates to differences in geological parent material and soil depth (Smith & Blake, 2014; Vale et al. 2016; Smith et al. 2018; Haddadchi et al. 2019).

We apply geochemical sediment fingerprinting to quantify sediment source contributions during a significant flow event in the Ōreti River catchment, Southland. Few international studies investigate intra-event sediment source dynamics. In New Zealand, intra-event sediment source contributions have only been measured at a single location for a minor flow event (0.5 x mean annual flood, MAF) in the Manawatū catchment (Vale et al. 2020). In contrast, we sampled a major flow event (~2 x MAF at the Wallacetown gauge) across four nested gauging locations. We present preliminary results from our analysis of a comprehensive source and suspended sediment sample set that shows how catchment sediment source contributions vary both longitudinally downstream and temporally during the event.

Method

The Ōreti River catchment has an area of 2201 km^2 upstream of the Wallacetown gauge. In the steep headwaters, the catchment is underlain primarily by greywacke with an area of ancient volcanic rocks (Fig. 1). Further downstream the catchment narrows and predominantly comprises alluvium as well as areas of loess with adjacent hills characterised by greywacke and sandstone.

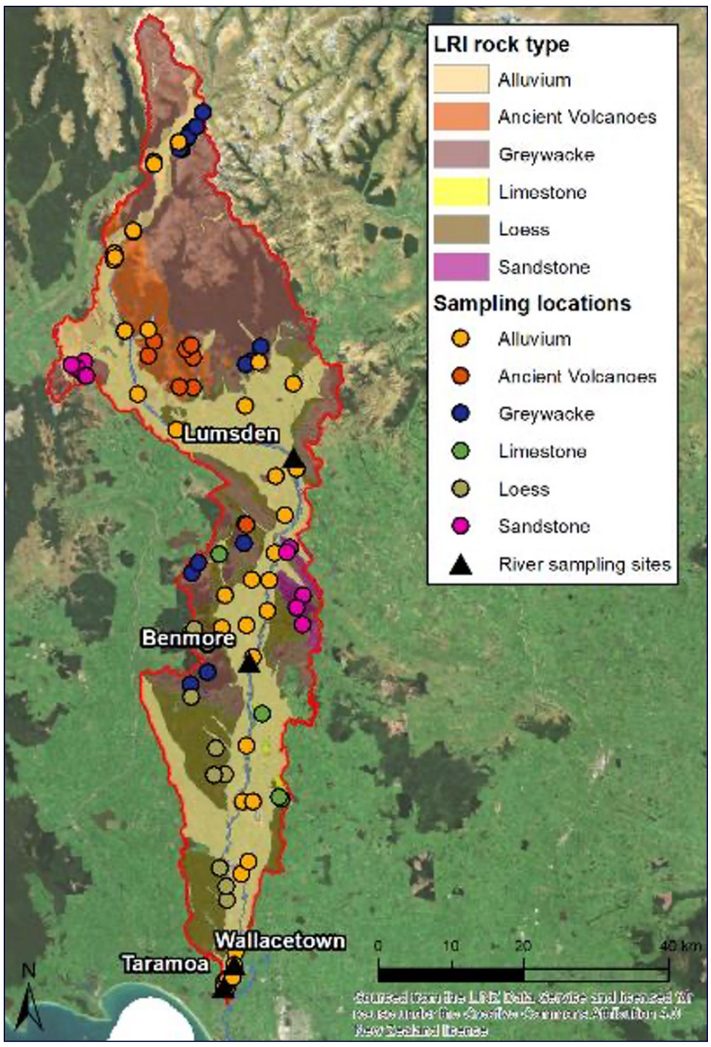
Source sampling focused on representing different geological parent materials. For each parent material, surface (0-2 cm) and subsoil (to 1 m depth) samples were collected to distinguish surface versus subsurface (e.g. shallow landslide) erosion sources. Alluvial channel banks were sampled along the Ōreti River as well as its tributaries. All source samples comprise at least 10 discrete samples mixed in the field.

Flow event sampling occurred on the 3-6 February 2020 at the Lumsden, Benmore, Wallacetown and Taramoa sites (Fig. 1). Bulk 20 L grab samples were collected to provide sufficient sediment mass for laboratory analyses. Between 4-6 samples were collected through time at each site during the event (Fig. 2). Source (n = 104) and sediment (n = 19) samples were dried, disaggregated, sieved to <63-µm, and underwent geochemical (x-ray fluorescence and laser ablation-inductively coupled plasma-mass spectrometry) and laser particle size analysis. In total, this provided 45 potential geochemical tracers.

Tracer selection used the widely applied combination of the Kruskal-Wallis H test and Discriminant Function Analysis to select a subset of tracers that maximise discrimination between sources (Collins & Walling, 2002). A Bayesian mixing model framework, MixSIAR v3.1.7 (Stock et al. 2018), was used to quantitatively un-mix parent material source contributions to the sediment samples.

Results

Preliminary results show that the main contributions to the suspended sediment samples were from greywacke and alluvial sources. Further work is required to a) examine contributions from different source groups and b) combine source proportions with suspended sediment load measurements to determine mass-apportioned source contributions to event load.



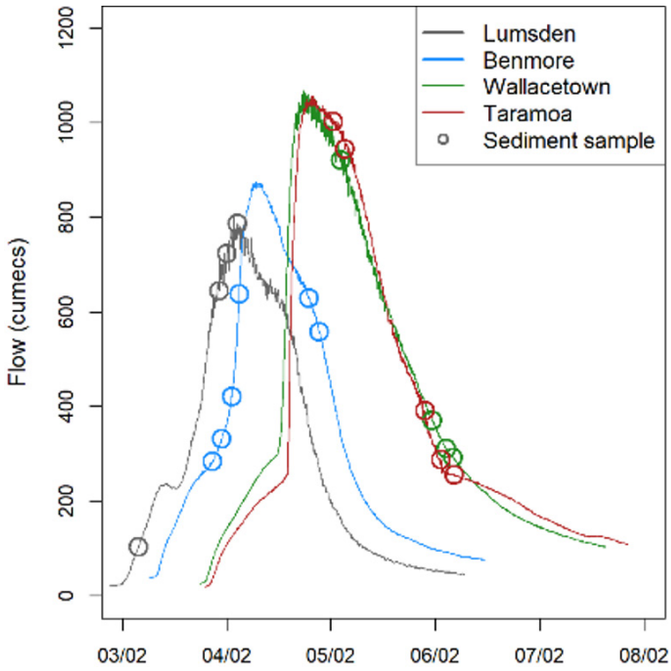


Figure 1. (left) Map of the Ōreti catchment showing parent material from the NZ Land Resource Inventory (LRI) and the location of source and sediment sampling sites.

Figure 2. (above) Event hydrographs and sediment sampling times.

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DEVELOPMENT OF A FLOOD FORECASTING SYSTEM FOR GREATER WELLINGTON

Smith, H.,[1] Harkness, M.,[2]
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[2] Greater Wellington Regional Council

There have been significant advancements internationally in operationalized hazard early warning systems since Greater Wellington Regional Council (GRWC) last updated its flood warning service. Consequentially, GWRC identified potential to improve their flood forecast warning capability across the region to proactively manage their emergency management.

It has been widely proven that issuing flood warnings to emergency responders and communities in advance of floods directly saves lives and properties. The warnings provide valuable lead time to implement appropriate responses.

This presentation will give an overview of GWRC's Flood Warning Project, including both an analysis of their current system and their prioritized programme of work to enhance their flood forecasting and warning system, including lessons learned along the way.

GWRC currently relies on a network of telemetered river gauges, rain gauges, and meteorological forecasts delivered by the Metservice to provide inputs to its flood warning service. Several catchments have operational flood forecast rainfall-runoff models. Some of these are able to provide useful lead times for warnings whereas others are not fully operationalized, and many catchments have no flood forecast models.

Two key components of a flood forecasting system are the platform. which enables control of the system and warnings, and forecasting models which produce advanced predictions of flood hazard. GWRC's platform needs to be flexible and capable of integrating rapidly advancing improvements in meteorological monitoring and forecasting and also enhance their telemetry network, over the course of their programme of improvements. In considering the choice of the new platform, careful planning and choices were made by GWRC to ensure a fit with its organizational capabilities and enables sufficient flexibility to be improved over time as technology advances. Business continuity considerations were a key aspect of this project as well as the integration between key stakeholders in emergency response such as Civil Defence, Metservice, local councils, and emergency response organizations.

AWARENESS, RESPONSE, AND WARNING – GREATER WELLINGTON'S COMPREHENSIVE FLOOD RISK MANAGEMENT PROGRAMME

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[1] Greater Wellington Regional Council
[2] Tonkin + Taylor

Greater Wellington Regional Council (GWRC) is responsible for managing flood risk for communities within the Region's major flood plains. This presentation will give an overview of the outcomes to date of GWRC's Flood Risk Management Programme one year into the programme. This programme focuses on reducing flood risk through effective response management, improved readiness, and the ability to deliver effective warnings.

Through recent studies GWRC had found that communities at risk had low levels of awareness of flood hazard, and existing flood response procedures could be improved and aligned with the national civil defense response incident management systems. GWRC has built relationships with the Wellington Region Emergency Management Office (WREMO) which co-ordinates Civil Defence and Emergency Management services on behalf of the nine councils in the Wellington Region.

The Flood Risk Management Programme plans to address these key issues with three core project workstreams:

- The Flood Response Project provides a new Response Procedure document aligned with the Coordinated Incident Management System, the national framework for incident response as well as a programme for building organizational capability.
- The Flood Warning Project provides a programme of work to enable reliable flood forecasts and warnings delivered to stakeholders with improved lead times, and has incorporated a formal market sounding to seek international best practice solutions.
- The Flood Awareness Project seeks to design a community engagement campaign to raise flood risk awareness particularly communities with low levels of hazard awareness to improve the publics ability to respond to warnings and recover from flooding. In developing the program, collaborating closely with Civil Defense community resilience specialists.

TEMPORAL PATTERNS OF GLOCHIDIA INFESTATION ON HOST FISH: A FIELD INVESTIGATION IN THREE WAIKATO STREAMS

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[1] Waikato Regional Council
[2] The University of Waikato
[3] National Institute of Water and Atmospheric Research

The New Zealand freshwater mussel *Echyridella menziesii* (Unionida: Hyriidae) has a current threat classification of 'At Risk, Declining', in part reflecting disruption of recruitment on host fish. The life cycle of *E. menziesii* includes a parasitic stage in which the larvae (glochidia) must attach to a host fish to transform into the juvenile stage. However, little is known about the spatial and temporal variations of mussel-host interactions in natural environments in New Zealand. This study therefore aimed to quantify fish host associations over the glochidial release period in three contrasting Waikato streams.

Infestation by glochidia was determined on the associated fish community, caught using a combination of electrofishing and minnow trapping. In parallel with these evaluations, mussel brood pouch development was assessed fortnightly from October 2018 to February 2019. Peak glochidia release occurred in February when average monthly water temperatures were >18.8oC. A field method was developed to quantify glochidial attachment on external surfaces of fish, while internal attachment (gills, mouth) was quantified by laboratory dissection. While a range of fish were identified as hosts, 86% of recorded glochidia were attached to *Gobiomorphus* species, including redfin bully (*G. huttoni*) and common/Crans bully (*G. cotidianus/G. basalis*). Most externally attached glochidia (73%) occurred on caudal, pelvic and pectoral fins. Host associations appeared to favour benthic rather than pelagic species and did not change throughout the mussel reproductive season despite seasonal change in fish communities.

This research demonstrates that *Gobiomorphus* species are likely to be important in the protection and restoration of *E. menziesii* populations, particularly in streams, and therefore conservation management must consider these host fish populations as well as other habitat and water quality factors affecting *E. menziesii*.

REPORTING STATE OF THE ENVIRONMENT DATA FOR THE AUCKLAND REGION

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This paper provides an approach for analysing spatial and temporal trends at river and stream ecology sites in Auckland Council's State of the Environment Monitoring Programme. The method aimed to identify significant ecological effects at non-reference sites, using Stream Ecological Valuation (SEV) scores as a proxy for ecosystem function and the Macroinvertebrate Community Index (MCI) for ecosystem health.

River and stream sites were first grouped according to a dominant land cover of native forest, forestry, pastoral or urban type. Variance in SEV and MCI scores were assessed at native forest (reference) sites to identify the percentage of variability likely to occur naturally at stream sites.

Best-case' sites were also identified within remaining 'modified' land cover groups and these were compared against other sites of their group for SEV and MCI scores.

Ecologically significant trends were identified using interval hypothesis testing of the Trends and Equivalence Analysis software version 6.3 (2017). An interval of +/- 15% natural variability was identified based on analysis of reference sites beyond which an ecologically significant difference was declared.

The best-case site for the urban group of streams was Eskdale Lower. Independent pairwise comparisons of urban streams with this site found most sites were in significantly poorer ecological health than Eskdale Lower.

The best site for the pastoral group of streams was Opanuku LTB for SEV and Matakana LTB for MCI. Pairwise comparisons of pastoral streams with these best-case sites found five had significantly poorer ecosystem function than Opanuku LTB, while two sites had significantly poorer ecosystem health than Matakana LTB.

The best site for the forestry group was Orere B. Pairwise comparisons of forestry streams with this site found Riverhead to demonstrate a significant impact for ecosystem health.

Results of SEV (ecosystem function) and MCI (ecosystem health) analyses did not always correlate. This could be due to a number of reasons, including:

- every site is different in its responses to land use pressures
- the two scores have different scales and variability
- the two scores are measuring different things (ecosystem function vs ecosystem health) and may have different land use pressure thresholds at which the scores drop or increase markedly

Most sites had insufficient sample size to undertake temporal trend testing; however, three urban stream sites (Oakley LTB, Otara LTB and Avondale @ Shadbolt Park) had a sufficient sample size (n=5) for preliminary analysis. This testing showed that Otara LTB displayed a significant decline in SEV while Avondale @ Shadbolt Park showed a significant decline in SEV and MCI.

This is the first time SEV scores have been used in State of the Environment analyses which has shown to be a valuable indicator to include in State of the Environment reporting.

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MONITORING KĀKAHI (FRESHWATER MUSSEL; ECHYRIDELLA) USING ENVIRONMENTAL DNA

Steiner, K.,[1] Dyer, N.,[1] Thomson-Laing, G.,[1] Lee, C.,[2] Ferris, K.,[2] Vandergoes, M.J.,[3] Wood, S.[1]
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[3] GNS Science, Lower Hutt, New Zealand

Three species of kākahi (freshwater mussel; *Echyridella*) are found in New Zealand's lakes and rivers. As filter-feeders, they play a crucial role in freshwater ecosystems and have high cultural importance being a traditional source of medicine and food for Māori. Kākahi populations are declining due to habitat loss and eutrophication. To protect this precious native species and their habitat, monitoring is required. Traditional monitoring tools involve diving, wading, or swimming and visually looking for mussels. This requires good visibility and is time consuming and costly. The use of environmental DNA in combination with PCR techniques allows organisms to be detected in environmental samples. Studies showed that DNA can persist for weeks in water and even longer in sediment which may also provide an opportunity to explore the historic distribution of organisms through analysis of sediment cores. In this study we successfully developed species-specific droplet digital Polymerase Chain Reaction (ddPCR) assays for *Echyridella menziessi, Echyridella aucklandica* and *Echyridella onekaka*. Assays utilised primers and probes designed in regions of the cytochrome c oxidase I gene. While assays were tested on contemporary water and sediment samples, further optimisation of the DNA extraction method is required to enable detection in historical samples. The new assays will assist in determining the current and historic distribution of kākahi at large temporal and spatial scales, and in habitats where the use of traditional sampling methods is not feasible.

