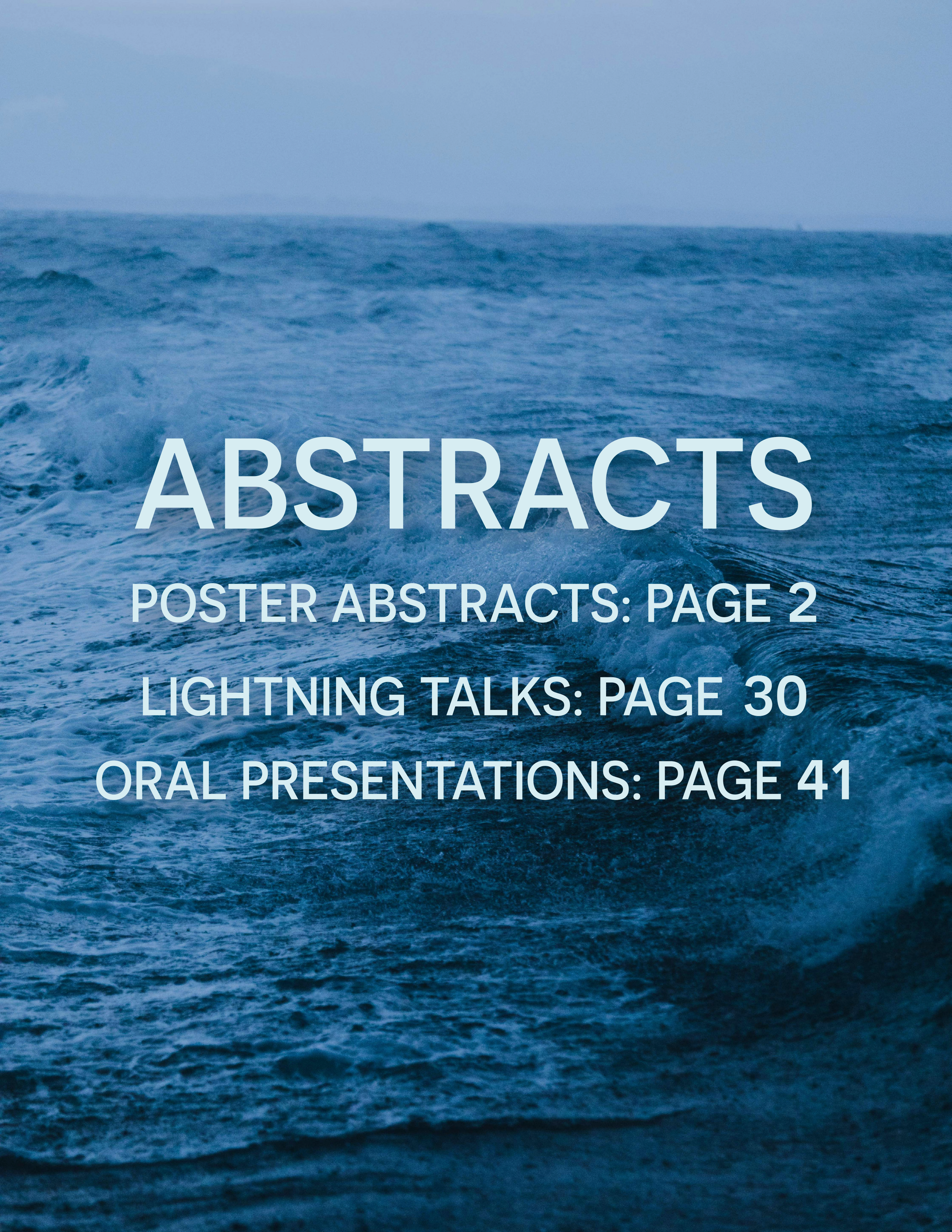


ABSTRACTS

POSTER ABSTRACTS: PAGE 2
LIGHTNING TALKS: PAGE 30
ORAL PRESENTATIONS: PAGE 41

POSTER ABSTRACTS

THE INFLUENCE OF TROPICAL-POLAR TELECONNECTIONS ON ATMOSPHERIC RIVER MOISTURE DELIVERY TO ANTARCTICA

Baldwin, J. C. and Kingston, D. G.
School of Geography, University of Otago, PO Box 56, Dunedin, New Zealand

Precipitation over Antarctica in the form of snow promotes ice sheet growth, most of which occurs during short-lived extreme events. These events are driven by amplification of hemispheric planetary waves that force moisture-bearing extratropical cyclones up and over the steep coastline. These cyclones are often associated with atmospheric rivers (ARs) which, despite occurring 1% of the time at any location, can deposit 40-60% of the annual precipitation budget. Tropical convection anomalies allow for AR development as well as Rossby wave initiation – the origin point of the latter steering ARs into different regions of Antarctica. Recent studies have found that the Madden-Julian Oscillation influences both maximum moistu e flux and event f equency by promoting weather regimes that direct ARs to landfall in Aotearoa; the contiguous nature of the AR condition means this influence is likely to be carried further south. Other la ge-scale climate variability modes in the Southern Hemisphere can enhance the coherency of Rossby waves that enable AR landfall over the Antarctic Plateau. This study builds on previous discrete studies to form a detailed and spatially comprehensive analysis that improves our understanding of how large-scale moisture transport dynamics across the Southern Hemisphere result in precipitation delivery to Antarctica.

RECENT USES AND FUTURE DEVELOPMENTS OF CSET (CONVECTIVE SCALE EVALUATION TOOLKIT)

Jorge Bornemann (1), Sylvia I Bohnenstengel (2), James Frost (2), James Warner(2), David Flack(2), John Edwards(2), Stuart Moore (1)
1. ESNZ, 2. Met Office (UK

The UK Met Office and Earth Sciences New Zealand have developed over the past two years CSE , a toolkit for evaluation of convective and turbulence scale models. Incorporating requirements from a wide range of users, CSET is built on modern software development techniques with useability, flexibility and portability as guiding principles, and focuses on helping understand physical processes. It is modularly designed around the concept of 'operators', individual transformations that are chained together following a 'recipe' to produce a diagnostic, so the user only requires a basic knowledge of computing techniques to create complex and powerful diagnostics.
After the first elease for operations in March 2025, CSET has been used extensively in the process-based evaluation of the new RAL3-LFRic, the regional configuration of the next generation LFric atmospheric NWP model that will replace the Unified Model; it has also been tested in di ferent scenarios, like climate simulations and kilometre-scale global data, probing scalability to long time-series, high spatial resolution and large number of experiments.
This presentation describes the CSET toolkit, reviews its usage and performance since its release, and outlines the future developments

LAND USE CHANGE IN AND AROUND AOTEAROA NEW ZEALAND'S BRAIDED RIVERS

Aimee Calkin1
1 Aqualinc Research Ltd, University of Canterbury, and Te Punaha Matatini

Aims
This research explores land use change around Aotearoa's baided rivers at a national scale and develops and tests a method to for tracking these changes over time. It addresses three questions:
1. Has land use changed in and around braided rivers?
2. Are there geographic patterns in this change?
3. Is the method developed effective for measuring change?
The study contributes to the broader challenge of making room for rivers, aiming to bridge the gap between environmental science and policy.

Method
Using QGIS and Google Earth Engine, the study applied multi-criteria analysis combining trained classification and NDVI th eshold methods to detect land use change across 163 braided rivers between 1990 and 2020.

A shapefile of the river cent elines was created, and subsequently a buffer around the rivers. Satellite imagery was analysed to detect NDVI changes indicating intensification. Results we e processed in QGIS and Excel.

A programme of work was developed to support legislative change aimed at creating the room that rivers need to move. This was develivered in the form of a parliamentry submission.

Results
The study found land use intensification dec eased in the North Island but increased in the South Island. Gravel and water coverage also shifted with an increase in the North Island and a decrease in the South Island. Canterbury showed the most significant changes

The research informed a change in the legal definition of a riverbed, highlighting implications for braided river management and making room for rivers.

MULTI GRIDDED DATA: ZARR CONVERSION AND CLOUD ACCESSIBILITY

Bryce Chen,[1] Ruotong Wang,[1] Jochen Schmidt,[1] Chen Wang[1]
[1] New Zealand Institute for Earth Science

We present the development process of converting multi-gridded datasets to Zarr stores using AWS cloud technologies, as part of our 'Data Platform' project for company-wide digital transformation. Zarr is a format for storing and accessing multi-dimensional array data, in a compressed and chunked manner. It is also a cloud native storage format, designed for scalable and efficient data storage in the cloud environment, enabled fast and convenient data access for scientific computing and data analysis. We also present Coiled, the lightweight cloud compatible computing platform, designed to scale the workloads without docker or Kubernetes for python-based data engineers and scientists. We use Coiled, together with Zarr, to realize high-speed access and analytics for our multi gridded data. Furthermore, we present the cloud infrastructure for the Zarr store update as well as the data versioning strategy. Lastly, we present the authentication system and AWS sandbox environment for the universal data access across the organization.

RIVER FLOW MODELLING BY MACHINE LEARNING: TOWARDS WATER RESOURCE AND RISK MANAGEMENT APPLICATIONS

Collins, D.B.G.
Pūtahi Research

Aims

There is a perennial need to simulate river flo , whether to better characterise flow statistics and risks, or to project flows under changing climatic conditions. While physically based catchment models have been the norm for such hydrological modelling for decades, advancements in machine learning are improving the capacity to model hydrological patterns with far fewer data and computational requirements. Moreover, for low flow statistics in particula , data-driven approaches have proven better than physically based modelling in New Zealand. With the goal of supporting water resource management, particularly under climate change, this research explores the potential for machine learning to provide useful river flow simulations

Methods

As an initial case study, machine learning methods are applied to river and weather data for a single catchment in Canterbury: the Rakahuri/Ashley River. The river has two flow ecords of usable length and several climate stations, while being less complex hydrologically than other, larger river systems. It is also used for irrigation. As consent conditions for water abstraction are based on previous days' average flows, the objective he e is to simulate average daily flow using weather (or climate change projection) data as the drivers.

Results

Preliminary findings suggest a machine lea ning approach to modelling daily flows in the Rakahuri is promising, with the potential to consider water supply and drought statistics, as well as the effects of climate change using downscaled climate projection data. However, several important factors must be addressed for the model to be useful and to be used. While physically based models have the benefit of underlying physical laws to constrain behaviou , data-driven models are much more constrained by the training data. This means the selection of data used for training and calibration has a larger influence on the model s potential applications. Moreover, because machine learning models are opaque and lack intuitive processes, additional effort must be devoted to demonstrating their utility to end-users. On the other hand, river flow modelling based on machine lea ning can offer a more accessible means of generating flow and water use p obabilities or projections when robustness and resilience are of concern.

DROUGHT PROPAGATION IN THE LINDIS RIVER CATCHMENT

Nick Harrison & Daniel Kingston
School of Geography, University of Otago, PO Box 56, Dunedin, New Zealand

Drought propagation refers to the movement of water deficits f om one part of the hydrological cycle to another. Here, the focus is on the propagation of meteorological (i.e. precipitation) water deficits into hyd ological (i.e. streamflow) d ought in the Lindis catchment, Central Otago. Using thresholds based on percentiles of daily precipitation and streamflo , the coincidence of meteorological and hydrological drought events is analyzed according to their timing, magnitude, duration, and deficit volume, and how these may be modified under climate change scenarios The HBV-Light rainfall runoff model is employed to simulate the Lindis catchment for this purpose. The model is calibrated using observed streamflow and climate data f om 2006–2024. The model is subsequently run using downscaled data for the SSP 2-45 and 3-70 scenarios from a series of GCMs for 2080-2099. The study highlights the complex ways in which precipitation deficits of different characteristics can combine to influence st eamflow under both p esent and future climates – findings that have important implications for managing water allocation, ecological health, and possible climate change adaptation options.

EVALUATING THE PERFORMANCE OF ERA5 IN CAPTURING NEW ZEALAND'S EXTREME SUMMER TEMPERATURES

Sayed Waseem Iqbal,1 Luke J. Harrington,1
1 Te Aka Mātuatua School of Science, University of Waikato, Hamilton, New Zealand

The accuracy of reanalysis datasets in representing local extreme heat remains uncertain in complex mid-latitude climates. This study assesses ERA5's ability to capture the frequency, magnitude, and spatial pattern of extreme summertime (December–February) 2-meter temperatures in New Zealand, using in-situ observations as reference. Daily biases were evaluated for all days and for observed-percentile extremes, and 10-year running hot-day counts were computed from monthly 90th-percentile thresholds defined separately for each dataset. ERA5 showed a systematic cool bias that intensified with higher observed temperatu es, warm-tail days (>95th percentile) typically 2–4 °C more biased than the all-day mean, with absolute warm-tail errors exceeding 6–10 °C at some inland, eastern, and sheltered coastal sites. Cold-tail (<5th percentile) biases were smaller. Biases were generally smallest in northern and western-lowlands, and largest in inland valleys, eastern-plains, and elevated basins. Wellington stood out as a North Island coastal site with a large warm-tail bias, also seen at some South Island coastal stations. Hot-day frequency trends were broadly reproduced, but ERA5 underestimated counts, especially in February at high-bias stations. The hottest-day analysis revealed ERA5 consistently underestimates annual-summer-maxima, with larger gaps in high-bias regions. Patterns reflect un esolved-microclimates, complex topography, and ERA5 gird-cell proximity to water body.

SPATIO-TEMPORAL VARIABILITY IN INFLOW AND INFILTRATION INTO SEWER NETWORKS UNDER DIFFERENT SOILS

KC, Birendra,*[1] Benadie, A.,[1] and Thompson, N. [2], Schultz, B.,[3] and Prasad, K.,[4]
[1] Rangitikei District Council, Marton, New Zealand
[2] Asset Monitoring Limited, Bay of Plenty, New Zealand
[3] Land and Water Development IHE Delft, the Netherlands
[4] Irrigation and Water Resources Management Consultant, Janakpur, Nepal
* Corresponding author: birendra.kc@rangitikei.govt.nz

Aims
The additional waterflo , due to groundwater and/or rainwater inflow and infiltration (I&I), into wastewater treatment plant (WWTP), is a growing concern, as the I&I can contribute a significant proportion of the total flow (sanitary flow plus I&I) entering WW , while in general only the sanitary flow is monito ed. The I&I is an unavoidable problem and is associated with soil types. The two objectives of this paper were: i) to investigate the impact of soils on I&I under wet weather and dry weather conditions; ii) to estimate the proportion of I&I in total wastewater.

Method
To cover different soils, wastewater flow and rainfall we e monitored at the entrance of five WWTPs selected from five towns of Rangitikei District Council: Bulls, Marton, Hunterville, Mangaweka and Taihape (Figure 1a). Soil information was collected from S-map which is a digital soil map for New Zealand. Asset Monitoring Ltd, Waihi Beach, New Zealand was engaged to monitor wastewater flow and rainfall for each flow monitoring location. astewater flow was monito ed by installing "in-pipe" flow meters in the incoming mains (inlet into a manhole) and ecording the effluent flows every fi minutes (Figure 1b). Rainfall was monitored by installing a tipping bucket rain gauge in each town and recording rainfall every two minutes (Figure 1c). Height/Velocity/Quantity (HQV) methodology was adopted as being the best solution for estimating wastewater depth, velocity and quantity for all flow monitoring locations. Manual depth and velocity calibrations was conducted during the monitoring period for different flow egimes for data accuracy.

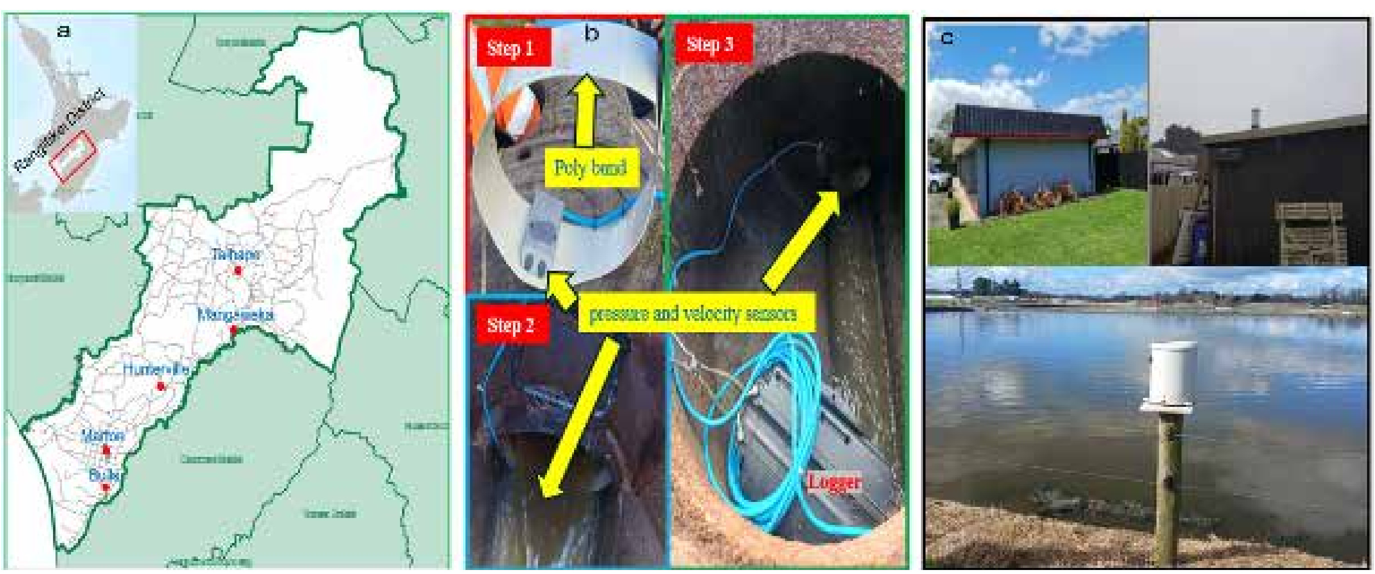


Figure 1. First figu e: Study area (Rangitikei District and its five towns used for the study). Second figu e: Instrumental set-up adopted to calculate water depth and flow rate. Thi d figu e: Instrumental set-up for rainfall monitoring

Results

Wastewater flow and rainfall data we e analysed for each town to investigate spatial and temporal variability in I&I measurements, enabling to correlate I&I with different soils. The soil types have a clear impact on wastewater flow after rainfall (Figu e 2). Compared to Bull, the soil in Marton is more clayey with low permeability thus releases water slowly. Therefore, wastewater after rain drops slowly.

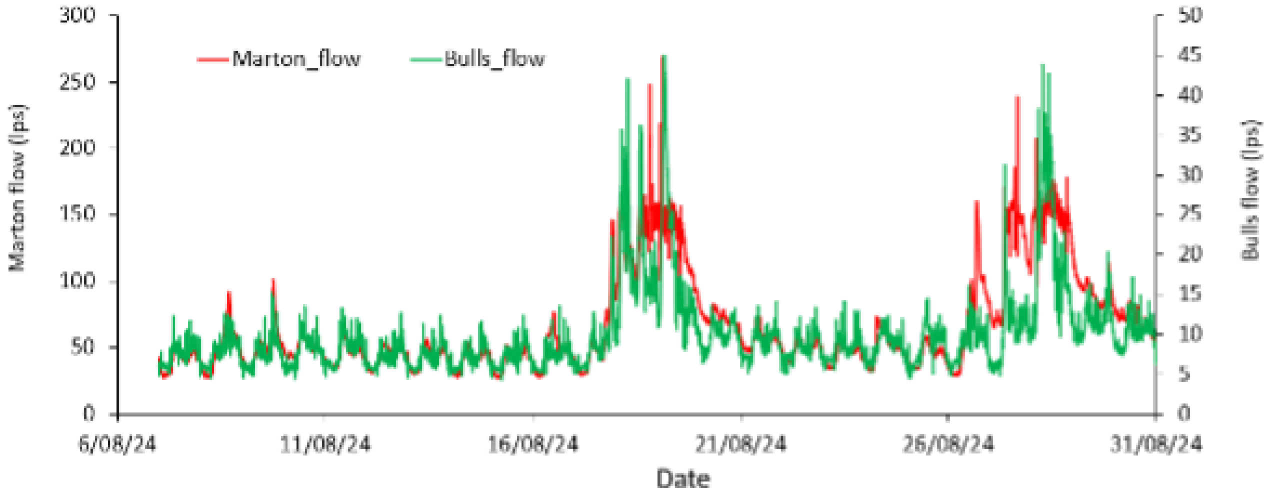


Figure 2. Wastewater flow in Marton and Bulls after rain even

The methodology recommended by the Environmental Protection Agency and the Massachusetts Department of Environmental Protection was adopted to divide the total effluent flow in four distinc components: i) sanitary flow; ii) g oundwater infiltration; iii) di ectly discharged rainwater; iv) rain-induced infiltration. As it can be seen in Figu e 3, only 14% of the total wastewater (TW) comprises of sewer wastewater (SF); 10% is contributed by rain induced infiltration (RII), a ound 25% is contributed by the groundwater infiltration (GWI), and almost 50% is contributed by di ect rainwater inflow (DRW).

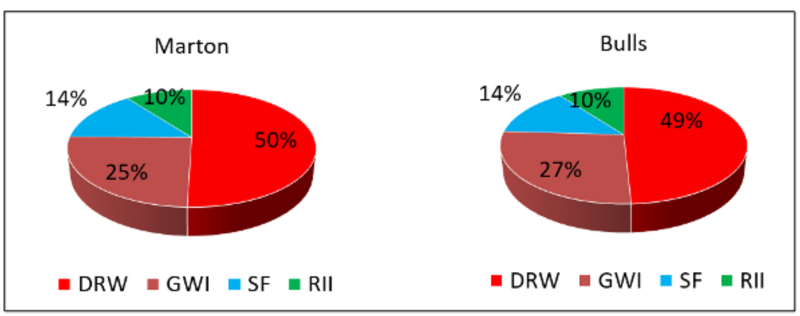


Figure 3. Four distinct components of the total effluent flow in Marton and Bul

Finding of the result will help to identify the areas susceptible to I&I thereby minimising improper wastewater flow into sewer network by undertaking p oper measures, and eventually contributing to wastewater management.

Keywords: Inflow and Infiltration, astewater, Irrigation, Groundwater, Rainwater, Soil, New Zealand

References

Environmental Protection Agency (EPA). 2014. Guide for Estimating Infiltration and Infl . Environmental Protection Agency: Washington, DC, USA, 2014. Available online: https://www3.epa.gov/region1/sso/pdfs/Guide4EstimatingInfiltrationInfl .pdf

FLOOD PROTECTION MODELLING AND ASSESSMENT FOR MARTON TOWNSHIP OF RANGITIKEI DISTRICT COUNCIL

KC, Birendra,*1 Benadie, A.,1 Haegoda, C.,2 Schultz, B.,3 and Prasad, K.,4
1 Rangitikei District Council, Marton, New Zealand
2 GHD Limited, Hamilton, New Zealand
3 Land and Water Development IHE Delft, the Netherlands
4 Irrigation and Water Resources Management Consultant, Janakpur, Nepal
* Corresponding author: birendra.kc@rangitikei.govt.nz

Aims
The Marton central business district (CBD) flooding is an ongoing p oblem due to the overtopping of the Tutaenui Stream and its tributaries (Figure 1). The Tutaenui Stream is the major waterway flowing th ough Marton. This study conducted a modelling assessment to investigate Marton CBD flooding and p oposes options for flood p otection. Two objectives of the paper were: (i) stormwater modelling to identify the flood p one area; and (ii) assessment to resolve potential flooding problems.

Figure 1: (a) Location of the study area Marton, (b) Indicative flood p one area in Marton CBD

Method
Rangitikei District Council and GHD Limited did a stormwater modelling assessment to investigate Marton CBD flooding f om the Tutaenui Stream and to propose options for flood p otection. A combination of detention ponds, stop banks and pipe upgrade options were investigated as shown in Figure 2 (a). Flood reduction potentials of those options were analysed based on three main areas [Figure 2 (b)]. Several stop bank (embankment) options were also investigated (Figure 3).

Figure 2: (a) Flood protection options assessed, (b) Base scenario – 100 year ARI RCP 6.0 flood extents with three focus areas circled in red

Figure 3: (a) Scenario I: full stop bank along the entire length, (b) Scenario II: partial stop bank, (c) Scenario III: no stop bank

Results

This paper presents the results for three focus areas: Focus Area 1 - Pukepapa Road/ Russell Street, Focus Area 2 - Calico Line to Hereford Street, and Focus Area 3 - Grey Street. As shown in Figure 4 (a), Scenario I provides the most flood eduction. In Scenario II (Figure 4 (b)), private property flooding (flood extents and depths) has significantly i   eased from Humphery Street to Cobber Kain Avenue (south of Hereford Street) when compared with Scenario I. In Scenario III [Figure 4 (c)], flooding has further inc eased and there is significant private p operty flooding f om Calico Line to Cobber Kain Avenue. Although the Scenario I predicted a significant flood eduction, the Tutaenui Stream flows very close to private p operty from Humphery Street to Lower High Street. Therefore, Scenario II has been recommended as the preferred final solution. Desirable size and location of detention ponds, pipe and stop banks are shown in Figure 4 (d).

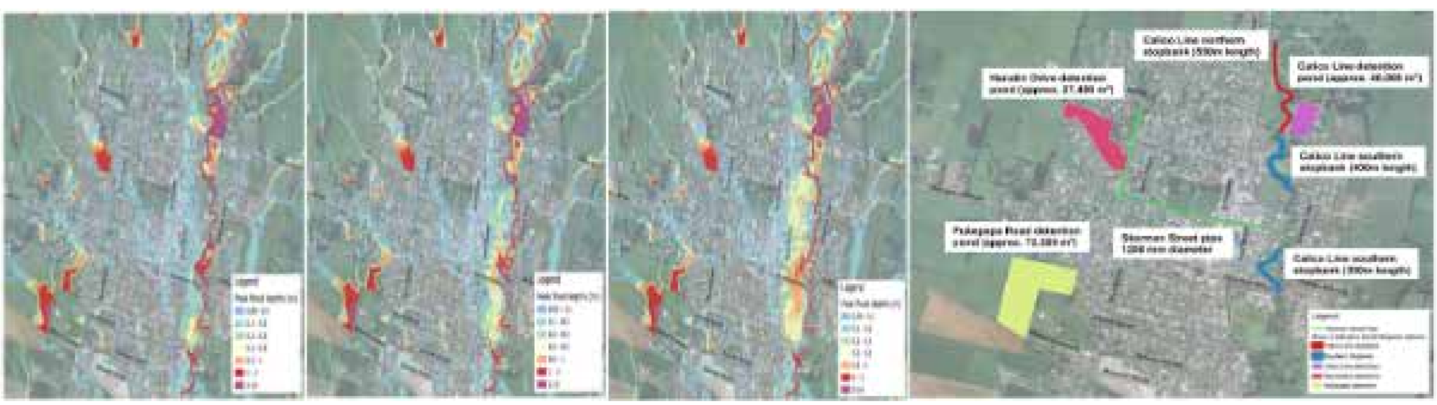


Figure 4: (a) Flood reduction from Scenario I, (b) Flood reduction from Scenario II, (c) Flood reduction from Scenario III, (d) The preferred final solution

The current practice of flood risk management a ound the world heavily relies on historical evidence to predict future extreme events and accordingly designing protective measures such as, building higher levees and increasing the capacity of drainage systems by installing bigger drainage pipes. However, as climate change causes unpredictable and higher intensity rainfall patterns, these historic design assumptions are inadequate. Therefore, attention has been shifting towards creating “sponge city”, which intends to absorb, store and reuse storm water utilising green, blue and grey infrastructure to mitigate flood damages. Howeve , the “sponge city” concept has also failed in several parts of the world. This necessitates adopting a improvised approach for flood risk modelling and management by incorporating the concept of “sponge city”; safely storing excess water in detention/retention tank; and increasing pipe diameters to increase drainage capacity. Thus, to achieve effective flood risk management in the Marton CBD, integration of the “sponge city” concept with recommended flood mitigation solutions is crucial, which can be the next step of assessment for the Rangitikei District Council.

Keywords: Flooding, Stormwater, Modelling, Detention Pond, Marton, Tutaenui Stream

References:

GHD Limited (GHD). 2025. Marton CBD Flood Protection – Modelling and Optioneering Assessment. A report prepared for Rangitikei District Council (RDC) by GHD Limited.

USING AETHALOMETER MEASUREMENTS AND EMISSION RATIOS TO CHARACTERIZE PRIMARY SOURCES OF BLACK CARBON

Erika Mari Macapagal-Taluban1, Jocelyn C. Turnbull1, Perry K. Davy1, Gustavo Olivares Pino2, Tamsin Mitchell3
1 Earth Sciences New Zealand
2 Auckland Council
3 Greater Wellington Regional Council

Traffic and woodbu ning are primary sources of black carbon (BC) in urban areas. Urban centres with heavy daytime traffic and suburban a eas reliant on wood for domestic heating, particularly during winter, are vulnerable to the adverse health and climate impacts of BC emissions.

This study investigates the temporal variation and relative contributions of BC sources using two years of BC and nitrogen oxide (NOx) measurements at four sites in two of New Zealand's most urbanized regions, Auckland and Wellington. In each city, two contrasting site types were included: roadside urban (Customs Street and Willis Street–Wellington Urban Motorway) and residential suburban (Henderson and Upper Hutt).

BC/NOx emission ratios were used to differentiate traffic influence om woodburning. Roadside urban sites exhibited lower BC/NOx ratios and stronger BC–NOx correlations, consistent with traffic dominated emissions. In contrast, suburban sites showed higher ratios and weaker correlations, indicating substantial woodburning contributions. Preliminary Aethalometer Model source apportionment confi med woodburning at suburban sites, contributing up to 75% of hourly BC concentration during winter nights at one location.

These findings highlight the variability of BC sou ces across sites and the value of source apportionment to inform site-specific emission eduction strategies for improved air quality and climate change mitigation.

OPTIMISING THE REGION'S GROUNDWATER MONITORING NETWORK: A STRATEGIC APPROACH FOR ENHANCED ENVIRONMENTAL OUTCOMES

Heather Martindale; Rob van der Raaij
(Greater Wellington Regional Council)

Effective groundwater management relies on monitoring networks that can accurately capture spatial and temporal changes across diverse aquifers and management zones. While Greater Wellington's network has been reviewed previously, those assessments have primarily focused on spatial coverage. This review takes a broader perspective—considering not only spatial representativeness, but also the network's potential to detect nutrient and water quality trends, assess groundwater level responses to allocation policies, and understand land use impacts on culturally significant and protected areas. It also explores how well the network can support evaluation of regional policies and plans.

Given resource constraints, a region-wide network that meets all objectives is not currently feasible. Instead, the review aims to inform the development of a prioritisation framework to guide future decision-making. To support this, a pilot study is underway in one groundwater management zone to trial and refine the p oposed review methods. Findings from this case study will help shape the approach for broader application.

FORECASTING WEATHER AND CLIMATE ACROSS SCALES AT EARTH SCIENCES NZ

Stuart Moore, Jorge Bornemann, Trevor Carey-Smith, Phil Andrews, Tristan Meyers, Bryce Chen, Neelesh Rampal, Nico Fauchereau, Stephen Stuart

Earth Sciences NZ (ESNZ) undertakes to forecast New Zealand's weather and climate across spatial scales spanning individual locations to trans-Tasman Sea domains, and temporal scales from a few hours ahead to seasonal outlooks. This is done using traditional Numerical Weather Prediction (NWP) and Machine Learning (ML).

For the shortest of timescales, NIWA operates the New Zealand Nowcasting System (NZNOW), a ML-based nowcasting service trained on data from the New Zealand Reanalysis. NZNOW provides forecasts of wind speed and solar irradiance to support NZ's renewable energy market with a rapid 30 minute update cycle. At the other end of the temporal scale, ML is used in the New Zealand Sub-seasonal to Seasonal (S2S) Prediction System to forecast drought conditions.

An Optimal Seamless Forecast (OSF), forecasting to 10 days ahead by combining data from ESNZ-run NWP models and globally available longer-range model output is also used, utilising data from each model where it is most performant via a series of calibrated weights associated with each input model.

This presentation provides an overview of these services and describes on-going work where regional Neural Weather Models (NWMs), ensembles and regional reanalyses are being developed to enhance ESNZ's forecasting services.

COMMUNITY VOICES IN FLOOD WARNING SYSTEMS: LEARNING FROM LOCAL INITIATIVES IN AOTEAROA NEW ZEALAND

Simone Philips[1], Emma Hudson Doyle[1], Marion Tan[1], Sally Potter[2], Sara Harrison[3]
[1]Massey University [2]Canary Innovation [3]ESNZ

Flood warnings save lives, but only if they reach and resonate with those most at risk. While forecasting and modeling technologies continue to advance, recent flood events in Aotea oa New Zealand and globally have revealed that a persistent disconnect remains between the issuance of official wa nings and the actions taken by communities.
This two-phase research explores how community knowledge, lived experience, and grassroots initiatives can support more inclusive and effective flood wa ning systems.
Phase one involved interviews with actors across the official wa ning chain and researchers with localized expertise in community resilience. These conversations highlighted both current practices and a shared recognition of the need to better integrate local knowledge and capacities into our official systems
The current phase focuses on case studies of communities actively engaged in local flood wa ning initiatives, contributing across the four pillars of effective warning systems: risk knowledge, monitoring, communication, and response. Using qualitative methods of interviewing, observing, and document analysis, this work explores how local priorities, relationships, and knowledge integration shape warnings.
As Aotearoa's communities navigate living with climate and water challenges, this research underscores the importance of co-navigating warning systems to ensure they are both scientifically robust and socially grounded.

HCLIMREP: A FOUNDATION MODEL FOR MULTI-ANNUAL CLIMATE SIMULATIONS

Julius Polz[1,2]
[1] Karlsruhe Institute Of Technology
[2] On behalf of the Helmholtz Foundation Model Initiative (HFMI) and the HClimRep Consortium

Traditional Earth System models face computational limitations in capturing complex Earth system interactions across seasonal to decadal timescales, particularly when considering high resolutions, ocean-atmosphere coupling, or long-term climate projections. As part of the Helmholtz Foundation Model Initiative (HFMI), the Helmholtz Representation Model for Climate Science (HClimRep) project addresses these challenges by developing a comprehensive AI-based foundation model for climate science, extending current capabilities beyond weather forecasting to climate simulations.