SYNOPTIC FLOW GAUGINGS/STREAM SAMPLINGS TO UNRAVEL HYDROLOGICAL AND HYDROCHEMICAL HETEROGENEITY WITHIN CATCHMENTS

Stenger, R.,[1] Rivas, A.,[1] Barkle, G.,[2] Owers, J.,[1] Clague, J.,[1] Moorhead, B.,[1] Morgenstern, U.[3]
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[3] GNS Science, Lower Hutt

Aims

Surface water monitoring sites in the State of Environment (SoE) monitoring programmes run by Regional Councils, Unitary Authorities and NIWA, typically have contributing catchment areas of hundreds or thousands of square kilometres. Accordingly, these catchments often comprise a wide range of meteorological, topographical, geological, soil, and land use conditions. The difficulty to relate an effect observed at a monitoring site to its cause within the heterogeneous catchment poses a challenge to the implementation of efficient and effective mitigation measures. To obtain a better understanding of the magnitude of this problem, we have begun unravelling the heterogeneity within two contrasting study catchments.

Method

The Waiotapu Stream catchment (≈ 300 km^2) on the North Island's Central Plateau represents a baseflow-dominated upland catchment (297 – 967m amsl) with large groundwater reservoirs in young volcanic deposits. Plantation forestry and native bush are the main land covers (≈ 55%), but highly producing pastoral land (≈ 45%) dominates in the Reporoa Basin. The Piako River headwater catchment (≈ 100 km^2) is a lowland catchment (38 – 488m amsl) in the upper Hauraki Plains with aquifer deposits of lower transmissivity and a large quickflow fraction in the river hydrograph. The catchment is dominated by intensive pastoral land use (≈ 84%), with the remainder being largely native bush (≈15%). Our study catchments are defined as the topographical areas contributing flow to the Waikato Regional Council (WRC) monitoring sites Waiotapu Stream at Homestead Rd. and Piako River at Kiwitahi, respectively.

Guided by real-time flow records available for one site in each catchment, we have begun a synoptic gauging/sampling scheme that comprises a minimum of 13 sites at Waiotapu and 11 at Piako. In the Waiotapu Stream catchment, we selected three sites along the Waiotapu Stream, sites at all nine significant tributaries near their discharge location into Waiotapu Stream, and an additional geothermal site (see Fig. 1). In our Piako catchment, we selected five sites along Piakonui Stream, three sites on the main stem of Piakoiti Stream, and two sites on its main tributary, additionally to the catchment outlet site (Piako at Kiwitahi).

Our autumn 2019 campaign targeted low flow conditions, which equated to flow percentiles of approx. Q21 at Waiotapu (at Reporoa Rd) and Q10 at Piako (at Kiwitahi). Flows during the winter 2019 campaign were just below median flow (Q47 at Waiotapu, Q42 at Piako). All campaigns were carried out within 2-3 days under rain-free conditions. FlowTracker2 systems were used for the majority of gaugings and a RiverSurveyor M9 for gaugings at higher flows.

At both sampling campaigns, field measurements of dissolved oxygen, electrical conductivity, pH, and temperature were made. While only nitrate nitrogen and silica concentrations were determined on the autumn samples, a comprehensive suite of analytes was determined on the winter samples (N, P, and C species; major ions, dissolved metals, etc). Tritium analysis for water dating was carried out on a total of 45 samples from both campaigns (Clague and Stenger, 2020).

Results

Hydrology: Water entering the Reporoa Basin from the headwater area of the Waiotapu catchment in the north (c.f. Fig. 1) accounted for a major proportion of the flow measured in Waiotapu Stream at the catchment outlet; 46% in autumn and 31% in winter. Mangaharakeke Stream in the north-east contributes the most flow within the basin, but all other eastern sub-catchments are characterised by lower flow than the western sub-catchments. At Piako, Piakonui Stream receives a substantial flow contribution from the largely bush-clad hills upstream of the first monitoring site, approx. 23% in autumn and 16% in the winter campaign, which means that the effect of agricultural land use in the remainder of this sub-catchment gets diluted by this 'clean' water from the headwater area. The lower flow in Piakoiti Stream presumably reflects lower rainfall in its sub-catchment, possibly combined with a higher fraction of deep recharge.

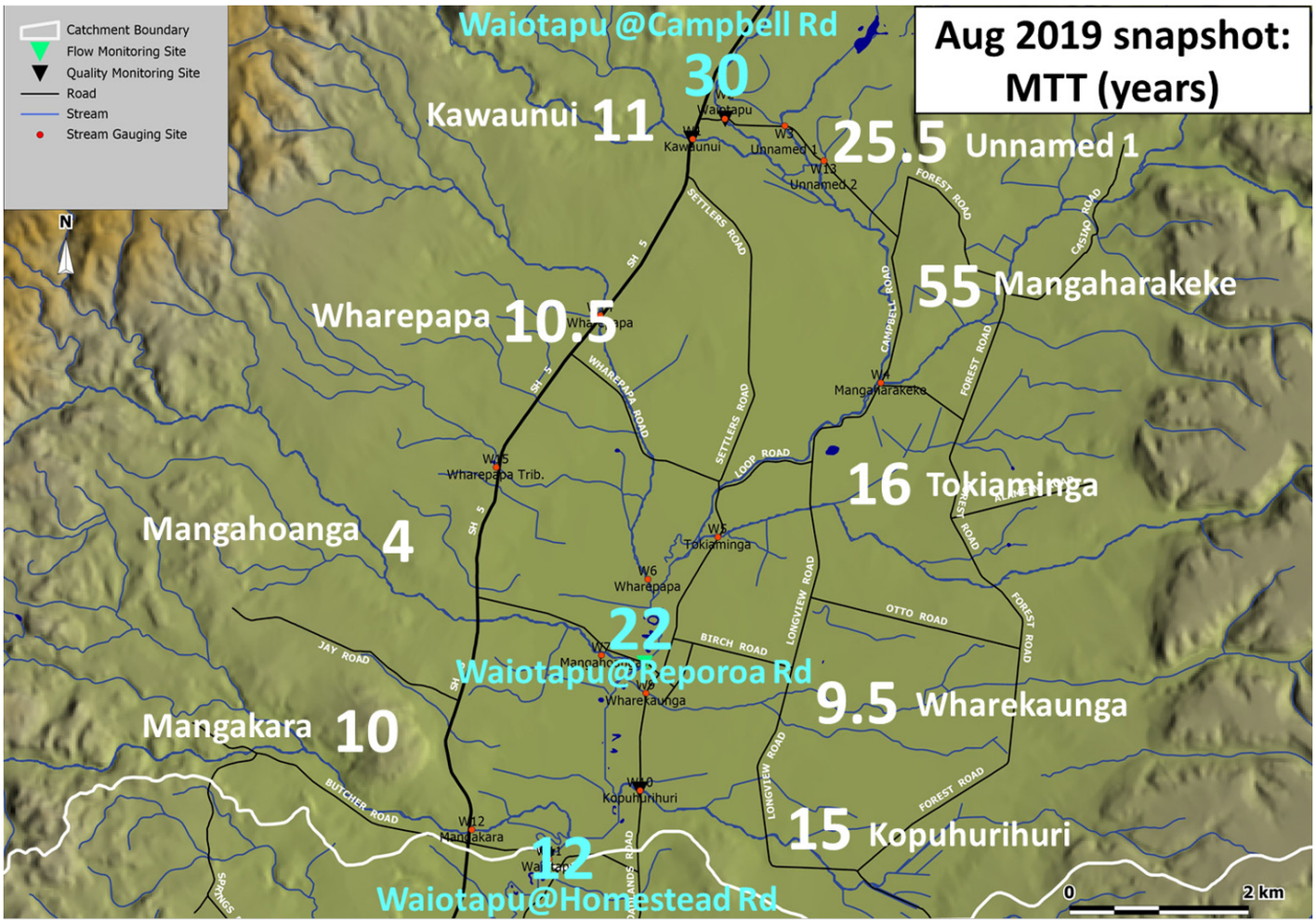


Figure 1. Mean transfer times (MTT, in years) determined on samples from Waiotapu Stream (turquoise) and tributaries (white) taken during the winter 2019 campaign.

MTTs: In autumn, the 3 Waiotapu Stream sites had similar MTTs (35 – 39 y), while the MTTs of the 9 tributaries ranged widely (13 - 70 y). Lower tributary MTTs in winter (4 – 55 y) resulted in the Waiotapu Stream MTTs to decrease from 30 y where it enters the basin to only 12 y at the outlet (Fig. 1). This result reinforces that the tributaries have only a small effect on the WRC monitoring site at the outlet at the low flows in autumn, but a substantial effect at the higher flows in winter. In Piako, there was a clear distinction in MTTs between our two sub-catchments in autumn, but it had nearly disappeared by winter. The Piakonui MTTs in autumn were in the narrow range 15.5 – 24.5 y, while Piakoiti MTTs varied widely 28 – 113 y. However, at the higher flow rates in winter, MTTs were much more uniform (6 – 9.5 y). This reflects a strong increase in shallow pathways contributions in winter, which was much more pronounced in the Piakoiti than the Piakonui sub-catchment.

Hydrochemistry: Nitrate concentrations showed a similar overall pattern at both Waiotapu campaigns, with particularly low concentrations (< 0.3 mg L^{-1} NO_3-N) at the two unnamed geothermal tributaries and Mangaharakeke Stream. Concentrations > 2 mg L^{-1} NO_3-N were only measured at Kawaunui Stream, and Mangahoanga Stream in autumn. All other concentrations were between 1 and 2 mg L^{-1} NO_3-N. At Piako, nitrate concentrations in autumn were at all locations ≤ 0.33 mg L^{-1} NO_3-N. Concentrations at the winter sampling ranged from 0.3 mg L^{-1} NO_3-N in the Piakonui headwaters to 2.6 mg L^{-1} in the unnamed Piakoiti tributary. As also observed for some other analytes, the strong concentration increase in the uppermost sampled reach of Piakonui Stream (from 0.32 to 0.93 mg L^{-1}) points to the important role of low-order stream reaches for surface water pollution.

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FRESHWATER MANAGEMENT TOOL - A NEXT GENERATION DECISION-SUPPORT TOOL FOR SCIENCE, POLICY AND CATCHMENT MANAGEMENT IN NEW ZEALAND

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Auckland Council has developed the first regionwide, continuous and process-based accounting framework for water quality in New Zealand – the Freshwater Management Tool (FWMT). The FWMT serves dual purposes for the unitary authority, guiding watershed decision-making for National Policy Statement for Freshwater Management (NPS-FM) planning and delivery of operational programmes to maintain and improve water quality.

The FWMT heralds a shift away from a statistical to deterministic and steady state to continuous understanding of water quality variation, at scale and resolution (e.g., of chronic and acute effects from cumulative sources). Simulated contaminants include total and dissolved forms or nitrogen and phosphorus, total suspended sediment, *E.coli,* total zinc and copper. Contaminant responses to meteorological and biophysical processes are resolved by up to 107 sources into ~100 Ha sub-catchments over 490,000 Ha of landscape.

Baseline simulation (2013-2017) is complete with truly representative outputs for the NPS-FM available across ten graded contaminants and for 3,085 km of permanent stream in the Auckland region (e.g., continuous in space and time). Contaminant time-series are now available from the FWMT to all coastal receiving waters, advancing integrated freshwater and coastal approaches.

The FWMT offers improved powers for translating science into policy, planning and management, but also increasing challenges. The process-modelling and continuous capabilities better enable explanations of existing and future water quality (e.g., under varied climate or development). However, with improved understanding comes increasing demand for better outcomes – raising the challenge of developing optimized approaches. Development is ongoing for exactly that, optimized scenario modelling of diverse rural and urban options (e.g., stormwater devices, edge-of-field devices, practice-based changes). Outputs will help bridge the scientific, policy and management divide by highlighting opportunities, costs and benefits of alternative management approaches, including whom is best placed to take targeted action for integrated benefit.

WATERFOWL HUNTING WETLANDS AS HABITAT FOR TWO NEW ZEALAND EEL SPECIES

Stewart, C.,[1] Garrick, E.,[1] Moss, Z.[1]
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Since European colonisation, wetland habitat has been greatly reduced in New Zealand and the loss of wetlands has been implicated in the decline of several native birds and fish. New Zealand's native shortfin eel (*Anguilla australis*) and endemic longfin eel (*Anguilla dieffenbachii*) are two native fish species that have been negatively affected by wetland loss. Fortunately, in Southland, the loss of some open water wetland habitat has been compensated for via the creation of waterfowl hunting ponds (duck ponds) on private land. In our presentation we outline the results from a series of eel population surveys conducted in Southland duck ponds and provide an estimate of the numbers and biomass of shortfin and longfin eels supported by Southland's ~7,500 duck hunting ponds. We contend that if it were not for the highly valued mallard duck (an introduced gamebird) and the enthusiasm for gamebird hunting in Southland, the availability of eel habitat would be greatly reduced.

AN EFFECT OF AUSTRALIA ON NEW ZEALAND PRECIPITATION

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[2] GNS Science

The recent (2019-2020) forest fires in Australia had dramatic effects on New Zealand, causing eerie lighting effects in the sky and dirty snowfields in the Southern Alps, because of ash in the air. These were visible signs of the extensive but often less perceptible effects that Australia has on the New Zealand atmosphere due to its position upwind of New Zealand in the "roaring forties".

One of the more subtle effects is on the isotopic composition of New Zealand precipitation as shown by the meteoric water line (mwl). The mwl is the relationship between oxygen-18 (^{18}O) and deuterium (^{2}H) contents of rainfall. Whereas the global mwl is given by $\delta^{2}H = 8 \times \delta^{18}O + 10$ with the intercept (d) being +10‰ reflecting its oceanic signature, the local mwl (New Zealand) has d about +13‰. We attribute this local effect to the presence of Australia west of New Zealand.

Air masses flowing eastward from Australia over the Tasman Sea have been dried and warmed on average by their passage over the continent. They are then able to extract moisture rapidly from the fetch over the Tasman Sea between Australia and New Zealand, causing greater relative kinetic fractionation in ^{18}O than in ^{2}H in their atmospheric vapour. This vapour produces rainfall with d values fluctuating around +13‰ in the westerly dominated climatic zones of New Zealand. Easterly dominated zones of New Zealand, on the other hand, have d values around +10‰ showing their more oceanic signature. These effects will be explored in the talk.

GREEN BOTTOMS: UNDERSTANDING DRIVERS OF NEAR-SHORE BENTHIC FILAMENTOUS ALGAE PROLIFERATIONS IN OLIGOTROPHIC LAKES.