HClimRep builds on the WeatherGenerator model framework. It leverages transformer-based architectures trained on large and diverse sets of simulated and observed climate system states to improve the representation of physical processes. Using masked token modeling and advanced representation learning, HClimRep extends this approach to encompass atmospheric, oceanic, and sea ice dynamics across multiple grids and resolutions. The project develops specialized components for stratospheric dynamics and the ocean-sea ice system, ultimately integrating these into a unified foundation model.

Among a wide range of climate applications, HClimRep aims to demonstrate its capabilities particularly for seasonal-to-decadal forecasting of stratospheric tracers (e.g. ozone, water vapor, methane) for climate assessments; counterfactual marine heatwave scenarios under varying climate conditions; and enhanced hydrological cycle predictions for water availability and extreme weather events, addressing critical uncertainties in climate modeling and supporting informed decision-making.

HYDRONETNZ: AI-DRIVEN, CROWD-SOURCED IMPACT-BASED FLOOD FORECASTING AT HOUSEHOLD LEVEL IN NEW ZEALAND

Malintha Ranasinghe,[1] Raj Prasanna,[1] Emma Hudson-Doyle,[1] Marion Tan,[1] Celine Cattoen[2]
[1]Joint Centre for Disaster Research, Massey University, Wellington
[2]Earth Sciences New Zealand

Flooding is New Zealand's most frequent natural hazard, regularly causing socio-economic impacts and highlighting an urgent need for more effective flood wa nings. Impact-Based Forecasts and Warning Services (IBFWS), endorsed by the World Meteorological Organisation (WMO), aim to provide more actionable information to decision makers and at-risk communities by focusing not only on the expected hazard but also on its potential impacts. However, the practical implementation of IBFWS for floods emains challenging, particularly in New Zealand. A key barrier is the need for rapid hazard and impact modelling within the short forecast lead time (often only a few hours) of weather events, which is computationally intensive using c onventional modelling approaches. This research addresses this modelling challenge by developing ‘HydroNetNZ’, an experimental household-level IBFW system for floods in New Zealand. The system employs a deep lea ning (DL)-based emulator modelling approach to forecast high-resolution flood inundation maps, which are then translated to household-level impact forecasts using a novel machine-learning-based method. The ‘HydroNetNZ’ mobile app, currently under development with ongoing engagement with key stakeholders including emergency managers and hydrologists, will facilitate a user-centric implementation of this experimental IBFW system across multiple case study areas, ultimately improving the resilience of flood-p one communities in New Zealand.

HOURLY EXTREME RAINFALL OVER THE PAST SIX DECADES

Dáithí Stone, Raghav Srinivasan, Linda Wang, Ruotong Wang and Andrew Harper
Earth Sciences New Zealand

Theory suggests that high-intensity, short-duration rainfall events should become more intense under enhanced greenhouse warming with a increasing tendency somewhat higher than 7% per degree Celsius. Here we present analysis of hourly rainfall records from 56 locations across Aotearoa New Zealand covering the 1986-2024 period, as well as from 17 locations covering the 1965-2024 period. We compare variability and trends across the locations in the highest and fifth-highest annual values, for one-hour and multi-hour durations. We finish with conclusions about the applicability of the data set for various applications.

PASTURE GROWTH UNDER CLIMATE CHANGE

Dáithí Stone, Trevor Carey-Smith, Tristan Meyers
Earth Sciences New Zealand

Here we present projections of future pasture growth across Aotearoa New Zealand. We use a model of pasture growth which, while based on process understanding, is developed through empirical comparison against weekly and monthly growth observations from a number of sites when the model is run using observed whether. We the run the pasture growth model using projections of future climate change from the new CMIP6-based downscaled projections. We evaluate the model performance and presented the projections.

DIGGING INTO WET-SNOW ACCRETION PATTERNS FOR SOME RECENT SNOWSTORMS

Richard Turner, Daniel Smith

Snow and ice accretion loads are an important design consideration for overhead power lines. AS/NZS 7000 (The overhead lines design code) is currently undergoing a review. In this poster we present a recent analysis of NZCSM-based estimates of wet-snow accretion, rime-ice accretion and glaze ice accretion for eight recent snow storm events, including the spatial patterns of key parameters such as stokes numbers, collision efficienc , and cloud liquid water contents. We also compare, for some other small icing events in the winter of 2023, the model estimates of accretion against that measured at a monitoring site at the Chateau EWS site at Mt Ruapehu. We also report on progress towards the production of return-periods for radial ice diameters in New Zealand.

AN UPDATED HAIL EVENT CATALOGUE FOR AOTEAROA NEW ZEALAND

Richard Turner, Stuart Moore, Trevor Carey-Smith

This poster reports on a 2025 update to the 2006 electronic catalogue of NZ hail events. This catalogue is a simple spreadsheet recording past reported hail events by either meteorological observations at recording stations or from searches of newspapers. The 2006 catalogue was compiled by NIWA (Salinger, 2006) and was, itself, an update of earlier compilations by MetService (Neale, 1977 and Steiner, 1986). In this update, media reports from the past 20 years, the historic weather events catalogue (https://hwe.niwa.co.nz) and monthly climate summaries (https://niwa.co.nz/climate-and-weather/monthly) were searched for hail events and details, such as date, damage that occurred and hail-stone size noted, and the events added to the catalogue. Hailstone sizes can vary within each event, and it is the maximum sampled that tends to be reported, with larger hail diameters tending to be more accurately measured (Neale, 1977). Maps of the hail occurrences were then created with simple summation and return-period statistics by region generated and presented here.
Maps and statistics derived from the hail reports were compared to similar products from the USA and Australia in order to gain an understanding of the relative risk compared to those countries.

IN-STREAM WETLAND SUITABILITY MAPPING USING ANALYTIC HIERARCHY PROCESS AND MACHINE LEARNING

Guaman Pintado, P.M.,[1] Muru, M.,[1] Uuemaa, E.[1]
[1] Department of Geography, University of Tartu, Estonia

Wetlands support diverse ecosystem services. In-stream wetlands, which are wetlands located within or alongside a stream or channel, are known to be effective at reducing non-point source agricultural pollution. Effective planning for in-stream wetland placement requires strategic identification of suitable locations. This study compares a knowledge-driven approach, the Analytic Hierarchy Process (AHP), with a data-driven machine learning method, Random Forest (RF), to determine the suitability for in-stream wetland placement in Estonia. We used five envi onmental predictors: slope, topographic wetness index, flow accumulation, soil o ganic carbon, and clay content, using global and local datasets at 10 and 50 m resolutions to evaluate the effects of spatial scale and data origin. Historical wetland maps were used for validation, assuming these locations are still ideal for wetland placement. Our findings eveal that AHP and RF performed comparably well, with RF effectively identifying areas corresponding to historical wetlands. Data origin (local vs. global) significantly impacted model performance, with local data outperforming global data. Spatial resolution had limited influence. This study highlights machine lea ning's potential to enhance expert-based wetland placement site selection. This study demonstrates that machine learning can enhance and scale the expert-based approach of wetland placement site selection.

A NEW NOBLE GAS ANALYTICAL CAPABILITY FOR NEW ZEALAND

Van Soest, M.C.[1] Curtis, J.,[1] Byrne, D.,[1] Morgenstern, U.[1]
[1] Earth Sciences New Zealand

A new noble gas analytical system with a focus on the analysis of water and gas samples has recently come online at Earth Sciences New Zealand. The original purpose of the system was to deliver high precision noble gas abundance data to aid with determination and quantification of in-situ denitrification in g oundwater samples. However, the addition of a Thermo Helix MC+ noble gas mass spectrometer has expanded the system's capabilities to include noble gas isotope analysis, which significantly inc eases the number of research questions in hydrology and other research fields that can be addressed.
We will present: 1) an overview of the fully automated noble gas system that has an inhouse built gas preparation line; 2) the setup of a separate processing line to extract gases from water samples; 3) the procedure and requirements for collecting samples; 4) data from the system to demonstrate capabilities and highlight some applications within the field of hyd ological research and beyond.

CONTEXTUALISING THE CHANGING PRESSURE ON OTAGO'S AQUIFERS AND ESTABLISH REFERENCE CONDITIONS FOR OTAGO

Yeo, S,[1] Moreau, M[2], Levy A[1]
[1] Otago Regional Council
[2] Earth Science New Zealand

Aim

Understanding land use changes through time is essential to inform the development of future planning frameworks to set reasonable nitrogen limits — particularly for aquifers experiencing elevated nitrate concentrations. In this study, we mapped historic land use change and developed regional land use indicators to derive nitrate threshold values for reference conditions for Otago's groundwaters, adapting the methodology used nationally (Daughney et al. 2023).

Method

To estimate land use intensity at groundwater bores, reclassified LUCAS land use data (Landca e Research, 2010; Harris et al., 2023) were combined with environmental typologies using a loss coefficient lookup table (Srinivasan et al., 2021; Marapara, 2022). This p oduced nitrogen yield estimates for each land parcel in Otago for 1990, 2008, 2012 and 2018. Nitrogen loss and load for 2012 and 2018 were calculated within a 2 km buffer around each bore and regressed against nitrogen concentrations at those bores.

In addition, nitrogen (N) load values for each timeseries were clipped to aquifer boundaries to assess relative change in on land N load over time. Using the LUCAS timeseries allows for linkages between land use change and relative change in N load (e.g. effects on approximate N load change when there's a parcel conversion from say Sheep to Dairy), unlike the national map of N-leaching estimates prepared by Manaaki Whenua for MfE (Ausseil and Manderson. 2018) that does not publicly provide land use class.

Finally, nitrate threshold values were calculated using a weighted approach combining regression against land use intensity using the aforementioned indicators, hierarchical cluster analysis (HCA) and regression between nitrate concentration and groundwater age, following the methodology of Daughney et al. (2023).

Results and Discussion

The assessment of changes in land-based N loading above aquifers over time from across Otago showed a slight increase in N loading between 1990 and 2008, followed by a relatively steep rise through to 2018 (Fig. 1). The aquifers showing the largest increases in land-based nitrogen loading from 2008 onwards were in the Manuherikia Basin, Lower Waitaki, North Otago Volcanics, and Maniototo. These increases were primarily driven by land-use conversion to more intensive dairy and a decrease in lower nitrogen loading land use types such as Sheep and Sheep & Beef. Nitrate threshold values obtained by regression between N load/loss and groundwater nitrate concentrations were consistent with those obtained using HCA and chemistry vs. groundwater age. The recommended combined nitrate-nitrogen threshold to use for environmental reporting is 1 mg/L (Moreau et al., 2025).

In addition to establishing a reference state, the project delivered a practical workflow and a test case for future assessments of the changes in land-based N loading through time. This includes opportunities to expand the temporal resolution by incorporating LCDB, tracking changes in irrigation over time (which was treated as steady-state in this project), and integrating land-use practice change. By analysing historical changes in nitrogen load and linking them to land-use change, this work provides a foundation for forward-looking scenario planning. Reference conditions once derived will provide an upper bound on target decision windows. This ensures discussions about targets take place within a window that can theoretically be achieved instead of attempting to reduce nutrient concentrations beyond natural conditions.

Figure 1. Nitrogen load summed within all Otago aquifers for each time step, showing a gradual increase in load from 1990-2008, followed by a steep increase through to 2018

References

Ausseil, A., Manderson, A. 2018. Spatial nitrate leaching extent: an update for environmental reporting. Prepared by Manaaki Whenua – Landcare Research for the Ministry for the Environment. Contract report LC3245

Couldrey M. 2022. Land use and digital elevation mapping for Otago Regional Council – April 2022. Invercargill (NZ): Great South. 28 p.

Daughney CJ, Morgenstern U, Moreau M, McDowell RW. 2023. Reference conditions and threshold values for nitrate-nitrogen in New Zealand groundwaters. Journal of the Royal Society of New Zealand.

Harris L, Shepherd J, Pairman D, Belliss S, Martin B. 2023. Establishing New Zealand's LUCAS 2020 Land Use Map. Manaaki Whenua – Landcare Research report LC4445. LUCAS Development:1-58

Marapara T. 2022. Science approach to assigning Nitrogen (N) and Phosphorous (P) baseload loss values to farm typologies and other categories of land use [memorandum]. Dunedin (NZ): Otago Regional Council. 18

Moreau M, Yeo S, Levy A. 2025. Groundwater nitrate threshold for reference conditions for Otago. Lower Hutt (NZ): GNS Science. p. Consultancy Report 2025/71.

Srinivasan MS, Muirhead RW, Singh SK, Monaghan RM, Stenger R, Close ME, Manderson A, Drewry JJ, Smith LC, Selbie D, et al. 2021. Development of a national-scale framework to characterise transfers of N, P and Escherichia coli from land to water. New Zealand Journal of Agricultural Research. 64(3):286–313.

REASONS FOR DIFFERENT PREDICTABILITY OF TROPICAL CYCLONE TRACKS IN WESTERN NORTH PACIFIC AND ATLANTIC OCEANS

Feifan Zhou, Yiwei Ye
Institute of Atmospheric Physics, Chinese Academy of Sciences

Recent several studies have focused on the predictability of tropical cyclone track forecast. Interestingly, the predictabilities are found to be different in the Atlantic (ATL) and western North Pacific (WNP) basins, as 1 day's improvement through 10 years was found in ATL, while 2 days' improvement through 15 years was found in WNP. To reveal the causes of this difference, the predictability of TC track in WNP is first investigated under the same framework as that in ATL. Then, important parameters that determine the predictabilities are found and analyzed. Results suggested that the growth rate of true track forecast error in WNP is higher than that in ATL, indicating a lower predictability in WNP. Further explorations suggested that TCs in the WNP basin have averagely larger sizes, stronger intensities, lower-latitude locations, and poorer forecast skills of their guided flows. All these factors contribute to the larger track forecast error growth rate. Moreover, it is pointed out that the improvement of forecast skills over years is mainly due to the reduction in initial analysis errors; although a lower predictability is found in WNP, the forecast skill improvement in WNP is faster than that in ATL.

LIGHTNING TALKS

NO ONE LIKES WET SOCKS

Cranney, O.,[1] Calder-Steele, N.[1]
[1] Aqualinc Research Limited

Development on greenfield and b ownfield sites can be an expensive and long p ocess, with delays making things more expensive and drawn-out.

As land development moves into increasingly marginal areas, traditional geotechnical assessment approaches can fail to adequately account for the risk posed from shallow groundwater, causing delays and making things more expensive if not considered early on. No one likes wet socks and we're making sure our clients keep theirs dry.

Aim

To explore how groundwater level data can improve outcomes for land development, infrastructure development, and construction projects.

Methods

We consider available groundwater level and geological information to understand how groundwater level may impact development during construction and beyond.

Results

Groundwater data analysis can result in insights far beyond those obtained from traditional geotechnical assessment. This includes being able to quantify the volume of dewatering necessary for project success, such as passive dewatering by stormwater infrastructure (e.g. detention basins). This can reduce uncertainty associated with (and risk arising from) shallow groundwater, increasing the potential viability of land development, infrastructure development, and construction projects.

ASSESSING AIR QUALITY IN NEW ZEALAND

Jamie Halla[1]
[1]Defense Science and Technology

This talk will focus on the current state of air quality monitoring in New Zealand and our work to help assess air quality throughout NZDF bases. Through the use of standard Vaisala monitoring devices we have measured gases such as NO_2 and ozone as well as PM_{25}. A quick overview will be given plus future plans for expanding our network.

COSTING FUTURE CLIMATE DISASTERS — MBIE SMART IDEA

Nathanael Melia[1,2], Ilan Noy[2], Dave Frame[3], Shaun Awatere[4]
[1] Climate Prescience Ltd
[2] Victoria University
[3] University of Canterbury
[4] Landcare Research Manaaki Whenua

This lightning talk will introduce our 2025 – 2028 MBIE Smart Idea — Costing Future Climate Disasters: Harnessing Climate Chirality and Sigma Space Extremes.

Public Statement:
"Aotearoa, New Zealand, holds a unique position globally, experiencing slower climatic warming compared to many other regions. However, extreme weather events like the Auckland Anniversary floods and yclone Gabrielle starkly underscore our vulnerability to climate change and the significant econ mic costs it imposes."

Our research introduces a novel approach using 'chiral climate twins' to predict the future impacts of extreme weather events across New Zealand. By analysing data from analogous locations in Europe—regions that historically shared similar climates with New Zealand but have warmed more rapidly—we can gain valuable insights into the varied impacts of extreme weather events and their economic implications.

Currently, limitations in economic modelling of the costs of future extreme weather events hinder effective planning. The chiral climate twin method will provide real-world foresight to address this gap, enhancing New Zealand's financial security and economic esilience. With this improved foreknowledge, Aotearoa will be better positioned to safeguard its economy, strengthen resilience, and ensure fiscal eadiness to navigate the escalating challenges of a changing climate."

A HOTTER FUTURE — CERTAINLY, BUT WETTER AND/OR DRIER?

Nathanael Melia[1,2]
[1] Climate Prescience
[2] Victoria University

As the climate warms, is Aotearoa New Zealand likely to get wetter or drier? Neither? Both? We don't know? Can you repeat the question?
I first stumbled ac oss this dilemma when assessing NIWA's CMIP5 RCM projections. I essentially couldn't get four or five of the six GCMs to ag ee on the sign of the gross change in total precipitation for most seasons for most of NZ. Was this a sign of model bias? Marked multi-decadal variability? Near-zero change? Incompetent analysis? I think so.

Let's look at some CMIP6 projections for NZ, and potentially some better metrics. Essentially, I think we now know more than we did before, and you likely already know the wetter gets flashier and dry gets d ought-y-er story (it's a word ok). I suspect the impact of these changes in rainfall is unhelpful in every conceivable way, and I remain deeply disturbed at its apparent unknowability.

OPERATIONAL NOWCASTING OF UV INDEX

Meyers, T[1], Geddes, A[1], Chen B[2]
[1]Earth Sciences NZ
[2]NVIDA AI Technology Centre

The UV Index (UVI) is a vital public health tool used to communicate the risk of overexposure to ultraviolet radiation. In New Zealand, where UV levels are elevated due to geographic and atmospheric factors, accurate UVI forecasts are essential for public safety, outdoor planning, and skin cancer prevention.
While UVI forecasts from numerical weather prediction (NWP) models are widely used, they lack real-time responsiveness to rapidly changing local conditions, particularly cloud cover, which is highly variable and difficult to p edict. To address this, we introduce a site-specific UVI nowcasting method using NZNOW (formerly NIWA NEXT), a real-time prediction system developed by Earth Sciences New Zealand.
NZNOW integrates observed solar irradiance and UV index into a deep learning time series model, merging these with NWP forecasts. This hybrid physics and machine learning approach updates six times more frequently than the New Zealand Convective Scale Model (NZCSM), and is shown to consistently improve short-term accuracy by assimilating local observations.
We present performance comparisons with NZCSM and outline future plans to operationalize NZNOW within forecasting workflows, with potential applications for public heal h agencies, outdoor event planners, and digital platforms.

THE NEW ZEALAND REANALYSIS

Stuart Moore[1], Amir Pirooz[1], Chun-Hsu Su[2], Trevor Carey-Smith[1], Richard Turner[1], Phil Andrews[1]
[1] ESNZ
[2] Bureau of Meteorology Australia

The New Zealand Reanalysis (NZRA) is a downscaled high-resolution atmospheric regional reanalysis dataset covering all of New Zealand (NZ) for the 1990-2018 time period based on the BARRA-R regional reanalysis from the Bureau of Meteorology. In the last year, NZRA has been extended from 2019 to the present day using the newer BARRA2 reanalysis dataset for its inputs. Produced at a 1.5km horizontal resolution and 30 minute temporal resolution, NZRA provides a long-term dataset that can be used for applications such as training data for Neural Weather Model and other AI/ML applications, studying long-term climatological trends across NZ and as a long-term scientifically consistent sou ce of input data for hazard modelling. In this presentation we provide an update on the production status and validation of the NZRA dataset, how users can begin to access it for research purposes and initial plans for future reanalysis work.

ASSESSMENT OF SF6 AND CFC CONTAMINATION PLUMES IN AQUIFERS AND RISK TO DRINKING WATER SUPPLIES

Uwe Morgenstern[1], Magali Moreau[1], Reuben Rodrick[1]
[1] Earth Sciences NZ

Shortly after Cyclone Gabrielle we assessed the impact of the extremely high hydraulic loading in the recharge area on the Heretaunga Plains Aquifers. While assessing historic age tracer data we discovered that an SF6 plume had moved through the confined aquifer a ound Hastings. We also noted increasing CFC-12 concentrations in the centre of the aquifer near the coast.

CFCs were commonly used in the past as a refrigerant gas in fridges and AC equipment, as spray can propellant, and with solvents. However, production had been phased out globally 35 years ago because the CFCs caused damage to the ozone layer in the upper atmosphere, with the result of elevated UV exposure on earth (ozone holes). It was unknown why CFC-12 concentrations are now increasing in the Heretaunga Plains Aquifers.

After further investigations we were able to link these increasing CFC-12 concentrations to a plume leaching out of a historic landfill located in the echarge area of the aquifer. CFC gear is abundant in historic landfills

As this has potential to pose a risk to drinking water supplies in the area, we assessed, together with Hawkes Bay Regional Council, if there are any harmful contaminants associated with this plume. In a quick response we designed a sampling campaign to assess the extent and evolution of the plume, and collected hydrochemistry, heavy metals, and VOC samples. Fortunately, we did not find any exceedance of Maximum Acceptable Values, even not in the monitoring wells around the landfill

We still don't understand the source of the SF6 plume around Hastings, but this plume was not associated with elevated CFCs and therefore unlikely to be related to a rubbish dump. It is more likely that this was from an industrial source, likely high-voltage switch gear. It is unlikely that harmful co-contaminants were associated with the SF6 plume.

THE SUFFOCATING WEIR

Wilding, T.K.[1]
[1] Waikato Regional Council

Introduction

Oxygen is necessary for aquatic life. The reaeration of oxygen in small lowland streams often relies on adequate velocity for turbulent mixing (Cox, 2003). Restrictions are set on water use to protect aquatic life, and this necessitates high quality flow data. Constructing a w ir can produce better stage-to-flow ratings by creating a consistent hydraulic control. But what if those weirs are doing more harm to aquatic life than the water takes that we are managing?

Aim

To investigate the effect of weirs on oxygen in warm, lowland streams.

Methods

From the many studies investigating oxygen levels in streams, weirs often emerge as outliers. The effect of weirs on oxygen appeared at several scales of investigation, providing multiple lines of evidence for their deleterious impact. Those studies included:

• Regional scale - the distribution of oxygen data was compared using 102 sites on Waikato streams, chosen because each site has more than 100 monthly oxygen measurements between 1990 and 2023 (Wilding, 2023). Examination of the relationship between 50%ile and 10%ile data revealed sites where oxygen showed greater variation.

• Catchment scale - same-day oxygen measurements were completed about dawn (time of diel minima) at 42 sites for modeling spatial variability in oxygen response to flow in the Karamu catchment, Hawke s Bay. A model was developed for predicting oxygen from physical drivers including flo , width, depth and slope.

• Reach scale - investigations included a longitudinal profile of oxygen measu ements taken about dawn, at points upstream and downstream of a weir on the Piako River, Waikato

Results

The distribution of oxygen levels across the Waikato region revealed that outliers were often sites associated with impoundments (Figure 1), and included:

• Piako River at Kiwitahi upstream of the flow monitoring wei

• Whangamarino River upstream of a level control weir

• Outlet of Lake Whangape at Glen Murray Rd

These were outliers in so much as the 10%ile of oxygen values was low relative to the median oxygen value. But not all sites with weirs produced lower oxygen levels. For example, the Waitoa River at Waharoa was not an outlier. This site has a small weir that produced only a short backwater.

This regional analysis made use of data collected for state of environment monitoring. A more targeted study was conducted in a Hawke’s Bay catchment, measuring oxygen at its worst (dawn on the same day at each of 42 sites, Wilding, 2018). Again, sites associated with weirs were outliers in terms of the oxygen predicted based on physical drivers of reaeration. The physical drivers included stream slope. If I changed from reach slope to the slope of the backwater behind the weir, then these sites were no longer outliers. This provides evidence for the hydraulic mechanism of the effect of the weir on oxygen reaeration.

The finest scale study focussed on a single each, at dawn, and revealed the gradual decline in oxygen levels as the water travelled through the backwater of the weir (Figure 2). There was a subsequent recovery of oxygen downstream of the weir.

The extent of the weir effect will increase in low-gradient streams. For example, a 1 m high weir in a stream with a slope of 0.5 m/km will produce a 2 km backwater. Weirs are not expected to impact oxygen in steep streams. The magnitude of effect was significant for some weirs, with fish kills observed i several streams when oxygen dropped to near zero. Small streams in warm areas are expected to be more at risk of low oxygen levels (Blaszczak et al. 2023).

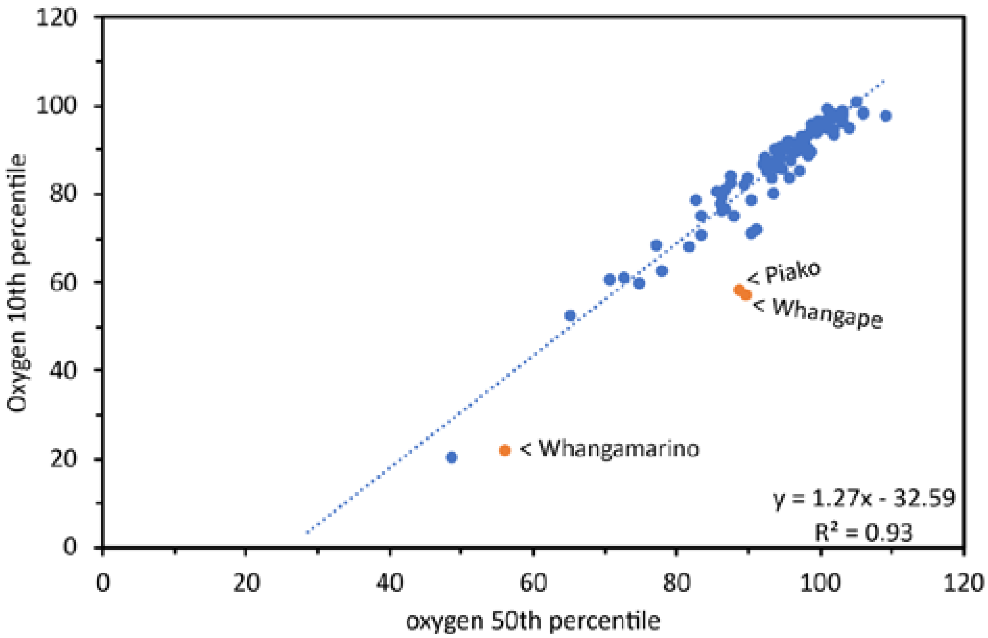


Figure 1: The 10th percentile of oxygen saturation values is plotted against the 50th percentile (median), where each point is a site in the Waikato region, each with at least 100 monthly measurements (period 1990-2023). Outliers with lower 10th percentile oxygen levels include Piako River at Kiwitahi, Lake Whangape outlet and Whangamarino River at Island Block Road.

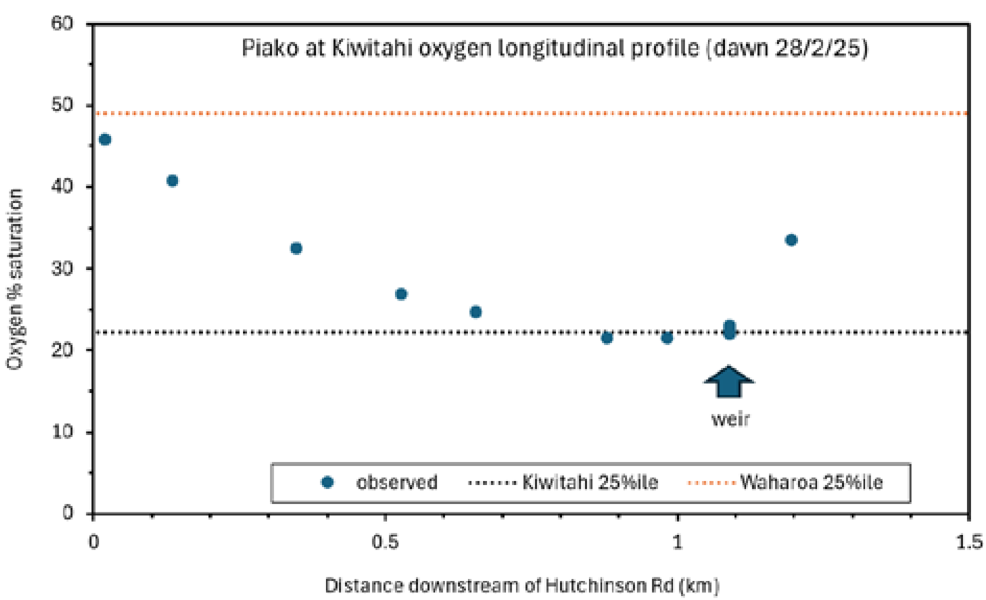


Figure 2: Longitudinal profile of oxygen saturation, demonstrating the inc ease in oxygen upstream of the Kiwitahi weir (location arrowed at 1.1 km on the x-axis). Spot measurements were taken after dawn on 28 February 2025 to represent daily minimum oxygen under low flow conditions (flow 0.14 m^3/s).

References

Blaszczak JR, Koenig LE, Mejia FH, Gómez-Gener L, Dutton CL, Carter AM, Grimm NB, Harvey JW, Helton AM, Cohen MJ 2023. Extent, patterns, and drivers of hypoxia in the world's streams and rivers. Limnology and Oceanography Letters 8: 453-463. DOI 10.5066/P99X6SIR

Cox, B.A. 2003. A review of dissolved oxygen modelling techniques for lowland rivers. Science of the Total

Environment, 314: 303-334, DOI 10.1016/S0048-9697(03)00062-7.

Wilding, T.K. 2018. Spatial oxygen-flow models for st eams of the Heretaunga Plains. HBRC Report No 15-06-4744.

Wilding, T.K. 2023. Developing monitoring attributes for oxygen and temperature in rivers. Waikato Regional Council IS 2023-28.

ORAL PRESENTATIONS

GROUNDWATER FLOW, CHEMISTRY AND NUTRIENTS ALONG A TRANSECT NORTH OF ASHBURTON

Philippa Aitchison-Earl[1] Courtney Bosse,[2]
[1] Environment Canterbury
[2] EOS Ecology

We sampled 50 wells at different depths along a 60 km transect from the hills to the coast north of the Ashburton River in Canterbury. The transect aimed to help us understand sources and fates of nutrients in an area where there are no coastal spring-fed streams and groundwater discharges directly to the ocean. The transect passed through areas of surface water irrigation derived from the alpine sourced Rangitata River and through areas of historically high nutrient concentrations including downgradient of effluent discha ges.

We found that concentrations of ions and nutrients increase along the groundwater flow path f om the foothills to the sea. Most samples had nitrate nitrogen concentrations over 5.65 mg/L and nearly half of samples were over the maximum acceptable value (MAV) of 11.3 mg/L.

The transect can be divided into three sections characterised by their different dominant groundwater recharge sources (Figure 1):

• Below the foothills local rainfall and river sources recharge groundwater and nutrient levels are relatively low
• Under the Ashburton-Lyndhurst irrigation scheme (ALIL), alpine sourced groundwater can be traced in groundwater isotopes and chemistry and contaminants from agricultural land use continue to flow towa ds the coast at depth
• In the lower third of the transect, from State Highway One to the coast there is a wedge of up to 100 m of high nutrient groundwater, recharged by local coastal rainfall and predominantly groundwater sourced irrigation infiltrating th ough intensive agricultural land use, and from major effluent discha ges to land

Ultimately, all the groundwater discharges to the coast with little impedance to offshore flo . Most groundwater is relatively young (< 50 years). At the coast deeper groundwater is older, and a small component may be upwelling to partially mix older waters with younger shallow groundwater. Milne et al. (2021) found that nitrate nitrite nitrogen and ammoniacal nitrogen did not meet aquatic ecosystem health guidelines in coastal waters for the two nearest sites to the transect. Our study indicates that groundwater discharge is a likely source of elevated nutrients in coastal waters.

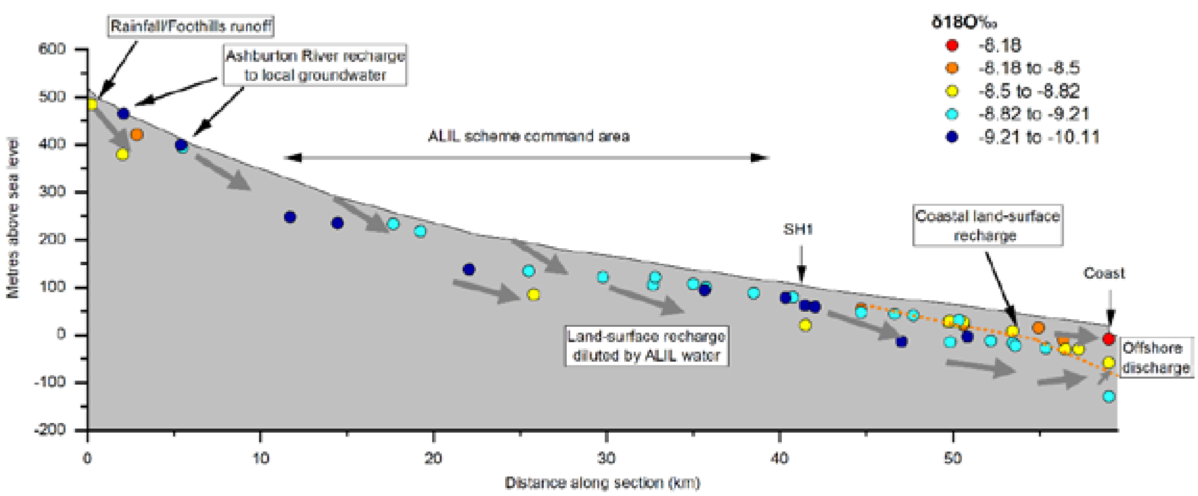


Figure 1: Conceptual model of groundwater recharge and flow path

Milne, J. McKenzie, A. Gadd, J. Dudley, B. and Zeldis, J. 2021. Coastal water quality in the Canterbury Region: An assessment of state and trends, NIWA report 2021199CH prepared for Environment Canterbury

HYBRID STATISTICAL DOWNSCALING OF RAINFALL USING REANALYSIS DATA IN BANGLADESH

Akter, M.,[1], Jovanoski, Z.,[1], Deng, D.,[1]
[1] University of New South Wales, Canberra, Australia

Aim

Bangladesh lies in one of the most climatically complex regions in the world, where interactions between coastal and inland systems, localised convection, and extreme cyclonic events create highly variable rainfall patterns (Das et al., 2020). Accurate daily rainfall estimation is crucial for flood fo ecasting, water resource management, and climate adaptation planning. However, high-resolution rainfall datasets—especially at the finer esolution suitable for local-scale applications—are scarce.

As illustrated in Figure 1, the coarse ERA5 predictor grids (left) lack the detail needed to capture local-scale rainfall variability (Hersbach et al., 2020), motivating the development of a robust statistical downscaling framework. This study uses ERA5 reanalysis variables as predictors and the Multi-Source Weighted-Ensemble Precipitation (MSWEP) dataset (Beck et al., 2019) as the reference to generate 10 km resolution rainfall fields, improving the representation of rainfall patterns and extremes across Bangladesh.

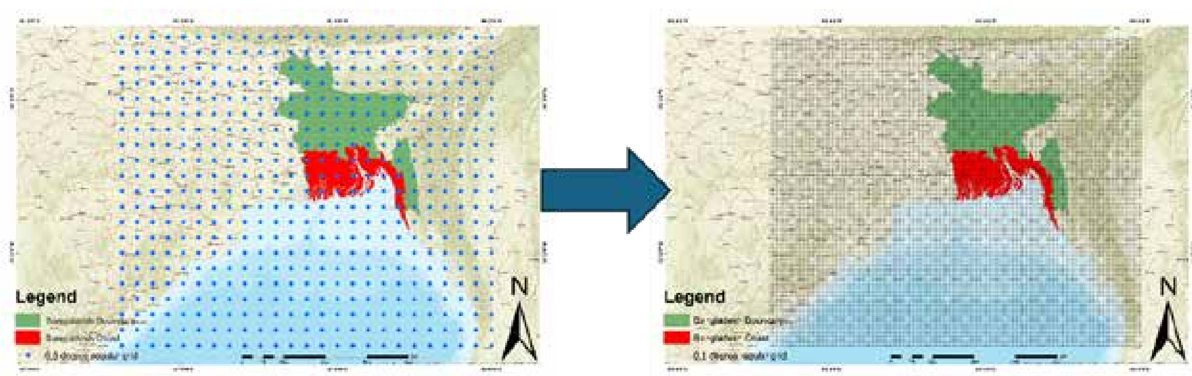


Figure 1: Transition from coarse grid resolution (left) to downscaled 10 km resolution grid (right) over the Bangladesh region.

Method

A two-stage statistical downscaling framework was implemented. First, a logistic regression model (Chandler & Wheater, 2002) was applied to classify wet and dry days, with thresholds optimised for precision and recall. For wet days, rainfall amounts were estimated using Multiple Linear Regression (MLR) (Hastie., et., al., 2009) after applying a natural-logarithmic transformation to stabilise variance and improve the normality of residuals. ERA5 reanalysis predictors (Hersbach et al., 2020) were tested for stationarity to ensure stable climatological relationships. The Multi-Source Weighted-Ensemble Precipitation (MSWEP) dataset (Beck et al., 2019) was selected as the target due to its long-term coverage, spatial continuity, and reliability, as evidenced by correlation coefficients ranging f om 0.45 to 0.65 against observations from 37 rain-gauge stations across Bangladesh. Model calibration was conducted for the period 1979–1996, followed by validation for 1997–2014.

Results

The downscaling framework substantially improved upon direct ERA5 rainfall estimates (Figure 2), showing reduced bias, better quantile matching, and more accurate reproduction of extreme rainfall events. Separation of rainfall occurrence and amount allowed independent assessment of precipitation frequency and intensity. The calibrated model maintained strong predictive performance across both calibration and validation periods, successfully capturing the spatial and temporal patterns of daily rainfall at the 10 km resolution (Figure 1, right).

To illustrate the statistical improvement in detail, a Quantile-Quantile (QQ) plot for a representative coastal central grid (Figure 3) shows markedly improved quantile alignment after downscaling, particularly in the upper tail, indicating a better representation of extreme rainfall. Building on this performance, the framework offers a robust pathway for translating coarse-scale rainfall projections from Global Climate Models (GCMs)—numerical models that simulate the Earth's climate system—into locally relevant, high-resolution datasets. This enables more accurate assessment of climate change impacts on precipitation extremes and supports targeted adaptation and risk management strategies.

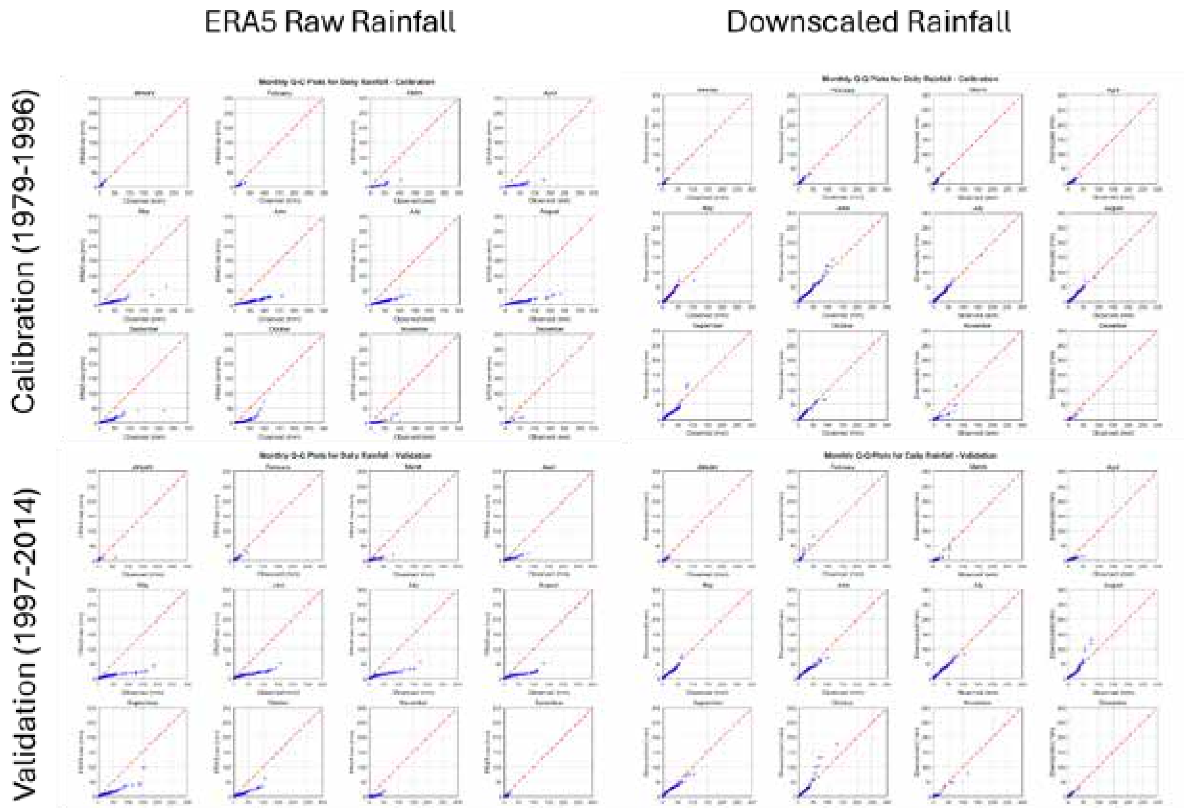


Figure 2: Monthly QQ plots of observed vs modelled daily rainfall for a coastal central grid during calibration (1979–1996) and validation (1997–2014). Red dashed line indicates 1:1 agreement.

Reference

Beck, H.E., Wood, E.F., Pan, M., Fisher, C.K., Miralles, D.G., van Dijk, A.I.J.M., McVicar, T.R. and Adler, R.F., 2019. MSWEP V2 global 3-hourly 0.1° precipitation: methodology and quantitative assessment. Bulletin of the American Meteorological Society, 100(3), pp.473–500.

Chandler, R.E. and Wheater, H.S., 2002. Analysis of rainfall variability using generalized linear models: A case study from the west of Ireland. Water Resources Research, 38(10), pp.1–11.

Das, S., Hazra, S. and Ghosh, T., 2020. Coastal vulnerability assessment for sustainable management of the Bengal delta, India. Ocean & Coastal Management, 187, p.105078.

Hastie, T., Tibshirani, R. and Friedman, J., 2009. The elements of statistical learning: Data mining, inference, and prediction. 2nd ed. New York: Springer.

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D. and Simmons, A., 2020. The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society, 146(730), pp.1999–2049.

Teutschbein, C. and Seibert, J., 2012. Bias correction of regional climate model simulations for hydrological climate-change impact studies: review and evaluation of different methods. Journal of Hydrology, 456–457, pp.12–29.

Wilby, R.L. and Wigley, T.M.L., 1997. Downscaling general circulation model output: a review of methods and limitations. Progress in Physical Geography, 21(4), pp.530–548.

CLIMATE DRIVEN VARIABILITY OF WIND ENERGY RESOURCES ACROSS SELECTED LOCATIONS IN FIJI

Shiraz Ali[1*], Kunal Kushal Dayal[2], Rajnesh Lal[3]
[1]Department of Pure Sciences, Fiji National University, Lautoka, Fiji
[2]Department of Science, School of Science and Technology, The University of Fiji, Lautoka, Fiji
[3]Department of Mathematics and Statistics, Fiji National University, Lautoka, Fiji

Abstract

Climate change is reshaping wind energy patterns in the Small Island Developing States of the Southwest Pacific egion, directly influencing the potential and eliability of renewable energy generation. In response, this research investigates the wind energy potential across different environments —onshore, interior, and outer islands, focusing on the influence of climate variability on wind patte ns and energy generation. Using a decade of historical wind and climate data from automatic weather stations, the study applies statistical and modeling approaches, including Pearson correlation, one-way ANOVA, and the Mann-Kendall test, to examine relationships between the Oceanic Niño Index (ONI), wind variability, and key atmospheric parameters. The Wind Atlas Analysis and Application Program (WAsP) is employed to simulate site-specific wind flow and ene gy potential, accounting for terrain and local meteorology. Key climatic drivers—ENSO, Madden-Julian Oscillation (MJO), Interdecadal Pacific Oscillation (IPO), alker circulation, ITCZ, and SPCZ are analyzed to quantify their impact on wind speed, direction, and power density. Results reveal pronounced climate-driven fluctuations that can significantly fect wind energy generation feasibility. This research provides critical insights for optimizing wind energy deployment, guiding policymakers and stakeholders, and enhancing climate-resilient renewable energy strategies in Fiji and other Small Island Developing States of this region.

THE HYDROLOGY OF THE LAKE ONSLOW PUMPED STORAGE SCHEME

Bardsley, W.E.[1]
[1] University of Waikato

After the 2023 election, the new government cancelled investigations into the possibility of a state-funded pumped storage scheme at Lake Onslow in Central Otago. The scheme's large 5 TWh energy storage capacity could potentially provide an emission-free energy buffer against dry years. Almost $30m had been spent on site investigations at the time of the election. Recently, this information has been utilised by a private consortium looking to construct the scheme as a commercial entity, independent of government funding. The consortium is seeking fast-track classification and investm nt funding for their proposal, which remains largely unchanged from the original concept. The government is now supportive of the Lake Onslow scheme, given its new private sector status and its potential for avoiding repeats of the high power prices experienced during the 2024 dry winter. Further information on the status of the scheme may be available by the time of the conference.

Hydrological and water resource implications of the scheme will be the focus of the presentation.

An example considers how the pumped storage operation could enable a new management option for Lake Pukaki. A simple model was constructed: releasing more water from Lake Pukaki over the 6 months of October-March, whenever lake levels exceeded 525 metres asl. This results in an increased mean discharge over the 6 months of about 50 m^3s^{-1}. The resulting power increment is then used for pumped storage, subject to commercial viability of selling this power to the Onslow scheme. The net hydrological effect is damping the Lake Pukaki water level fluctuations (Fig. 1). This has a useful side-benefit of educed Lake Pukaki spill loss: the model created no Lake Pukaki spill over the period 2000-2025. The Pukaki canal simulations gave a mean flow increase of 10 m^3s^{-1}, which is close to the time-averaged spill discharge from Lake Pukaki over the same time period.

The model is only a crude approximation. In particular, inflow into Lake Pukaki f om the Tekapo B station is lumped together with Pukaki natural tributary inflows. Also, water release to the Pukaki canal is assumed unconstrained by operational factors like water input from Lake Ohau.

Nonetheless, the Pukaki model's damping effect of the Lake Onslow scheme operation is likely to be a qualitative indication of actual future operations with Onslow, probably also replicated in Lake Taupo and other hydro lakes, reflecting eduction in seasonal electricity price variation. In addition, there is likely to be a tendency toward higher hydro lake levels generally because the Onslow scheme will unleash an overbuild of new wind and solar generating capacity.

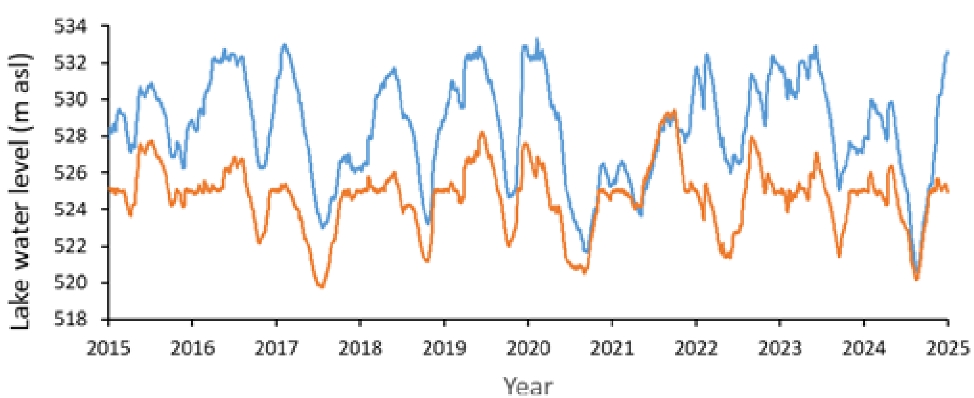


Figure 1: Lake Pukaki water levels for 2015 to 2025, as recorded (blue) and as simulated (orange).with greater water release at higher lake levels for an additional power component for pumped storage at Lake Onslow.

For the Clutha River (the lower reservoir), there is a corresponding variation in discharge, depending on the sequence of Onslow pumping/generation operations.

As a water resource, the scheme's large 3 km^3 water storage capacity could provide backup of Dunedin city water against extended drought. Similarly, a short rock tunnel would allow the option of providing additional water to the Taieri River for the duration of a future extreme drought.

METEOROLOGY AND FLOOD HYDROLOGY, PATEA HYDRO-ELECTRIC POWER SCHEME

Barrett-Garnier, O. O.
Riley Consultants limited

Riley Consultants Limited are updating the meteorology and flood hyd ology of the 870 square kilometer Patea Dam catchment in Taranaki, for Manawa Energy Limited (dam owner), with peer review from Tonkin + Taylor. This 82m high earth fill dam is the fourth highest in New Ze land, and retains the countries longest manmade lake. A robust understanding of the meteorology and flood hyd ology is required, to ensure the dams spillway facilities have adequate capacity to avoid overtopping of the High Potential Impact dam. An overtopping failiure could cause catastrophic damage to the environment, community and infrastructure downstream.

Manawa Energy collect a wide range of hydrological data within the Patea catchment. The presentation will touch on the meteorological datasets considered/selected for calibration of a hydrologic model (within HEC-HMS). As well as the methods used for deriving precipitation, losses, baseflow/g oundwater contributions, and routing through the reservoir. It will present the degree of calibration achieved, while also conveying the relative uncertainties with the selected datasets and methods. It will then outline challenges extrapolating the calibrated model and associated meteorology/hydrology, to assess design inflow events for the eservoir. These events vary from Annual Exceedance Probabilities of 1 in 100, to the Probable Maximum Flood.

1981 KERIKERI STORM, AND POSSIBLE MAXIMUM PRECIPITATION

Barrett-Garnier, O. O.
Riley Consultants limited

In 1981, the 170km^2 Kerikeri and Waipapa Catchments in Northland, experienced the largest rainfall recorded in New Zealand (outside the Southern Alps) over durations from 3 to 8.5 hours. Despite coinciding with a low tide, the rainfall caused the most significant flooding in the tchments since european development in the floodplain began in 1832 (the la gest flood in at least 200-years). The rainfall which caused th flooding was identified to be nationally significant, such that it could in ease 6 hour estimates of the Possible Maximum Precipitation in New Zealand, by 25%.

This presentation aims to share knowledge about the March 1981 event, and the meteorological and hydrological information subsequently collected. It will summarise previous reporting from NIWA (McKerchar and Ibbit, 2009), and the Ministry of Works and Development (Kooge, Thakar and Dymond, unpublished). It will highlight key unresolved questions, relating to short duration (less than 12 hour) estimates of Possible Maximum Precipitation in New Zealand (Thompson and Tomlinson, 1993). And it will present the effect, which the event currently has for rainfall and flood f equency estimates in the area.

SOME PITFALLS OF A RISK-BASED APPROACH TO ADAPTATION PLANNING FOR FLOODING

Rob Bell[1,2]
[1]Bell Adapt Ltd
[2] Environmental Planning Programme, School of Social Sciences, University of Waikato

Risk-based approaches, including risk treatment, have a long track record as a structured framework to managing risk that is supported internationally by ISO 31000 standards.

Increasingly, risk-based approaches have been applied to climate adaptation, particularly for flooding. Such an approach is embedded in the 2010 NZ Coastal Policy Statement and the 2024 MfE coastal guidance, with hazard and risk assessments and addressing the question "What can we do about it?" and "When?". Dynamic adaptive pathways planning, now commonly used as an adaptive and pre-emptive approach, is primarily informed by risk assessments and evaluation methods relative to risk or adaptation thresholds.

However, there are pitfalls in translating conventional risk analysis and treatments of time-varying risks (both extremes and progressive change), and in some cases for coastal lowlands, irreversible risks such as compound flooding.

Pitfalls, relying too closely on conventional risk-based "likelihood" approaches for adaptation planning, include: addressing ongoing increase in frequency and magnitude of hazards; deepening uncertainty and its estranged link with likelihood; tyranny of the urgent in prioritizing risks; common foci on just safety, critical infrastructure and economic values, rather than a systems view; and limited attention to compound coastal/pluvial/fluvial flooding and cascading risks that could expose   ladaptation.

A FRAMEWORK FOR USING MLOPS APPROACHES IN DECISION-SUPPORT MODELLING

Jeremy Bennett,[1] Tara Forstner,[2,3]
[1] INTERA Incorporated
[2] Waterways Centre for Freshwater Management, University of Canterbury
[3] Earth Sciences New Zealand

Aims
Decision-support modelling involves combining data, environmental simulators, uncertainty analysis, predictive scenarios, and visualisations to provide information for decision makers regarding key predictions (Doherty and Moore, 2020)groundwater modeling is generally aligned with the most difficult of these. It is suggested that these difficulties can generally be ameliorat d through appropriate model design. This design requires strategic abstraction of parameters and processes in a way that is optimal for the making of one particular prediction but is not necessarily optimal for the making of another. It is further suggested that the focus of decision support modeling should be on the ability of a model to provide receptacles for decision-pertinent information rather than on its purported ability to simulate environmental processes. While models are compromised in both of these roles, this view makes it clear that simulation should serve data assimilation and not the other way around. Data assimilation enables the uncertainties of decision-critical model predictions to be quantified and maybe educed. Decision support modeling requires this.","container-title":"Groundwater","DOI":"https://doi.org/10.1111/gwat.12969","ISSN":"1745-6584","issue":"3","language":"en","license":"© 2019 The Authors. Groundwater published by Wiley Periodicals, Inc. on behalf of National Ground Water Association.","note":"_eprint: https://ngwa.onlinelibrary.wiley.com/doi/pdf/10.1111/gwat.12969","page":"327-337","source":"Wiley Online Library","title":"Decision Support Modeling: Data Assimilation, Uncertainty Quantification, and St ategic Abstraction","title-short":"Decision Support Modeling","volume":"58","author":[{"family":"Doherty","given":"John"},{"family":"Moore","given":"Catherine"}],"issued":{"date-parts":[["2020"]]}}],"schema":"https://github.com/citation-style-language/schema/raw/master/csl-citation.json"} . Scripted groundwater model workflows a e commonly used in this context for their reproducibility, transparency, and flexibilit . These workflows, howeve , tend to be specific to particular contexts or predictions, which may obscure the underlying methods for data processing, model parameterisation, and uncertainty analysis. This specificity ca create difficulties when it comes to testing, validating groundwater modelling workflows, or adapting them to other types f predictions.

Machine learning operations (MLOps) refers to the systematic integration and continuous delivery of processes related to machine learning model development, training, deployment, and evaluation (Figure 1). While data integration and operational requirements are typically more extensive within MLOps than in groundwater modelling, the adoption of these methodologies has the potential to improve transparency, reproducibility, and efficiency in g oundwater modelling workflows, while supporting AIR (Findable, Accessible, Interoperable, Reusable) principles.

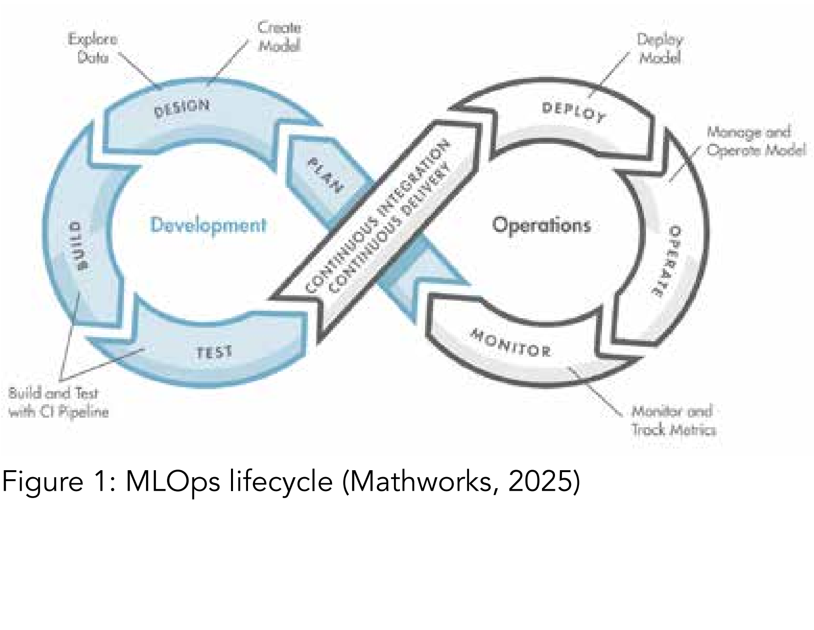


Figure 1: MLOps lifecycle (Mathworks, 2025)

Methods

We have developed a novel framework for decision support modelling that leverages MLOps paradigms with software engineering and data science tools. The decision support operations framework (DSOps) centres on the prediction (or decision) of interest and encapsulates the iterative process inherent in most applied groundwater modelling (Figure 2). The components of DSOps comprise:

- Data analysis, including data pre-processing and exploratory analysis
- Simulation design, including problem decomposition and simulation build
- Model development, including parameterisation, history-matching and uncertainty quantificatio
- Model operations, including predictive scenarios, monitoring and visualisation.

- The approach is intended to be agile, in that it is responsive to changes in predictions, data and model design.

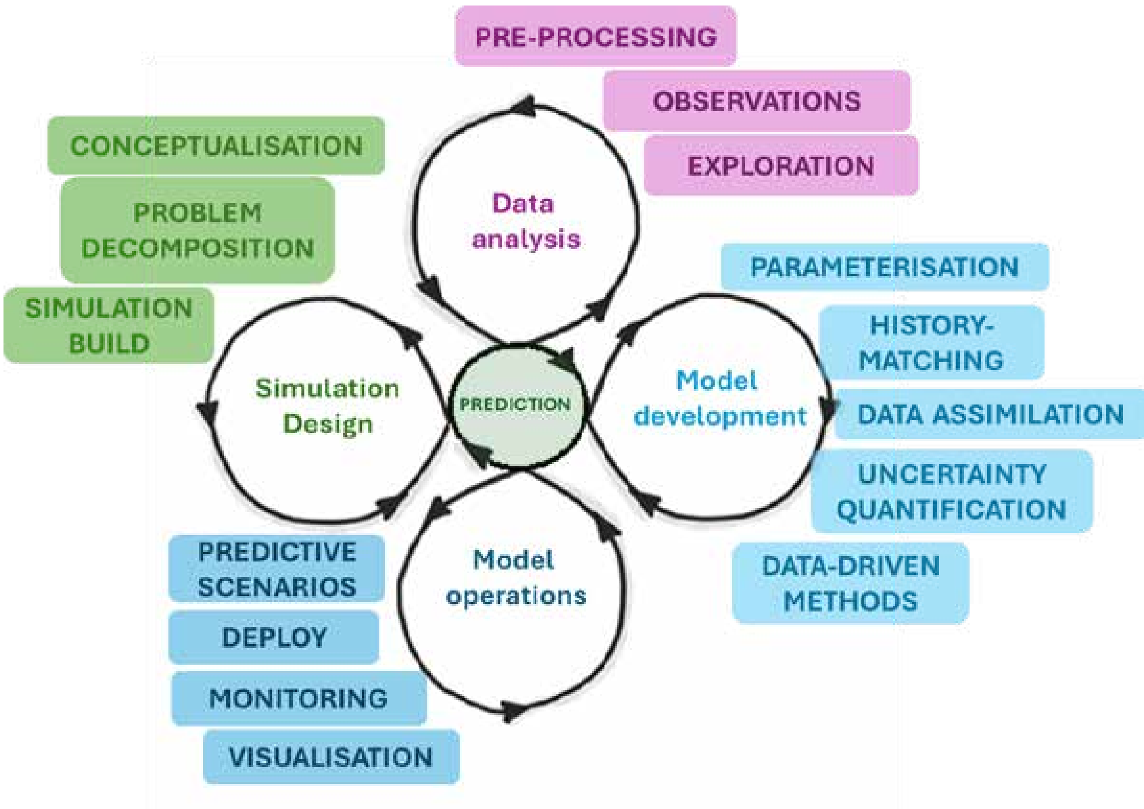


Figure 2: Decision support operations framework (DSOps).

Results

We have applied the DSOps framework to an example groundwater model using the data science tool Data Version Control (DVC, https://dvc.org/). We will demonstrate how DVC can support the decision support modelling applications, including versioning of data and models through experiments, as well as subsequent model use by modellers and decision makers.

References

Doherty, J., Moore, C., 2020. Decision Support Modeling: Data Assimilation, Uncertainty Quantification, and Strategic Abstraction. Groundwater 58, 327–337. https://doi.org/10.1111/gwat.12969

Mathworks, 2025. MLOps [WWW Document]. URL https://www.mathworks.com/discovery/mlops.html (accessed 8.15.25).

SIMULATING PAST AND FUTURE SNOWPACK DYNAMICS ON THE CRAIGIEBURN RANGE IN AOTEAROA NEW ZEALAND

Maya Berg[1], Nicolas Cullen[1], Jono Conway[2]
[1]University of Otago
[2] ESNZ

Maritime mountain snowpacks exist near critical temperature thresholds, where small warming causes disproportionate snow loss. The Craigieburn Range, in the lee of New Zealand's Southern Alps, supports five ski a eas despite marginal snow conditions. This study analyses past and projected changes in seasonal snowpack dynamics using the Flexible Snow Model (FSM2.0), driven by New Zealand Reanalysis (NZRA) data and validated with ski patrol records. A 26-year baseline (1992–2018) was used to simulate historical conditions and adapted for three Shared Socioeconomic Pathways (SSP1-2.6, SSP2-4.5, SSP3-7.0) to assess future variability.

Results demonstrate the sensitivity of this maritime snowpack: mean ski-season (July–September) air temperatures at ~1600 m a.s.l. rose from −1.8 °C (1990s) to +0.3 °C (2010s), crossing the freezing threshold. This warming coincided with a 40-day reduction in snow cover and a 58% decline in snow water equivalent. By 2100, snow cover days are projected to fall from 113 (1995–2014) to 56 (SSP2-4.5) or 36 (SSP3-7.0), while SSP1-2.6 stabilises at ~88 days by mid-century.

Although some near-term loss appears unavoidable, the growing divergence in emission scenarios after 2040, and the corresponding differences in seasonal snow outcomes, highlights the critical importance of climate mitigation in limiting long-term snow loss.

THE ROLE OF BEDROCK AQUIFER POTENTIAL CHARACTERIZATION IN UNDERSTANDING BASIN SCALE GROUNDWATER SYSTEM BEHAVIOUR: A CASE STUDY OF RUAMĀHANGA VALLEY, NEW ZEALAND

Berhe, DT.,[1] Stewart, GC.,[1] Westerhoff, R.,[1] White, P.,[1] Kellett, RL.,[1] Sahoo, TR.,[1] Herpe, M.,[1] Griffin, A.[1] Van Der Raaij, R.,[2]
[1] Earth Science New Zealand (GNS Science)
[2] Greater Wellington Regional Council

Objective

Groundwater is a vital component of New Zealand's freshwater system, contributing approximately 80% of surface water flo , primarily from shallow aquifers. However, increasing pressures from over-abstraction, vulnerability to contamination and climate change threaten the sustainability of these aquifers. Deep bedrock aquifers offer a promising alternative to shallow aquifers as an anthropogenic water source due to their potential climate resilience and capacity to augment water security while reducing ecological impacts. International research shows 60% of global groundwater is stored in deep systems (Gleeson et al.2016). This study investigates the potential of bedrock aquifers in the Ruamāhanga catchment, part of the Wairarapa coastal aquifer system (Begg et a. 2005). A desktop study and stakeholder engagement identified potential and strong interest in improving knowledge of deep aquifer resources despite limited technical familiarity.

Method

A comprehensive desk-based technical assessment was conducted, integrating multiple data sources and analytical techniques including machine learning algorithms. Outcrop geological formations were mapped from QMAP data (Heron 2023) and assigned representative hydraulic conductivity values based on literature, creating a spatially variable hydraulic conductivity map. To overcome limited deep borehole data, relationship between SkyTEM airborne electromagnetic resistivity and facies were established by training a machine learning algorithm (random forest classifier) to infer bed ock facies and conductivity beneath Quaternary deposits. Structural geological features (faults, folds, lineaments, and drainage) were incorporated via distance decay functions to refine hydraulic conductivity estimates along these zones, ackn wledging their influence on groundwater flo . Bedrock thickness was estimated by subtracting quaternary sediment thickness estimated from facies model from the gravity-derived basement depths and combined with conductivity to derive a transmissivity map. Groundwater storage was assessed by downscaling GRACE satellite-derived anomalies through a national residual gravity-storage relationship, enabling catchment-level estimation These three parameters (i.e., hydraulic conductivity, bedrock thickness, and groundwater storage) were integrated into a weighted Bedrock Groundwater Storage Potential Index (BGSPI) (Figure 1).

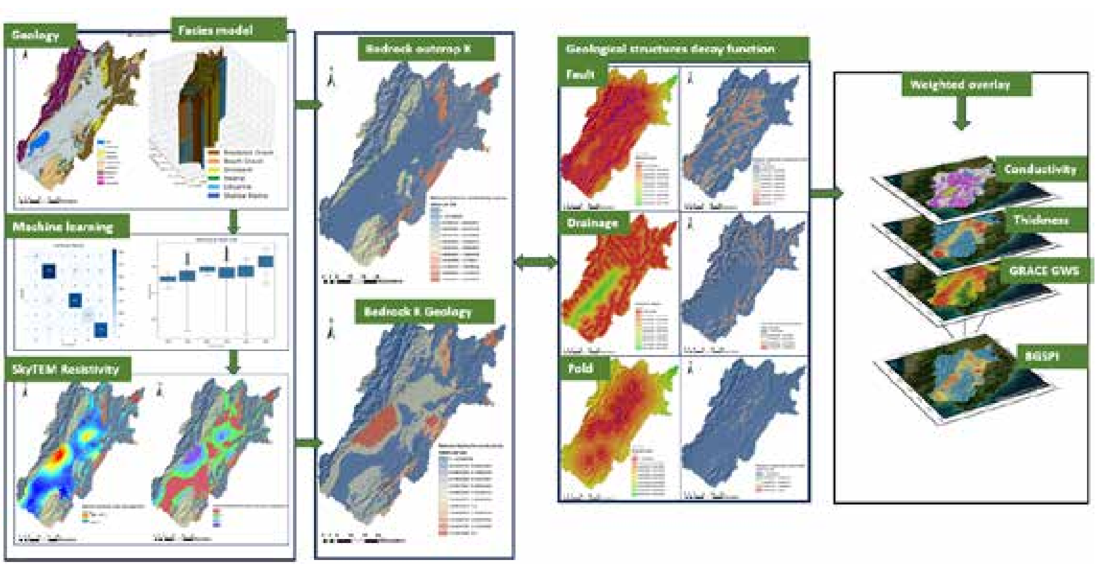


Figure 1. Method graphical abstract.

Results

When considering geophysical and remote sensing data it should be understood that the resulting products are models and are not a definitive map of g oundwater. This study identified potentially high bed ock groundwater potential storage zones in the west near the Wairarapa Fault, beneath Featherston, and localized areas around Gladstone, associated with permeable gravel conglomerates, limestone, and sandstone. Conversely, mudstone and greywacke dominated areas exhibited lower potential, except near major geological structures where moderate potential was observed (Figure 2).