Stewart, S.,[1] Kelly, D.,[1] Wood, S.,[1] Waters, A.S.,[1] Hawes, I.,[2] Vadeboncoeur, Y.,[3] Chandra, S.,[4] Moore, M.[5]
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[4] University of Nevada Reno, Nevada, USA
[5] Wellesley College, Massachusetts, USA

Recently around the world clear lakes with exceptional water quality have experienced a new phenomenon, proliferations of benthic filamentous algae, or filamentous algae blooms (FABs). Such proliferations have occurred in iconic systems Lake Baikal (Russia), Lake Tahoe and Crater Lake (USA) and Lakes Wakatipu and Taupō. These filamentous algae proliferations severely degrade near-shore habitat which globally is the most biodiverse area within lakes. Limnology has traditionally focused on pelagic algae blooms. Benthic proliferations present a conundrum for limnologists as they do not fit within current eutrophication paradigms developed in pelagic systems. However, the synchronized global emergence of these proliferations in lakes alludes to the potential significance of global climate change drivers.

In October 2019 a group of 30 researchers gathered at Lake Tahoe (USA) to develop conceptual models describing the mechanisms driving filamentous algae proliferations. This presentation will give an overview of: i) what exactly FABs are; ii) current understanding of the drivers of FABs focusing on potential changes in top-down (loss of benthic grazers) and bottom up control (e.g., sediment and groundwater nutrient enrichment); iii) an overview of future work including a summer monitoring program at Lake Taupō. FABs are an emerging issue, this presentation aims to stimulate further discussion on this topic.

STATISTICAL UNCERTAINTIES SHAPE ADOPTION OF RIVERINE REFERENCE CONDITIONS DURING POLICY REFORM

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The transition of scientific evidence into environmental policy is complex, and the rate of transition is low. Translational science aims to improve adoption, but there is a need for case studies of science-informed policy development that report lessons learnt.

We present a case study of how science was generated and incorporated in the development of national water policy, completed in partnership with central government. We estimated turbidity (suspended fine sediment) reference states throughout the river network of New Zealand. A critical question was: how region-specific should reference states be? This is an outstanding challenge that has hampered water policy implementation in several countries.

We developed classifications of the national river network that grouped rivers with similar turbidity states into classes at four spatial resolutions. The most parsimonious classification of turbidity reference states was found at the highest spatial resolution. As resolution of the classification decreased, reference states of individual rivers were biased towards that of a regional average. We show that low resolution classifications may result in management resources being allocated to the wrong places; rivers that do not necessarily require intervention may receive it, and those that do require intervention may be overlooked.

Although the highest-resolution classification was arguably the most effective, decision-makers selected the classification with the second-lowest resolution. A factor in this decision was an accuracy-precision trade-off across resolutions; as we grouped more rivers into fewer classes, precision of reference estimates increased, but accuracy declined. Contrasting perceptions among decision-makers about which form of statistical uncertainty was less risky—higher precision, lower accuracy *versus* lower precision, higher accuracy—eroded the legitimacy of what was likely the most effective classification.

Environmental policy options that scientists consider most effective will not necessarily be the most legitimate. Statistical uncertainties may play a greater role in policy development than the literature suggests; they can generate discordance between efficacy and legitimacy. Such discordance may be minimised with development of translational tools that communicate how different forms of uncertainty affect implementation of contrasting policy decisions. Such translational work needs to precede the brief opening of policy windows.

CLEARING THE WAY TO IMPROVING WATER QUALITY USING NATIVE FRESHWATER MUSSELS (KÅKAHI/KÅEO)

Stott, R.,[1] Hofstra, D.,[1] Thompson, K.,[1] Montemezzani, V.,[1] Heubeck, S.,[1] Albert, A.,[1] Bell, S.,[1] Hopkins, A.,[2] Nikau, T.,[3] Brown, R.,[4] Barnhart, C.,[5] Clearwater, S.J.[6]

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Water processing by bivalve suspension feeders can play a significant role in clearing lake water of particulates. However information on the clearance rates of native freshwater mussels *Echyridella menziesii* (kāeo) for microbial particulates is sparse, limiting our understanding of the potential role of this tāonga species in improving health-related water quality.

In collaboration with mana whenua, we trialled an approach to assess the capacity of kāeo to clear lake water of *Escherichia coli* (the indicator bacteria for freshwater faecal contamination) and effect of filtration on expulsion of *E. coli* in biodeposits (faeces and pseudofaeces). This initial study was conducted at Lake Ohinewai, Waikato. Differences in water quality over time due to kāeo filtration activities provided estimated clearance rates of 0.5L/h/mussel (range 0.13-1.2), equivalent to the removal of $2x10^3$-10^4 *E. coli*/h/mussel from the water column when compared to control mesocosms containing dead mussels. *E. coli* levels were around 10^4 higher in ejected pseudofaeces in comparison to lake water indicating substantial removal of *E. coli* from the water column due to flocculation of *E. coli* bound in mucus.

Follow-up trials will use the biodeposition method to refine measurement of clearance rates and assess fate and viability of ingested *E. coli,* and clearance of other particulates (e.g., cyanobacteria refer Thompson) and contaminants (e.g nutrients). Potentially, kāeo filtration activities could be exploited using mussel rafts (refer Hofstra) deployed to improve suitability of water for swimming, particularly in lakes where high *E. coli* bacterial counts exceed health guidelines alongside toxic cyanobacterial blooms.

PERSISTENCE AND GROWTH OF FAECAL INDICATOR BACTERIA EXCERBATES REMOVAL RATES FROM AGRICULTURAL WETLANDS

Stott, R.,[1] Sukias, J.,[1] Cookson, A.,[2,3] Devane, M.,[4] McKergow, L.,[1] Tanner, C.[1]
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A constructed wetland treating episodic (rain event driven) dairy pasture subsurface drainage was found to be a net exporter of the faecal indicator bacterium, *Escherichia coli*. Monthly monitoring of farm drainage to the wetland during the wetter months of the year indicated a relatively low median inflow concentration of 23 *E. coli*/100mL increasing to 98 *E. coli*/100mL in the outflow. This is a surprising finding given that constructed wetlands treating steady-flow wastewaters usually achieve net *removal* of *E. coli*. Investigating if the increase in *E. coli* was an artefact of sampling biased towards flow recession after rain events entailed considerable flood-chasing work using time-based and flow-proportional sampling to calculate inflow and outflow fluxes (cfu/s) and loads (cfu/event and cfu/yr). Testing this "hypothesis" concluded that the wetland was indeed a net exporter of *E. coli* with increases in *E. coli* export ranging from 2 to 34-fold.

Subsequent work has sought to understand if increased *E. coli* export is due to environmental "naturalised" populations that may survive and grow in the wetland. Further investigation into the diversity of *E. coli* isolates collected from water, sediment, soil and faecal material from the constructed wetland and adjacent pasture, found evidence of naturalised cryptic clades of *Escherichia* species phenotypically indistinguishable from faecally-derived *E. coli* but divergent at the genetic level. This raises interesting questions regarding the microbial ecology of *E. coli* and interpretation of *E. coli*-based water quality in relation to waterborne disease and health risk downstream from wetland environments.

IDENTIFICATION OF WHITEBAIT SPAWNING ZONES IN THE BAY OF PLENTY

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[1] Bay of Plenty Regional Council
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Aims

Whitebait and whitebaiting are hugely important to many New Zealanders, for both cultural and recreational reasons. The majority of the whitebait catch is inanga, yet there is growing concern about their conservation status. Inanga spawn at the "salt-wedge" in the lower, tidally influenced reaches of waterways amongst vegetation that is submerged on spring tides. The location of the salt wedge varies, reflecting differences in tides and river flow.

A major threat to inanga is the loss of spawning habitat by activities such as installation of rip rap, or loss of riparian vegetation through mowing, spraying or stock grazing. Although many councils have policies to protect specific whitebait spawning sites, one of the difficulties is accurately identifying other potential spawning zones within specific waterways.

This study thus aimed to:

- identify zones of potential whitebait spawning habitat on the basis of locations of the salt wedge in a number of Bay of Plenty rivers
- quantify habitat conditions within the salt wedge zone to identify the degree to which this has been adversely affected by human activities
- develop and test a GIS-based model to predict where potential whitebait spawning zones could be other rivers in the region

Method

Potential spawning zones within 18 waterways were identified from a boat by measuring conductivity at Mean High Water Springs in February to May in 2017 and 2018. A minimum of two surveys were conducted in each river. The suitability of spawning habitat within the salt wedge zone was also assessed in each waterway by scoring 12 habitat parameters known to affect spawning. Scores were summed to give a total of 125.

A GIS-based model was also developed to map potential salt wedge zones in sea-reaching rivers, based on estimates of saltwater wedge intrusion at spring high tide. This model was based on a detailed Digital Terrain Model and tide height information. It was also validated from the results of the salt-wedge surveys.

Results

The length of potential spawning areas varied from 110 m in the Kaikokopu canal to 5 km in the Whakatane River. The median length of potential spawning reaches was 1020 m. Potential whitebait spawning zones were longer in deeper rivers than shallow rivers, and the salt wedge travelled further inland in wider rivers. Spawning suitability scores ranged from 64 to 91. Four habitat factors (fish access, saltwater access, bank material, vegetation type) were ranked "good" at 75% of sites, while bank angle and vegetation height scored "poor" in 75% of sites. Average spawning suitability scores were lowest in canals, followed by stop-banked rivers, while natural waterways had the highest scores.

The GIS analysis identified 223 waterway segments as in the potential salt wedge zone, of which 92 drained directly to the sea. Channelised rivers had the longest combined length of potential spawning areas (100.9 km), followed by natural waterways (59.9 km) and stop-banked waterways (40.4 km). Most of the sea-draining waterways only had short salt wedge zones (< 500 m long), although larger rivers had potential spawning zones ranging from 1 to 5km in length.

Better conservation outcomes for whitebait could be met by implementing more nuanced rules to protect spawning sites within salt-wedge zones. Such rules could include 1) temporarily fencing sites from stock access; 2) not allowing grazing, mowing or spraying of bankside vegetation from December to June; 3) requiring rip rap placed along the banks of rivers in salt wedge zones be "inanga friendly"; 4) removing barriers such as flood gates to migration at some lowland sites; 5) create specific inanga spawning ponds adjacent to large rivers. It is only by improving the way that activities are undertaken within potential whitebait spawning zones can we help protect this iconic species.

NEW GUIDELINES FOR CONSTRUCTED WETLAND TREATMENT OF PASTORAL FARM RUN-OFF

Tanner, C.C.,[1] Sukias, J.,[1] Woodward, K.B.,[1] McKergow, L.,[1] Goeller, B.,[1] Matheson, F.,[1] Kalaugher, E.,[2] Depree, C.,[2] Wright-Stow, A.[2]
[1] NIWA, Hamilton
[2] DairyNZ, Hamilton

Constructed wetlands are a key edge-of-field technology for reducing agricultural contaminant loss to waterways. Preliminary guidelines for constructed wetland treatment of diffuse run-off and drainage from pastoral farms have been developed as part of the INTERCEPTOR project, a joint initiative between DairyNZ and NIWA. Based on an extensive review of relevant New Zealand and international CW studies, the guidelines have been developed to support uptake by farmers and acceptance by regulatory agencies. They provide performance estimates for reduction of suspended sediments, nitrogen and phosphorus in relation to the percentage of wetland area in the contributing catchment. Information is also provided on siting, design, construction, maintenance and planting of constructed wetlands.
Our objective was to provide sufficient certainty regarding expected contaminant reductions to enable farmers to incorporate constructed wetlands within farm nutrient management plans, and for regulatory agencies to confidently assess their efficacy. To incorporate feedback from policy makers and practitioners, and ensure regulatory acceptance, the content and derivation of the guidelines has been assessed by a Riparian and Wetland Practitioner Technical Group. Further work is continuing to demonstrate constructed wetland application and extend the database on treatment performance across a range of New Zealand farmscapes.

FLOOD DAMAGE RECOVERY: FEBRUARY 2020 OTAGO STORM

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[2] Otago Regional Council

Recovery from the February 2020 storm that caused flood damage across Otago is described, including an initial risk-based assessment of damage, followed by more detailed damage assessment and investigation leading to prioritized flood damage repairs. The magnitude of the flood event and flood response are described in separate abstracts.

Initial high priority flood damage repairs have been completed, while more complex repairs have required further investigation and design. Flood damage repairs are ongoing and will continue at least through to mid-2021. Major damage in some areas has posed challenges that will be presented, together with lessons learned through the flood damage recovery process.

Extent of Flood Damage

A total of 35 sites across Otago (Figure 1) were identified as requiring flood damage repair as a result of the February 2020 floods. The majority of these were in the Lower Clutha (Figure 2) where the 9th largest flow in the Clutha River since 1863 was recorded at Balclutha. This flow of 3,175 m3/s is the largest flow in the Clutha River in the last 20 years.

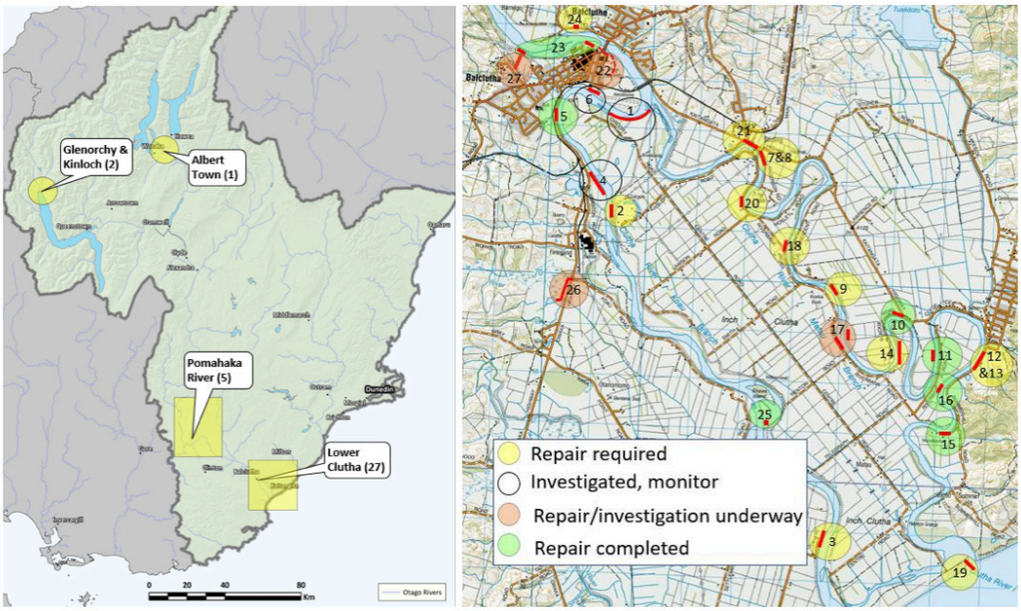


Figure 1. Otago-wide location of flood damage. Figure 2. Lower Clutha flood damage.