While these findings highlight p omising bedrock aquifer targets, they are based solely on desk studies. Further field validation th ough ground geophysical surveys, electrical resistivity tomography, Ground TEM, drilling, and aquifer testing is essential to validate these estimates, in particular constraining aquifer properties and sustainable yields. At present the focus for water management in the Wairarapa is still the shallower unconsolidated units.

Bedrock aquifers may be present in parts of the Ruamāhanga catchment, and the current study is an approach to estimating their potential alongside the shallower unconsolidated aquifers. Combining geological, structural, facies, hydrogeological, geophysical, remote sensing data, and leveraging machine learning algorithms provides a pathway for improved sustainable groundwater management amid growing environmental challenges due to changing climate and land use.

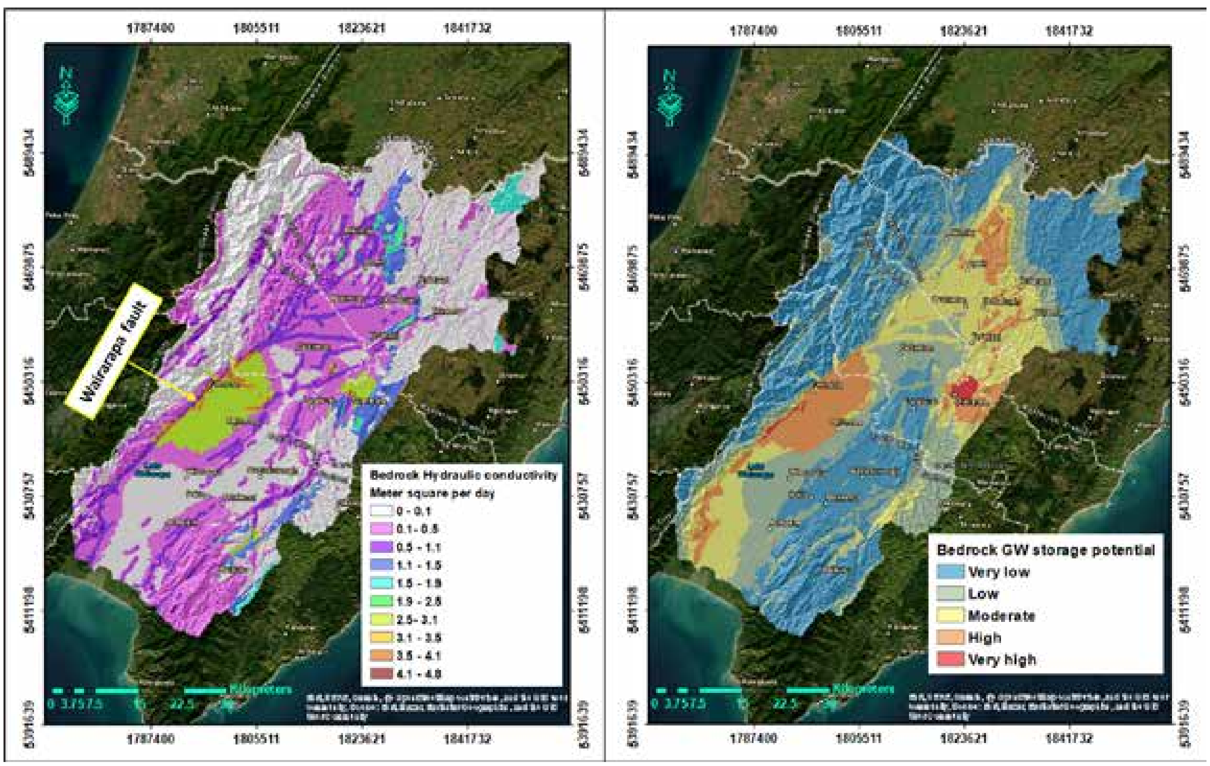


Figure 2. Spatial variability of bedrock hydrauliclic conductivity (left) and BGSPI (right).

References:

Gleeson, T.,Befus, K.M.,Jasechko, S., Luijendijk, E., and Cardenas, M.B.2016, The global volume and distribution of modern groundwater. Nature Geoscience 9(2):161-167

Heron, D.W. (custodian) 2023: Geological Map of New Zealand 1:250 000 (4th ed.) [digital data]. Lower Hutt (NZ): GNS Science. (GNS Science geological map; 1). https://doi.org/10.21420/5XTJ-5718.

Begg JG, Brown LJ, Gyopari M, Jones A. 2005. A review of the Wairarapa geology – with a groundwater bias. Lower Hutt (NZ): Institute of Geological & Nuclear Sciences. 34 p. Client Report 2005/159. Prepared for Greater Wellington Regional Council.

FLOOD MAPPING TOOLS: USING SYNTHETIC APERTURE RADAR (SAR) TO QUANTIFY FLUVIAL AND PLUVIAL FLOODING IN CANTERBURY (APRIL/MAY 2025 EVENT)

Biggs, H.J.[1]
[1] Earth Sciences New Zealand

Abstract
Synthetic Aperture Radar (SAR) satellites provide a valuable source of data for flood inundation mapping. Unlike optical satellites, they are able to operate at night and see through cloud cover, providing data at critical times during floods. ools for mapping fluvial and pluvial flooding have ecently been developed by Earth Sciences New Zealand and applied to mapping the April/May 2025 flood event in Canterbur . This event included significant flooding in Christch ch and throughout the Selwyn district, with severe impacts around Wairewa (Little River township). This talk shows how freely available SAR data (i.e. Sentinel-1) can be used to quantify fluvial/pluvial flooding and to investigate th recession of the flood event. It also discusses the strengths and weaknesses of flood inundation mapping f om SAR and the importance of SAR acquisition time. For dynamic flood events (i.e. fluvial flooding i asman) further work is needed to include tasking of commercial SAR satellite acquisitions to coincide with flood peaks, w ereas for large scale mapping of persistent surface water (i.e. slow recession following pluvial flooding in Selwyn) f eely available SAR data provides a valuable resource.

FLOOD MEASUREMENT SYSTEMS: STEREOSCOPIC CAMERA STATIONS, DRONES WITH RTK GPS, TOWED DEPTH SOUNDER SYSTEMS, AND AERIAL GPR

Biggs, H. J.,[1] Starr, A.,[1] Smith, B.,[1], Sutton, H.,[1] and Haddadchi, A.[1]
[1] Earth Sciences New Zealand

Aims
Flood discharge measurements are essential for various applications, such as developing stage-discharge rating curves, calibrating and validating flood models, issuing flood wa nings, and evaluating the impacts of climate change. However, accurately and safely conducting these measurements remains a challenge. The extreme flow conditions and the p esence of in-stream debris often prevents the use of traditional monitoring equipment like Acoustic Doppler Current Profilers (ADCPs) or tethe ed current meters deployed from bridges or cableways. Non-contact measurement methods, such as Surface Velocity Radar (SVR), surface image velocimetry using drones/UAVs, and oblique imagery from riverbanks, are becoming more common, but they still face significant challenges. Key issues include: aligning measurement timing with flood peaks, safely reaching flooded river sites during ext eme weather, conducting measurements in very wide rivers and floodplains (often equiring oblique drone measurements or nadir measurements in certain sections), cross-section changes during floods (due to sediment transport), nd setting up oblique camera stations with Ground Control Points (GCPs).

To tackle these challenges, Earth Sciences New Zealand are developing "Next Generation Flood Measurement Systems," which include: (1) stereoscopic camera stations for oblique surface image velocimetry in small streams and rivers (5-30 m wide), triggered by water level or time-lapse, and which do not require GCPs; (2) drones with Real-Time Kinematic Global Positioning Systems (RTK GPS) for nadir surface velocimetry in wide rivers and floodplains (30 m to >4 km); and (3) c oss-section measurements that coincide with surface velocity measurements, using echosounder systems towed by drones or aerial Ground/Water Penetrating Radar (GPR) mounted on drones.

Methods
Prototype stereoscopic camera stations were developed for the World Meteorological Organization (WMO) and deployed in Fiji to measure floods in emote locations (Figure 1: Left). These camera stations can be triggered by timelapse, triggered manually by local residents, or triggered by changes in water level when connected to a water level recorder. They have successfully provided the first flood flow mea ements at sites in the mountainous Rakiraki catchment, where access is cutoff during floods. This has helped to establish stage discharge rating curves for downstream flood wa nings.

Next generation stereoscopic camera stations have now been developed that include telemetry of stereoscopic image pairs for river monitoring and measurement of water level, and solar for long term deployments without requiring battery changes. To date, four of these camera stations have been built, with the first successfully deployed in the Selwyn River in Canterbu y.

Figure 1: Stereoscopic camera station deployment in Fiji at a remote gauging site where access is cutoff during floods (left). D one towed echosounder boat, with RTK GPS for origin and IMU for orientation (right).

To address the issue of concurrent cross section measurements during floods (Biggs, 2024) we a e developing two measurement systems that can be deployed from drones. The first measu ement system is a towed echosounder boat (Figure 1: Centre). It builds upon the work of Bandini et al., (2018) and Diaz et al., (2022), but offers significant advances by combining a dual f equency (200 kHz and 450 kHz) echosounder (Echologger ECT D24S), with RTK GPS (Emlid Reach M2) for echosounder origin and an IMU for echosounder orientation. This enables the echosounder beam to be projected in space to create a 3D point cloud from which the cross section is sampled. This accounts for echosounder beam angle near channel banks, as internal tilt correction is only valid for planar riverbeds. The system is light weight (less than 2 kg) so that it can be flown down onto the flooded river surface and lifted out of the water (Figure 1: Right) when debris approaches from upstream.

The second cross section measurement system is a lightweight Ground Penetrating Radar (GPR) antenna deployed on a drone (Figure 2: Top). This builds upon the work of Biggs, (2022), but with changing antenna orientation being used to filter out transient radar eflections not di ectly below the drone to increase the accuracy of cross section measurement near channel banks.

Finally, to overcome surface velocimetry measurement limitations in wide rivers, where fixed eference points at water level are typically needed (Figure 2: Bottom), we are developing methods for stitching together surface velocimetry imagery in sections. We are leveraging RTK GPS data for imagery origin and IMU data for orientation to project imagery onto the water surface.

Figure 2: MALÅ GeoDrone 80 aerial Ground Penetrating Radar (GPR) system (top left) for flood c oss section measurements (top right). Surface velocity measurements in sections in the Waimakariri River (bottom).

References

Bandini, F., Olesen, D., Jakobsen, J., Kittel, C.M., Wang, S., Garcia, M. & Bauer-Gottwein, P. 2018. Bathymetry observations of inland water bodies using a tethered single-beam sonar controlled by an unmanned aerial vehicle. Hydrology and Earth System Sciences, 22(8): 4165-4181.

Biggs, H.J. 2022. The Drone Flow User Guide, NIWA Report, Christchurch, New Zealand.

Biggs, H.J. 2024. Cross section measurement methods during floods for surface velocimetry: A eview of contact and non-contact methods. Envirolink Advice Report, Christchurch, New Zealand.

Diaz, A.L., Ortega, A.E., Tingle, H., Pulido, A., Cordero, O., Nelson, M. & Ifju, P.G. 2022. The Bathy-Drone: An autonomous uncrewed drone-tethered sonar system. Drones, 6(294): 1-19.

TRANSFER OF HYDROLOGICAL MODEL PARAMETERS TO UNGAUGED CATCHMENTS

Doug Booker[1], Jing Yang[1]
[1] Earth Sciences New Zealand, Christchurch

Lack of streamflow monitoring ac oss many catchments is a major challenge to hydrological modelling and water resource management. Despite the absence of observed flow time-series ungauged catchments experience demand for water abstraction or hydroelectric power generation, and face similar risks from drought, land use intensification, and climate variability as gau ed catchments. Scarcity of flow data limits the ability to accurately simulate hydrological processes to assess water availability and respond to emerging climate and land use pressures because model calibration cannot be applied without flow dat . Where observed flow data a e available, calibration is often used to produce sets of hydrological model parameters that optimise predictive performance. Hydrological models can also produce hydrological estimates at ungauged locations, but require numeric values to be set for their input parameters. In this talk we will describe a procedure to extend hydrological insights from gauged to ungauged locations. The procedure firstly involves cont olled calibration of a hydrologic model at 360 gauged catchments across New Zealand and then transferring calibrated model parameters to ungauged catchments. We will demonstrate whether hydrologic model results produced from parameters transferred to ungauged locations can be used for various applications because they give reasonable model performance.

REFRESH OF NWP OBJECTIVE VERIFICATION AT EARTH SCIENCES NEW ZEALAND

Jorge Bornemann[1], Stuart Moore[1], Trevor Carey-Smith[1], Phil Andrews[1]
[1]ESNZ

MET is a highly flexible and configurable verification toolkit weather and climate models, developed at the Developmental Testbed Centre (NCAR, NOAA, USAF) and used extensively around the word by research and operational NWP institutions. MET is the engine of METPlus, a framework for verification that incorporates Python scripts to provide an interface with MET, as well as other utilities to collate, explore and visualise results. MET and METPlus are open-source, written in C++ and Python respectively and benefit f om modern software development techniques.
The Momentum Partnership has chosen MET as the verification com onent of its Next Generation Modelling Systems. It will replace the verification systems of individual Partnership membe s, which are generally disjointed, often difficult to port ac oss sites and some times older than 30 years. A common verifica ion system for research will help the delivery of joint research activities, reduce technical overheads and enable comparison of results between different partner sites.
This presentation will cover the implementation of MET/METPlus at Earth Sciences New Zealand, describe the MET tools more relevant to us, show relevant results both in research and in operations, and outline the plans for expanding our pool of verification diagnostics

IMPROVING THE PERFORMANCE OF FLOOD FORECASTING MODELS BY REDUCING UNCERTAINTY IN RATING CURVES – A CASE STUDY FROM TE TAIRĀWHITI (GISBORNE DISTRICT)

Bridget Bosworth[1]
[1]Te Kaunihera o Te Tairāwhiti (Gisborne District Council)

Flood forecasting models need robust rating curves to ensure that simulated water levels are realistic. This paper focuses on how Gisborne District Council's work to improve confidence in rating curves at higher flows has benefited the distric s new flood fo ecasting model. It reviews conventional methods of defining high flows, as well as new technolog , specifically Space- ime Image Velocimetry (Hydro-STIV software) and hydraulic modelling. It examines the importance of understanding the uncertainty between observed and modelled data in the context of flood fo ecasting.
Calibrating a flood fo ecasting model is complex when there is out-of-channel flo , hysteresis and bypass flo . High flow gaugings can help info m rating curves, but there comes a point where bespoke modelling is required. Hydraulic modelling at one site has helped to inform the impact of out-of-channel flow on the rating curve.
New technology requires cross-sections which accurately represent the channel, but most river channels in the region are unstable. How channels change shape during flood events and he impact this has on flows is the focus of an Earth Sciences NZ (formerly NIWA) project, which GDC is contributing to.
Lessons learned from this work can help improve the performance of flood fo ecasting models throughout New Zealand.

HOW DO NEW ZEALAND'S DOWNSCALED CMIP6 CLIMATE PROJECTIONS COMPARE WITH CMIP5?

A.M. Broadbent[1]; P.B. Gibson[1]; A. Sood[1]; N. Rampal[1]; S.J. Stuart[1]
[1] Earth Science New Zealand, Wellington New Zealand.

We compare New Zealand's regional climate projections from NIWA's downscaled CMIP5 and CMIP6 datasets for two emissions scenarios (moderate, high) and two periods: mid-century (2031–2050) and end-century (2081–2100). Both project broadly similar patterns for annual rainfall, heavy rainfall, wind speed, and solar radiation, agreeing on a warmer future, generally drier in the northeast and wetter in the southwest. Differences emerge in magnitude: CMIP6 projects mean air temperatures 0.2–0.3 °C higher than CMIP5 by mid-century and 0.6–0.9 °C higher by century's end. Rainfall differences are notable, with CMIP6 projecting greater drying in the east and north—North Island rainfall is 5.5% drier than in CMIP5—and fewer dry days, more hot days, and reduced drought risk (based on potential evapotranspiration deficit). Sea onal and regional analyses show further contrasts, including wetter summers and drier conditions in other seasons under high-emissions scenarios by century's end. Differences stem from factors including bias-correction methods, equilibrium climate sensitivity, regional model design, and scenario definitions, with bias-cor ection identified as a key eason for CMIP5's lower warming. These findings p ovide stakeholders with clearer context for interpreting the updated CMIP6 projections in their regions.

USING THE PAST TO INFORM FUTURE RISK FROM RECORD-SHATTERING WEATHER

Adam Brown[1], Luke J. Harrington[1]
[1]Te Aka Mātuatua School of Science, University of Waikato

The 2012/13 New Zealand drought ranks among the most severe events in recent memory, with estimated economic losses at NZ$1.5 billion and increased likelihood attributed to anthropogenic climate change (Harrington et al., 2016). However, multiple historical droughts surpass this event in terms of both severity and duration. Here, we use daily precipitation data from NIWA's climate station network to delineate the spatio-temporal characteristics of the most severe past drought events across New Zealand. By constructing station-level climatologies and calculating multi-month precipitation anomalies and rankings, the relative severity of past events was assessed.

Results show extreme droughts occurred in 1907/08, 1945/46 and 1982/83, each lasting approximately four months (typically from November to February). A notable exception to this was the 1914/15 drought, exhibiting a prolonged duration due to the earlier onset of dryness from July 1914. Consecutive worst-on-record rainfall deficits we e recorded over the eight-month period from July 1914 to February 1915 for many stations, including the entire North Island. Similarly dry late-winter conditions were observed in 1993/94, leading to a significant water crisis in Auckland. The 1914/15 rought provides a useful foundation for developing storyline scenarios of future record-shattering droughts impacting New Zealand in the twenty-first century.

COMPOUND DROUGHTS IN NEW ZEALAND: LOW–FLOW DRIVERS AND PROCESS HETEROGENEITY

Sameen Bushra[1], Svenja Fischer[2], Markus Pahlow[1], Céline Cattoën[3]
[1] Department of Civil and Environmental Engineering, University of Canterbury, Christchurch, New Zealand
[2] Hydrology and Environmental Hydraulics, Wageningen University, Wageningen, The Netherlands
[3] Earth Sciences New Zealand, Christchurch, New Zealand.

Abstract
Low-flow events pose significant challenges to water esource management. Yet the seasonal variation of these events remains insufficiently understood. While summer low flows and oughts are often the primary focus, winter low flows can be equally or mo e severe. This study compares summer and winter low flows using the 100-year return period. The season with the smaller 100-year low flow is considered dominant, and the relative difference between summer and winter values is used to assess seasonal variability.
To investigate the climatic controls on low-flow seasonalit , the Standardised Precipitation Index (SPI), Standardised Precipitation Evapotranspiration Index (SPEI), and Standardised Temperature Index (STI) are used to evaluate associated climatic conditions and to understand the role of single and compound stressors. It was found that the dominant drought drivers vary by season, with an increasing presence of compound events involving multiple climate stressors.

The results address a limitation of conventional low-flow statistics, which is he reliance on annual aggregation. This conceals seasonal patterns and masks distinct low flow and d ought mechanisms. The season-specific analysis carried out in the cur ent work, combined with analysis of climate and catchment characteristics, provides insight into low flow dynamics and supports ta geted, climate-responsive water management under changing conditions.

AN OVERVIEW OF THE AQUIFER INTEL AOTEAROA REGIONAL WATER ASSESSMENT PROGRAMME

Cameron, SG[1]; Frances, J[2]; Pasco BN[3]
[1] Earth Science New Zealand (GNS Science)
[2] Saphron Consulting
[3] Tetra Tech Coffey

Aqua Intel Aotearoa (AIA) is a partnership between MBIE Kānoa - Regional Economic Development & Investment Unit (Kānoa - RDU) and Earth Science NZ, formally GNS Science, established in 2020 to undertake regional water storage projects. The programme evolved into a four-stage approach, with the first 3 stage due for completion by end December 2025:

- Stage 1: Describe water availability at regional level.
- Stage 2: Regional engagement and recommendation of specific water esource investigations in priority regions.
- Stage 3: Undertake physical investigations into water availability in the four regions through techniques such as airborne geophysical surveying, drilling investigations, and monitoring of surface water flows
- Stage 4: Identify potential funding sources and models to expand airborne geophysical survey to other regions.

A key objective of the Government at the time and thus the programme was to reduce data gaps and facilitate Maori land being brought into production.
This presentation provides a high-level summary of the water resource assessments undertaken in the Northland, Gisborne, Otago and Southland regions and some of the findings. It also p esents some of the challenges that programme encountered in terms of science deliverable along side community expectations and data sovereignty.

INCORPORATING HISTORICAL NON-STATIONARITY INTO HIRDS

Trevor Carey-Smith[1], Sam Dean[1], Stephen Stuart[1], Dáithí Stone[1]
[1]Earth Sciences New Zealand, Wellington

Previous and current versions of the High Intensity Rainfall Design System (HIRDS) have treated historical rain gauge observations as if they were from a stationary climate. This is a common approach when dealing with extremes as long-term trends derived from relatively short records can be easily distorted by individual large events. Despite the non-stationary assumption being applied in the past to ensure robust design rainfall estimates, this is becoming increasingly untenable due to the continued acceleration of climate change and its corresponding effects on extreme precipitation.

Here we describe initial analysis being conducted as part of Phase 1 of a HIRDSv5 update, where possible methods of including non-stationarity are assessed for their ability to capture observed trends in extreme rainfall while ensuring the resultant design estimates remain robust.

LESSONS FROM 2023: THE YEAR OF STORMS

M. P Cave[1]
[1] Gisborne District Council

2023 was a difficult year for the Gisbo ne-Tairawhiti region with eight severe storms and several irritating ones hitting the region. As a result of those storms, in particular, Cyclones Hale and Gabrielle, and the June and November 2023 storms, thousands of landslides were generated in rural areas, many houses were flooded and some damaged by landslides. The region had one direct fatality and 22 near misses in 14 life threatening incidents.

We thought we were well practiced and prepared. We'd identified Cyclone Gabrielle days out and had mobilised civil defence and had personnel from adjacent districts that were unlikely to be impacted on site before the storm arrived. But we were not and could not be fully prepared and that's OK; a perfect response is not possible but in the context of the scale of the event we did okay.

But a few lessons were learnt. It was the first time in several years that our flood w   ning manual was severely tested and some gaps identified and subsequently ectified following an independent eview. Our flood warning system was bespoke (a.k.a. inhouse and not fit for purpose for an event of that scale) but we have now upgraded to a state-of-the-art system. We had little understanding of the threat to life posed by severe storm events but we have undertaken work to address this issue.
But significant gaps emain.

- There was limited inter-regional operability and visibility of adjacent out-of-region rain gauge data real-time; a real time (nowcast) view of rainfall was seen as essential and has since been addressed.
- Rain radar coverage remains inadequate;
- The does not appear to have been a concerted or coordinated process to document and understand the events of 2023 at a national level. Climatologically we don't fully understand what happened in 2023 (for us, January Revive Festival storm, January Cyclone Hale, February Cyclone Gabrielle, February Son of Gabrielle, June 2023 storm, September 26th storm, October 30-31st storm and November 25-26th storm).
  If we don't have a good understanding of what happened in the year of storms in 2023, how can we prepare for the next series of severe storms?
  The question I pose is;
  Whose job is it to prepare us for the next year of storms?

SENSOR DATA PIPELINE AND TIME SERIES OPERATION IN THE CLOUD

Bryce Chen,[1] Ruotong Wang[1], Jochen Schmidt[1], Chen Wang[1]
[1]New Zealand Institute for Earth Science

Abstract

We present our approach for environmental sensor data ingestion and running the modern data pipeline on the cloud. We leverage from existing AWS services such as IoT Core, Transfer Family, S3, SNS, EC2 and Kinesis Data Stream to create real-time sensor data pipeline which could potentially serve multiple downstream applications required real-time capability such as anomaly detection and nowcasting. We make use of S3 as the intermediate data storage and MongoDB Atlas as the final storage des ination for scalability and efficienc . We present our infrastructure set-up to modernize sensor data QAQC process and anomaly detection, making use of AWS EC2 and SageMaker machine learning pipeline. For anomaly detection solution, we present the implementation of our detection algorithms, methodologies including MLOps procedures for production-ready operation in the cloud, leveraging from latest technologies. Last but not least, we present the use of Model Context Protocol (MCP) server in MongoDB to streamline our day-to-day operation, data analysis and data discovery. MCP is a framework which standardizes how AI models like Large Language Models (LLMs), access and interact with external data and tools. We specifically implement MongoDB MCP server as an AI assistant to alleviate human workloads on data curation and exploration.

THE ROLE OF MARINE HEATWAVES IN AMPLIFYING COMPOUND WEATHER EXTREMES IN NEW ZEALAND

Matthew Chinappa,[1] Luke Harrington,[1] Hamis Lewis,[1,2] Peter Gibson[2]
[1]The University of Waikato, Hamilton, New Zealand
[2]National Institute of Water and Atmospheric Research

This study analyzes 40 years (1984–2024) of marine heatwave (MHW) characteristics around New Zealand (NZ), emphasizing their physical drivers and cascading impacts on extreme weather. Using satellite SST and reanalysis data, we identify a pronounced northeast-southwest gradient in MHW frequency, duration, and intensity, driven by boundary current dynamics (e.g., East Australian Current extension), mesoscale eddies, and atmospheric modes (SAM, ENSO). The Tasman Sea emerged as a hotspot, with MHW frequency increasing by 46–106 events and durations extending to 257 days. A mixed-layer heat budget analysis of the record 2017/18 MHW (152 days, +3.1°C peak) revealed surface heat flux dominance (shortwave radiation >70%), accumulating ~20°C excess heat. Critically, this event triggered compound extremes: persistent atmospheric blocking (SAM +1.73) and anomalously warm SSTs (+3.7°C) amplified northeasterly moistu e advection, suppressing rainfall initially but later fueling extreme precipitation via ex-tropical cyclones (e.g., Fehi). The MHW-ocean-atmosphere coupling intensified land temperatu es (NZ's hottest summer: +2.2°C), with Tmax anomalies ranking among the top 5% in 40 years. CMIP6 projections indicate a 300% rise in MHW frequency by 2050, heightening risks of concurrent heat-drought-flood events. This study undersco e MHWs as amplifiers of weather ext emes in NZ's unique oceanographic setting, necessitating adaptive strategies for vulnerable coastal systems.

MODELLING GROUNDWATER DISCHARGE AND SALTWATER INTRUSION AT POCKMARKS IN THE WELLINGTON HARBOUR

Connor Cleary,[1,2] Jeremy Bennett,[3] David Dempsey,[1] Leanne Morgan[4]
[1]Department of Civil and Environmental Engineering, University of Canterbury
[2]Kōmanawa Solutions Ltd
[3]INTERA Inc.
[4]Waterways Centre, University of Canterbury

Aim

Submarine springs at seafloor pockmarks in the ellington Harbour discharge groundwater from the Hutt Valley aquifer system, and are thought to be a possible preferential pathway for seawater intrusion. However, the rate of discharge at these pockmarks is not well constrained, and consequently, the magnitude of potential seawater intrusion. This means that the risk of seawater intrusion through these pockmarks is not well understood. This study aims to assess the uncertainties around groundwater flow at pockmarks using the Wellington Harbour as a case study.

Methods

A 3D, variable-density numerical groundwater model was built for a subregion of the Wellington Harbour near the Hutt River mouth, where a cluster of pockmarks is located approximately 1 km offshore. The model structure is based on the regional geological model (Begg, 2023), to which a high-resolution bathymetry is incorporated (Figure 1). An unstructured grid was created with the Leapfrog Geological Modelling Software, including local grid refinement to captu e pockmark structure in high detail. Aquifer parameters and boundary conditions were derived from the existing HAM5 regional groundwater model (Bennett et al., 2024) and available data. The MODFLOW 6 model was run for the present day for three different conceptual models of pockmark structure (Figure 2a), which were then compared to observations of discharge (Harding, 2000) and salinity (Hoffmann et al., 2023). Aquifer depletion (i.e via onshore pumping) and sea-level rise scenarios were simulated for each conceptual model.

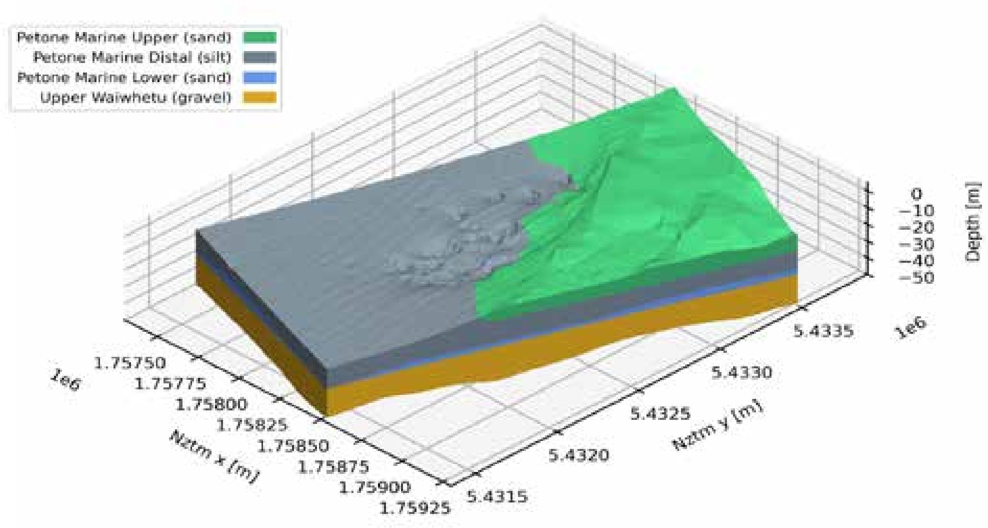


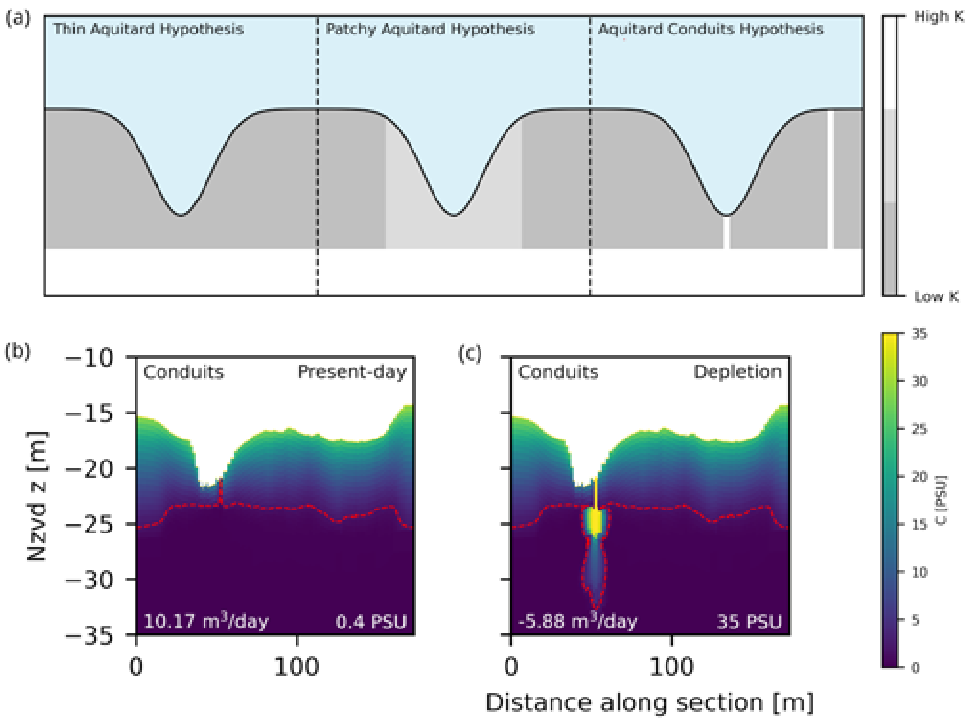
Figure 1: Geological model of the study area incorporating high-resolution bathymetry.

Results

For the Thin Aquitard model, groundwater was found to be discharged at the highest rate, and the lowest salinity was predicted around the edge of shallow pockmarks, or at the base of deeper pockmarks. Comparing existing observations to the three conceptual models, measured salinities were able to be produced with the Thin and Patchy Aquitard models, while the flux measu ements were able to be produced by the Aquitard

Conduits model. The greatest rate of submarine groundwater discharge and reduction in discharge under sea-level rise occurred in the Aquitard Conduits model (Figure 2b). Likewise, during significant aquifer depletion, the greatest seawater intrusion into the underlying aquifer occurred in the Aquitard Conduits model (Figure 2c).

Figure 2: (a) Conceptual models of pockmark hydrogeology. (b) Present-day conditions at a pockmark featuring a conduit. (c) Seawater intrusion through a conduit.



This study demonstrates the importance of model conceptualisation on the prediction of submarine spring discharge dynamics and provides useful insights for modelling and managing seawater intrusion risk in coastal environments.

References

Begg, J. (2023). Revised 3D Geological Model of the Lower Hutt Valley (RLHGM) (Tech. Rep.). J Begg Geo Ltd.

Hoffmann, J. J. L., Mountjoy, J. J., Spain, E., Gall, M., Tait, L. W., Ladroit, Y., & Micallef, A. (2023, August). Fresh submarine groundwater discharge offshore Wellington (New Zealand): hydroacoustic characteristics and its influence on seafloor geomorpholo . Frontiers in Marine Science, 10 , 1204182.

Harding, S. J. (2000). The characteristics of the Waiwhetu artesian aquifer beneath Wellington Harbour including the spatial distribution and causes of submarine spring discharge (Unpublished master's thesis). Victoria University of Wellington.

Bennett, J.P., Gyopari, M.,& Moore, C. (2024). Hutt Aquifer Model, 5th Revision: Final Technical Report (Tech. Rep). Prepared by Tonkin & Taylor for Wellington Water Ltd.

ESTIMATING ASSET EXPOSURE TO SEA-LEVEL RISE INDUCED WATER TABLE RISE ACROSS NZ USING LOCAL-SCALE MODELS

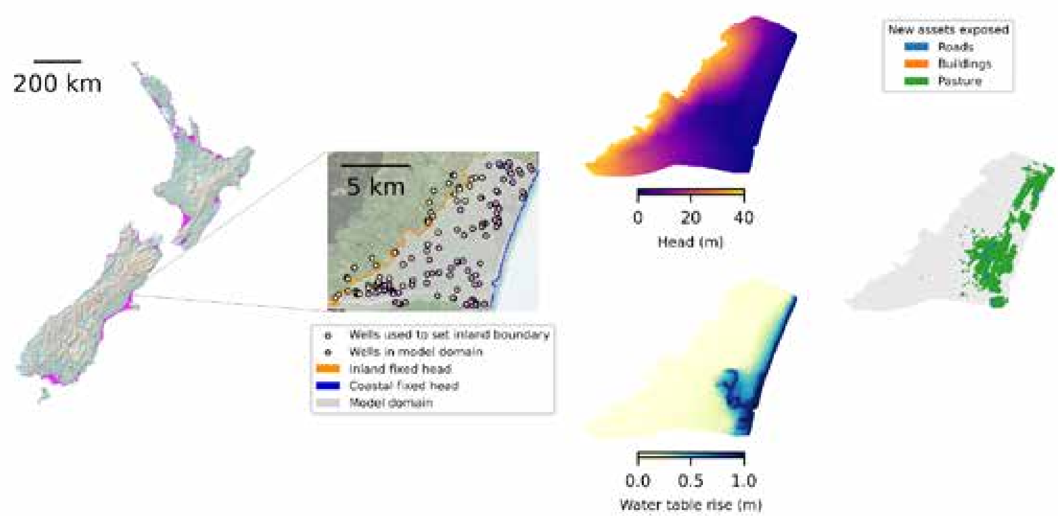
Connor Cleary,[1] Matt Dumont,[1] Zeb Etheridge[1]
[1]Kōmanawa Solutions Ltd

Aim

There is a need to understand the extent of exposure to sea-level rise-induced water table rise of assets such as buildings, roads, and pasture at a national scale. A challenge to predicting this is that the model/s used must be sufficiently simple to educe computational expense, while also representing the relevant physical processes. Water table rise following sea-level rise is influenced by the t pography and surface water features of the coastline (Michael et al. 2013), the hydraulic conductivity, and the diffusivity (related to the lag between rising sea-level and groundwater level, e.g. Bosserelle and Morgan, 2025) of the groundwater system. The amount of rise may also be limited by the initial location of the water table before sea-level rise occurs.

Methods

We carried out a nationwide assessment using hundreds of simple, local-scale, numerical models of areas that are known to have shallow groundwater occurrence or that are at risk of shallow groundwater hazard exposure. After initially delineating our proposed areas of interest, we engaged regional councils and territorial authorities to increase the coverage of our models. This ensures that the assessment can provide information where it is needed most.



The modeling framework follows that of Befus et al. (2020), which uses a fine disc etisation. The use of a fine discretisation ensures that topographic lows, which limit water table rise, are captured in the model surface. The models have a single layer, are informed by current depth-to-water measurements, and are run to a steady state for different sea-level rise increments. Models are uncalibrated; however, realisations are run for an a priori range of hydraulic conductivities, recharge values, and inland boundary conditions. Comparisons of the modelled water levels to depth-to-water data for each of these realisations provide a basis for reducing the uncertainty of the predictions. For each sea-level rise increment, asset exposure is extracted based on depth-to-water thresholds.

Figure 1: Methodology to assess asset exposure to shallow groundwater hazard.

Results

Preliminary results show that water-table rise and asset exposure are most sensitive to the value chosen for recharge and hydraulic conductivity, whereas little sensitivity was found to the inland boundary water level. The sensitivity to recharge and hydraulic conductivity varied between asset classes, likely caused by the different exposure thresholds for each class. Asset exposure also differed across the domains, which is influenced by the size of the domain, the amount and distrib tion of assets, and the hydrogeological conditions (Figure 2). Early results suggest that calibration of models to depth-to-water data via rejection sampling or other means may reduce the uncertainty of exposure estimates; however, the amount of reduction will likely vary between asset classes.

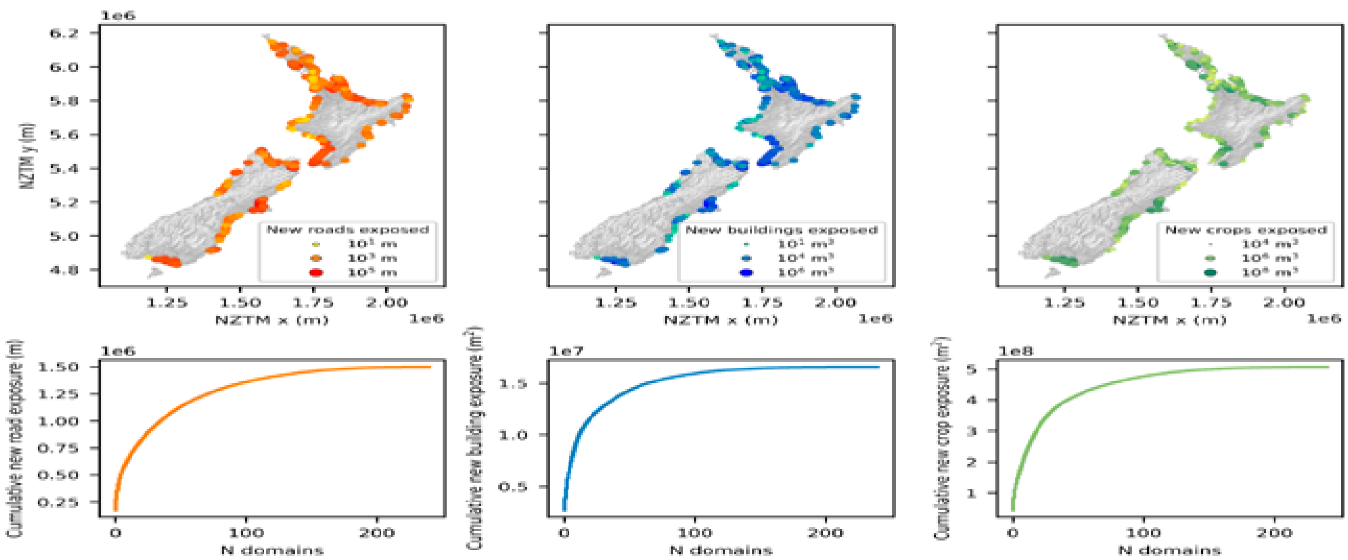


Figure 2: Preliminary estimate of assets newly exposed to shallow groundwater hazard under 1 m sea-level rise.

References

Befus, K. M., Barnard, P. L., Hoover, D. J., Finzi Hart, J. A., and Voss, C. I. (2020). Increasing threat of coastal groundwater hazards from sea-level rise in California. Nature Climate Change, 10(10):946–952.

Bosserelle, A. L. and Morgan, L. K. (2025). Transience of Coastal Water Table Rise in Response to Sea-Level Rise. Groundwater.

Michael, H. A., Russoniello, C. J., and Byron, L. A. (2013). Global assessment of vulnerability to sea-level rise in topography-limited and recharge-limited coastal groundwater systems. Water Resources Research, 49(4):2228–2240.

FORECASTING INUNDATION MAPS IN REAL-TIME WITH MACHINE LEARNING

Deidre M. Cleland[1], Céline Cattoën-Gilbert[1], Richard Measures[1]
[1]Earth Sciences New Zealand, Christchurch

Flooding is the most frequent natural disaster both globally and in New Zealand. When forecasting flood impacts, predicting river flows alone is insufficient. Inundation maps e the most effective tool for guiding evacuations, informing emergency management, and clearly communicating risk. However, the hydrodynamic modelling required to generate these maps is computationally intensive and too slow for real-time predictions. In this work, we present a machine learning (ML) surrogate model capable of predicting hourly inundation maps over a 5-day forecast horizon, in real time.

This ML model has been developed using Westport as a case study. Westport is highly susceptible to compound flooding f om simultaneous fluvial and coastal drivers, and has experience significant floo impacts in recent years, including "red alert" heavy rainfall warnings in July 2021 and twice in February 2022. We show how a ML model can be trained using a library of pre-computed scenarios that span a wide range of river flow and sea level combinations. e demonstrate the potential of our ML model through application to a diverse set of test flood events as well as ensemble fo ecasts for the July 2021 Westport flood. Additionall , we present ongoing work to generalise this approach across other flood-p one regions.

CLIMATE CHANGE RISK ASSESSMENT FOR THE URBAN ŌPĀWAHO/HEATHCOTE CATCHMENT, CHRISTCHURCH

Collins, D.B.G.
Pūtahi Research

Aims

As the impacts of climate change become more pronounced, and communities become more concerned by the impacts, there is a growing need to develop and implement climate change mitigation and adaptation strategies. These strategies, in turn, are underpinned by climate change risk assessments, which synthesise how climate change is affecting or may affect hazards and opportunities, and communities' exposure and vulnerabilities to these hazards. Assessment details and scopes need to be commensurate with the community's decision-making capacity, which have multiple layers of complexity in urban settings. The purpose of this study is to develop a first pass climate change risk assessment for the urban Ōpāwaho/ Heathcote River in Christchurch, with a focus on the natural and human systems directly connected to the catchment's streams, river, and estuary.

Methods

The climate change risk assessment reviewed and synthesised published material with bearing on the natural and human systems overtly connected to the river. This included an environmental history of the area, descriptions of its current state, and projections of potential climate change impacts. While no new modelling was carried out for the study, inferences were drawn from studies of other locations or at larger scales in order to help fill in knowledge gaps, whe e valuable and defensible. The risk assessment culminated in mitigation and adaptation considerations for the catchment and its communities.

Results

The Ōpāwaho catchment has been shaped and reshaped by a myriad of natural and human processes over time. They include volcanic eruptions, sea level fluctuations, inland erosion, human settlement, colonisation, urbanisation, hazard management, and restoration. Today, the river is a defining featu e of southern Christchurch, with a variety of values for members of the community, as well as the notable hazards of flooding and poor water qualit .

With projected changes in the climate system, plausible risks to the catchment include:

- higher estuary and groundwater levels
- an upstream shift in saline conditions and tidal influenc
- greater sediment load, higher water temperatures, and shifts in water quality
- shifts in habitat suitability, spawning sites, and food gathering
- more extreme and frequent flooding
- disruption and damage to infrastructure and the community's presence and activities within the catchment

These risks range from highly likely and relatively unavoidable (e.g., estuary level rise), to likely but manageable (e.g., flooding), to possible but contingent on othe factors (e.g., catchment erosion and sediment load).

In response and in anticipation, the community will and may face a number of decisions in the years and decades to come. All will be underpinned by ethics and finances Firstly, it is valuable to retain mitigation alongside adaptation as reasonable climate actions, and several options help to meet both goals. Options include: making room for the river; restoring river ecosystems; building and restoring the catchment's absorptive capacity; reducing urban and industrial pressures (e.g., pollution control, denser housing, lower intensity transport); and future-proofing wastewater and transport infrastructu e. When it comes time for the community to deliberate on a climate change strategy, this and many other analyses will be of use.

THE ART (AND SCIENCE) OF NEW ZEALAND'S WATER CYCLE

Collins, D.B.G.
Pūtahi Research

Aims

The issues of flooding, water sca city, and climate change are applying increasing pressures for communities to engage with hydrological and climate sciences. Among the challenges facing science and policy communicators in supporting this is the need to establish a personal connection between non-technical audiences and data, to spark curiosity, and to foster an emotional reaction often as a precursor to more cerebral reactions. Incorporating art in these discussions has been gaining increasing traction as a way to help achieve these communication goals. At the same time, researchers are increasingly using historical artworks, in a way as proxy data, to infer environmental and climatic change. This project sought to use existing historical and contemporary artworks as a means of supporting community engagement with science and policy relating to the water cycle and hydrological change.

Methods

Artworks were identified f om online gallery and museum catalogues, past art-science project material, and private collections. In selecting artworks, consideration was principally given to how well they depicted or explored different components of the water cycle, with other criteria being diversity of the artists, artwork age, artistic materials and styles, subject location, potential for narrative interest, and any necessary permissions from the artist, artist's estate, or current owner. Building up narrative interest and scientific insight was mo e ad hoc, variously tying the artworks to current or historical events, archival news coverage, literature and poetry, or basic hydrological literacy.

Results

Given New Zealand's long history of landscape painting, scenes featuring different components of the water cycle were generally easy to identify. They start with some of the earliest paintings in NZ that date to Captain Cook's 1773 visit to Dusky Sound, featuring an iconic waterfall. Two subjects that received less artistic attention were irrigation and groundwater. Among the artworks selected were:

- A painting of rainfall over Ashburton, with the paint applied in such a way as give a visceral sense of both wet and cold.
- A typically sombre oil painting of the Ōtira River by Petrus van der Velden, painted after the loss of a travelling companion due to a severe June snowstorm.
- A watercolour of a 1947 Southland flood depicting the immensity of the inundation and the impacts to the local community.
- A print of the Canterbury Plains that depicts the geometry of agricultural fields befo e the rise of centre pivot irrigation.
- Two works depicting hydropower schemes, one before and one after the birth of New Zealand's environmental movement.
- A print depicting human appropriation of the water cycle, within the saucer of a gravy boat.
- Paintings by Colin McCahon with his characteristics writing that can spark as much reflection as the pictu ed scene.

Taking individually or as a group, artwork depicting the water cycle can help audiences connect with hydrological science and related policy.

PROGRESS SIMULATING SEASONAL SNOW ACROSS AOTEAROA

Jono Conway[1], Yinjing Lin[2], Matt Wilkins[3], Pascal Sirguey[4], Stuart Moore[2], Amir Pirooz[5], Richard Essery[6], Céline Cattoën[3], Todd Redpath[7], Trevor Carey-Smith[2], Rasool Porhemmat[3], Nicolas Cullen[4], Doug Booker[3].
[1]Earth Sciences NZ, Lauder; [2]Earth Sciences NZ, Wellington; [3]Earth Sciences NZ, Christchurch; [4]University of Otago, Dunedin; [5]Earth Sciences NZ, Auckland; [6]University of Edinburgh, Scotland; [7]Interpine Innovation, Rotorua.

Seasonal snow has a significant e fect on hydrology and climate across large parts of Aotearoa. Snow accumulation and melt modulates seasonal patterns streamflo , while also altering heat and moisture fluxes into the lower atmosphere. A robust understanding of past and future hydrology and climate resources and hazards, therefore, depends on an accurate representation of snow processes in modelling and analyses. Despite these effects, snow remains under observed; invaluable data from in-situ monitoring sites are scarce and complex terrain hampers direct retrievals of important snow properties such as snow water equivalent (SWE) from satellites. In this context, snowpack models in combination with numerical weather prediction model output and satellite snow cover datasets provide new opportunities to improve estimates of snowpack properties at scales relevant to water resources and hazards. Here we present progress on several strands of work including i) quantifying seasonal patterns and trends in snowmelt contribution to streamflow f om 1990-2025, ii) assimilation of satellite snow cover data into historical snow simulations, and iii) mapping SWE in marginal snow environments using satellite-derived snow depth maps and climatological snow density curves.

SEARCHING FOR GROUNDWATER RESILIENCE SOLUTIONS: DEVELOPMENT OF A CANTERBURY PLAINS CASE-STUDY

Dark A.L.,[1] Weir, J.J.,[1] Moore C.R.,[2] Kitlasten, W.,[2] Ford, S.[3]
[1] Aqualinc Research
[2] Earth Sciences New Zealand
[3] The Agribusiness Group

Aims
Many rural communities in New Zealand depend on groundwater for irrigation, and often the groundwater system is linked to surface waterways. Therefore, improving the health of surface waterways may negatively impact groundwater availability. This project, funded by MPI's Sustainable Land Management and Climate Change (SLMACC) programme, develops practical water management solutions to assist with the challenge of increasing the resilience of rural businesses and waterway health in the face of climate change and variability.

Prompted by evidence that the low-flow egime of groundwater-dependent surface waterways is not being maintained by the current approach to managing groundwater allocation, previous work by Bright et al. (2023) found that allocation policy options that are the most effective in terms of increasing river and stream flows during summer/autumn significantly educe groundwater supply security. Implementing such policies to improve stream flows would esult in a significant eallocation of climate-related risk such that more risk would be borne by the primary sector. This would have both economic and social impacts.

We are seeking optimal adaptation solutions for improving rural groundwater users' resilience to lower water supply reliability when faced with water allocation policy changes and a changing climate.

Methods
To identify the efficacy of potential management solution op ions, a hydro-economic framework has been developed, encompassing:

• a MODFLOW model of a sub-zone of the central Canterbury Plains (Figure 1), set up in a way that allows pumping rates and depths and recharge rates to be varied, reflecting changes to water sou ces and abstraction regimes,
• economic response functions describing the relationship between water supply reliability and farm revenue for current and potential land-uses in the study area,
• unit cost estimates for infrastructure solutions such as water storage and bore deepening,
• relationships between water supply reliability, irrigation system capacity and water storage requirements,
• empirical habitat functions to indicate the efficacy of flow egime changes that can be achieved,
• Python code that links the above components.

A multi-criteria optimisation under uncertainty (MOU) approach will be implemented with PEST++ to explore the tensions between achieving economic and environmental objectives for different combinations of water management solutions. The MOU approach will allow us to test the balance between restoration of stream flows and water levels, and the costs of di ferent combinations of adaptation options (or the economic impact of doing nothing in the face of decreasing water availability).

The MOU optimal solutions will be identified ac oss the multiple options identified for surface water and groundwater management. The objective functions in the MOU algorithm will be designed to find solutions which deliver sufficient water supply eliability to ensure economic resilience, where this depends on water use, while giving effect to Te mana o te Wai (TMOTW) under projected future climates.

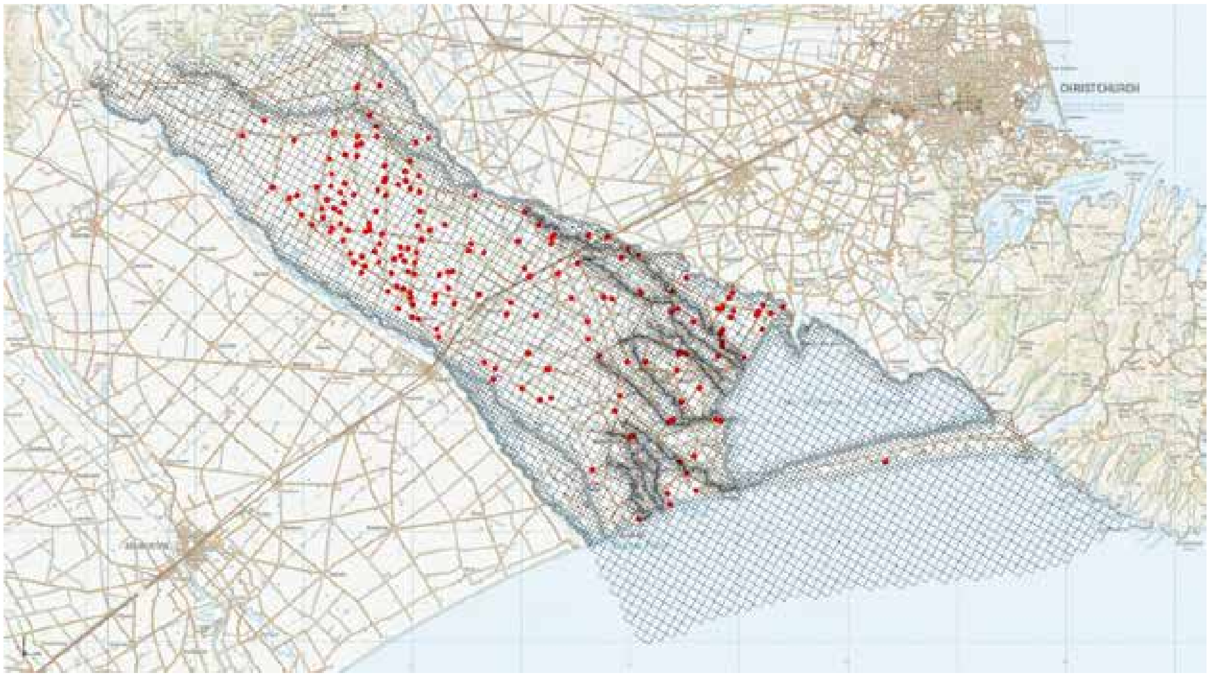


Figure 1: Case-study model domain

Results

Work on the project to-date has been focussed on setting up the "building blocks" required to search for optimal water management solutions, including history-matching of the MODFLOW model.

The range of potential solutions, and their relevance to the case-study area, has been explored with a stakeholder group (including Ellesmere Sustainable Agriculture, Te Taumutu Rūnanga, Central Plains Water Ltd and ECan).

Current work is focused on setting up the MOU framework.

Next steps entail generating an initial iteration of an optimised combination of adaptation options, with results compared to baseline data. These results will be explored with the stakeholder group, with feedback taken into a second iteration.

References

Bright, J., Dark, A., Weir, J, Alexander, J. 2023. Agile Adaptive Water Allocation Policy. MPI Technical Paper No: 2023/14, Prepared by Aqualinc Research Ltd.

HIGH-RESOLUTION SIMULATION OF TROPICAL CYCLONE DEBBIE (2017): THE CURRENT AND FUTURE CHANGES IN THE INNER-CORE STRUCTURE AND EVOLUTION DURING OFFSHORE RAPID INTENSIFICATION

Difei Deng[1]
[1]School of Science, University of New South Wales

Abstract

Tropical Cyclone Debbie (2017) made landfall near Airlie Beach on 28 March 2017 causing 14 fatalities and an estimated US$2.67B economic loss and was ranked as the most dangerous cyclone to hit Australia since TC Tracy in 1974. In addition to the extreme flooding as TC Debbie moved onsho e and down the east coast of Australia, it intensified rapidly just o fshore from Category 2 to Category 4 in approximately 18 hours and finally made landfall as a Category 4 TC

A high-resolution WRF simulation (1-km horizontal, and 10-min temporal resolution) is used to analyze the inner-core structure and evolution during the offshore rapid intensification period in the cur ent conditions and potential future change. In current condition, Debbie's a rapid intensification stage is characterized by three rounds of eyewall breakdown into mesovortices and re-development events. Each round of breakdown and re-establishment brings high potential vorticity and equivalent potential temperature air back into the eyewall, re-invigorating eyewall convection activity and driving intensification. The potential futu e changes in the eyewall evolution will also be discussed using WRF with the Coupled Model Intercomparison Project Phase 6 (CMIP6) perturbed conditions to better assess the possible TC intensity change under different climate change scenarios.

AOTEAROA'S FIRST PALEOCLIMATE DEBATE: MAKING SENSE OF THE ICE AGE IN THE SOUTHERN ALPS, 1860–80

Ciaran Doolin[1,2]
[1]School of Science in Society, Te Herenga Waka – Victoria University of Wellington.
[2]Te Ratonga Tirorangi – Meteorological Service of New Zealand.

The first wave of debate about Aotea oa's past climate occurred in the context of geological investigations into the Ice Age in the Southern Alps between 1860 and 1880. The protagonist was Julius Haast, whose reports on his extensive fieldwork in Nelson and Canterbury we e focal points in the discourse that played out on the pages of the Transactions and Proceedings of the New Zealand Institute. The causative role of climate change in bringing about past glaciations was a contentious issue within the broader geological debate. The scientific consensus ultimately went against a colder clima e as the driver of past glaciation, with an elevation of the land instead being the favoured explanation; New Zealand geologists' interpretation of Lyell's uniformitarianism was the primary reason for this outcome. However, alternative ideas were mooted, including Croll's orbital theory of climate change. The debate was often acrimonious, even after the fundamental questions were 'settled'. The persistent bitterness is partly explained by the importation of ongoing international geological controversies, such as the debate over Ramsay's ice excavation hypothesis. At the same time, New Zealand science was criss-crossed by intense rivalries, and these tensions were the source of much of the acrimony of the Ice Age debate.

FORECASTING EVOLVING LANDSLIDE HAZARD AND IMPACTS IN AOTEAROA NEW ZEALAND UNDER A CHANGING CLIMATE

Livio Dreyer
University Of Canterbury

Cyclone Gabrielle (February 2023) triggered one of New Zealand's largest recorded landslide events (>800,000 landslides), causing widespread losses and severe infrastructure damage. With climate change projected to increase the frequency and intensity of extreme rainfall, understanding how future extreme rainfall events modulate landslide hazard and consequent impacts is crucial.
Our study utilises the latest high-resolution, dynamically downscaled CMIP6 climate projections for New Zealand to explore changes in the frequency and intensity of future landslide triggering rainfall events. We use coupled susceptibility-runout models to simulate inundation downslope of landslide source areas to understand potential exposure of the built environment. To overcome prohibitive computational expense, we develop a surrogate modelling approach that establishes unique relationships between potential landslide source areas and their downstream impacts on critical assets, enabling rapid, multi-scenario analysis.
Our work aims to deliver the first quantitative p ojections of future landslide hazard and impacts for a New Zealand case study region. The research provides a transferable workflow to di ectly address critical gaps in regional hazard assessment, offering crucial evidence to support climate adaptation strategies, land-use planning, and infrastructure resilience.

LAND SURFACE RECHARGE – ALLOCATION, VARIABILITY, AND DOES S-MAP MATTER?

Matt Dumont,[1] Linda Liliburne,[2] Sam Yeo[3]
[1] Komanawa Solutions Ltd.
[2] New Zealand Institute for Bioeconomy Science.
[3] Otago Regional Council.

Aims

Land surface recharge (LSR) typically forms the basis of groundwater allocation either through explicit modelling or via percentage of rainfall estimates. Unfortunately, modelling LSR is a wicked problem as many of the input datasets; particularly soils, irrigation, and land use are uncertain. Additionally, LSR is highly temporally variable. This variability is often simplified to th mean annual recharge or a percentage of annual recharge to support resource management. Eschewing the parameter uncertainty and temporal variability of LSR risks unintended policy error.

We assessed the historical record of LSR (1970-present) in Otago, incorporating parameter uncertainty from multiple input data sources. Of special interest was assessing the additional value of the S-map soils database over the more widely available Fundamental Soils database.

Methods

We developed and implemented a stochastic LSR model based on Rushton (2007). Rushton (2007) is a soil water balance model, which has been widely used in New Zealand and has been compared favourably to existing lysimeter data. Rushton is a daily time step model with a range of spatial resolutions. The model includes the effects of slope and roughness-based rainfall runoff partitioning and multiple irrigation approaches including irrigation efficienc , scheduling, availability and storage.

We used this model to conduct sensitivity analyses and estimate LSR across the parameter space of four key variables: Profile vailable Water (PAW), Proportion Readily Available Water (RAW_p), the rainfall-runoff partitioning parameters, and irrigation practices. Soil parameters were drawn from both S-map and Fundamental Soils databases to assess differences in uncertainty and bias between these two datasets.

We further attempted to constrain the posterior LSR using remotely sensed 8-day cumulative estimates of actual evapotranspiration. Finally, we compared the LSR estimates to previous estimates made by Wilson and Lu (2011).

Results

Although our results vary by aquifer, we found LSR to be highly variable across parameter uncertainty. S-map soils data typically suggests far lower LSR than Fundamental Soils data, but the distributions often overlap. Where available, S-map soils data provides important improvements over Fundamental soils data. Where S-map is unavailable, accepting the minimum LSR across the Fundamental Soils parameterisation will lower the risk of over-estimating LSR.

Unsurprisingly, LSR shows significant variability over the historical tempor l period. Annual LSR as a percentage of rainfall shows significant cor elation with annual rainfall, though the timing of rainfall also has a significant e fect. Based on these observations we question the utility of mean annual recharge as an allocation mechanism and raise serious concerns about allocating groundwater as a percentage of rainfall.

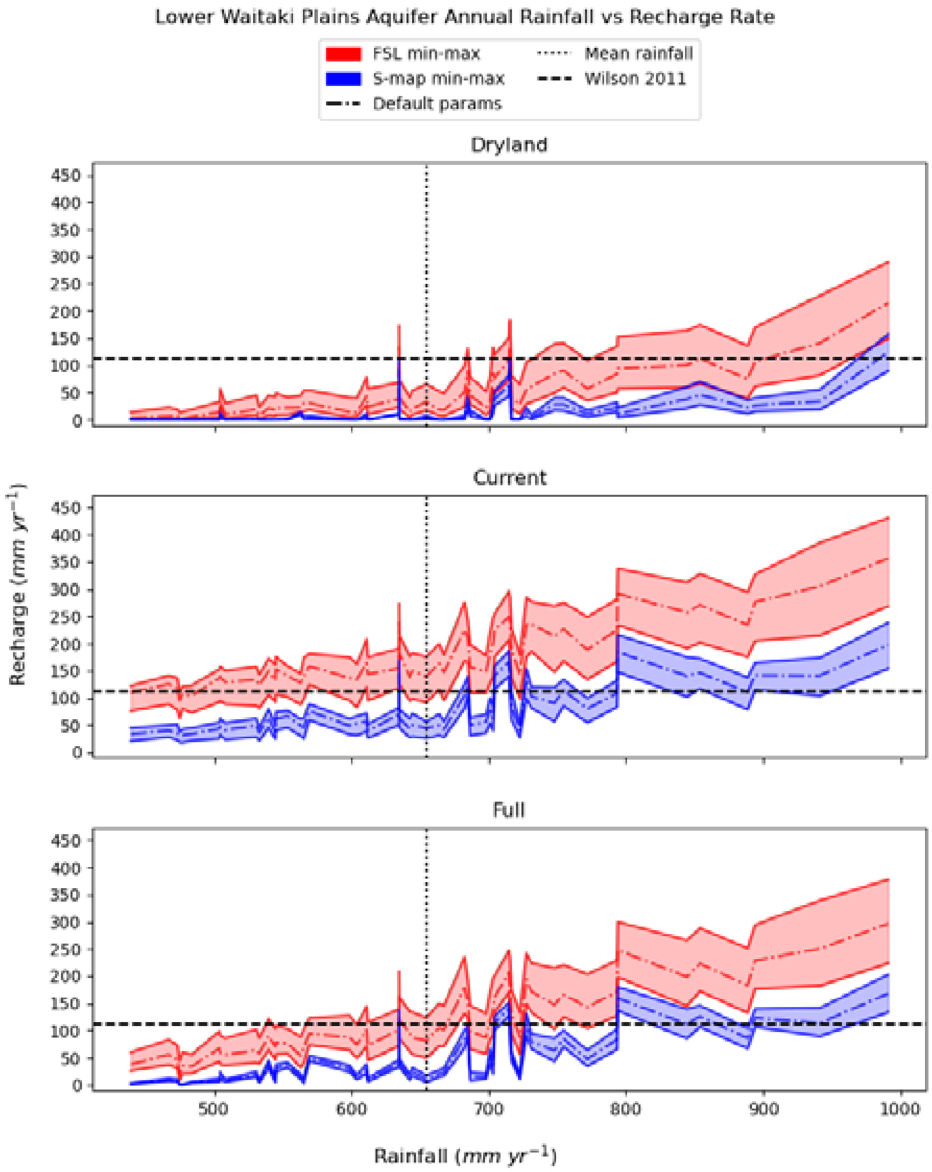
Excluding the impacts of parameter uncertainty and temporal variability risks policy error. This is particularly true as we leave the historical climate and enter a new and more variable world. Stochastic LSR modelling provides a useful tool to support water allocation policy.

References

Rushton, K., Eilers, V., and Carter, R. 2006. Improved soil moisture balance methodology for recharge estimation. Journal of Hydrology, 318(1-4):379–399.

Wilson, S. and Lu, X; 2011. Rainfall recharge assessment for Otago groundwater basins. Technical report, Otago Regional Council, Dunedin

Figure 1. An example of the range of annual recharge averaged over the Lower Waitaki Plains aquifer with comparisons between Fundamental Soils, S-map, and Wilson and Lu (2011). Recharge assessments are conducted for 3 irrigation profiles: "Dryland" (no irrigation), "Cur ent" irrigation practices, and "Full" irrigation practices where all area with a slope less than or equal to four degrees.



HOW MUCH BLOOD CAN WE SQUEEZE FROM A TURNIP?: EXTRACTING NEW INFORMATION FROM OLD MODELS

Matt Dumont,[1] Jens Rekker,[1] Sam Yeo[2]
[1] Komanawa Solutions Ltd.
[2] Otago Regional Council.

Regional Councils archives and digital servers are littered with previous decision support groundwater models. All too often these models were developed for a single purpose, summarised with a report, and left on the shelf to gather dust. When further decision support information about a catchment is needed, new models are often generated rather than consulting the previous modelling exercises or considering their reuse. The key question is: "How much information sits on the shelf in these old models, can we extract that information in a cost-effective manner, and can previous decision support models provide new insights after additional data collection?" Here we conduct a case study to answer this question by investigating a previous decision support model for the Northern Volcanics Aquifer in the Otago region. The area was originally modelled in 2008-2009. Here we attempt to revive the model, assess the model predictions in the light of the subsequently collected data, and conduct data-worth assessments.

THE DEVELOPMENT OF AN AUTOMATED AVALANCHE TERRAIN EXPOSURE SCALE IN THE SOUTHERN ALPS

Philip Elder[1], Nicolas Cullen[1], Aubrey Miller[2], Pascal Sirguey[2]
[1] School of Geography, University of Otago, New Zealand
[2] National Schol of Surveying, University of Otago, New Zealand

New Zealand lacks a terrain classification system to p ovide mountain visitors, including tourists, with detailed information about potential snow avalanche hazards they may encounter. This is highly problematic given the surge in backcountry activity in our rapidly changing mountains, which have become increasingly unpredictable due to climate change. Avalanche risk is a complex interaction between snowpack, weather, terrain and people, where terrain is the only factor that remains constant over time. Given it is well-known that "when unstable snow is the problem, terrain is the solution", we propose that a high-resolution terrain classification system should be used as the primary tool for mi igating avalanche risk in New Zealand. Professional mountain and ski guides have long considered terrain assessment and route selection to be critical in reducing exposure to avalanches - when nothing is exposed, nothing is at risk. Using very detailed topographic information, recently obtained from aircraft flying over the Southe n Alps with specialised LiDAR (light detecting and ranging) instruments, we will develop a world-class, fully automated avalanche terrain classification system that will transfo m how we currently assess and communicate the threat of snow avalanches. The goals of this system are twofold: one, to enable recreational and professional users to be able to simplify complex terrain attributes into clear, easy-to-understand categories, making it straightforward for them to plan and carry out their activities; and two, to assess its potential use as a foundation for a comprehensive avalanche prediction model, by combining it with existing snowpack and weather forecast models.