Major Challenges

Seven areas of flood damage pose significant challenges requiring extensive investigation and design. These include:

- piping failure and slumping of floodbanks on the Waitepeka River upstream of the Owaka Highway, and at Hospital Creek upstream of Balclutha township;
- riverbank erosion leading to erosion scour and slip of district roads at Riverbank Road (Figure 3) and Burning Plain Road, requiring closure of both roads;
- undermining of rock buttress and revetments at Albert Town upstream of the SH6 bridge (Figure 4) and at Riverbank Road bridge near Stirling; and
- failure of pressure relief wells providing protection to Balclutha township.

Investigations and design of repair solutions are underway for these areas of major flood damage. High risk areas have been closed to public access until repairs can be undertaken. To address the risk of possible failure of the Hospital Creek floodbank in a similar sized event, an evacuation plan with water-level based triggers has been developed for Balclutha.

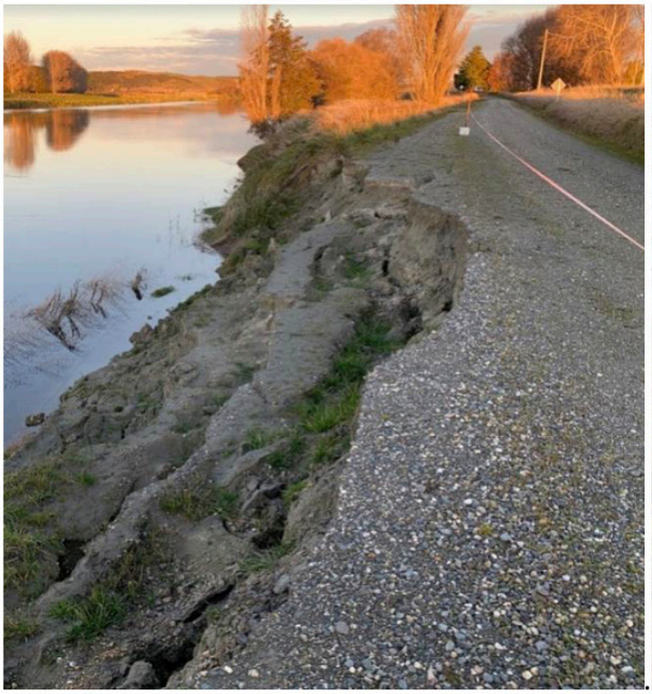
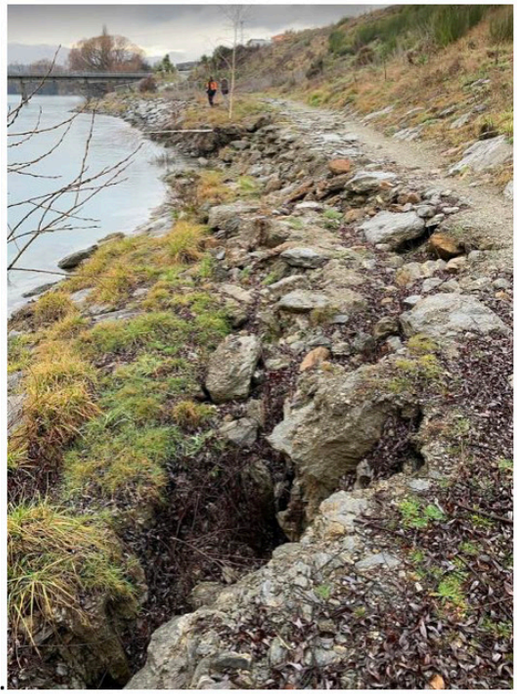



Figure 3. Scour erosion at Riverbank Road. Figure 4. Rock buttress collapse, Albert Town.

Monitoring of the collapsed rock buttress and scarp slope at the Albert Town flood damage site (by Geosolve, 2020) has indicated ongoing movement of the slope hence the need for urgent flood damage repairs.

Lessons Learned

A number of lessons have been learned through undertaking these repairs as part of flood recovery, including:

- The importance of investigating repair options at a high level, prior to undertaking detailed design for the preferred repair option. This allowed cost benefit analysis using indicative repair costs, and in some cases, required further investigation to come up with fit for purpose repairs significantly cheaper than the initial options proposed.
- The value of good asset records and as built drawings. The lack of these for many of the areas of damage has necessitated making engineering judgements and design assumptions in order to designs like-for-like repairs.
- The unusually quiescent period over the last 20 years has meant that relatively little repair works have been required to river scheme assets. The February 2020 flood event has highlighted this lack of maintenance of assets and the return to a more active period could result in increasing damage in flood events and could accelerate deterioration of scheme assets (Williams, 2020).
- Vegetative river bank protection has become inconsistent, again with the long quiescent period, to the point where isolated trunks and tall branches overhanging into the channel are more of a liability than a benefit in places (Williams, 2020).

Summary

The latest status of flood damage repairs including before and after repair comparisons, challenges involved and lessons learned will be presented.

References

Williams, G. 2020. Clutha & Pomahaka Rivers February 2020 Flood Review of Flood Damage & Repairs and Assessment of River Management. Report to Otago Regional Council

Geosolve. 2020. Albert Town Rock Buttress Design. Report to Otago Regional Council. August 2020.

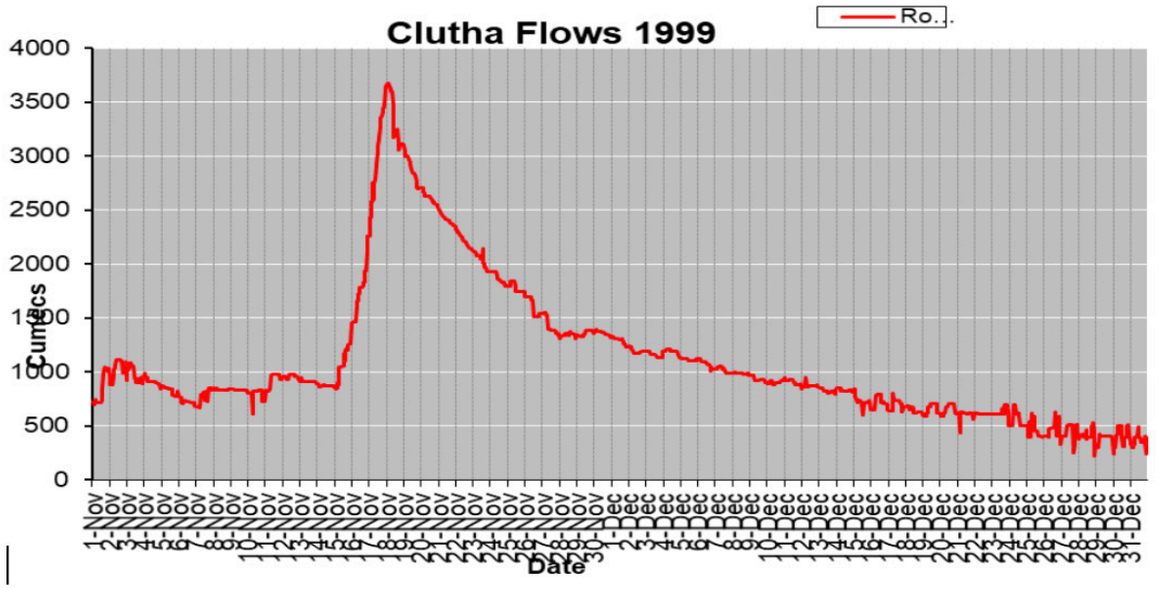
TOO MUCH DATA (THE 1999 AND 2019 EXTREME FLOODS IN THE CLUTHA CATCHMENT)

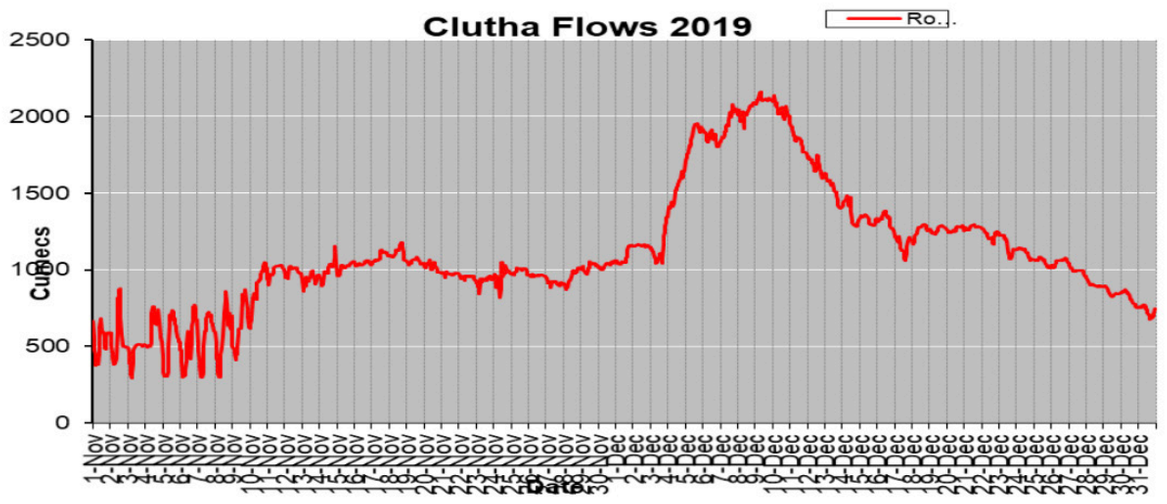
Taylor M. J.[1]
[1]University of Waikato

The largest peak discharge through any hydro Dam in New Zealand occurred in November 1999 with a flow through the Roxburgh dam of 3679 cumecs. The flood also caused a large amount of damage throughout the Clutha Catchment costing many millions of dollars. During this flood live data was limited due to flow stations being washed out or drowned, yet control of the situation was conducted in an orderly manner

In November and December 2019 another large flood occurred in the Clutha River. The peak discharge was only 2163 cumecs, but the total volume of water during this flood event was 30% greater than the 1999 flood. There was very little damage anywhere except downstream of the junction with the Pomahaka River and on the edges of Balclutha township. During this flood all data was fully available, but data from different sources did not agree, and controllers on the Clutha dams found the situation quite confusing.

This presentation looks at the hydrographs from both floods, and shows how they were managed.





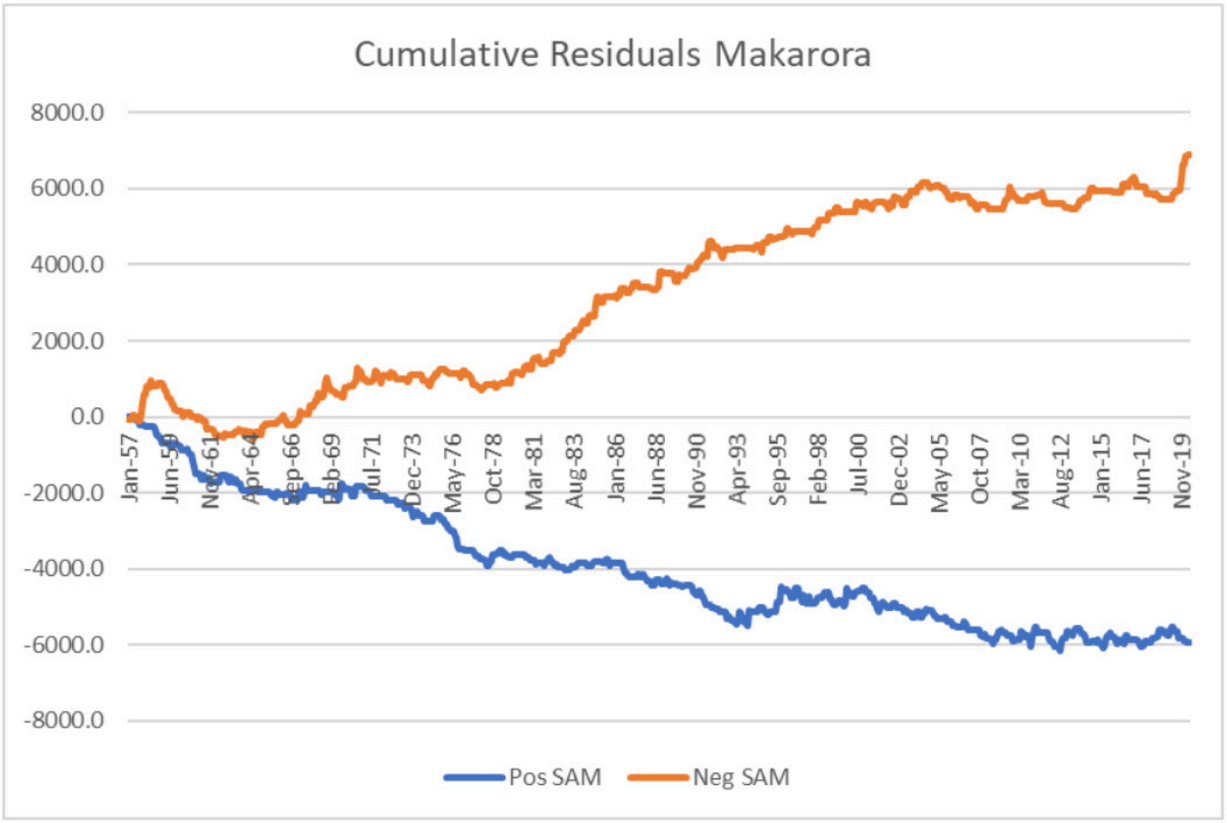
THE SOUTHERN ANNULAR MODE AND RAINFALL AROUND THE 45TH PARALLEL

Taylor M. J.[1]
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There have been a number of studies in Australia showing that the positive phase of the Southern Annular Mode (SAM) is often associated with drier than normal conditions. Here in New Zealand the 2008 drought was also linked to a long-lasting positive phase of the SAM. The main concern of studies in New Zealand is the lack of rainfall in the South Island hydro catchments, even though in 2008 it also affected farming in both islands. That raises the question of how wide spread are these drier conditions and why.

This study looks at the rainfall in a number of places around the southern hemisphere, including Tasmania, West and East coasts of the South Island, Chatham Islands, Chile and the Falkland Islands.

It is found that there is a significant difference in rainfall, at all the sites studied, between the positive and negative phases of the SAM. The difference is more pronounced in western facing catchments, but also noticeable on the east coast of the South Island in a rain shadow location. A surprising finding is that the island sites at Chatham and Falkland Islands also show the difference indicating that the cause is more than a simple decrease in westerlies at this latitude. The lower rainfall is significant for 3 months or more at most sites, which can make the SAM a good indicator of future low river flows.



EFFECTS OF FOOD AND SUSPENDED SOLIDS ON RESPIRATION, CLEARANCE AND WASTE PRODUCTION RATES OF NEW ZEALAND'S FRESHWATER MUSSEL *ECHYRIDELLA MENZIESII*

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[3] Manaaki Whenua – Lancare Research, Lincoln, NZ
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Freshwater mussels, or kāeo as they are commonly referred to in the Waikato, are a keystone species affecting water clarity, nutrient cycling, biodiversity and biodeposition in waterways. Freshwater mussels are in decline both in Aotearoa and worldwide with decline partly attributed to habitat degradation and environmental stressors. Using kāeo as a bioremediation tool in shallow lake restoration projects could be more effective if mussels were stocked on rafts and their survival and clearance/filtration rates optimized.

We undertook laboratory experiments to understand the environmental conditions that adult kāeo could tolerate on a bioremediation raft. Concentrations of suspended solids typical of shallow eutrophic (nutrient rich) lakes were used to determine the effect on respiration, clearance/filtration rates, and production of faeces and pseudofaeces. Feeding trials have also been undertaken with diets comprising of different sizes and types of plankton, including potentially toxic blue-green algae (cyanobacteria).

This presentation details experimental designs and discusses the findings of these laboratory trials. Respiration, clearance/filtration and waste production rates are reported, and comparisons made between different mussel size classes and reproductive states.

Complementary oral presentations will discuss the ingestion and degradation of *Escherichia coli* by *Echyridella menziesii* (Stott) and modelling the impact of kāeo at different densities on shallow lake ecology (Allan).

USING ENVIRONMENTAL DNA TO DETECT LONG- AND SHORT-FINNED FRESHWATER TUNA (EEL)

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The freshwater tuna (eel) is one of New Zealand's most ecologically and culturally important freshwater fish. The endemic long-finned eel (*Anguilla dieffenbachii*) and the native short-finned eel (*Anguilla australis*) are apex predators in rivers and lakes, playing an important role in ecosystem functioning. Although still common, over the last few decades there has been a national decline in their population due to habitat destruction and commercial take. The emergence of targeted environmental DNA detection methodologies provides an exciting opportunity to enhance information about their past and present distributions. In this study we successfully developed species-specific droplet digital Polymerase Chain Reaction (ddPCR) assays to detect *A. dieffenbachii* and *A. australis* DNA in both water and sediment samples. Assays used primers and probes designed in regions of the mitochondrial cytochrome b and 16S ribosomal RNA genes for *A. dieffenbachii* and *A. australis*, respectively. Eleven river water samples were analysed by metabarcoding (using fish specific primers) and were compared with the ddPCR assays. The presence of *A. dieffenbachii* and *A. australis* DNA was detected in a greater number of water samples using ddPCR in comparison to metabarcoding. Detection of eel eDNA in sediment samples was more consistent in lake sediments compared to river sediments. These new ddPCR assays provide novel opportunities for assessing both spatial and temporal distributions of *A. dieffenbachii* and *A. australis* in a range of environments and sample types.

ASSESSING THE RANDOMNESS IN TRANSPORT PROCESSES OF CONTAMINANTS IN GROUNDWATER USING MATHEMATICAL MODELLING

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Background and issues

Groundwater is the largest reservoir of liquid freshwater on Earth. Groundwater circulates inside the land surface and is one of the most important natural resources for human life. Groundwater contamination is a serious problem that is growing with each passing day, but its true extent is not known and it is difficult to determine because of the heterogeneity of the medium, complexity of contaminant transformation and fate in the groundwater system. One of the factors of groundwater contamination that makes it so serious is its long-term nature. Generally, groundwater moves slowly, so do contaminants. Due to these slow movements, the contaminants remain concentrated in the form of a plume.

Generally, the quality of New Zealand's groundwater is good, but shows trends in deterioration with time and there are variances across the country. Nitrate-nitrogen (N) in groundwater is a major concern in New Zealand. N contamination in water resources can lead to a condition known as methemoglobinemia or "blue baby syndrome" and has also been linked to cancer through the formation of carcinogenic N-nitroso compounds (Wedge et al., 2001), to spontaneous abortions (Centers for Disease Control and Prevention, 1996) and to non-Hodgkin lymphoma (Ward et al., 1996). There is no one single cause for groundwater N contamination. Applying pesticides and fertilisers, significant agricultural and urban land use are few examples of activities that contribute to N contamination. Sources of ground water contamination are immense and diverse.

Groundwater modelling is an effective tool to understand and predict the behaviour of a groundwater system. Models simplify reality and may not be perfect but are useful tools. Thus, it becomes a challenge to the modellers to untangle the real-world complexities in a simple setting without compromising on the accuracy. As an example, we may consider groundwater flow system in which permeability of the medium behave randomly, or boundary conditions are often uncertain and/or velocity term is characterised as a random variable with respect to space and time. Processes of groundwater flow and contamination transport (Natarajan et al., 2018) can be expressed through mathematical models based on differential equations. However, modelling real-world stochastic phenomena is complex due to heterogeneity in the parameters or unavailability of sufficient information or both. These situations necessitates consideration of data such as permeability as random magnitudes and thus there is a need to formulate stochastic models by transforming traditional deterministic models to improve system performance. Stochastic models help the modellers to characterise this randomness in several ways and suitable mathematical modelling and efficient numerical simulation plays crucial role in predicting the behaviour of a natural system. Depending on the objectives of a study and the intended outcome, selection of model approach and data requirements can be made to suit the area of study and the objectives. For example, if the objective is a regional groundwater flow assessment, then a coarse model may satisfy this objective, but if the area of study is for a local area to understand specific details then a fine-grid model with high data density should be used.

Model Development and Results

We developed a model based on Wiener Chaos Expansion (WCE, Zhang et al., 2012) technique to determine the concentration profile of a groundwater flow system, generally known as Polynomial Chaos Expansion. WCE is a non-sampling technique to quantify the probabilistic irregularity in a dynamic system. The advantage of using this approach lies in the fact that Wiener Chaos coefficients can be calculated by reducing the uncertainty propagator into lower triangular matrix. The fundamental concept of using this method is to develop a solution as part of an infinite series that may converges in Wiener Chaos space. Thus, this technique works as an efficient analytical and theoretical tool to study current and peculiar kind of solutions. We obtained results (Figure 3) for first and second order moments of concentration at a distance of m analogous to the results obtained by Monte Carlo (MC) method but with less computational time and efforts. However, the amount of computational effort depends on the choice of basis and the technique used to solve the system of equations. It is also observed that WCE coefficients diminish with higher rate by increasing order of polynomials as compared to increasing number of used random variables. Thus, this approach can be used as a substitute to MC type methods under specified boundary and initial conditions.

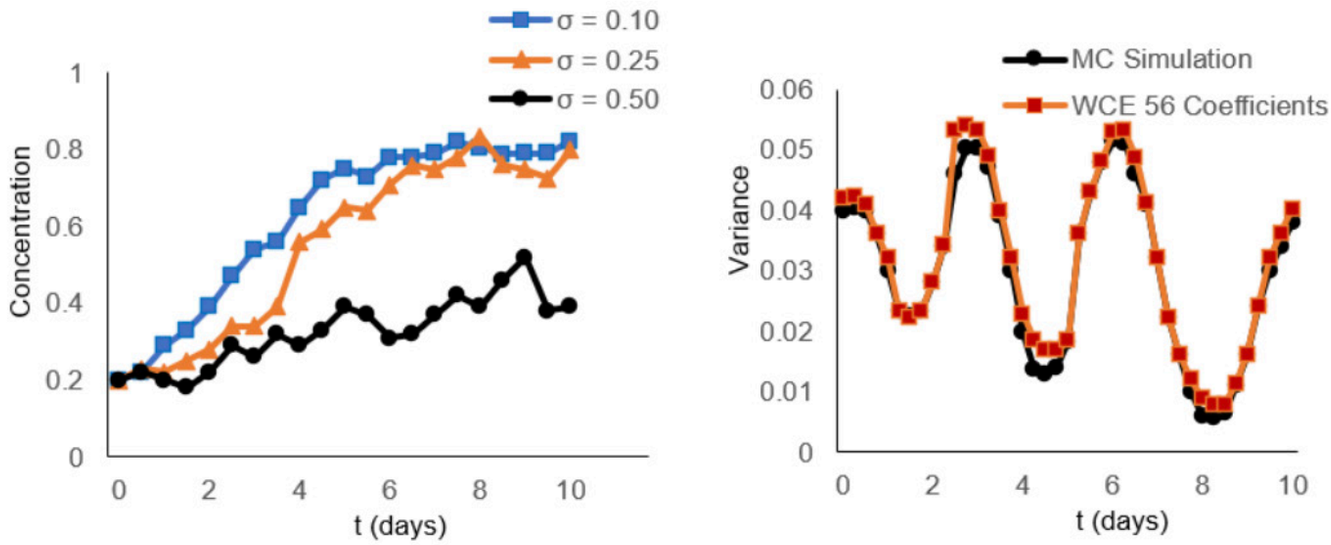


Figure 3 Concentration profiles (left) at m for different values of noise controlling parameter by maintaining the concentration value of 1.0 unit at the boundary of and running simulations by choosing initial concentration (0.2 unit). For simplicity, dimensionless parameter values were used. Increased values of noise parameter show randomness in concentration profile. Figure on the right side shows the convergence comparison for variance between WCE method and MC simulation. The WCE method with 56 coefficients has the similar accuracy as MC simulation with 10,000 realisations. However, the CPU time is only 12 seconds for the WCE method, as opposed to 315 seconds for the MC simulation.

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PROJECTING FISH COMMUNITY RESPONSES TO ALTERED FLOW REGIMES USING INTERACTION-NEUTRAL MODELS: DOES THE COMMUNITY CONTEXT MATTER?

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Riverine organisms fundamentally depend on natural fluctuations in river flow for their life histories. Rapidly changing climatic conditions have shifted drought and flood regimes, which may have severe effects on species distributions and interactions. We employed a mechanistic multispecies demographic model that links population dynamics with river flow regimes to explore the consequences of potential flow regime futures on riverine fish communities and their interactions, including scenarios of increased drought, flooding and flow homogenisation. Species were coupled together into a multispecies framework through density-dependent relationships in reproduction. We parameterised the model with vital rates and flow-response relationships for a community of native and nonnative fishes in the Verde River, Arizona, USA, a major tributary within the Colorado River Basin. For each simulated flow regime (projected forward 250 years), we simulated all possible species combinations: four-, five-, six- and the whole seven-species community (64 unique communities). Early results indicate that altered flow regimes led to different community trajectories over time, but that particular combinations of species enabled greater long-term coexistence over a range of flow conditions. Thus, although the flow regime is a key driver of fish population persistence in dynamic river systems, species interactions and the presence of nonnative invaders interact strongly to determine population persistence under environmental change. Seeking to maintain biodiversity in dynamic rivers under global change will therefore require management of both flow and invasive species.

PREDICTING EROSION SOURCE ATTRIBUTES FOR USE IN MODELLING SEDIMENT-RELATED WATER QUALITY

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Accelerated erosion of fine sediment and its delivery to river channels presents a significant issue for freshwater quality. Presently, a range of modelling, monitoring, and measurement techniques are employed to inform spatial and temporal understanding of erosion processes and guide the targeting of erosion mitigation strategies. These approaches largely focus on the mass or quantity of sediment, while quality aspects, notably particle size of the sediment being eroded and its impact on water quality, is often not evaluated. This is problematic as the attributes of sediment that affect environmental behavior and water quality vary across catchments, geological parent materials and erosion processes.

Sediment sources sampled in situ and representing a range of parent materials and erosion processes across four catchments were analysed for a set of sediment quality attributes including, particle size represented by D10, D50, and D90 for number, surface area and volume distributions in combination with Particulate Organic Carbon (POC), Particulate Organic Nitrogen (PON), Inorganic Suspended Solids (Inorg SS), Volatile Suspended Solids (VSS), Suspended Solids (SS), and light attenuation (Beam c).

These quality attributes and their relationship to parent material and erosion terrains were investigated through supervised and unsupervised learning techniques to train and test an erosion source quality attribute model with the purpose of predicting spatial patterns in quality attributes of sediment source materials within a catchment. These spatial source quality attributes should assist with constructing models that aim to couple representation of erosion processes, sediment transport, and sediment-related water quality effects.

UNLOCKING THE VALUE OF VOLUNTEER FRESHWATER DATA: PROGRESSING A NATIONAL QUALITY ASSURANCE (QA) FRAMEWORK

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[3] Greater Wellington Regional Council

The number of freshwater volunteer monitoring groups continues to increase across many parts of New Zealand, along with the expectation of some groups that their data can or will be used to inform freshwater reporting and management. There is now also a growing interest across many regulatory agencies for volunteers to contribute credible and relevant data at meaningful spatial and temporal scales, as well as from geographically remote locations. Central to unlocking greater use of volunteer data is ensuring that data are of a known quality and 'fit for purpose'. Volunteer groups will also need adequate resourcing and support. NIWA is partnering with a group of regional councils and other interested parties to develop a national quality assurance (QA) framework for volunteer freshwater monitoring initiatives. In this presentation we report on the key findings from the first phase of the project; a review of existing overseas frameworks that could potentially be adapted for use in New Zealand. Both the US and Canada, as well as some European countries, already heavily rely on volunteer data and have therefore developed QA-related systems to manage data quality. It is intended that the framework, which would be developed separately and in partnership with regulatory agencies and volunteer groups across the country, would cover QA requirements for a range of monitoring purposes, from engagement and education, through to model development and validation, environmental reporting and informing regulatory decision-making.

PLASTICS: AESTHETIC NUISANCE OR EMERGING FRESHWATER CONTAMINANT?

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[1] NIWA
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[4] Massey University

From food packaging to cigarette butts to wayward road cones and trapped plastic bags, a walk along most urban streams reveal the ubiquity of plastics in our society and the ease in which they escape into the environment. The presence of plastics and other litter in stream and rivers is a well-known aesthetic nuisance and its presence may have long-lasting impacts on how people value (and therefore care for) their local waterways. Litter also has significant health and safety consequences, with ACC claims due to beach litter increasing over the past decade. But do plastics and litter impact the ecology and functioning of freshwater habitats or is our do lakes and river deserve attention primarily as vehicles for transferring of plastics to the ocean? Is the focus on plastics "environmental greenwashing" that distracts from more serious threats? Here we discuss the state of environment concerning plastic pollution in New Zealand's lakes, rivers, and river mouths. We outline how we are monitoring and reporting on plastics and other litter in both freshwater and marine systems and the recent efforts to align methodologies to ensure nationally consistent reporting. We also review what the current science says about the impact plastics have on freshwater ecosystems with respect to biodiversity, recreation and clean drinking water. We conclude with a 5-year roadmap and recommendations on where we should focus our efforts and how territorial authorities can collaborate with NGO's and communities for improved freshwater outcomes.

KĒKĒWAI (CRAYFISH) AS A STREAM RESTORATION TOOL TO DISRUPT UNHELPFUL BIOTIC INTERACTIONS AND FACILITATE BIOLOGICAL RECOVERY

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Snails, worms and fly larvae, typical of degraded streams, possess traits that allow them to dominate, even following improvements in abiotic conditions, potentially preventing recolonisation of more desired species like mayflies, stoneflies and caddisflies (EPT). These traits likely make degraded invertebrate communities resistant and resilient to stream restoration. To move beyond just abiotic restoration, we considered biotic interactions, and investigated disrupting degraded fauna dominance through top-down control. The snail *Potamopyrgus antipodarum* often persists in high densities (e.g. 30,000/m2) in degraded and abiotically-restored streams, thus, was used here as a model organism for a degraded community. In New Zealand, kēkēwai (crayfish, *Paranephrops zeleandicus*) are one of the few known predators of *Potamopyrgus*. We added kēkēwai to stream mesocosm communities containing high snail densities and densities of sensitive EPT larvae typical of natural streams, with colonist drift simulated through regular EPT addition. We compared snail and EPT densities after 90 hours, measured drift out over time, and calculated consumption for degraded and colonist species groups. Final EPT density in snail-EPT treatments was higher when kēkēwai were present compared to when they were absent. This occurred because kēkēwai had a positive indirect effect on EPT via strong direct negative effects on snails through consumption and inducing drift. Thus, by reducing the dominance of a tolerant species, predation by kēkēwai indirectly opened up opportunities for more-desired species. This approach will be useful in overcoming resistance to restoration, and highlights the importance of incorporating biotic interactions and associated indirect effects into restoration planning.