MAPPING WEATHER EXTREMES TO CIRCULATION REGIMES IN AOTEAROA NEW ZEALAND

Fauchereau, N., [1] Lorrey, A.[1]
[1] Earth Sciences New Zealand Ltd., Auckland, New Zealand

Aims
This study seeks to identify robust atmospheric circulation regimes (CRs) over Aotearoa New Zealand (ANZ) and develop an alternative regionalization of ANZ's climate by mapping the occurrence of rainfall and temperature extremes to the dominant CRs associated with these events.

Method
Daily anomalies in 1000 hPa geopotential height (Z1000) are computed from ERA5 (0.25°) and NCEP/NCAR (2.5°) reanalyses for 1979–2023. Principal Component Analysis is used for dimensionality reduction, followed by Affinity P opagation on random subsets (1000 samples of 1000 days) to estimate the optimal number of CRs. K-means clustering is then applied to derive archetypal CRs, illustrated via composite analysis. Daily rainfall and mean temperature data are sourced from NIWA's Virtual Climate Station Network (VCSN, 0.05° grid). Extremes are defined as values exceeding the seasonally varying 90th pe centile; temperature data are detrended prior to thresholding. For each VCSN grid cell, the dominant CR during extreme events is identified, along with: i) the p oportion of extremes linked to that CR, ii) the frequency factor (relative to baseline CR frequency), and iii) the 'frequency gap' (difference between the dominant and second-most frequent CR). These statistics provide the basis for the definition of cohe ent regions where rainfall and temperature extremes are unambiguously related to a dominant circulation regime.

Results
Both ERA5 and NCEP yield nine optimal CRs (Figure 1), highly consistent in spatial structure and daily classification (80–92% ag eement). Differences mainly reflect esolution-driven detail in topography–pressure interactions.

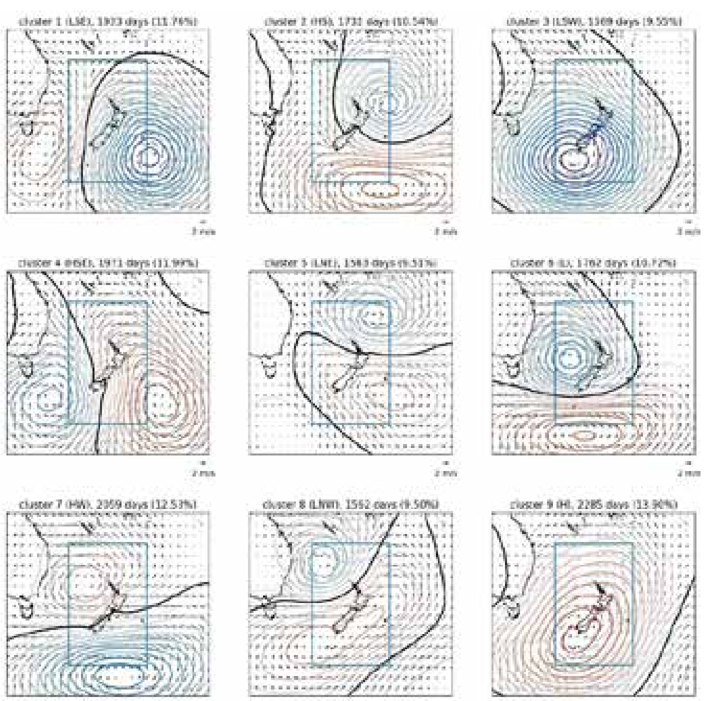


Figure 1, Atmospheric pressure anomalies and associated flow patte ns for the nine once-daily New Zealand Circulation Regimes (CRs) defined using affinity opagation and k-means clustering on de-seasonalised and detrended ERA5 daily geopotential (1000 hPa) data for 1979-2023. The domain over which the clustering exercise was conducted is delineated by the blue box.

Rainfall extremes show strong, regionally distinct CR associations (Figure 2), notably:

- The Eastern North Island (NI) is dominated by CR#2 (High to the South – HS), with up to 50% of extreme rain days associated with this CR and frequency factors >3.
- In the northern & western NI, CR#6 (Low over NZ – L) dominates.
- In the West Coast South Island (SI): CR#3 (Low to the Southwest – LSW) dominates, with up to 5× baseline frequency during rainfall extremes.

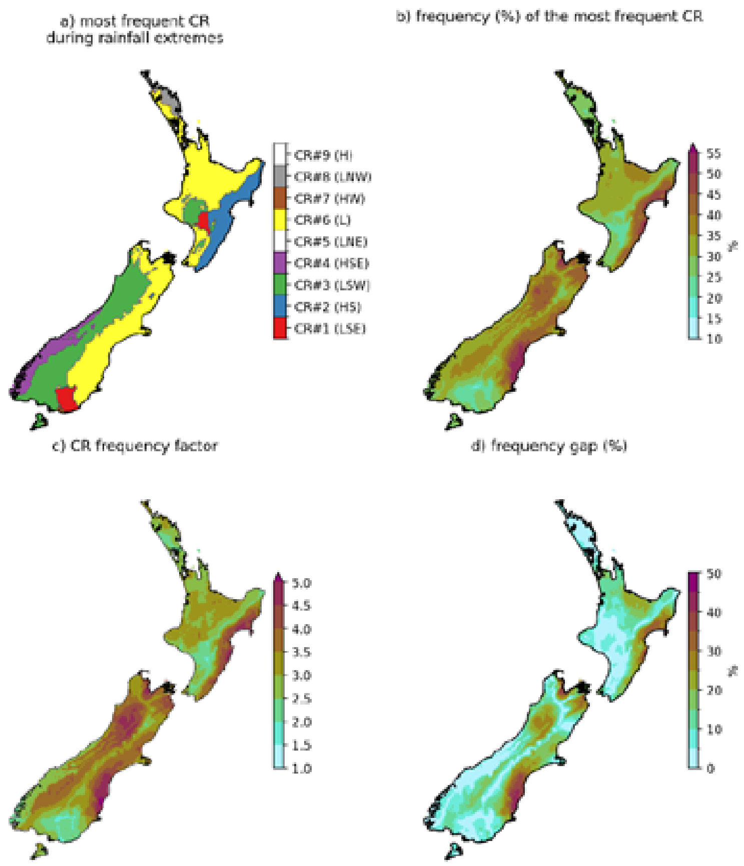


Figure 2, a) Most frequent CR (CR number 1 to 9) during days with extreme rainfall (rainfall exceeding the climatological 90th percentile). b) Proportion of days with extreme rainfall associated with the dominant CR, i.e. a value of 50 means that 50% of extreme rainfall occurrences are associated with the dominant CR shown in Figure 8a. c) Frequency factor for the dominant CR, i.e. a value of 3 indicates that the dominant CR is 3x more frequent during extreme rain days than for all days confounded (i.e. 3x the baseline frequency for that CR). d) Gap (in %) between the frequency of the dominant CR and the second most frequent CR during extreme rain days, e.g. if the most frequent CR occurs 50% of extreme rain days, and the second most frequent CR 30%, the gap is 20%.

Temperature extremes show weaker CR associations. Only limited regions (e.g., far south SI) exhibit frequency factors >3. Dominant CRs in these areas feature strong northerly/northeasterly advection, suggesting advective processes outweigh local radiative forcing. Notably, CR#9 (High over NZ – H) is not a dominant driver of temperature extremes anywhere.

References

Hersbach, H. et al., 2020. The ERA5 global reanalysis. Q.J.R. Meteorol. Soc., 146, 1999–2049.
Kalnay, E. et al., 1996. The NCEP/NCAR 40-year reanalyses project. Bull. Amer. Meteor. Soc., 77, 437–471.
Kidson, J.W., 2000. An analysis of New Zealand synoptic types and their use in defining weather egimes. Int. J. Climatol., 20, 299–316.
Rampal, R., Lorrey, A., Fauchereau, N., 2022. [Details as per RLF2022 publication].
Yiou, P., Nogaj, M., 2004. Extreme climatic events and weather regimes over the North Atlantic. Geophys. Res. Lett., 31, L07202.

ENSO FORECASTING IN A WARMING CLIMATE: DEVELOPMENT OF DETERMINISTIC AND PROBABILISTIC RELATIVE OCEANIC NIÑO INDEX FORECASTS

Nicolas Fauchereau[1], Tristan Meyers[2], Chris Brandolino[3], Ben Noll[4]
[1] Earth Sciences New Zealand, Hamilton.
[2] Earth Sciences New Zealand, Wellington.
[3] Earth Sciences New Zealand, Auckland.
[4] The Washington Post, Washington DC, USA.

The aim of this study is to present results on the evaluation of the impact of different methodological choices on the development of an operational Relative Oceanic Niño Index (RONI) forecast system.
Traditional ENSO indices such as the Oceanic Niño Index (Niño 3.4 index) are increasingly challenged by the non-stationarity of tropical sea surface temperatures (SSTs) under climate change. In response, Earth Sciences New Zealand is developing deterministic and probabilistic forecasts based on the RONI, which expresses SST anomalies in the Niño 3.4 region relative to the tropical mean. This approach aligns with recent recommendations for ENSO monitoring and forecasting in a warming world (Van Oldenborgh et al., 2021, L'Heureux et al., 2024, Wheeler et al., 2024).

We evaluate methodologies for generating RONI forecasts using the C3S (Copernicus Climate Change Services) Multi-Model Ensemble forecast system (10 Global Climate Models, 600+ ensemble members), including the impact of different variance scaling factors, derived from observational datasets (OISST, ERSST) or the models' hindcasts. Preliminary results show that variance scaling significantly a fects forecast calibration and probabilistic ENSO outcomes.
This work contributes to the discussion on how to monitor and forecast climate drivers relevant to New Zealand's climate in a warming world.

REFERENCES

L'Heureux, M. L., and Coauthors, 2024: A Relative Sea Surface Temperature Index for Classifying ENSO Events in a Changing Climate. Journal of Climate, 37, 1197–1211, https://doi.org/10.1175/JCLI-D-23-0406.1.
Van Oldenborgh, G. J., H. Hendon, T. Stockdale, M. L'Heureux, E. Coughlan De Perez, R. Singh, and M. Van Aalst, 2021: Defining El Niño indices in a wa ming climate. Environ. Res. Lett., 16, 044003, https://doi.org/10.1088/1748-9326/abe9ed.
Wheeler, M. C., and Coauthors, 2024: Making Progress on the Operational Alerting of El Niño and La Niña in a Warming World. Bulletin of the American Meteorological Society, 105, E1042–E1044, https://doi.org/10.1175/BAMS-D-24-0095.1.

TŪRANGANUI-A-KIWA, POVERTY BAY FLATS GROUNDWATER MODELLING

Ferry, J.,[1] Sinclair, B.,[1] Houlbrooke, C.,[1] Schaetzl, P.,[2] Luo, J.,[2] Murphy, P.,[3]
[1] Wallbridge Gilbert Aztec
[2] Aquasoil Ingenieure & Geologen GmbH
[3] Gisborne District Council

The looming pressures of declining groundwater levels, combined with projected climate change impacts on weather patterns and rising sea levels, highlighted the need for Gisborne District Council (GDC) to improve the management of groundwater resources in the Tūranganui a Kiwa (Poverty Bay) flats a ea.
Using existing data and knowledge from Council, mana whenua and the community, GDC developed a range of groundwater allocation management scenarios, including the potential for managed aquifer recharge (MAR) to replenish local groundwater resources. The Council then looked to develop a numerical groundwater model to evaluate the effects of various abstraction and recharge scenarios.
WGA led the development of a 3D numerical geological model subcontracting Aquasoil for a FEFLOW groundwater model (Figure 1) based on information provided by GDC to simulate the groundwater system of the Poverty Bay flats. The g oundwater model was then used to simulate each of the groundwater management scenarios. The simulated scenarios incorporated the effects of predicted short and long-term climate change pressures on the resource, including additional irrigation demands, increasingly extreme droughts and sea level rise.
Working in close collaboration with GDC and Iwi representatives, detailed consultation enabled local perspectives to be embedded into the model design, predictive scenarios, and features of interest. Iwi representatives attended online workshops and training sessions on groundwater modelling and scenarios, which enabled technical staff to adapt the model to incorporate local cultural knowledge and concerns.
After two years of meticulous work, the models and model outcomes have ensured the Council has the tools and knowledge to enable effective management of the Poverty Bay flats g oundwater system.
The results assisted with current knowledge of the functioning relationships between each of the aquifers underlying the Poverty Bay flats, p oviding:

- Predictions of potential impacts of changing groundwater usage on the groundwater system
- Predictions of potential impacts on surface water systems.
- Insight into where changes could be made to the current groundwater management policies.
- Insight into concepts of surface water security and the impacts enhanced replenishment can have on supply and security and surface water features (river baseflows)
- Emphasis on the importance of increased groundwater monitoring in the western and coastal aquifers to assess saline intrusion and whether interventions are having an impact.

This project showcases the capacity for groundwater modelling to support future community and regional plan development, to build climate change resilience and to enhance community engagement in strategic planning processes.

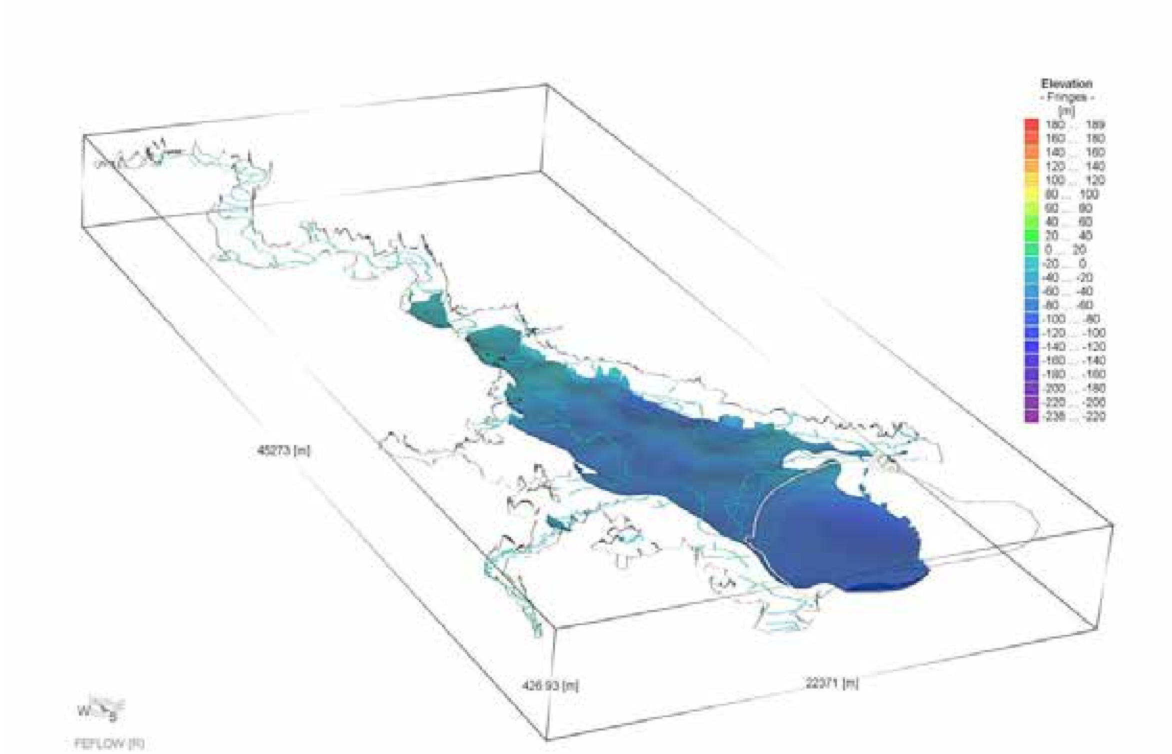


Figure 1: 3D View of Makauri Aquifer in FEFLOW Model (Aquasoil, 2022)

WGA. 2023. Poverty Bay Flats Groundwater Modelling Programme Summary Report. Report produced for Gisborne District Council by Wallbridge Gilbert Aztec. WGA report WGA210398-RP-HG-0008 Rev. F. November 2023.

WGA. 2022a. Poverty Bay Flats geological and conceptual hydrogeological models. Report produced for Gisborne District Council by Wallbridge Gilbert Aztec. WGA report WGA210398-RP-HG-0004 Rev. B. November 2022.

WGA. 2022b. Poverty Bay Flats conceptual groundwater quality model. Report produced for Gisborne District Council by Wallbridge Gilbert Aztec. WGA report WGA210398-RP-HG-0005 Rev. B. October 2022.

AQUASOIL. 2022. Groundwater modelling of the Poverty Bay Flats – Turanganui a Kiwa (Gisborne). Report produced for Gisborne District Council by AQUASOIL Ingenieure & Geologen GmbH. AQUASOIL reference AS210425. 24 October 2022.

GDC. 2024. Turanganui-a-Kiwa Poverty Bay Flats Groundwater Modelling. https://www.gdc.govt.nz/__data/assets/pdf_file/0032/75596/G oundwater-Modelling-Poverty-Bay-Flats.pdf

SEASONAL SNOW, VOLCANIC SUPER ERUPTIONS AND NZ ELECTRICITY CRISES

Blair Fitzharris[1]
[1] Queenstown Country Club

Can such an event of three decades ago happen again? I make a retrospective analysis of my involvement as to what happened. This links the three elements of seasonal snow storage to the Pinatubo super volcanic eruption of June 1991 (VEI = 6) and to a major New Zealand electricity crisis. The eruption now appears to have caused the biggest global cooling impact of any for much of the 20th Century.

Could such an event happen again, despite an obviously warming world? I describe my experience on a coincidental visit to the Philippines, a retrospective reflection on a ca eer in snow modelling and the urgent reaction of Government to a lack of electricity in the winter of 1992. This led to the development of SnowSim, now widely used in the electricity pricing market. It was a fir t attempt to model seasonal snow storage in the hydro catchments of New Zealand and to provide real time information to electricity companies so as they could better manage their generation.

During 1992, there was continued drought for the West Coast, so there was little spillover precipitation for the Southern Alps. Hydro lake storage was much less than average. Snow storage over winter 1991 was lower than normal, but we had no measurements, so hydro managers did not realize this. In retrospect we now see that the third strongest El Nino of 20th century begins from 1991. During the following summer and autumn, snowmelt runoff was suppressed and much less than expected. Runoff did not recharge hydro lakes. At about the same time, the Government established Electricorp, a new corporate entity, but electricity became squeezed on both supply and demand. Power cuts were introduced and not a good look for the recently elected Bolger government. Panic!

CONCEPTUAL CHARACTERIZATION OF A CULTURALLY IMPORTANT SPRING: TRACING SPRING SOURCE AND FLUX, HERETAUNGAPLAINS, NZ

Forstner T[1], Morgan LK[1], Moore C[2], Kitlasten W[2],
[1] Waterways Centre for Freshwater Management, School of Earth and Environment, University of Canterbury, Christchurch, New Zealand | Te Whare Wānanga o Waitaha
[2] Earth Sciences New Zealand

Aims

Globally, 85% of groundwater-dependant-ecosystems (GDEs) within protected areas are still at risk from activities within the under-protected regions of the groundwatershed due to activities such as land use change, agriculture and urban expansion. Accelerated land use change in the last six decades has impacted more than a third of global land area, with calls for urgent conservation of critical natural and cultural assets. One often overlooked dimension in groundwater management is historical catchment developments. The timing and severity of impacts to groundwater quality and flow f om historical changes is still not well understood, and in many cases requires local place-based assessments.

Hindcasting, modelling of past groundwater conditions, is often an underutilized tool which can provide critical insights to legacy impacts. This study presents a local example of a conceptual hindcast which is used to explore historic changes to a culturally important GDE within a highly developed catchment.

Methods

Characterization of GDEs often uses multiple lines of evidence in order to conceptualize source and flow dynamics, such as hydrochemical analyses, hydrodynamic responses, and lithological characteristics. We use a combination of existing datasets, and novel field data to unt ngle the complex nature of source and flux to the Te Puna a Hinetemoa spring.

Results

Based on the integrated assessment, we present a novel conceptual model of the spring which shows significant sensitivity to echarge from the regional system, both likely hydraulic connectivity with the confined aquifer which is heavily utilized for irrigation and the limestone hills. We present a series of hypotheses of flow dynamics based on p esent day stressors and discuss spring conditions pre-European arrival. This novel approach to a hydrogeological conceptual modelling highlights the importance of considering complex groundwater connected systems in future water management and conservation.

WHAT TO EXPECT WHEN YOU'RE NOT EXPECTING – DRILLING IN TAURANGA GEOTHERMAL SYSTEM

Rochelle Gardner
Bay Of Plenty Regional Council

The council undertakes drilling throughout the region to improve its groundwater and geothermal state of the environment (SOE) monitoring networks. Council uses the lithological information collected during drilling to improve 3-D geological modelling.

BOPRC drilled 3 bores in Te Puke, the planned targets were the deeper aquifers, the Aongatete, Waiteariki, and the Pokai-Chimp-Pokopoko formations, to better monitor effects from the inland horticulture takes. Based on the existing drilling, modelling and consented data the estimated depth for the deepest of the bores was 480m, anticipating a water temperature of approximately 40/45 °C, typical for the Tauranga Geothermal System.

During drilling flowing artesian p essures of 8 litres per second were unexpectedly encountered at 318m, with a temperature of 68.6°C. A Pressure, Temperature, Spinner (PTS) survey was subsequently undertaken to determine downhole temperature, and where the main flows a e. The highest temperature recoded was 76.34°C, with the spinner indicating that there were flows at 310 – 312m and f om below 320m (the maximum depth we could get the spinner to).

Analysis of the drill chip samples by GNS show that that we discovered a new unit in the Minden Rhyolite Subgroup. Council is currently working with local iwi to name the new Rhyolite.

NATIONAL CMIP6 DOWNSCALING: AN OVERVIEW OF RESEARCH FINDINGS AND SOME IMPORTANT REMAINING SCIENTIFIC QUESTIONS

Peter Gibson
Earth Sciences NZ

In 2024, Earth Sciences New Zealand (then NIWA) released updated national climate projections derived from dynamically downscaling top-performing CMIP6 global climate models. The downscaling was primarily conducted using CCAM – a variable-resolution global atmospheric model providing 12km resolution over New Zealand and approximately 12-30km resolution over the wider South Pacific egion. Additionally, these projections have been bias corrected to a 5km nationwide grid and hosted by MfE on a web-portal. In this talk I provide a wide-ranging overview of our recent research, where we have used the updated projections to delve deeper into the changing nature of various hazards, including atmospheric rivers, ex-tropical cyclones, heatwaves and drought. Lastly, I provide my thoughts on some remaining scientific questions and challenges such as the importance of narrowing projection uncertainty stemming from large-scale dynamics and the value of large ensembles.

THE WASHINGTON STATE CLIMATE CORPS NETWORK: EMPOWERING A CLIMATE-READY WORKFORCE THROUGH COMMUNITY SERVICE

Glazewski, M.[1]
[1] State of Washington, USA

Aims

Created by the Washington State Legislature in 2023 by a bill requested by then-Governor Jay Inslee, The Washington Climate Corps Network (WCCN) is creating a climate resilient Washington through enterprising service projects, community partnerships, and investments in the next generation of environmental leaders. The WCCN funds service projects and training opportunities for young adults (17-31), veterans (any age), tribal members, and overburdened communities across Washington state. These service projects are focused on building clean energy and developing climate-resilient communities, economies, and ecosystems. The WCCN is funded by the state's Climate Commitment Act, Washington's signature carbon cap-and-trade legislation. Service members (called 'architects') walk away from their experiences with a skill or credential that sets them up on an employment pipeline in climate careers.

Method

The WCCN partners with the state's Clean Energy Technology Workforce Board, local economic development agencies, and industry leaders to identify projects that use a "by-and-for" the community approach. This enables a just transition into a climate economy whereby Washingtonians receive stipends to earn a skill or credential in both tested as well as emerging technology sectors.

Through the network model, organizations both funded by the WCCN and those aligned with its mission share their successes, resources, and stories easily to projects across the state. This model empowers communities and accelerates adaptation of successful models and programs.

The robust structure and reporting mechanism for the network involves facilitated community meetings, community-based education from locally trusted organizations, and extensive media generation for member storytelling.

Results

The WCCN is at the forefront of a niche form of climate workforce development with a model for the nation, and other parts of the world. This uniquely positions its investments to nimbly meet current and future workforce needs for a just transition, while at the same time meeting UN Sustainable Development goals. The model is unique, but applicable to other governments and structures. The success model of the WCCN could be easily copied and set-up to accomplish similar goals of climate workforce development across Aotearoa in a spirit of kaitiakitanga.

Reference List

Tipton, E. 2023: Global Environmental Change and Workforce Need. An AMS Policy Program Study. The American Meteorological Society, Washington, D.C. https://doi.org/10.1175/global-env-change-workforce-2023

RESONANCES AND PERCEPTIONS REGARDING CLIMATE CHANGE ADAPTATION

Glynn, P.D.[1]; Santamaria Cerrutti, M.E.[2]; White, P.A.[3]; Moreau, M.[3]; Crundwell, M.P.[4,5]; Rogers, K.[6]; Cockerill, K.[7]; Drummond, J.K.[3]; Glynn, S.A.[8]
[1] Arizona State University; [2] Formerly at GNS Science; [3] Earth Sciences New Zealand; [4] University of Auckland; [5] Victoria University of Wellington; [6] EnviroTrace NZ; [7] Appalachian State University; [8] Grand Lake, CO

Introduction

People construct and express narratives constantly. These narratives reflect and shape the mental models that people use to simplify and understand their perceptions of themselves, each other, and the word around them (Cockerill et al., 2024)physical, chemical, economic, political and other social processes are tightly interwoven. Global change within these systems presents an increasingly untenable situation for long-term human security. Further, knowledge that humans possess about ourselves and SES represents a complex amalgamation of individual and collective factors. Because of various evolutionary pressures, people often reject this complex reality in favor of more simplistic perceptions and explanations. This thought paper offers an overview of how and where people acquire knowledge and how that knowledge acquisition process reflects and influences narratives, which subsequently fect efforts to address challenges in SES. We highlight three narratives as examples of constraints on finding ways forwa d toward a more resilient future. Our focal narratives include tendencies to conflate tame and wicked problems; to posit a false human-nature duality; and to resist the explanatory evidence from biocultural evolution. We then discuss the human cognitive propensity to create narratives to think about how we might intentionally develop narratives that are more appropriate for living in coevolving SES.","container-title":"Mitigation and Adaptation Strategies for Global Change","DOI":"10.1007/s11027-024-10151-3","ISSN":"1381-2386, 1573-1596","issue":"6","journalAbbreviation":"Mitig Adapt Strateg Glob Change","language":"en","page":"54","source":"DOI.org (Crossref, including the changes that affect their natural resources and environments. For the purposes of this study, narratives are (Glynn et al., 2025):

> Human-sourced (or interpreted) information threads and packets, or ensembles thereof, that reflect or create mental models with emotional affect. These conscious-to-unconscious mental models create meaning, characterization, memorability, and expectations for living and non-living entities, individuals and communities, beliefs, causal relations, and event sequences.

We have identified a set of 81 esonances, grouped into 10 categories, that can be used to assess and understand narratives, and consequently the mental models that individuals and communities create (Glynn et al., in preparation). We define esonances as foci of emotional attention that relate to the preferences, beliefs, needs, and motivations that individuals and groups have and are willing to express in the narratives they create. Resonances reflect what di ferent communities care about as well as their belief and knowledge systems. Different groups may exhibit different frequencies of use, or assign different importance, to given resonances – especially across different cultures or ways of life – but in all cases, there are good reasons explaining why these resonances are present. Our set of resonances was constructed based on our knowledge of social science theories and tested and refined by analyzing written documents mainly focused on governance and management of Lake Taupo (NZ) and the Chesapeake Bay (USA) regions.

Our set of resonances can be used to assess what people care about and are willing to express regarding any type of issue, physical location, or environment. Here we discuss the use of our resonances to assessing community knowledge and attitudes regarding climate change adaptation (CCA) in the Wairau Plain, Marlborough region.

Method

We used our set of resonances and resonance categories to design a CCA survey suitable for different interest groups in the Wairau Plain. The 16 questions that we used in our survey were based on all 10 of our resonance categories: group and identity (GI), credibility and responsibility (CR), mark and ownership (MO), power and control (PC), valuing the past (PST), valuing the present into the future (VPF), rebelling the past or present (RPP), seeking better futures (SBF), immediacies of the future (IF), and focal idealizations (FI). While we initially designed a set of 20 questions that would have given equal weight to each resonance category, our question refinement p ocess ultimately led to an uneven weighting with the following numbers of questions per resonance category: GI (3), CR (1), MO (1), PC (1), PST (1), VPF (1), RPP (1), SBF (2), IF (1), FI (4).

The nine authors of this paper also provided independent rankings of the relative importance of the 10 resonance categories used for the CCA survey, giving separate rankings for both personal opinions as well as projected opinions of relative rankings for an typical WPc respondent. The results, which show interesting divergence between personal and projected opinions, will be presented at the conference, after being augmented by personal opinions from attendees during our presentation through the use of a real-time survey tool.

In a first phase, our CCA survey was piloted with an community group, Climate Karanga Marlborough (CKM), following a set of informative presentations relating to past and present climate impacts in the Wairau Plain, including geologic evidence (White et al., 2023). We plan to use the survey again in future years, with the CKM group, and with other Wairau Plain groups.

Results

Our pilot CCA survey – 19 respondents providing written explanatory comments – shows strong desire for CCA planning and action from local Wairau Plain residents while also suggesting that the broader Wairau Plain community (WPc) would likely not be united with respect to implementing CCA measures. Respondents felt that the WPc was not currently well-equipped to address CCA. CKM respondents believed that CCA was something that could be controlled or influenced by WPc actions, including actions and chang s relating to the different economic enterprises and sectors in the Wairau Plain. Importantly, the survey suggested that WPc, including its different groups and economic sectors, needed to lead and own CCA in the Wairau Plain. CKM respondents showed a strong commitment to change current behaviours, land-use, and/or natural and built infrastructure as part of CCA efforts – not sometime in the distant future but instead starting today or in the next year. They saw CCA and changes made by their generation as being essential to the well-being of the next generation. Lastly, the respondents thought that improved connections to nature could help the WPc, and the next generation, better adapt to climate change. For all responses, the survey showed strong convergence in CKM respondent agreements (or disagreements), with some greater variability for neutral responses.

Written respondent comments showed great concerns with flooding and a deg ee of cynicism regarding the efficacy of Regional Council flood otection measures and plans – given current economic development pressures, and societal tendencies to “kick the can down the road”. CKM respondents shared personal information regarding their background. Most respondents had high degrees of knowledge related to understanding of climate, land management, agriculture, ecological restoration issues – not only in New Zealand but also through overseas experiences, as well as formal education. They also strongly believed that educating communities and the next generation was essential to CCA, including by fostering greater understanding of the interconnectedness of ecosystems.

The written comments provided by CKM respondents voiced resonances in the following important categories (with italicized individual resonances): GI (group disaffi mation or contrast), IF (care of the next generation), FI (knowledge idealization), PST (veneration of past beliefs), RPP (change seeking), SBF (visioning of an ideal future, SES).

In summary, our thesis is that identifying resonances and resonance categories can help concretize what people emotionally care about, and more specificall , the preferences, beliefs, needs, and motivations that drive their attitudes and behaviours, including with respect to climate change adaptation issues. Resonances can be used in many ways, including for analyses of documents, but also to plan community and stakeholder engagements or to plan and interpret surveys of community attitudes, knowledge and beliefs. Understanding resonances is critical to enabling facts and evidence to be used for policy decisions, and more broadly to co-developing and enabling community and stakeholder acceptance of policy decisions.

Reference List

Cockerill, K., Glynn, P., Cerrutti, E.S., Little, J.C., 2024. Knowledge sources, narratives, and living in social-ecological systems. Mitig Adapt Strateg Glob Change 29, 54.

Glynn, P.D., Cockerill, K., Helgeson, J.F., Newman, G.J., Glynn, S.A., White, P.A., 2025. Biocultural evolution, narratives, and emerging cultures of sustainability. Mitig Adapt Strateg Glob Change 30, 16.

Glynn, P.D., Cerutti, E.S., Cockerill, K., Glynn, S.A., White, P.A., Drummond, J., Penton, J., in preparation, Resonances to Improve Environmental and Natural Resources Management, to be submitted shortly to the Journal of Integrative Environmental Studies.

White, P.A., Crundwell, M., Moreau, M. 2023. Coastal groundwater system characterisation and climate change impacts, with the example of the Wairau Plain. Australasian Groundwater & New Zealand Hydrological Society 2023 Joint Conference, 28 November-1 December.

AN ASSESSMENT OF THE WATER ALLOCATION OF THE ŌTAIKA CATCHMENT

Gonah, T
Northland Regional Council

Aims

The Ōtaika catchment is one of the catchments in Northland that was identified as fully allocated for surface water in 2017 in accordance with the Proposed Regional Plan for Northland (PRPN) (Northland Regional Council, 2024). This was because of its existing allocation (consented water takes and permitted activity takes) exceeding the regional default limit based on regional modelling at the time of notification of the PRPN (in 2017). As a result, the existing allocation (at the time) became the allocation limit for the catchment in accordance with the PRPN and the catchment was declared fully allocated. The means that no further low flow water allocation may be consented from the catchment.

It is against this background that the catchment specific assessment was initiated takin into account local catchment specific info mation and environmental pressures to ascertain if the water allocation is sustainable and to consider any alternative catchment specific allocation egime which considers the local values and water use pressures. Specificall , it aimed to evaluate the current water allocation regime and water use within the catchment, assess the impacts of the status quo allocation regime on instream values and the security of supply and examine the pressures affecting the catchment's water resources. Additionally, the study aimed to identify existing information gaps and recommend key data collection and monitoring strategies to inform future management decisions.

Method

This study employed a multi-scale assessment approach to evaluate surface water allocation within the Ōtaika catchment. The analysis focused on both individual consent holders and catchment-wide water use patterns. Particular attention was given to the six largest consent holders, identified based on annual allocation and water take rate. For these users, actual water use and consented allocation were assessed over eight water years, spanning from 2015/2016 to 2022/2023. In addition, the study examined actual water use at the catchment scale on an annual basis. This was compared against various allocation and flow indicators to evaluate trends and potential pressures. Key hydrological statistics, including the 7-day mean annual low flow (7d-MALF) and the 1 in 5 year 7-day low fl , were estimated using observed flow data f om the Ōtaika at Kay flow ecorder site. The assessment also included an evaluation of environmental and anthropogenic pressures on the catchment's water resources. Finally, alternative water allocation scenarios were considered to explore potential improvements in the water allocation regime.

Results

Some of the key findings a e as follows:

- The mean annual actual water use for the six biggest water users ranged between 0% and 69% of their consented annual volume (Refer to Figure 1 for an example).
- The small water take consent holders typically abstracted less than 30% of their annual allocation.
- At the catchment level, the current allocation still exceeds the regional default allocation limit based on flo statistics from the flow ecorder site.
- Despite the high level of consented allocation, actual water use was consistently and significantly lowe , indicating that a substantial portion of the allocated water remains unused.
- The catchment is characterised by localised pressures including significant allocation p essure in the headwaters, high paper allocation, some consents without minimum flow limits
- Flow and state of the environment monitoring are undertaken towards the outlet of the catchment while approximately 89% of the water takes occur in the headwaters. This spatial mismatch means the localised impacts of the takes may not be reflected in the monitoring data
- High instantaneous water takes during critically low flow pe iods pose significant risks to inst eam values.

• Based on catchment-specific data, the Ōtaika catchment emains confi med as fully allocated.

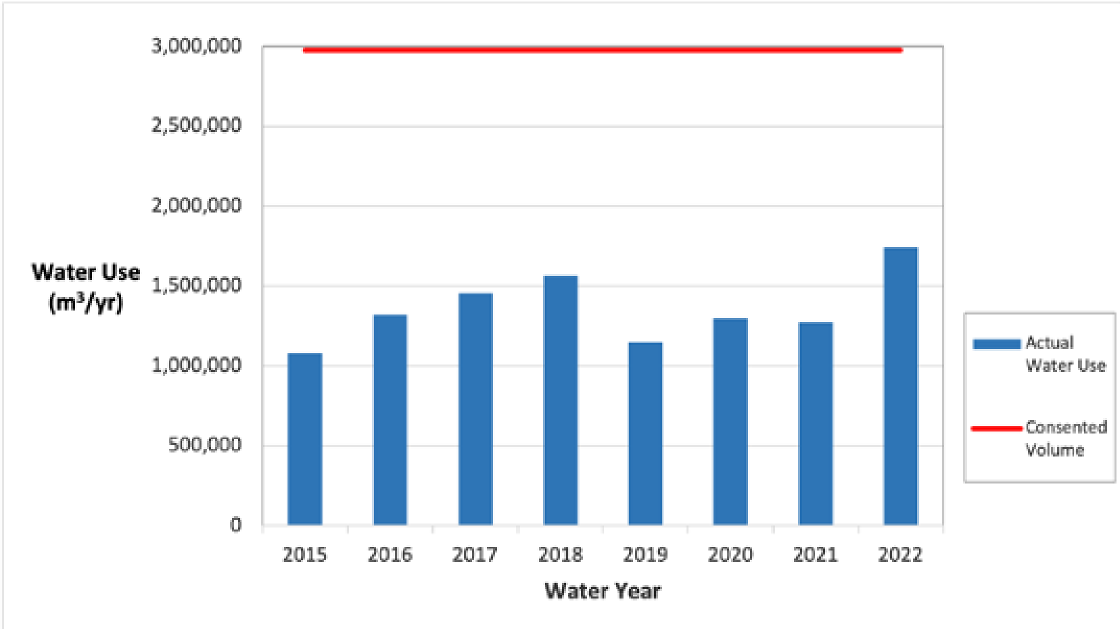


Figure 1: Actual compared to consented annual water take for biggest consent holder in the catchment

Some of the key recommendations of the study include:
• There is need to explore ways to reduce the allocation levels in fully allocated catchments through mechanisms such as plan changes or when processing consent renewals.
• Fully implement the efficient allocation policy when enewing consents, especially where actual water use is significantly lower than the consented allocation
• Improve the estimation of permitted activity (PA) takes, particularly in highly and fully allocated catchments.
• Ensure consistent application and management of minimum flow conditi ns across all water take consents.
• Implement targeted flow and water quality monitoring to better captu e and understand the localised impacts and pressures associated with water takes.

References

Northland Regional Council 2023. Proposed Regional Plan for Northland. Northland Regional Council. 1-358

Osbaldiston, S. 2020. Updated approach used to determine freshwater allocation in Northland. Freshwater quantity accounting system. Northland Regional Council

Roke, D.L. and Mc Lellan, C.H. 1983. The Water Resources of the Maunu – Maungatāpere - Whatitīri Area. Water Resources Report No 5. Prepared by the Northland Catchment Commission and Regional Water Board: 1-99

MACHINE LEARNING PREDICTIONS OF SUMMERTIME WARMING JUMPS ON DECADAL TIMESCALES

Emily M. Gordon[1,2], Noah S. Diffenbaugh[2]
[1]Department of Physics, University of Auckland
[2]Doerr School of Sustainability, Stanford University

Abstract:
Predicting regional climate variability in the near-term (i.e. the next 5-10 years) remains a matter of scientific urgency. In particular, predictions of extreme events on these timescales are crucial for adaptation decisions and disaster preparation. However, predicting climate extremes on these timescales is incredibly difficult as their drivers are largely stochastic. Here, we demonstrate that the likelihood of a short-term extreme heat event is heightened by a coinciding jump in regional summertime temperatures. We then use machine learning to learn the precursors to these summertime warming jumps within climate simulations, therefore learning the climate patterns that most likely lead to extreme heat events in the near future. The trained machine learning model can be then used to predict the observational record, demonstrating regions where extreme heat prediction is most likely to be predictable in the coming decades.

LINKS BETWEEN FLOOD HYDROLOGY AND FINE SEDIMENT DEPOSITION

Arman Haddadchi,[1] Richard Measures,[1]
[1] Earth Sciences New Zealand

1. Aims

Excessive deposition of fine Sediment in gravel bed rivers can significantly alter benthic communities by filling the interstitial spaces between gravels which a e vital habitats for aquatic invertebrates (McKenzie et al., 2024) and essential for fish spawning (Pilkerton et al., 2025). These fine sediment build-ups can also disrupt hyporheic exchange processes by clogging the riverbed (Gupta et al., 2023).

To address these impacts, regional councils and unitary authorities are required to manage fine sediment deposition in rivers (Haddadchi et al., 2022)C.</author></authors></contributors><titles><title>Guidance for implementing the NPS-FM sediment requirements. Prepared for Ministry for the Environment</title><secondary-title>ME 1663: 88</secondary-title></titles><dates><year>2022</year></dates><pub-location>Wellington: Ministry for the Environment </pub-location><urls></urls></record></Cite></EndNote>. This requires reliable and repeatable monitoring techniques to accurately measure the extent of fine sediment accumulation

This presentation reviews existing methods used in Aotearoa–New Zealand for monitoring fine sediment deposition and evaluates their ability to consistently capture sediment build-up in a meaningful way.

We draw on findings f om past and ongoing projects within Earth Science New Zealand, including reach-scale modelling of sediment deposition under different flood scenarios and event-based sediment budget assessments at the catchment scale. These insights offer valuable context for assessing the effectiveness of monitoring programmes (e.g., State of the Environment - SOE) used by councils and unitary authorities to measure fine sediment deposition

2. Method

To model fine sediment deposition, we applied a morphodynamic model using Delft-3D in a braided reach of the Rangitata River, Canterbury, located downstream of several water abstraction points (Figure 1). The model was used to assess the influence of various hydrograph characteristics—such as flood duration, peak fl , and the length of the recession limb—along with variability in sediment supply, including hysteresis patterns, particle size distribution, total event load, and peak concentrations across different sediment size classes.

Upstream measurements of flow and size-fractionated suspended sediment concentrations from multiple flood events were used as boundary conditions in the model. Simulated deposition patterns within the reach were compared against pre-event sediment conditions to quantify changes resulting from each flood event

In a separate project investigating event-scale sediment budgets, high-resolution sediment load data were collected from four monitoring sites across the Oreti River network, Southland (Figure 1). This dataset enabled an assessment of spatial variability in fine sediment deposition by comparing net sediment gains and losses between reaches during floods of varying magnitudes.

3. Results

Morphodynamic modelling of fine sediment deposition in the Rangitata River reach revealed that flood recession characteristics play a key role in controlling deposition patterns. Floods with longer recession durations led to increased sediment deposition. Similarly, events exhibiting anticlockwise hysteresis—indicating higher sediment transport during the recession phase—also resulted in greater deposition.

Event-based sediment budgets for the Oreti River revealed considerable variability in suspended sediment storage and transport during floods of similar magnitude. This variability was influenced by hydrological factors such as rainfall distribution and flood peak, as well as the timing of sediment delivery and flow suspended sediment concentration hysteresis across the catchment. Despite these differences, larger floods consistently resulted in greater diffuse source erosion and net deposition within the braided river reach.

These results highlight the significant influence of flood characteristics on fine sediment deposition in gravel-bed rivers. To detect long-term trends, it is essential to monitor sediment deposition under consistent conditions. For example, if monitoring is conducted monthly, it should ideally occur following floods of similar magnitude and hydrograph characteristics.

Establishing State of the Environment (SOE) monitoring sites for sediment deposition near existing flow monitoring stations is also recommended. This co-location enables the application of statistical methods to account for confounding flow-related factors, improving the reliability of trend analysis.

Furthermore, high-frequency sediment monitoring using surrogate techniques—such as optical or acoustic sensors—can provide valuable data beyond total sediment load. These measurements can help assess temporal changes in fine sediment deposition more effectively and support improved river management decisions.

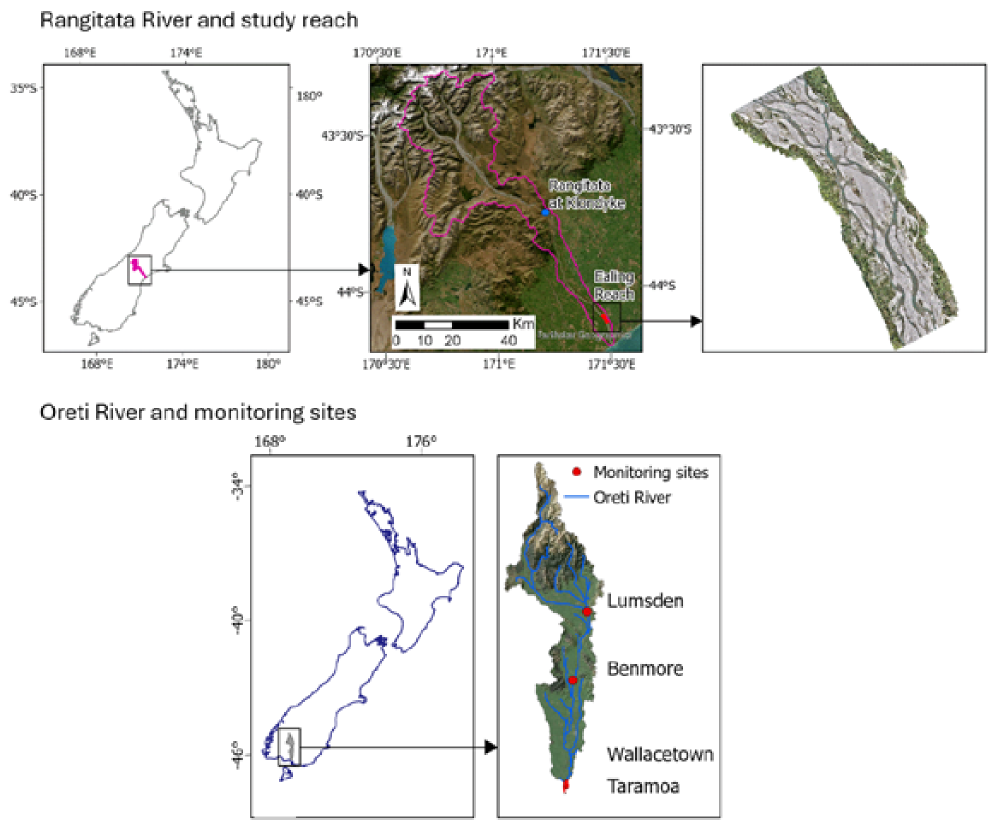


Figure 1. Ranigtata River and modelling study reach (top), Oreti River and four sediment monitoring sites (bottom).

4. References

Gupta, L. K., Pandey, M., Raj, P. A., & Shukla, A. K. (2023). Fine Sediment Intrusion and its Consequences for River Ecosystems: A Review. Journal of Hazardous, Toxic, and Radioactive Waste, 27(1), 04022036. https://doi.org/doi:10.1061/(ASCE)HZ.2153-5515.0000729

Haddadchi, A., Hicks, M., Milne, J., Semedeni-Davies, A., Mathews, Y., Swales, A., & Rautenbach, C. (2022). Guidance for implementing the NPS-FM sediment requirements. Prepared for Ministry for the Environment (ME 1663: 88, Issue.

McKenzie, M., Brooks, A., Callisto, M., Collins, A. L., Durkota, J. M., Death, R. G., et al. (2024). Freshwater invertebrate responses to fine sediment stress: A multi-continent perspective. Global Change Biology, 30(1), e17084. https://doi.org/https://doi.org/10.1111/gcb.17084

Pilkerton, A. M., Alexander, J. S., Patterson, L. S., Burckhardt, J. C., Rahel, F. J., & Walters, A. W. (2025). Linking Suspended Sediment Conditions to Hyporheic Dissolved Oxygen and Fine Sediment Deposition in Salmonid Spawning Habitat Below an Irrigation Dam, Park County, Wyoming. River Research and Applications, 41(5), 980-999. https://doi.org/https://doi.org/10.1002/rra.4412

MAPPING FRESHWATER LENSES IN COASTAL AQUIFERS USING ELECTROMAGNETIC IMAGING: FINDINGS FROM PINES BEACH, NEW ZEALAND

Riley Hamlyn[1], Amandine Bosserelle[1], Leanne Morgan[1]
[1] University of Canterbury Te Whare Wānanga o Waitaha, Christchurch, New Zealand

Freshwater lenses within unconfined coastal aquifers are vital resources for ecosystems and communities but are susceptible to saltwater intrusion due to their proximity to the ocean. Freshwater lenses occur throughout the New Zealand coastline, but little is known of their extent or their seasonal and tidal dynamics. In this study, we mapped freshwater lenses in the Kairaki Creek- Pines Beach area ~10km north of Ōtautahi Christchurch. Geophysical surveys were conducted over approximately 8 km using electromagnetic imaging (EMI) tools (e.g., a CMD Explorer), with the first survey campaign in May–June and the second scheduled for October. Apparent conductivity (mS/m) was used as a proxy for the groundwater salinity and cross-sectional maps (down to a depth of X m) were developed allowing for an assessment of changes in groundwater salinity over seasonal and tidal cycles. This presentation will detail our findings and also offer some reflections on the whether EMI is a robust approach for rapidly assessing and monitoring the extent of freshwater lenses in coastal aquifers.

A FIRST NATIONAL ASSESSMENT OF FUTURE FLOOD HAZARD FOR AOTEAROA NEW ZEALAND

Alice Harang[1], Emily Lane[1], Sam Dean[2], Cyprien Bosserelle[1], Céline Cattoën[1], Graeme Smart[1], Rose Pearson[1], Trevor Carey-Smith[2], Raghav Srinivasan[2]
[1]ESNZ, Ōtautahi Christchurch, [2]ESNZ, Te-Whanganui-a-Tara Wellington

Flooding is one of the most common and costliest natural hazards in Aotearoa New Zealand, and its impacts are expected to increase in the future due to climate change. Flood hazard will be affected through three main mechanisms: increased moisture retention in a warmer atmosphere, rising sea levels, and changes in antecedent conditions.
Focusing on the first mechanism, a wa mer atmosphere is expected to produce more localised and intense rainfall events. To support long-term planning and better protect communities, we need nationally consistent flood mapping that eflects futu e conditions.
The Endeavour project Mā te Haumaru ō te Wai: Flood Resilience Aotearoa, has produced such maps using a cascade of models. The developped workflow includes generatin design storms for each catchment, using a hydrological model to route water from the upper catchment, and applying a hydrodynamic model to simulate floodplain inundation
Different sets of maps were created for the current climate, as well as for future scenarios corresponding to 1°C, 2°C, and 3°C of global warming relative to present conditions. These maps help identify areas most at risk from both fluvial and pluvial flooding in the fut e.

EXPLORATION OF GROUNDWATER SALINISATION RISK IN THE LOWER HUTT GROUNDWATER ZONE

Brioch Hemmings,[1] Jeremy Bennett,[1] Rui Hugman,[1] Heather Martindale[2]
[1] INTERA Incorporated
[2] Greater Wellington Regional Council

Aims
Wellington Harbour overlies a fresh groundwater body which supplies up to 70% of New Zealand's capital region's drinking water via nearshore groundwater abstraction from the Waiwhetū aquifer. Increased water demand and sea level rise pose recognised risks of salinisation to this critical water supply. The regional council and water supplier want to develop a tool for exploring and illuminating these risks.

While the risks to the aquifer relate to salinisation of a coastal freshwater aquifer, an exercise in problem decomposition highlighted that the initial concerns relate to flow dynamics rather than saltwater transport dynamics. Consequently, the modelling efforts could focus on flow conditions of the specific aquifer un   of interest.

Methods
Using boundary conditions (freshwater density equivalent, where appropriate) to represent the harbour, deeper aquifer units, and the foreshore, abstraction-affected, driving heads, we constructed a reduced-order, single-layer, numerical model to target the specific mechanisms of conce n, these were:

• drawdown of harbour water, primarily via reversal of freshwater outflows at known (and unknown) spring locations,
• increased upward flow f om a deeper aquifer unit of poorly defined qualit .

The MODFLOW 6 model supported rapid simulation of aquifer behaviour under evolving driving heads and sea level rise scenarios. The modelling workflow included u certainty analysis and history matching with high-density parameterisation using ensemble methods, as implemented in PyEMU (White et al., 2021) quantifying uncertainty in the important simulated outputs, and reducing uncertainty through assimilating historic system-state observations, is as important as the numerical model. However, implementing high-dimensional and stochastic workflows a e challenging, often requiring that practitioners have theoretical and practical understanding of several advanced topics. Worse, implementing these important analyses can take substantial time and effort. This additional effort is often cited as justification for postponing, or even forgoing, these analyses. Herein, we present scripting tools to facilitate the efficient and epeatable construction of high-dimensional, geostatistical-based PEST interfaces, including uncertainty analyses. As demonstrated, these tools can be applied with minimal effort to a model with varied temporal and spatial discretization. Ultimately, these tools can enable low-cost access to valuable decision-support analyses earlier and more frequently during the modeling workflo .","container-title":"Environmental Modelling & Software","DOI":"10.1016/j.envsoft.2021.105022","ISSN":"1364-8152","journalAbbreviation":"Environmental Modelling & Software","language":"en","page":"105022","source":"ScienceDirect","title":"Towards improved environmental modeling outcomes: Enabling low-cost access to high-dimensional, geostatistical-based decision-support analyses","title-short":"Towards improved environmental modeling outcomes","volume":"139","author":[{"family":"White","given":"Jeremy T."},{"family":"Hemmings","given":"Brioch"},{"family":"Fienen","given":"Michael N."},{"family":"Knowling","given":"Matthew J."}],"issued":{"date-parts":[["2021",5,1]]}}}],"schema":"https://github.com/citation-style-language/schema/raw/master/csl-citation.json"} .

Results
Initial results indicate low probability of reversal of freshwater spring flows and drawdown of the harbour into the aquifer until foreshore heads are depleted by over two metres (well over current risk management levels). However, incorporation of sea-level rise scenario simulations highlight that rising sea levels increase the probabilities of flow eversal (Figure 1), driven by increases in harbour-floor p essures.

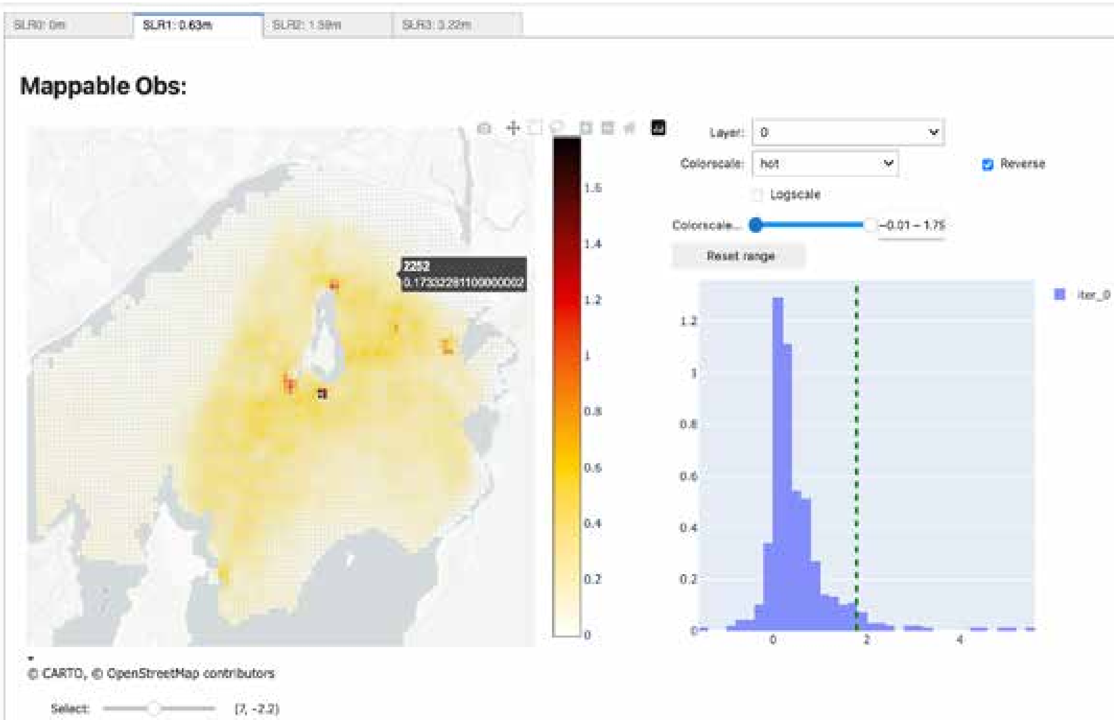


Figure 1: Simulated 95th probability percentile for flow (^{3}d^{-1}) into Waiwhetū aquifer from Wellington Harbour, under 0.63 m of sea level rise and a 2.2 m decrease in foreshore water levels.

The development of a targeted, reduced-order numerical description of a poorly constrained hydrogeological system supported a rapid assessment of risk while expressing the inherent (and multiple) system uncertainties. Furthermore, by following a scripted workflo , it facilitated full-stack testing, rapid error catching and reproducibility for model outcomes.

With the co-development of an interactive model uncertainty visualiser (Figure 1), the whole workflow also supports end-user engagement in both the modelling process and the results. The visualiser has been developed in consultation with water managers and suppliers and will be used to support limit-setting decisions to ensure sustainable use of this important groundwater supply.

References

White, J.T., Hemmings, B., Fienen, M.N., Knowling, M.J., 2021. Towards improved environmental modeling outcomes: Enabling low-cost access to high-dimensional, geostatistical-based decision-support analyses. Environ. Model. Softw. 139, 105022. https://doi.org/10.1016/j.envsoft.2021.105022

TEST DRIVING HYDROSTRATIGRAHIC MODELLING OF AIRBORNE ELECTROMAGNETIC DATA IN THE NEW ZEALAND CONTEXT

Herpe, M.,[1] Rawlinson, ZJ.,[1] Foged, N.,[2] Westerhoff, RS.[1]
[1] Earth Sciences New Zealand, Wairakei, NZ
[2] TEMcompany, DK

Aims

In order to use resistivity model information (such as from airborne electromagnetic data) to inform properties within groundwater models, it is important to understand the relationship between electrical resistivity and hydraulic conductivity in different geological settings. Here, a data-driven interpretation approach was assessed in four geological settings in New Zealand.

The HydroStratigraphic Modelling (HSM) concept was developed for glacial depositional systems in Denmark for rapid and reproducible groundwater characterisation using Airborne ElectroMagnetic (AEM) SkyTEM data (Christiansen et al., 2014, Foged et al., 2014 and Marker et al., 2015). The concept was developed considering the relationship between clay content and hydraulic conductivity in these depositional systems. This concept was assessed for application in four geological distinct areas in New Zealand where SkyTEM data were available:

- A coastal area with a high gravel deposition rate mixed with marine transgressional sequences (Heretaunga plains, Hawke's Bay; Foged 2022)
- An inland area with recent alluvial sediments that have a high instance of clay-bound gravels (Ruataniwha Plains, Hawke's Bay; Herpe and Rawlinson 2023)
- A coastal dune sand and shell- dominated area (Aupōuri Peninsula, Northland; Westerhoff et al. in prep)
- An inland alluvial area with schist-derived gravels and clay (Manuherikia and Ida valleys, Otago; Herpe et al. 2025)

The aim of this paper is to show how depositional settings impact the HSM feasibility and results.

Method

The resistivity models utilised were generated from time-domain AEM data in Hawke's Bay and Northland (Rawlinson et al. 2021, Rawlinson et al. 2022, Westerhoff et al. 2024) and from frequency-domain AEM data in Otago (Kass et al. 2024).

The HSM-concept provides a framework to estimate permeability at resistivity model locations. The method estimates spatially-varying relationships between resistivity and permeability, utilising lithological logs classified into pe meability classes. It uses a binary approach to the input log data which are classified as 'aquifer' (most permeable /coarse sediments), 'aquitard' (clay-rich /least permeable sediments) or 'unknown'.

The HSM-concept was developed for modelling unconsolidated sediments and relied on the assumption that a lower electrical resistivity corresponds to a lower hydrological conductivity, fine sediments, aquita d-like, and vice versa, to coarse sediments, aquifer-like. This assumption is valid in areas where hydraulic conductivity is primarily driven by clay content. To respect this assumption, each resistivity model was clipped laterally and at depth to remove the influence of consolidated sediments and saline

The HSM was implemented through four steps: (1) selection of AEM derived resistivity models corresponding to unconsolidated sediments; (2) a permeability classification of the lithological logs; (3) Accumula ed Clay Fraction (ACT) modelling; and (4) a k-means clustering routine. The ACT modelling (step 3) is an inversion process and ideally requires a good spatial distribution of boreholes throughout the resistivity model extent.

To estimate how well the HSM responds to local depositional settings, and to set-up the initial modelling parameters, histograms of the resistivity model values corresponding to the most aquifer-like lithology (pure gravel or sand) and to the most aquitard-like lithology (pure clay) were generated.

Results

In the Hawke's Bay and Northland survey areas, the difference in resistivity distribution between the most aquifer-like and aquitard-like lithologies were sufficient to establish a good starting point for the HSM. However, in Otago, due to the provenance and properties of the gravels, there is a lack of clear resistivity character distinction from the clay. The borehole distribution is highly concentrated around the populated areas, leaving most of the valleys with little lithological information. Because of the combination of uneven spatial borehole distribution and lack of clear resistivity distinction between gravel and clay, the HSM was not pursued in this area.

In the Hawke's Bay and Northland survey areas, at locations of SkyTEM-derived resistivity models, this HSM framework translated the resistivity models into different hydrostratigraphic units (between 5 and 8), ranging from the most clay-rich unit (aquitard) to the most permeable unit (aquifer). In Hawke's Bay, thanks to the geology of the area respecting the assumption of hydraulic conductivity driven by clay content, the HSM results were sufficient to be used alone. In Northland howeve , because the highest hydraulic conductivity estimate comes from a shell/sand aquifer, the change in hydraulic conductivity is not solely driven by clay content, and with the shell distribution having a lower mean resistivity than the sand, the clustering results of the HSM were combined with other methods to inform the interpretation.

Measures of uncertainty are provided by the clay fraction standard deviation and the clustering silhouette index. In this paper the results will be compared alongside key geological characteristics of the different systems.

References

Christiansen AV, Foged N, Auken E. 2014. A concept for calculating accumulated clay thickness from borehole lithological logs and resistivity models for nitrate vulnerability assessment. Journal of Applied Geophysics. 108:69–77. https://doi.org/10.1016/j.jappgeo.2014.06.010

Foged N, Marker PA, Christansen AV, Bauer-Gottwein P, Jørgensen F, Høyer A-S, Auken E. 2014. Large-scale 3-D modeling by integration of resistivity models and borehole data through inversion. Hydrology and Earth System Sciences. 18(11):4349–4362. https://doi.org/10.5194/hess-18-4349-2014

Foged N. 2022. Hawke's Bay 3D Aquifer Mapping Project: Heretaunga Plains, 3D hydrostratigraphic modelling. Aarhus (DK): Aarhus University HydroGeophysics Group. 27 p. Prepared for Hawke's Bay Regional Council.

Herpe M, Rawlinson Z. 2023. Hawke's Bay 3D Aquifer Mapping Project: hydrostratigraphic modelling in the Ruataniwha Plains. Lower Hutt (NZ): GNS Science. 13 p. Consultancy Report 2023/102LR. Prepared for Hawke's Bay Regional Council.

Herpe M, Rawlinson ZJ, Kellett RL. 2025. Value assessment of reprocessing FEM data in the Otago region for the provision of additional groundwater information. Wellington (NZ): Aqua Intel Aotearoa. 41 p. Report 2025/01.

Kass A, Pedersen JB, Christiansen AV, Rawlinson ZJ. 2024. Resolve Otago 2024. HydroGeophysics Group – Aarhus University. 40p. Report number 10012024. Prepared for GNS Science.

Marker PA, Foged N, He X, Christiansen AV, Refsgaard JC, Auken E, Bauer-Gottwein P. 2015. Performance evaluation of groundwater model hydrostratigraphy from airborne electromagnetic data and lithological borehole logs. Hydrology and Earth System Sciences. 19(9):3875–3890. https://doi.org/10.5194/hess-19-3875-2015

Rawlinson ZJ, Foged N, Westerhoff RS, and Kellett RL. 2021. Hawke's Bay 3D Aquifer Mapping Project: Heretaunga Plains SkyTEM data processing and resistivity models. Wairakei (NZ): GNS Science. 90 p. Consultancy Report 2021/93.

Rawlinson ZJ, Reeves R, Westerhoff RS, Foged N, Pedersen J, and Kellett RL. 2022. Hawke's Bay 3D Aquifer Mapping Project: Ruataniwha Plains SkyTEM data processing and resistivity models. Consultancy Report 2022/38, 79.

Westerhoff RS, Herpe M, Rawlinson ZJ, Sahoo TR, Kass A. 2024. Hydrogeological mapping of the Aupōuri Peninsula, Northland: SkyTEM processing and resistivity models. Wellington (NZ): Aqua Intel Aotearoa. 99 p. Report 2024/01.

Westerhoff RS, Herpe, MH, Sahoo, T., Teka Berhe D, Santamaria Cerruti ME, Strogen D, Rawlinson ZJ, Narvaiza M. in prep. Hydrogeological mapping of the Aupōuri Peninsula, Northland: interpretation of SkyTEM resistivity models. Aqua Intel Aotearoa Report.

EVALUATION OF WEST WERRIBEE AQUIFER STORAGE AND RECOVERY (ASR) SCHEME FOR RECYCLED WATER

Brett Sinclair,[1] William Dench,[1] Russell Martin,[2] Javier Osma,[3] Clare Houlbrooke,[1]
[1] Wallbridge Gilbert Aztec, New Zealand
[2] Wallbridge Gilbert Aztec, Australia
[3] Greater Western Water, Australia

Background
The potential use of aquifers around Melbourne, Victoria, to store treated effluent water for subsequent recovery and use has been considered as far back as 1972 (Thompson 1972). After considerable investigation, City West Water (known as Greater Western Water (GWW) from 2021 onwards) constructed an Aquifer Storage and Recovery (ASR) scheme to the southwest of Werribee. The West Werribee ASR scheme is designed to store and recover excess salt-reduced Class A treated recycled water from GWW's West Werribee Salt Reduction Plant (WWSRP) for the supply of non-potable water to the growing western suburbs. Irrigation demands for the recycled water during summer exceed availability, whereas the availability exceeds demand during winter.

The West Werribee ASR scheme consists of four production bores distributed at distances of approximately 95 m around a central production bore, and up to 14 local and regional monitoring bores for the trials. City West Water performed operational trials at the scheme from 2017 through 2020, using the central production bore as the primary injection and recovery bore.

The ASR scheme targets the confined lower erribee Formation aquifer for recharge and storage. The Werribee Formation comprises interbedded early Tertiary fluvial-lacustrine sand, gravel, cla , and coal deposits.

Groundwater in the lower Werribee Formation is characterised by a salinity too high to be acceptable for irrigation (modelled at 2,225 mg/L total dissolved solids (TDS)). The recycled water was expected to have a salinity of between 500 and 600 mg/L TDS. The water quality delivery criterion for GWW customers was 700 mg/L TDS. The objective of the ASR scheme was to create and maintain a bubble of recycled water within the aquifer. Winter operations would result in the bubble increasing in size and volume, with summer abstraction drawing against the stored water reserve.

In 2020 GWW (Javier Osma, Strategic Projects Engineer, Project Manager) engaged Wallbridge Gilbert Aztec (WGA) to undertake 3D groundwater numerical modelling of several scenarios for future scheme operations.

Aims
There were three key outcomes required from the modelling:

1. What was the recovery efficiency of the ASR scheme, using blended water f om the production bores to meet the customer criterion?
2. How rapidly would the projected annual volumes of recovered water meet the salinity criterion decline?
3. If the relative recharge and abstraction rates for each of the production bores were adjusted, or potentially an additional production bore installed, could the operational life of the ASR scheme be significantly extended

Method
Javier Osma developed the operational scenarios to be tested with the groundwater model. He also evaluated the model outcomes with regards the operational and financial viability for GW .