OUR LAKES HEALTH; PAST, PRESENT AND FUTURE. INVESTIGATING TRENDS IN LAKE HEALTH AT A NATIONAL SCALE

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The health of our lakes is central to Aotearoa's environmental, economic and cultural wellbeing. Yet we cannot robustly assess the water quality or ecological health of our 3,800 (> 1 ha) lakes because over 95% of them are not monitored. Even for the few lakes that are monitored, datasets are short (<10 years), and assessment incomplete, because monitoring started after those lakes had deteriorated. With increasing pressure to improve national water quality, it is now vital to have informed benchmarks of natural lake state and an enhanced understanding of causes of degradation. Lake sediments are natural archives that continuously record environmental history, providing measures of current and historical aquatic communities and water quality – equivalent to many centuries of monitoring. The 'Our lakes' health; past, present, future (Lakes380)' project aims to use a novel toolbox of paleo-based approaches to define natural states and reveal historic trends in lake health and ecosystem change on a national scale. To date we have collected sediment cores from over 230 lakes across Aotearoa. In this talk, examples from a subset of lakes will be presented to show how the data can be applied to track spatial and temporal patterns in water quality, catchment change, and lake productivity. We focus on data from pollen analysis to measure catchment and vegetation change, and hyperspectral (infrared) core scanning as a measure of lake productivity and algal abundance. These data will assist in identifying the timing and trends of changes in lake health and help guide their management.

CHATHAM ISLANDS FRESHWATER INVESTIGATIONS

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[1] Pattle Delamore Partners Ltd
[2] Environment Canterbury

The Chatham Islands are located approximately 800 km east of New Zealand's South Island. The islands form a small archipelago consisting of about ten islands. The largest islands are Chatham Island and Pitt Island which are the only two permanently inhabited islands.

A freshwater investigation was undertaken to review and report on the state of the water resources on Chatham Island. The investigations included a review of information and analyses on rainfall and evaporation, climate change, surface water quantity and quality and groundwater. This also included a water balance, review of potential uses and abstractive pressures on the water resources and analysis of the suitability of water bodies for potable and domestic use.

Key analyses undertaken included a review of the spatial variability in rainfall, evaporation and streamflow as well as analyses to determine increasing or decreasing trends in the data. The work also included an overview of the key projected changes in temperature, rainfall and sea level rise for the Chatham Islands under different climate change scenarios.

Long term surface water quality monitoring data from 2005 to 2019 was analysed to determine current state and temporal trends in waterbodies of the island and to compare current state data against national standards, where available. In addition, a nutrient flux analysis was undertaken for the large Te Whanga Lagoon, identifying key rivers with significant nutrient loads flowing into the lagoon.

Based on the analyses undertaken, recommendations were made to improve the freshwater monitoring programme on the island.

METHODOLOGY FOR MONTHLY-TO-SEASONAL FORECASTING OF REGIONAL CLIMATE CONDITIONS IN NEW ZEALAND: MACHINE LEARNING APPROACH

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The ability to successfully predict future climate conditions, such as rainfall and temperature, is of significant benefit to various community groups in New Zealand. In this work, we aim to evaluate the forecasting skill of selected machine learning (ML) methods for climate prediction on time scales between a month and a season.

The objective of all models in our work is to predict quantiles in rainfall and temperature by using global circulation models and historical climate records as inputs. The models are evaluated for the 6 regions of New Zealand, namely – the East, North and West of the North and the South Islands.

We present here preliminary results for both standard ML methods and specifically designed deep learning networks. Our findings indicate an upper limit of around 60% accuracy for temperature terciles and 50% for rainfall. The findings and methodology could be applicable to other areas of hydrology.

REDUCING CONTAMINANT LOADS TO THE WAIROA RIVER - MAKING BIG IMPROVEMENTS TO A SMALL WASTEWATER TREATMENT PLANT

Wadworth, G.H.,[1] Chang, R., [1]
[1] Beca

The Wairoa River is the second largest river in the Auckland region, running from the headwaters in the Hunua Ranges, before flowing over the Hunua Falls, towards Clevedon and finally entering the Hauraki Gulf via an estuary at Pouto Point. YMCA Camp Adair is situated in the foothills of the Hunua Ranges, adjacent to the Wairoa River and upstream of the Hunua Falls. The Wairoa River is used recreationally by participants of Camp Adair's community and school programmes and particularly at the popular Hunua Falls.

In order to service the camp facility, YMCA Auckland own and operate an onsite wastewater treatment plant (WWTP) which discharges into the Wairoa River. After exploring alternative discharge options, and since being granted consent to continue to discharge to the river in 2016, the YMCA Auckland have been committed to continually improve the quality of the treated wastewater discharge. Beca has assisted the YMCA Auckland to monitor the WWTP performance and implement process changes, resulting in appreciable reductions to discharge contaminant concentrations. For example, average total nitrogen and nitrate concentrations over peak periods have decreased by approximately 60% since upgrades were commissioned.

This presentation will discuss the wastewater monitoring results from the past 5 years and analysis which has led to the implementation of the process upgrades. The importance of wider river management practices to enhance the quality of the Wairoa River will also be discussed, including reflection on river water quality results from upstream and downstream of the discharge, along with other initiatives Camp Adair are undertaking, including planting riparian margins along the extent of the Camp property.

DEVELOPING ATTRIBUTES FOR SOUTHLAND ESTUARIES

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[2] Land Water People

The National Policy Statement for Freshwater Management (2017) was the catalyst for the objective setting process for Environment Southland. Estuaries have been included as part of freshwater management units (FMUs) within this process. Though the inclusion of estuaries is not explicitly required it has been recognised that they are fundamentally important to achieving catchment management in Southland. Environment Southland has set about developing attributes that could be used to define both narrative and numeric objectives for estuaries, using a similar A to D banding system as required by the NPSFM (2017) national objectives framework for upstream freshwater environments. Such an approach has been considered and discussed in Southland and nationally for several years. It has been echoed most recently in the Parliamentary Commissioner for Environment's recent *Managing our Estuaries* report (August 2020). In the absence of national compulsory attributes defined for estuaries Environment Southland has developed regional attributes and associated threshold tables from the growing local, national and international science literature. Regional attributes have been proposed for Southland which include ecosystem health indicators, but not limited to muddiness, macroalgae (seaweed), chlorophyll and metals (Norton et al. 2019a).

The following will be discussed with regard to Southland estuaries: How were these attributes derived? What makes a good attribute and how do you form bands? What are the problems and challenges with these attributes? What are the implications of some of these metrics to catchment management?

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PERFORMANCE OF WHITEBAIT RESERVES FOR FISHERIES CONSERVATION

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New Zealand's iconic whitebait fishery (mostly Galaxias maculatus, or īnanga) is unique, with numerous complexities for management. As a precautionary conservation measure decades ago, several areas on the West Coast were closed to fishing to prevent overexploitation, although at different hierarchical spatial scales. For example, there have been full closures at the watershed scale (with no fishing downstream) and partial closures at the stream-segment scale (with fishing downstream). We quantified the effects of these different reserve types and evaluated their performance as reproductive reservoirs for fisheries enhancement. We used 10 streams based on known fishing pressure, stream order, catchment size, modelled land use and distance from the coast, latitudinally along the West Coast of the South Island. Data were collected monthly to (1) quantify īnanga population size and structure, (2) estimate īnanga egg production, and (3) characterize fish communities of different reserve types. We found that closed streams had greater abundances, biomasses, and estimated egg production of īnanga despite having a greater proportion of smaller fish compared to partially closed and open streams. Community-level analyses indicated differences in fish assemblages between closure types and suggested that closed streams support higher numbers of native large fish predators than partially closed and open streams. Overall, there were notable reserve effects related to closed streams, but partially closed streams fell short of meeting fisheries enhancement expectations. We conclude that for whitebait reserves to be effective, closure must occur from the mouth of a watershed with no fishing downstream.

ACROSS TAXA DIVERSITY IN AOTEAROA GROUNDWATER: CAN GROUNDWATER DEPEND ECOSYSTEMS WEATHER THE STORM?

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[1] Environmental Science and Research (ESR) Ltd.
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Increasing demand for freshwater and land use intensification has resulted in an increased risk of contamination entering groundwater supplies. The effect of increasing and prolonged contaminant entry into groundwater is having an unknown effect on the groundwater communities present in the aquifer. These communities are the underground food web that protect our drinking water supply by utilising contaminants as energy (carbon) sources. Currently, there is little information available as to the complex processes that take place below ground to remove contaminants. Another risk is that there is no knowledge of the cumulative and chronic effect of contaminant addition into groundwater.

We undertook a study across four regions in Aotearoa (Canterbury, Southland, Nelson, and Hawkes Bay) to identify diversity across taxa (microbial, meiofaunal and macrofaunal). The aquifer type, land use, climatic conditions as well as normal field parameters were noted for each site. Variation in the diversity present was compared with field, climatic, land use and lithology at each site and region. From these comparisons was can begin to predict the resilience of groundwater systems to future changes in land use activities and climate change stress.

Across all regions samples there was a low abundance observed across taxa. Diversity was generally high, but some sites within regions showed a lower diversity (e.g. Figure 1). The same dominant bacterial (over 1%) phyla were seen across the regions and a significant difference in in bacterial phyla was seen in the Southland region. When identifying bacterial genera present, differences across the regions were observed but again only significant in Southland region.

When comparing the microbial diversity observed with field parameters, significant differences were seen when comparing well depth, pH and temperature. Looking into these parameters further, it was observed that the biggest variations seen were related to pH and temperature. This was especially observed in samples taken from Southland, which had the lowest pH and lowest groundwater temperature.

Seasonal variation was observed at sites (Figure 2) which, were sampled on more than one occasion, indicating that multiple samplings may be needed to gain a total picture of the across taxa diversity present in groundwater.

We will present the results of this North and South Island study undertaken as part of the National Science Challenge New Zealand's biological heritage. Once the diversity, across taxa present in groundwater is established, we can begin to predict impacts of changes in land use activities and climate change effects on key taxa present. The impact of land use or climate change stresses can be identified by the changes in taxa present, and the impact these changes will have on groundwater ecosystem services.

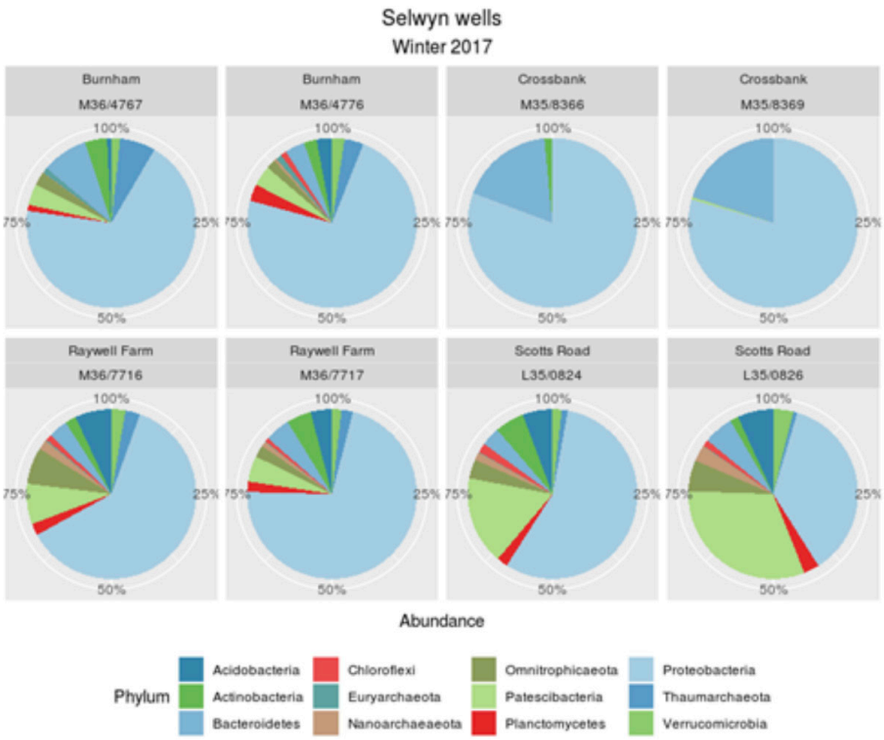


Figure 1: Example of bacterial diversity across wells samples in Selwyn in Winter 2017.

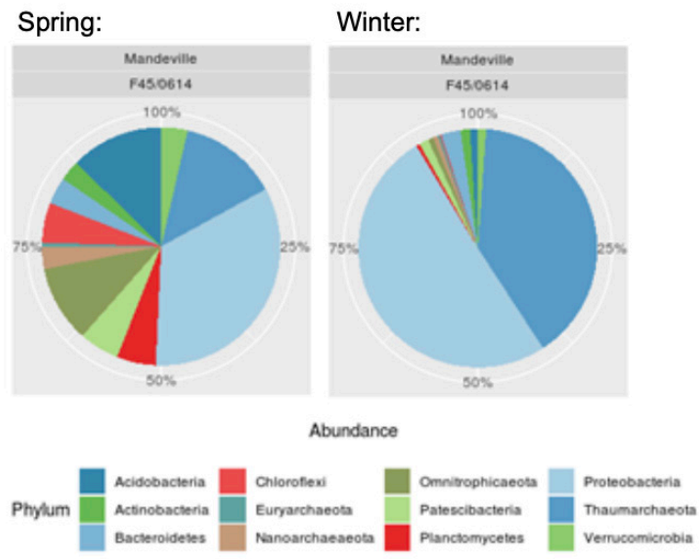


Figure 2: Example of changes in bacteria diversity between seasons.

MONITORING THE FRESHWATER BENEFIT OF MANAGEMENT ACTIONS: IDENTIFICATION OF MONITORING TECHNOLOGIES

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[2] AgResearch
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The recent National Policy Statement for Freshwater Management (NPS-FM, 2020) revolves around the fundamental concept of Te Mana o Te Wai, the fundamental importance of freshwater and the need to sustain itself and its living ecosystems. The NPS-FM requires that the quality of freshwater be maintained, or improved where it is degraded, and introduces additional monitoring and reporting requirements. In this context, land stewards need to be confident that their actions will be effective. Water stewards also need confidence that improvements in the state of our freshwater resource are identified robustly and in a timely manner, and that causal links can be established between management actions and freshwater outcomes.

In partnership with central government, the Our Land and Water (OLW) National Science Challenge (Toitū te Whenua Toiora te Wai) has identified critical knowledge gaps in the design of environmental monitoring capable of verifying the impact of action on the ground as well as the most appropriate technologies for facilitating verification of actions. In response, OLW has instigated three working groups.

Working Group 2: Monitoring Technologies, aims to give those responsible for monitoring freshwater improvement an objective overview of monitoring technologies currently available. Hence, this project builds a comprehensive and searchable inventory of available technologies that can be applied to monitor freshwater quality and quantity attributes. The inventory includes key information such as cost, precision, targeted attribute, resolution, capability required; it is envisaged to be adjustable to incorporate the rapidly advancing sensor technologies and changing user requirements over time.

This presentation will dig more into the project concepts and will report on most recent progress and results. It will also include an interactive online survey to be filled in by the audience.

OVERVIEW OF GROUNDWATER RESEARCH ACTIVITIES IN THE NEW ZEALAND WATER MODEL

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The New Zealand Water Model Project (NZWaM) aims to develop hydrological understanding across the New Zealand landscape with a combination of data on surface water, soil, subsurface (geology), and groundwater. GNS Science is providing subsurface and groundwater information to the NZWaM, with the long-term aim to enable a better coupling of surface water to groundwater.

We present the context and overview of GNS Science research activities to the NZWaM, consisting of:

- Data provision, including updates, of nationwide information on subsurface hydraulic properties, i.e. hydraulic conductivity, porosity, depth to basement;
- Inter-comparison of multiple groundwater recharge data from both NIWA and GNS Science;
- Sharing nationwide and local groundwater flow modules, including inter-comparison with NIWA-derived groundwater conceptualisation, e.g. on dynamic losing and gaining reaches, groundwater-take modules;
- Testing the modelling chain for a combined surface water / groundwater prediction and improved uncertainty estimates.
- Stable isotope and tritium measurements of rainfall and surface water with the aim of inferring young water fraction for the NZWaM;
- Incorporation of groundwater flow information into the HydroDesk interface of NZWaM;
- Data provision compatible with the NZWaM user interface (HydroDesk).

Aiming for a long-term sustainable collaboration between groundwater and research institutes in New Zealand, GNS Science aims to provide, as much as possible, NZWaM groundwater information and models in an open source and open access format.

MOTUEKA / RIWAKA PLAINS GROUNDWATER QUALITY SURVEY 2019

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A groundwater quality synoptic survey in the Motueka / Riwaka Plains was conducted in 2019. The purpose was to identify any health risks to the groundwater users observed during the sampling, describe the current groundwater quality status in the Motueka / Riwaka Plains and discuss any changes from previous groundwater quality synoptic surveys.

184 bores and 10 river and spring sites across the Motueka / Riwaka Plains were sampled during October and November 2019. In addition, Tasman District Council monitors various groundwater sites as part of the state of the environment monitoring programme. Council also participates in national surveys conducted by the Institute of Environmental Science Research (ESR) in selected bores across the region. Data relevant to the Motueka / Riwaka Plains was incorporated.

Chemically, groundwater in the Motueka / Riwaka Plains is of good quality. The majority of the parameters tested for in 2019 was well below the Drinking Water Standards for New Zealand 2005 (Revised 2018) (DWSNZ) for both the health significant and aesthetic factors. Comparisons with previous synoptic surveys confirmed that the groundwater quality has remained consistently of good quality, with no significant changes throughout the years. River water, which is the main source of recharge for the Motueka / Riwaka Plains aquifer is also of good quality.

All pesticides residues detected by ESR in 2018 were well below the maximum acceptable values in the DWSNZ. Two bores in the Motueka / Riwaka Plains had detections of emerging organic contaminants (EOC) from the 2018 ESR survey which are being followed up on accordingly. None of the selected bores in the Tasman region had glyphosate detected.

Due to its unconfined nature, the aquifer underlying the Motueka / Riwaka Plains does not meet the DWSNZ definition for secure groundwater. The survey did identify various risks to the security of the unconfined aquifer which could have negative consequences to public health. These include inappropriate sitting of bores, boreheads not sealed and the storage of chemicals in close vicinity to the bores. In most instances these were not intentional but more of a lack of knowledge. The presence of UV disinfection units in some places acknowledges the potential contamination risk to the groundwater.

AQUIFERWATCH 2.0: OPERATIONAL PREDICTION OF GROUNDWATER LEVELS FOR THE WAIRAU AQUIFER USING RAINFALL-RUNOFF AND EIGENMODELS

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The operational AQUIFERWATCH tool was set up previously to predict groundwater heads in the unconfined Wairau Aquifer during flow recession times (Wöhling & Burbery, 2020). The tool uses eigenmodels to provide an early warning for the Marlborough District Council (MDC) when critical groundwater levels are likely to be reached in wells that are used for operational management of the Wairau Plain groundwater resources. This has become increasingly relevant as these critical levels have been approached more frequently during the past summers when the natural recession of groundwater storage is exacerbated by groundwater abstraction to satisfy the irrigation water demand of the Plain's viticulture.

AQUIFERWATCH requires as input (amongst other data) daily forecasts of Wairau River flows because the river is the major recharge source for the aquifer (Wöhling et al. 2018). The river flow forecasts are provided (with uncertainty) by a master recession curve derived from historic flow data. In this work, the tool is extended by a rainfall-runoff model which provides the river flow forecasts instead. The main advantage of this extension is that groundwater level forecasts with AQUIFERWATCH can be made for all time periods, not only recession times. This allows for a more broad evaluation of scenarios and the implementation of rainfall forecasts. A prototype of the extended tool is presented and corresponding results demonstrated and evaluated for historic data (hindcasting). The performance of the prototype tool is promising in predicting groundwater levels beyond recession times. But the analysis also points at bottle-necks and uncertainty in the model chain. In particular, the performance of AQUIFERWATCH could be potentially improved if groundwater recharge is not treated as a function of river flow alone. For that purpose, a deeper understanding of the recharge mechanisms in braided rivers is needed, which is currently investigated by a corresponding MBIE program.

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DEVELOPING STRATEGIC PATHWAYS – FISH PASSAGE

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Many organisations develop a vision, a purpose and overarching goals that guide their work. These are often called 'strategies', reaching out 30-50 years from now and are aspirational top line outcome statements. But how do you connect that vision and strategy to your current workplan? How do you develop a line of sight between long-term goals and the here-and-now?

At Te Papa Atawhai we have trialed a process to develop this 'missing thing in the middle', the connection between vision and workplan, and called it our Strategic Pathway. The pathway identifies a specific problem, analyses the situation (e.g. who, where, why etc.), articulates a long-term goal (taken from the vision), assesses why this has not already been achieved (e.g. what are the blockages to progress), identifies who has the power to make the change and, based on all of this intelligence, makes choices on what the most effective course of action would be to achieve change given strengths/weaknesses and resources of our organisation.

We chose Fish Passage as the topic to trial the process, a national issue in freshwater ecosystem health that has been identified as a critical issue to solve as part of our biodiversity crisis.

We will showcase the process, the learnings and the human and contextual challenges we tackled. The key message we will present is a practical guide to connect your vision to your work on the ground, communicating a clear line of sight for your staff to get excited about.

AN R SHINY WEB APP TO EXPLORE MONITORING DATA AND MODEL PREDICTIONS RELATED TO STREAM AND ESTUARY EUTROPHICATION IN A CATCHMENT

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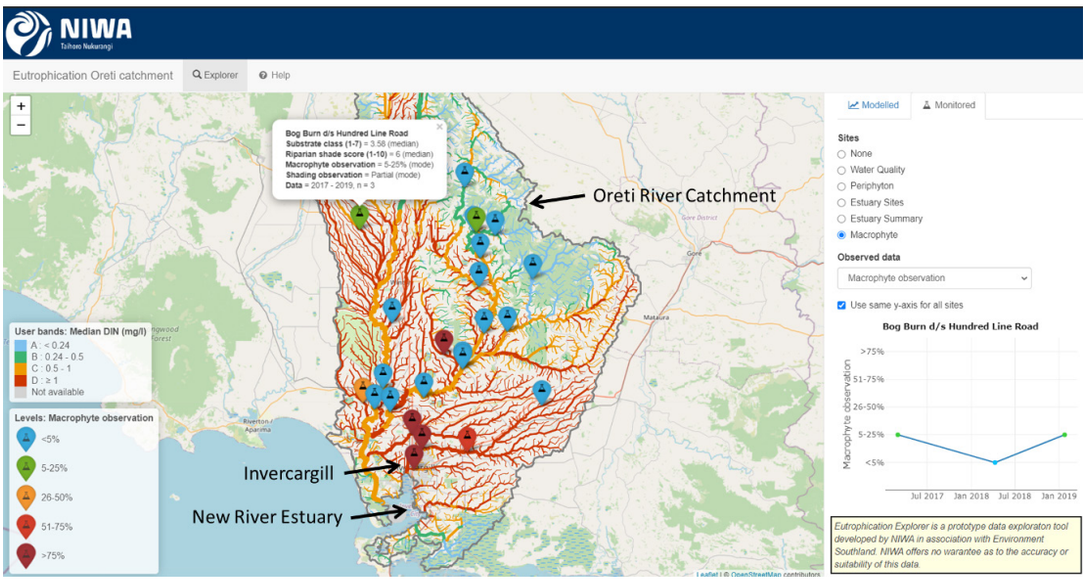


Figure 1. Screenshot of the NIWA Eutrophication Explorer app, showing bands of predicted median concentration of dissolved inorganic nitrogen (DIN) (coloured lines) and most commonly observed levels of macrophyte abundance (coloured markers) at Environment Southland monitoring sites.

Introduction

The "Eutrophication Explorer" is a map-based web tool that allows exploration of data sets and model predictions related to stream and estuary eutrophication in a catchment. The tool is being developed by NIWA and Environment Southland based on model predictions and data from the Oreti River catchment and the New River Estuary near Invercargill (Figure 1).

Concerns about the state of New Zealand's freshwater has motivated a wide range of data collection and spatial predictive modelling by organisations such as Regional Councils and Crown Research Institutes. Monitoring data is typically collected at a small number of sites, repeatedly over time (e.g., Moreau and Hodson, 2015), whereas model predictions often have greater spatial coverage but may only represent median annual values (e.g., Whitehead et al., 2018). The different spatial locations, timing, methodology and purpose of these data sets make it challenging to combine them to obtain an integrated understanding of environmental conditions at specific sites or across a catchment. This motivated the development of an easy-to-use tool for visualising and exploring catchment these data sets.

The prototype tool can be accessed at https://shinylabs.niwa.co.nz/explorer/.

Underlying Data

The catchment data required for the app includes:

- geographic information system (GIS) shape files describing the stream and estuary network,
- spatial predictions of median water quality, periphyton variables (e.g., Chlorophyll-a), and stream physical characteristics (e.g., Whitehead et al., 2018; Kilroy et al., 2019; Morel et al., 2019), and
- routine observations of water quality, and periphyton and macrophyte abundance time series (e.g., Larned et al., 2018).

In addition to these, derived model predictions can be included, such as predictions of macrophyte and periphyton habitat suitability bands based on the framework of Matheson et al. (2012).

App Development

The app was built with the R-language-based "shiny" web application framework, particularly the JavaScript-based "leaflet" interactive mapping library (R Core Team, 2014; Cheng et al., 2019; Chang et al., 2020). Spatial predictions and monitoring observations were collected from various sources into two data tables which were uploaded with the app. A graphical user interface was designed to allow users to independently select a spatial prediction and a monitoring observation to display simultaneously, with various display options including raw values, fixed bands (i.e., ranges labelled as A, B, C, or D), ratios and spatially-varying bands.

Data values related to specific stream reaches or monitoring sites can be viewed by clicking on the map, and are displayed in a pop-up table and/or a time series chart showing the raw data (Figure 1). Nutrient bands and ratios can also be tracked upstream to identify possible source areas contributing to sensitive downstream locations.

Future Plans

Current development of the app is aimed at allowing multiple variables to be combined and traced spatially upstream or downstream, and allowing hypothetical management scenarios to be applied in order to achieve desired environmental limits. Feedback on the prototype app is welcomed.

Acknowledgement

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INVESTIGATING RHIZOSPHERE OXYGEN DYNAMICS AND PHOSPHORUS FRACTIONATION UNDER A SUBMERGED MACROPHYTE, ISOETES KIRKII.

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The quillworts (Genus, Isoëtes) are a genera of submerged macrophyte known for their gas permeable roots uptake of CO2 and oxygen release into the sediment, potentially altering sediment biogeochemistry. Here we report on the use of PreSens optical oxygen planar spots to measure rhizosphere oxygen dynamics and impact of released oxygen on sediment phosphorus fractionation. Previous measures of root oxygen release in submerged and emergent macrophytes have been undertaken by submersing macrophyte roots in de-oxygenated water or a reducing medium. We measured rhizosphere oxygen dynamics in nine locations, in a garden soil and sediments from a degraded lake with and without *Isoetes kirkii*. The incubations were carried out under a reduced but natural light climate and were concluded by measuring root and shoot weights, lengths, and collecting sediment samples for phosphorus fractionation extractions. The overnight rate of change in oxygen concentration was regressed against the deficit to oxygen saturation (the night-time regression method - used to estimate rates of stream metabolism) to partition photosynthetically fueled oxygen release, overnight oxygen release and sediment oxygen demand. For the available light, Isoetes in the degraded lake sediment were close to being unable to oxygenate the lake sediment. The released oxygen in both sediment types increased the amount of non-mobile phosphorus, reducing the risk of release to the overlying water column. This study has demonstrated a new approach to assessing the ability of Isoetes to aerate sediments, that could be used to assess additional macrophyte species, providing fundamental information to guide the selection of macrophyte species for waterbody restoration.

NEW DIRECTION IN FRESHWATER POLICY: WHAT HAPPENS NEXT?

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New rules to protect and restore New Zealand's freshwater passed into law this year. These include the new National Policy Statement on Freshwater Management (NPS-FM), National Environmental Standards for Freshwater (NES-FW), stock exclusion regulations, and regulations on the measurement and reporting of water takes. The new NES will require rapid action to limit some high-risk farming practices, and new regulations will require farmers to exclude stock from waterways. The new NES also includes immediate measures to prevent further loss of natural wetlands and streams and preserve connectivity of fish habitat. The new NPS-FM sets out requirements for regional councils for managing freshwater and requires everyone to plan now for changes across the next 30 years and beyond. The fundamental concept of the NPS-FM is Te Mana o te Wai, a concept and framework which is derived out of Te Ao Māori and reflects the recognition of freshwater as a natural resource whose health is integral to the social, cultural, economic and environmental wellbeing of communities. This presentation will include an overview of the new policies as well as answering the question: so what happens with these policies next?

THE IMPACT OF CLIMATE CHANGE ON GROUNDWATER SYSTEMS: A CASE STUDY IN EDENDALE, SOUTHLAND

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[2] Environment Southland

Climate and its variability have a considerable impact on seasonal water resources availability. Little is known on how groundwater systems (and associated groundwater fluxes and characteristics) react to climate change. Understanding the impact of climate change and the time lagged response in areas where groundwater is the main water resource supporting human activity (water supply, agriculture and industry), is necessary to manage potentially damaging consequences for hydrologically-driven ecological functions, ecosystem services, economic response and adaptation, cultural values and recreation. Such reasonably foreseeable effects of climate change require an approach to address future planning on sustainable groundwater resources.

We present a case study in Edendale in Southland, New Zealand. A terrace aquifer recharged through land surface process, the study area has an increasing trend in abstractive demand paired with a long-term declining trend in groundwater level. We aim to develop better understanding of potential changes in the timing and scale of the hydrological response to change in land surface recharge, groundwater discharge to stream and reliability of supply and the necessary adaptation of water users of the Edendale aquifer.

Our approach to assess the impact of future climate change on groundwater resources will use downscaled CMIP5 IPCC climate predictions (Ministry for the environment, 2018) to drive simulations of the change in land surface recharge (LSR). Then, the Environment Southland's Edendale groundwater model (MODFLOW) will be coupled with an ensemble of LSR, which will enable analysis of the potential changes in groundwater table and discharge to the streams and its implications for water resource management in the groundwater dominated area.

WHAT'S BEING DONE? RECORDING LAND MANAGEMENT ACTIONS TO IMPROVE RIVER HEALTH

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[1] Cawthron Institute
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[3] University of Otago
[4] Scion
[5] Effect

The health of New Zealand's aquatic ecosystems is under pressure, but many farmers, community groups, iwi, forest managers and others are doing things to improve the situation. Unfortunately, it is unclear what is being done, where it's being done or how much is being done because little of this information is being recorded. The small amount of information that is recorded is held by specific sectors or hidden in farm environment plans. Therefore, we are missing the opportunity to learn what actions are most effective at improving outcomes at a catchment scale or to determine the scale of the task still ahead. Similarly, the efforts that people have made are not visible and therefore not acknowledged by the wider community.

A 3-year project funded by the Our Land & Water National Science Challenge is aiming to build and populate a register of information on land management actions. Our initial focus has been on understanding the range of purposes that people may want from the register so it can be designed to meet their needs. We are working with a range of stakeholders at a national level and also diving deeper into data availability and needs at four focus areas, including two Māori-led pilot catchments where we are working with both Māori entities and iwi/hapū/whānau. We are investigating the range of indicators that can be used to measure actions, along with the challenges of protecting confidential information, addressing issues associated with collating data collected at different scales in different ways, and ensuring that the register will have a life beyond the term of this project. We anticipate that information from the register will be reported via a new module in LAWA (Land, Air, Water Aotearoa; www.lawa.org.nz).

DELINEATING GROUNDWATER CONTRIBUTING AREAS TO SURFACE WATER CATCHMENTS

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Aims

New Zealand rivers are influenced by groundwater in many parts of the country. The complex interactions are dependent on local geology and connectivity between rivers and groundwater sources. When model simulations of streamflow are made these groundwater influences must be taken into account to achieve the correct water balance and a more realistic estimation of streamflow. Current surface water models either have simple groundwater processes representation or introduce groundwater fluxes through transfer functions based on parameterisation of regional groundwater flow patterns at surface water boundaries. An alternative, and possibly complementary, approach to the estimation of groundwater flux at surface water boundaries is defining the spatial extent and direction of groundwater flow contributing to a particular surface water catchment. This will enable the hydrological simulations over a unified domain encompassing all source of flow generation mechanism.

This paper describes a novel method to define a-priori the extent of groundwater contribution by using a similar approach to surface water catchment delineation (Maidment, 2002), using topographical digital elevation models (DEM). Here, the surface DEM is replaced by a "groundwater DEM" (gw-DEM) , comprised of a national hydraulic head raster coverage provided by the 'Equilibrium Water Table' (EWT, Westerhoff et.al., 2018) model that calculates the long-term average of the global scale water table surface.

Method

Using ESRI's ArcGis 10.6 and ArcHydro (Maidment, 2002), we initially pit filled the gw-DEM to remove sinks, and then computed flow direction and flow accumulation rasters. The resulting connected networks allow tracing, hence upstream contributions of "groundwater catchments" and "groundwater flow lines" can be quickly determined anywhere in a river catchment

Results

An initial investigation for the Mataura catchment in Southland was carried out using this methodology. The results of "groundwater catchment" delineation is shown in Figure 1 below. The "groundwater network" is displayed in red and the upstream traced contribution at the Mataura outlet is shown in cyan. The outer boundary of the surface water catchment is shown as a purple line, and the groundwater contributing catchment area as dotted lines. From the map it appears that there is contribution to the flow in mid-Mataura from parts of the Oreti catchment in the north west, near the Eyre Mountains, and extending through the fluvial deposits of the Waimea Plains. The underlying geology of gravel and sand gives rise to a higher hydraulic conductivity than the surrounds, as seen in Figure 1, almost creating a swath (shaded yellow) facilitating the flow of groundwater. In future work we will investigate the classification and use of hydraulic conductivity to "weight" groundwater flow contributions, when modelling water balance.

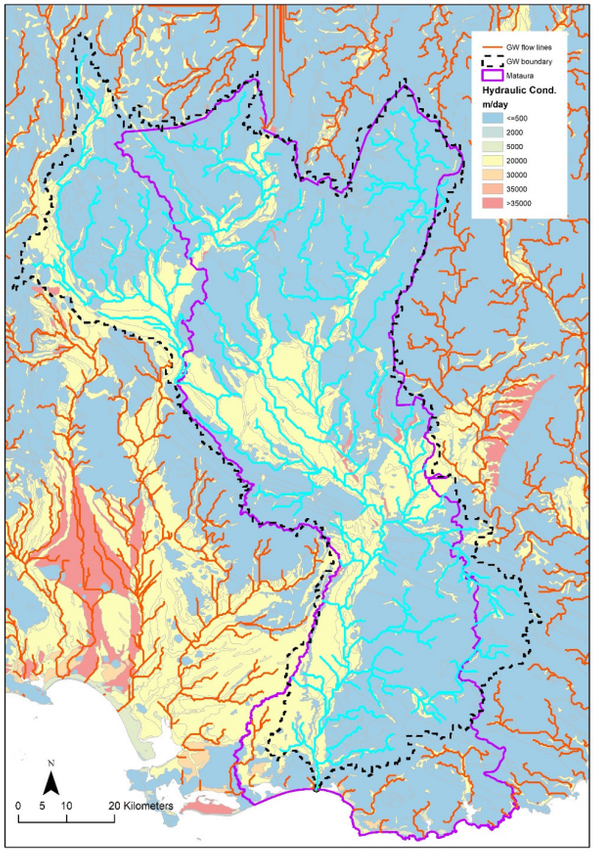


Figure 1. Map of the Mataura catchment showing potential groundwater contributing areas overlaid on a surfaceshowing hydraulic conductivity.

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UPDATE ON THE NEW ZEALAND WATER MODEL-HYDROLOGY PROJECT

Zammit, C.,[1] Westerhoff [2], R., Lilburne L3, Griffiths, J., [1]
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[2] GNS Science
[3] Manaaki Whenua Landcare Research

Aims

Over-allocation of water and water quality degradation are key issues in New Zealand. To address these issues, the National Policy Statement for Freshwater Management requires Regional Councils, in collaboration with iwi and communities, to set limits on water use and water quality, and establish allocations to stay within these limits.

Effective and efficient limit-setting and allocation require tools that can accurately predict the transport of water and contaminants, such as nutrients or sediment, from their source areas to the receiving water bodies where their effects occur. The scarcity of direct measurements of surface and groundwater flows and contaminant concentrations at spatial and temporal scales suitable for limit setting, means simulation models are urgently needed. These models are used to make predictions and develop scenarios of the future by combining scarce measurement data, information about processes like runoff and nutrient leaching, and detailed maps of streams, aquifers, soils and other catchment properties.

One of the challenges for modelling flows and contaminants is the complex arrangement of land and receiving waters in NZ catchments. Another challenge is posed by the time and effort needed to build models for the many places that require limit setting. The New Zealand Water Model – Hydrology (NZWaM-Hydrology) was set up by NIWA in December 2016 to answer those challenges and needs, through the development of a single, highly adaptable system focused on determining the key environmental controls of water movement across the landscape at relevant scales. Another objective is to develop a model that is transferable, scalable and can be simplified based on data availability. The NZWaM-Hydrology will provide essential information for the implementation of the NPS-FM, as well as key knowledge for the success of the National Science Challenge programmes that aim to relate pressure on New Zealand eco-systems to ecosystem responses (e.g. Our Land and Water Challenge and Deep South Challenge).

The aim of this paper is to report the progress made during the third year of the project and future developments of this project.

Method

The NZWaM-Hydrology aims to develop a catchment-scale combined surface water and groundwater model coupled to a model of age of surface water and groundwater, that can be applied and parametrized at the national scale. It primarily focusses on water quantity, extending existing models, as well as providing a framework to ingest new model developments and conceptualisations. These goals will be accomplished through

- Development of a "living" geospatial database targeting catchment scale hydrological processes, linking geospatial data layers to their hydrological interpretation through key mechanistic and empirical relationships and parameters;
- Development of a national scale surface water-groundwater model, coupling existing national scale surface water and groundwater models through an integrated modelling framework;
- Development of a water age model, i.e., a conceptualisation of water age in the surface water and groundwater models. The water age model will be based on a national scale understanding of hydro-geochemistry as well as observed young and old water isotope signatures;
- On-going co-development and implementation with key regional council partners and iwi. Programme interactions with these various partners will allow exploration of the effects on model outputs of different levels of 'data availability' to drive such a model. This will result in a better understanding of the potential uses and limitations associated with model simulations and prediction.

The NZWaM-Hydrology structure is presented in the diagram below (Figure 1).

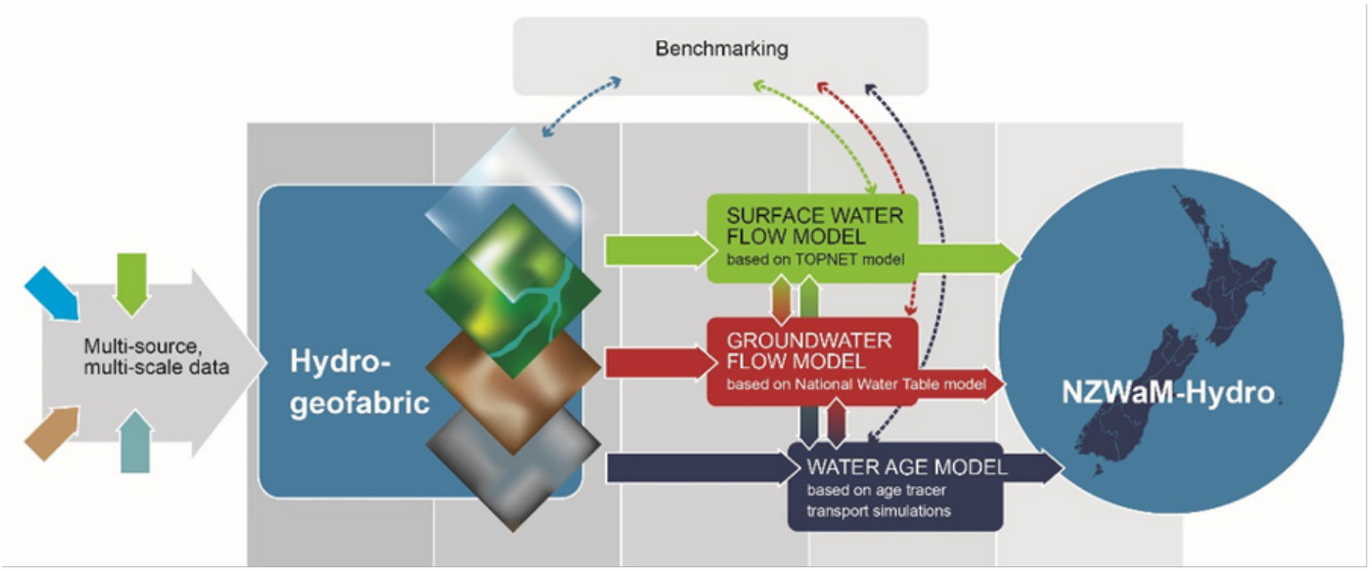


Figure 1: Conceptual organisation of the NZWaM-Hydrology project.

Results

A large component of the NZWaM-Hydrology work over the period 2017-2020 focused on developing the basic components of the model. As a result, the development of the geospatial framework includes the following components:

- Geospatial database (Hydro-Geofabric) containing up-to-date and harmonised datasets relevant to parameterise the national hydrological model for different applications and scales (e.g., rainfall, soil, topography, geology).
- New Digital River Network combining advances in national scale DEM and availability of Lidar information.
- National scale soil characterisation combining Fundamental Soil Layer information with advances in soil mapping (S-map and S-map Next Gen MBIE contestable program) in collaboration with Manaaki Whenua Landcare Research.
- National-scale groundwater related information based on aquifer characteristics in collaboration with GNS Science (effective porosity, depth to groundwater basement, subsurface hydraulic conductivity).
- Documentation and guidance manual for end user of Hydro-Geofabric.

Additional work was carried out across other objectives on:

- Development of a benchmarking procedure to test model development, conceptualisation and parametrisation across New Zealand;
- Incorporation of a National Water Table model, based on the Equilibrium Water Table concepts, into the national hydrological model;
- Collection of surface water and groundwater isotope information to inform the development, conceptualisation and assessment of the water age module across the regions of three partners (Environment Southland, Gisborne District Council and Horizons Regional Council);
- Implementation of surface water and groundwater take modules with their respective hydrological models;
- National parameterisation of TopNet-GW as one of groundwater model available;
- Provision of information generated by the program to end users through HydroDeskNZ,
- Co-development with regional council partners of test case application of NZWaM to support science investigation lead by Regional Councils.

CONCENTRATION AND CATEGORISATION OF MICROPLASTICS FROM INNER-CITY WATERWAYS IN INVERCARGILL

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Microplastics are smaller than 5 mm and occur in a variety of shapes and colours. Primary microplastics are purposefully manufactured to be plastic pieces, whereas secondary microplastics are fragments resulting from the breakdown of larger plastic debris. Microplastics have two main impacts on the environment: 1. microplastics can accumulate in the food chain; and 2. microplastics can absorb contaminants and toxic substances on their surfaces, polluting the natural ecosystem. The aim of this research is to investigate whether microplastics are present in the Waihopai River and the Otepuni River in Invercargill, and to analyse the most common shapes and colours of microplastics, in order to provide clues to possible pollution sources. A 234 µm plankton net was used to collect water samples at each site, followed by a stacked arrangement of 0.3 mm and 5 mm sieves to filter the materials in the water samples by size. Organic matter was separated from the microplastics using the Wet Peroxide Oxidation method, and the Density Separation method was used to separate out the microplastics from the samples (Masura et al., 2015). Once isolated, the microplastics were identified, counted, and categorized using a digital microscope. After two months of sampling (n = 16), results showed that the two rivers were polluted by microplastics in varying degrees (0 to 3.87 particles per m3). These microplastics were categorised into four main shapes: foam, film, fibre, and fragment, and into seven different colours. The most common shape by far was hard plastic fragments (up to 219 pieces per sample) and the prevailing colours were white and transparent pieces. It is very important to strengthen the monitoring of microplastics in Invercargill, and other cities in New Zealand. Ongoing monitoring would allow researchers to see whether there is an increase of microplastics in the ecosystem over time and the categorization could help to inform targeted measures to reduce the flow of microplastics into the natural environment.

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