Four general scenarios were considered, with each scenario requiring production bores to comply with maximum operating injection pressures and maximum allowable drawdowns.

The availability of recycled water for recharge at the ASR scheme was forecast to decrease significantly over time, due to projected increasing demand for this water during winters (Figure 1). Summer demands would continue to increase. For the purposes of this assessment, it was assumed no additional sources of recharge water would become available in the future.

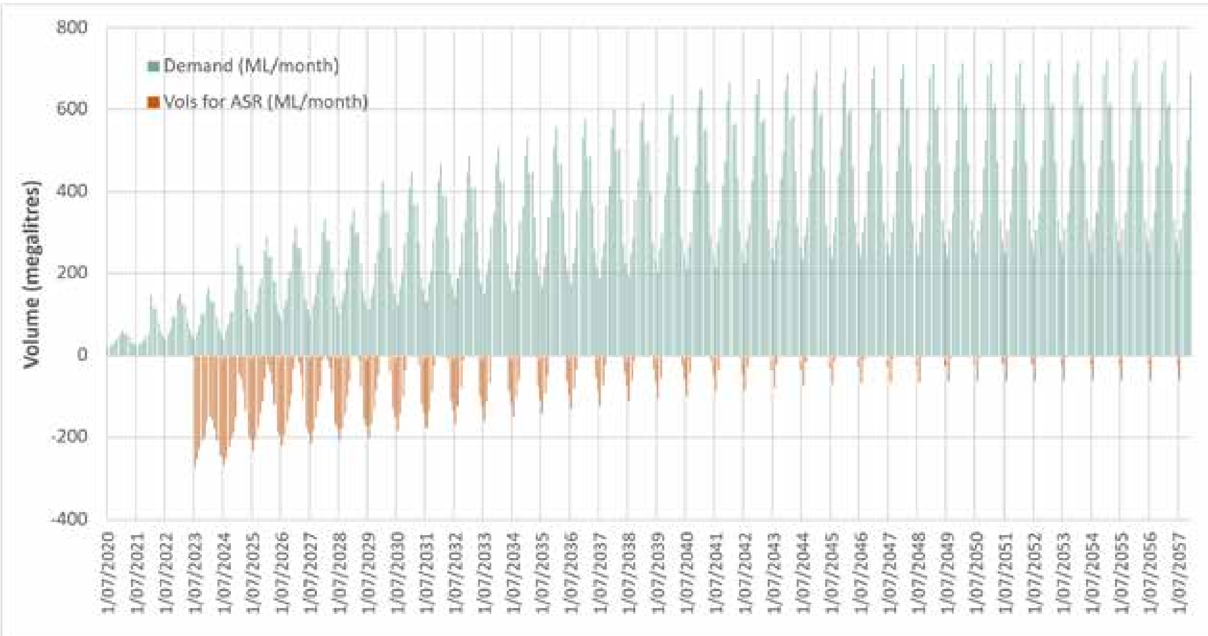


Figure 1: Model Scenario 1 Injection and Extraction Volumes

Results

The results indicated:

- The longer the ASR scheme could operate, the higher the overall recovery efficienc . Recovery efficiencies of 50% could be achieved
- When managing recharge water using a recharge to recovery ratio of 120%, the recovered water never exceeds the delivery criterion of 700 mg/L TDS over the 35-year modelled time period, but water recovery efficiency is less than 40%
- Optimisation of the scheme through increasing the recovery rates from the down-gradient bores achieves a significantly higher ecovery efficiency than the other scenarios
- The relatively low recovery efficiencies achieved arise because the echarge envelope moves beyond the capture zone of the ASR scheme bores within 10 years under the influence of the egional hydraulic gradient.
- Operationally pumping from the ASR scheme would cease once the delivery criterion of 700 mg/L TDS was exceeded. Although pumping could then revert to the 120% recharge to recovery ratio to maintain some supply, this would not meet the demand.

Overall, the ASR scheme itself could function effectively to store and recover recycled water. However, the projected increasing shortfall between the volume of recycled water available for storage and the projected demand limits the long-term effectiveness of the scheme. Options were recommended to improve the recovery efficiency or operational life of the scheme. These gen rally involve additional availability of water for storage or blending.

References

WGA 2022. Numerical Groundwater Modelling Assessment. Report produced for Greater Western Water by

Wallbridge Gilbert Aztec. 31 March 2022. 105 p.

Thompson, B.R. 1972. A review of the aquifer systems near Melbourne and the possibility of using treated effluent for artificial echarge. Geological Survey Victoria Report 197211 1.

LESS FLOODING, LESS SEDIMENT: EFFECTS OF PASTURE-TO-PINE CONVERSION IN A HEADWATER CATCHMENT

Andrew O. Hughes,[1] Thanh D. Dang,[1]
[1] Earth Sciences New Zealand

Aims
Plantation forestry is an important land use in New Zealand, covering around 7% of the country, and recent central government incentives for tree planting will result in further increases in the future. Plantation forestry in New Zealand is often established on steep, high-erodible land, often as a form of catchment restoration and/or erosion control. However, the harvest phase of planation forestry can leave the land highly vulnerable to increased erosion for around 2-3 years after tree removal. Recent major storm events in New Zealand (including Cyclone Garbielle in February 2023) have brought attention to the impact of large storms on land with little cover (e.g. harvested land and pasture). However, Cyclone Gabrielle was an extreme event, with flood levels in some Cyclone Garbielle a fected rivers being classed as 1 in 400-year events. Hence, it is important to understand the impact of converting land to pine plantation (including the harvest phase) during more frequent (or 'average') weather conditions.

We use long-term hydrology and suspended sediment data to evaluate how converting a pastoral headwater catchment to plantation forestry influences flood magnitude and equency and its consequent impact on suspended sediment loads.

Methods
This study focussed on two headwater catchments (Mangaotama and Whakakai streams) located within, and adjacent to, the former Whatawhata Research Station (WRS). We used a paired-catchment approach, within a BACI (before-after-control-impact) design, to track change in suspended sediment loads within the Mangaotama catchment in response to partial conversion from grazed pasture to forest cover (mainly with P. radiata; "impact"). Monitoring covers a 31-year period (1994 – 2024), which includes an eight-year period prior to planting ("before") and 23 years after planting ("after" – including the first eight years prior to canopy closure). The nearby native-forested Whakakai catchment ("control") was monitored in tandem within the BACI design.

Results
We found that the amount of suspended sediment exported from the Mangaotama catchment decreased threefold in response to increasing forest cover (mostly P. radiata plantation) from ~2% to of ~62% of the catchment. Under pasture conditions, the catchment exported about 1600 tonnes of sediment per year. After the 8 years of pine forest growth, the catchment exported about 540 tonnes of sediment per year. The conversion from pastoral grazing to plantation forest may have immediately reduced the amount of sediment exported from the catchment, but the most significant eduction occurred after canopy closure (~8 years after planting). This reduction in the amount of sediment exported from the catchment is a response to the reduced number and size of flood events, particularly la ge events which mobilise and transport most sediment. The reduction in the number and size of flood events is a esult of the interception, slowing down, and loss of rainfall by the dense pine forest canopy.

No change in the flood hyd ology or suspended sediment loads was detected within the Whakakai ("control") catchment over the same period.

Given such field-based studies f om New Zealand are rare, these findings he e will be useful for informing the debate around the environmental impacts of pastoral land conversion to plantation forestry. This work also demonstrates the value of long-term datasets and well-controlled experimental sites for informing important land use management decisions.

RAINFALL-RUNOFF MODELLING OF EXTREME FLOODS USING MACHINE LEARNING

Jamieson-Lucy, T.,[1]
[1] Riley Consultants Limited

Aims
Dams are designed to safely pass extreme flood events which a e likely larger than what has been observed in historic hydrological records. The flood design standa ds necessitate rainfall-runoff modelling to predict the inflows of low p obability flood events. The suitability of using rainfall-runo f models developed using machine learning for the prediction of extreme events, such as the probable maximum flood (PMF), was investigated.

Method
A direct comparison was made between a machine learning modelling approach and a traditional rainfall-runoff modelling approach in HEC-HMS using physics-based models (i.e. initial and continuing loss). The project entailed rainfall-runoff modelling of the Cobb River at Trilobite catchment, a location immediately upstream of the Cobb Dam in Tasman, New Zealand. Modelling was completed using both a machine learning approach and an approach based in HEC-HMS.

The machine learning modelling was completed using the NeuralHydrology package in Python. The model was trained (i.e. calibrated) using a large hydrologic dataset incorporating many catchments and provides continuous predictions including floods and low flows for the catchment of i erest.

The HEC-HMS model was developed using a selection of the largest observed flood/rainfall events. The model was calibrated to each event individually and design model parameters derived from the range of calibrated values.

Results
Both models provided a good match to the observed large floods and to flood equency analysis estimates (peak flow and volume) up to the 1 in 100 AE . Results from both models were considered reasonable for more extreme events such as the 1 in 1,000 AEP through PMF. In design modelling, the machine learning model was sensitive to the antecedent flow and rainfall. In the HEC-HMS modelling, adjustment of model parameters for each simulation was required to achieve acceptable results across both observed and design events.

Other learnings included the requirement to use a machine learning model class which conserves mass to achieve reasonable flow p edictions for design flood events which lie outside of the his oric record.

The investigation highlighted the potential for machine learning models to be effective for the simulation of extreme flood events up to the PM . The models present some advantages over a traditional approach, with a single model able to represent low flow periods, observed floods and design flood events esign modelling was sensitive to antecedent flow and rainfall, with the magni ude of this uncertainty like that of a traditional modelling approach.

SCOPE OF POTENTIAL SEAWATER INTRUSION TO 2150 IN AOTEAROA NEW ZEALAND

Allanah Kenny[1], Andy Pearson, Phil Abraham, Rachel Qiu, Laura Banasiak, Theo Sarris
PHF Science[1]

In many coastal areas, groundwater represents a critical resource for drinking, irrigation, industry, and agriculture. However, seawater intrusion into coastal aquifers is an escalating global threat. In Aotearoa, rising sea levels, increasing groundwater extraction, and land subsidence are expected to significantly heighten this risk. Once an aquifer is contaminated with seawater, it can take decades for salt to be flushed out and intrusion fully reversed. Identifying vulnerable aquifers is therefore essential for informing resource management and averting the worst impacts.

In Aotearoa, although seawater intrusion has occurred in some aquifers, no studies have examined the potential threat on a national scale, nor how the risk profile may change under p ojections of future sea-level rise. We use water-level monitoring data and AI-based modelling to identify coastal areas with landward hydraulic gradients (i.e. where groundwater level is at lower elevation than sea-level), combined with future sea-level and vertical land movement projections, to develop the current seawater intrusion risk profile and how this changes to 2150 under three Shared Socioeconomic Pathways (SSPs)). The findings p ovide the first nationwide screening of seawater intrusion potential, offering a foundation for prioritising local investigations and informing adaptation strategies to safeguard water, infrastructure, and coastal communities.

DROUGHT PROPAGATION IN UNDISTURBED CATCHMENTS OF THE SOUTHERN ALPS OF NEW ZEALAND

Daniel G. Kingston[1], Sarah M. Mager[1], Kim De Vantier[1], Sophie L. Horton[2]
[1]School of Geography, University of Otago, Dunedin
[2]School of Earth and Environment, University of Canterbury, Christchurch

As with many major mountain regions of the world, Kā Tiritiri o te Moana/the Southern Alps of New Zealand act as a substantial water tower for the surrounding lowland regions. Correspondingly, water shortages (i.e. drought) in alpine and high-country catchments can lead to substantial impacts beyond the catchment boundary – for instance on electricity generation, availability of water for irrigation purposes and environmental flows. Making use of the New Zealand contribution to t e recently developed global Reference Hydrometric Basin Network (ROBIN), here we identify the occurrence of and time series variation in hydrological drought over the period 1965-2022. A variable threshold approach is employed to ensure seasonal drought events are captured, as well as the more obvious periods of absolute low flo . Subsequently the drivers of these events are tracked back through the hydrological cycle: to meteorological drought, temperature-related factors (evaporation and precipitation type), and on to the national and larger-scale atmospheric circulation situations that provide the context for and connections between these catchment-level anomalies.

AI FOR QUALITY MANAGEMENT OF WATER LEVEL DATA IN SOUTH KOREA

Chanwoo Kim, Eunjeung Shim, Dongheon Oh, Jaehyun Song
Korea Institute of Hydrological Survey

Abstract
Ensuring the quality of high-frequency water level data is essential for accurate hydrological analysis and effective water resources management. Anomalies in gauging station data have traditionally been identified th ough manual techniques such as visual comparison with neighboring stations, application of physical tolerance limits, and periodic staff gauge readings. In South Korea, data correlation and staff gauge readings are the most commonly used for detecting and correcting anomailies. These approaches, however, often struggle to capture nonlinear patterns and time-lagged responses resulting from complex flow dynamics

This study proposes an AI-based anomaly detection approach for 10-minute water level time series, incorporating spatial correlations between a target station and its neighboring stations. The target stations were selected based on known issues, including float-type gauge ov rturning, sensor setting errors, data spikes, and persistent deviations caused by stilling well obstructions. An Extended Long Short-Term Memory (xLSTM) model was used to learn typical water level behavior and simulate expected values. Based on differences between raw and simulated data, three thresholding strategies were applied: (1) a fixed th eshold using a specific di ference value, (2) a dynamic threshold based on the distribution of residuals, and (3) a hybrid threshold applying range-specific limits. As each metho exhibited different performance across stations and occasionally produced false positives, a rule-based classification app ocah was developed. Data points detected by at least two of the thresholding methods were initially labeled as potential anomalies. If these detections continued over consecutive time intervals, the points were futher classfied as persistent anomalies, indicating g eater confidenc in their validity.

The three thresholding strategies proposed in this study each have their own strengths and limitations. However, relying on any single threshold alone made it difficult to intuitively dete mine whether flagged points epresented true anomalies or false positives. The rule-based classificatio approach effectively addressed this issue by improving reliability. The model successfully identifie over 90% of actual anomalies within segments labeled as persistent anomalies. Although points flagged as potential anomalies also showed a elatively high level of reliability, many of them corresponded to areas affected by subtle sensor calibration errors or baseline shifts caused by channel bed changes. These cases still require expert review for validation. Even so, the ability to reduce the scope of manual inspection from full dataset to specific segments detected by the mode demonstrates the practical value of this approach. Additionally, we are currently developing an automated correction algorithm using backup data from dual water level sensors. The findings of thi study may serve as a basis for AI-based automation in water level data quality management and the production of more reliable hydrological data.

Acknowledgements

This work was supported by Korea Environment Industry & Technology Institute(KEITI) through Research and Development on the Technology for Securing the Water Resources Stability in Response to Future Change Project, funded by Korea Ministry of Environment(MOE)(RS-2024-00332300)

GENERATING NON-STATIONARY GEOSTATISTICAL FIELDS WITH ANISOTROPIC SPATIAL CORRELATION

Kitlasten, W.[1], Taves, M.[1], Rawlinson, Z.[1], Moore, C.[1],
[1] GNS Science

The spatial variability of hydraulic parameters plays an important role in groundwater flow and transport modelling. Aquifer hydraulic properties are typically characterized using geostatistical fields that cap ure spatial variability, where parameter variance increases with increasing separation between points. The relationship between separation ("lag") and variance is typically defined using a variogram model. In groundwater modelling, a single variogram model or nested variogram models (i.e., multiple levels of variability) are often used to characterize spatial variability across the model domain (i.e., assuming stationary). However, the nature of spatial variability is often fundamentally different between different hydrogeologic facies or deposits (e.g., fluvial deposits juxtaposed with coas al deposits).

To address these limitations, we introduce a Python utility that generates non-stationary geostatistical fields with anisotropic spatial correlation. The utility facilitates highly parameterized model calibration (e.g., using PEST or PESTPP) with flexible parameterization of: orientation f variance anisotropy, correlation lengths, local means, and local variances. We discuss the theory, required inputs, workflo , and implications of this approach. We show some examples of inputs and resulting fields info med by: 1) hydrogeological facies models derived primarily from borehole information, and 2) hydrogeological interpretations of airborne electromagnetic data. This utility is open source and available on github.

DETECTION OF DRAINAGE DITCHES FROM LIDAR DTM USING U-NET AND TRANSFER LEARNING

Virro, H.,[1] Kmoch, A.,[1] Lidberg, W.,[2] Muru, M.,[1] Chan, W.T.,[1] Moges, D.M.,[1] Uuemaa, E.[1]

[1] Department of Geography, University of Tartu, Estonia
[2] Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, Sweden

Drainage ditches are crucial for water management and flood risk mitigation, but m pping them from remote sensing imagery is difficult due to their nar owness and coverage by vegetation, especially in forests. Traditional methods are labor-intensive and often incomplete, while deep learning requires extensive labeled data that is not always available. To overcome this, we used a transfer learning approach with a U-Net model pre-trained on a Swedish dataset and fine-tuned on a smaller Esto ian dataset, utilizing a single-band LiDAR DTM raster as input. This method minimized preprocessing and identified optimal model configuration through testing kernel sizes and data augmentation. The fine-tuned model achieved n F1 score of 0.766, effectively detecting drainage ditches in regions with limited training data. Accuracy varied by land use, being highest in peatlands (F1 = 0.822) compared to forests (F1 = 0.752) and arable land (F1 = 0.779), highlighting its adaptability for large-scale mapping. This method enabled national-level mapping of drainage ditches with reasonable accuracy. Fine-tuning on a small dataset highlighted transfer learning's potential for environmental mapping in data-scarce regions. Experiments revealed that increasing the kernel size beyond 3×3 did not improve accuracy, while basic augmentation techniques boosted performance, underscoring the importance of balancing model performance with computational efficienc .

FIELD INVESTIGATIONS OF GROUNDWATER-SURFACE WATER INTERACTION IN THE UPPER TAIARI SCROLL PLAIN, CENTRAL OTAGO

Levy, A.[1], Khan, S[1], Lu, X.[1]
[1]Otago Regional Council

Aims

Groundwater can substantially impact surface water hydrology, quality, and ecology. This project investigated the interaction between groundwater and surface water in the Upper Taiari Scroll Plain, Central Otago. The Scroll Plain holds unique ecological, landscape, and cultural values. However, there is currently little knowledge regarding the influence of g oundwater on this system.

The specific objectives for this p oject were:
- Understanding the hydrological relationship between the Taiari River, groundwater, and wetlands
- Delineating the spatial/temporal variability in groundwater geochemistry within the Scroll Plain
- Calculating groundwater fluxes in the Sc oll Plain

Method

Groundwater-surface water interaction in the Scroll Plain was investigated using field measu ements of groundwater and river levels, temperature, quality, and geochemistry. Groundwater and river levels were continuously monitored in shallow piezometers installed in four transects across different land uses (sheep, beef, deer, and conservation). Each transect included river level monitoring, with groundwater levels monitored in a piezometer near the river and two further away from it. All measuring points were surveyed to a common datum to delineate hydraulic heads and groundwater flow di ection. The results were then combined with short aquifer tests to calculate groundwater fluxes using Da cy's Law.

Results

Groundwater levels in the near-river bores closely followed the fluctuations in river stage, albeit wi h a varying time lag. The relationship between river and groundwater levels then became weaker as the distance from the river increased. Groundwater hydraulic heads were mostly higher than river levels, indicating that groundwater mostly flows towa ds the river, which usually gains groundwater. However, short periods of higher river levels, where groundwater flows away f om the river which temporarily became losing, were also observed. These periods indicate temporary or 'bank' storage of water in the shallow riparian aquifer along the river margin and play an important role in the Scroll Plain's hydrology.

River water temperatures were substantially more variable than groundwater temperatures. The highest variability in groundwater temperature was measured in the near-river bores, with variability decreasing with distance from the river. The temporal variations in groundwater temperatures were also much smaller and lagged changes in river temperature, suggesting very low discharge of river water into the groundwater system.

The geochemistry of river water was similar across all sites. Conversely, groundwater geochemistry displayed spatial variability between the different positions in the transects. The highest groundwater dissolved ionic and nitrate concentrations were mostly measured in the distal bores, with substantially lower concentrations near the river. These results suggest dilution and redox reactions are important controls on groundwater geochemistry at these sites. However, despite the river's predominantly gaining conditions, river concentrations of most ions and nutrients, particularly nitrate, were lower than those in groundwater. These low concentrations in river water suggest low groundwater-river interaction. If the interaction was greater, it is expected that this would manifest in higher ionic concentrations in river water.

Drilling indicated that the Scroll Plain is underlain by a shallow sands and gravels aquifer that contains a variety of fine fractions (silt). G oundwater flow th ough the shallow aquifer was calculated using Darcy's Law. Flux calculations indicated predominantly gaining conditions, where groundwater discharges to the river. However, temporary flow eversals were observed following rapid increases in river levels. The highest calculated flux ranged between 55 to 90L/s. These exceeded thos calculated in the remaining transects by approximately 1-2 orders of magnitude. However, even the highest calculated groundwater discharges comprised less than eight percent of the Taiari River flo .

The low calculated groundwater fluxes, the observed lag in g oundwater temperature changes, and differences in geochemistry between groundwater and river therefore suggest that, despite the close relationship between groundwater and river levels, groundwater only exerts a minor influence on the Sc oll Plain's surface water quality and hydrology. t

SAFER WATER (SERVICE FOR ADVANCED FLOOD EMERGENCY RESPONSE)

Marcel Alderlieste[1], Brian Jackson[2], Rick Liefting[3].
[1] HydroLogic Systems, Netherlands
[2] Water Technology, Australia
[3] Waikato Regional Council, New Zealand

Aims
The SAFER-Water project seeks to address the increasing flood risks in New Zealand, focusing on the aikato region, where floods a e frequent, severe, and costly due to the region's extensive river systems and low-lying agricultural lands. Climate change has heightened the intensity and frequency of such events, putting communities, ecosystems, and critical infrastructure at growing risk. The project aims to enhance flood preparedness and emergency response through the development and deployment of an advanced flood probability forecasting and emergency response system.

SAFER-Water tackles these issues by integrating advanced technologies with local data, processes, and protocols to deliver real-time, impact-based flood fo ecasts and actionable emergency responses. The SAFER project concept ultimately aims to provide a real-time, scalable, replicable, customisable, impact-based flood forecasting and emergency response service framework, as outlined in Figure 1.

Figure 1: SAFER Concept

The key SAFER deliverables are: Live connections with data, models and platforms; A Weather and Water Control Room; A real time Rainfall Exceedance Service; A Machine Learning based Flood Forecasting Service demonstration (piloted in the Kauaeranga River Catchment); Pilot SAFER Flood Emergency Response Service; A Data Driven Water Management Course.

This initiative aligns with the Sustainable Development Goals (SDGs) 11 (Sustainable Cities) and 13 (Climate Action), promoting resilient communities and improved climate adaptation strategies.

Method
At the core of SAFER-Water's innovation is its use of advanced computing and machine learning technologies, including Long Short-Term Memory (LSTM) neural networks (Hop et. al. 2024), to generate real-time probabilistic inundation forecasts. These technologies enable faster and more precise predictions compared to traditional methods, with the ability to process data hundreds of times faster. The platform incorporates high-resolution weather data from the New Zealand MetService, local water data, and advanced modelling tools, ensuring solutions tailored to the region's unique needs. A cloud-based infrastructure enhances scalability, reliability, and cost-effectiveness, reducing the need for extensive local infrastructure.

The project will be implemented through several key steps, starting with workshops to gather user requirements and assess local data and protocols. Next, weather and water data will be integrated into the HydroNET platform, a proven decision-support system used by water managers worldwide. The system will be validated through extensive testing, user feedback, and real-world simulations, ensuring it meets local needs. A significant component involves capacity building, including an e-learning platform to train local water managers in effectively utilizing the system.

The SAFER-Water consortium, led by HydroLogic BV, includes key partners such as Water Technology, World Water Academy, and MetService New Zealand. Together, they bring expertise in meteorology, hydrology, machine learning, and training. Local engagement is a cornerstone of the project, with active participation from the Waikato Regional Council. This collaboration ensures the system is embedded within local processes, fostering community trust and sustainability.

Results

The initial user requirements workshops have been successfully held and the weather and water data dashboards have been defined acco dingly and integrated into the HydroNET platform (Figure 2).

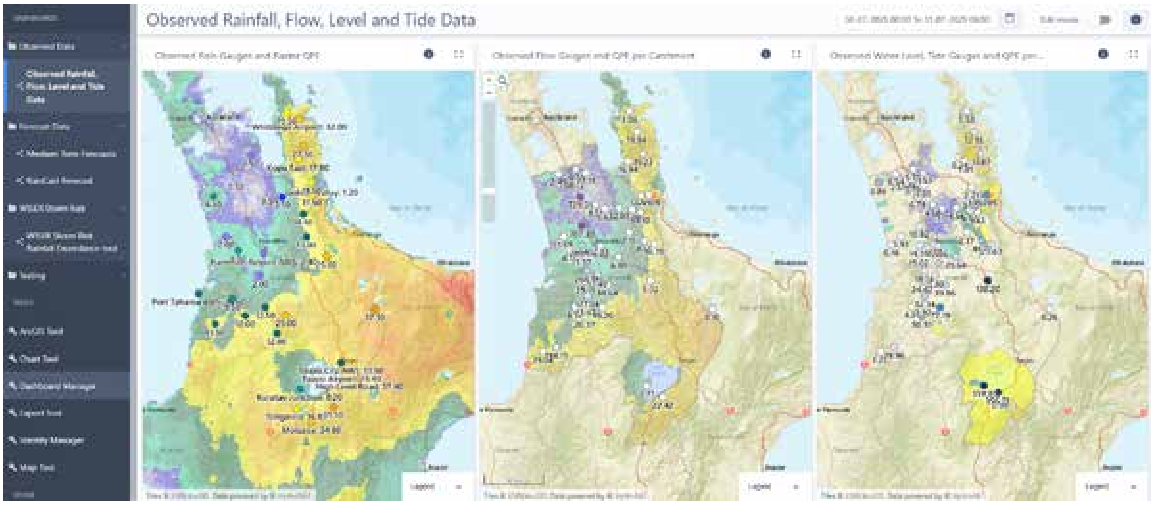


Figure 2: Example of a HydroNET dashboard configu ed for Waikato with observed weather and water data (point, gridded and polygon data)

The real time rainfall exceedance information service, dubbed WISER Storm Risk, has also been configu ed (see Figure 3). This is already providing Waikato Regional Council with forecast and observed rainfall exceedance information (gauge, gridded radar rainfall QPE, catchment aggregated radar rainfall QPE) to improve knowledge of the rainfall intensity, timing, duration and severity before, during and after events, thereby improving decision making.

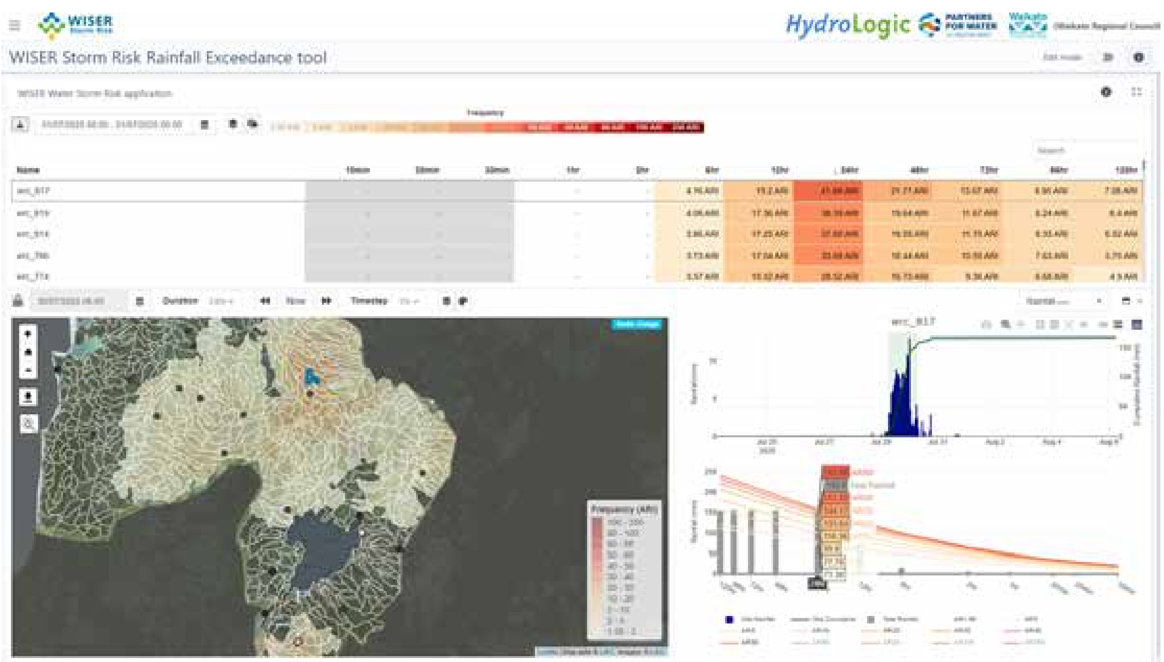


Figure 3: WISER Storm Risk Rainfall Exceedance information service dashboard for Waikato Regional Council

Expected outcomes include a fully operational SAFER-Water system by the end of 2026, providing reliable flood fo ecasts, actionable emergency responses, and reduced flood impacts on lives, p operty, and ecosystems. The process flow for the main technical activities in po gress are shown in Figure 4

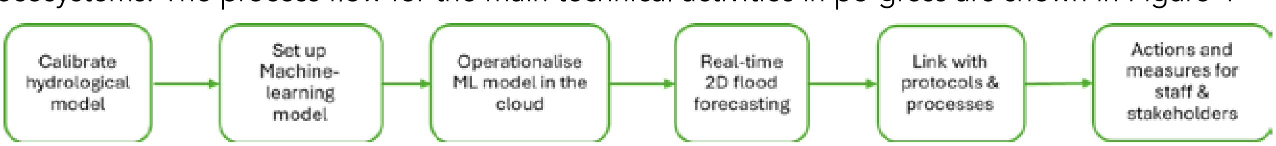


Figure 4: Key remaining technical activities workflow

The project's scalable design positions it as a model for extending similar services to other regions in New Zealand and the Pacific Islands, which face similar challen es from climate-induced weather events. By blending cutting-edge technology with local expertise, SAFER-Water represents a critical step toward sustainable water management and climate resilience.

References

Hop, F. J., Linneman, R., Schnitzler, B., Bomers, A., & Booij, M. J. 2024. Real time probabilistic inundation forecasts using a LSTM neural network. Journal of Hydrology, 635, 131082.

DOWNSCALING CLIMATE PROJECTIONS USING FOURIER NEURAL OPERATORS

Liu, O[1]
[1]Auckland University

Global Climate Models (GCMs) simulate large-scale climate dynamics and the response to in- creasing greenhouse gas emissions, but their coarse spatial resolution limits their ability to represent regional climate processes and impacts. This presents challenges for impact assessments at the local scale, where decisions around adaptation and resilience are typically made. Physics-based dynamical downscaling using high-resolution Regional Climate Models (RCMs) can produce fine-scale projections, but is computationally expensive and impractical for downscaling large climate model ensembles - key to capturing the full range of future climate responses and associated uncertainties. As a computationally efficient alternative, empirical statistical downscaling and deep learning methods, especially those using Convolutional Neural Networks (CNNs) and Generative Adversarial Networks (GANs), have shown promising skill in reproducing historical variability, including means and extremes, and in extrapolating to unseen scenarios when trained on combined historical and future simulations. However, these methods often lack physical interpretability and may rely more on statistical correlations than physically grounded relationships. In this study, we investigate the use of Fourier Neural Operators (FNOs) for RCM emulation, leveraging their ability to capture global spatial dependencies and cross-scale interactions in the frequency domain. We integrate FNOs into a GAN framework to improve fine-scale realism while preserving coherence with large-scale atmospheric drivers. Experiments using reanalysis and high-resolution RCM simulations demonstrate that FNO-based approaches perform comparably to CNN-based baselines while offering improvements in spatial coherence and the representation of fine-scale climate variability. These results highlight the potential of spectral learning as a complementary strategy for advancing data-driven climate downscaling.

WHERE WILL THE FIRE GO: DEVELOPMENT OF THE NEW COUPLED ATMOSPHERE-FIRE MODEL PALM-FDS

Alena Malyarenko
University Of Canterbury

In recent decades, the escalating impacts of wildfies, exacerbated by climate change, have raised concerns in our society. Urban areas and/or Rural-Urban Interfaces (RUIs) possess unique features, including local wind flow dynamics and surface structu es, which create internal boundary layers and may in luence ire behaviour. As human activities expand into wildlands, RUIs face increased risks of wildland fi e hazards. Understanding fi e-atmospheric dynamics and interactions is crucial for effective wildfi e management and mitigation strategies.

To address those issues, we have developed the first fully coupled atm sphere-fi e model within FDS framework. This coupled model takes PALM output, initialises FDS fields, and fo ces primary variables, i.e. temperature and wind components, at the lateral boundaries of the domain. Our model is unique in its ability to develop fi e-atmosphere interaction by accurately predicting vegetation fi e (the fi e is allowed to propagate in space as it develops) and reacting to large-scale changes in circulation (developed in PALM). In this presentation, we will showcase the model development and show test cases that highlight the importance of coupled fi e-atmosphere interactions.

MACHINE LEARNING PREDICTIONS OF NEW ZEALAND RIVER FLOWS USING LSTMS

Gemma Mason, Matt Wilkins, Céline Cattoën-Gilbert
Earth Science New Zealand

River streamflow fo ecasts play a vital role in flood p ediction, agricultural planning, and water resource management. Such forecasts are often found by using conceptual or physics-based hydrological models. Machine learning time series prediction presents a new set of possible techniques that may be used to make these predictions. International results have shown that LSTM (Long Short-Term Memory) models trained on publicly available daily datasets can improve reliability and lead times of forecasts of extreme events (Nearing et al, “AI Increases Global Access to Reliable Flood Forecasts,” 2023).

This study presents the first application of the CAMELS-NZ dataset (covering over 300 catchments) to train LSTM models for hourly flow fo ecasting in New Zealand’s fast reponding rivers. LSTMs may be used to post-process the output of a physics-based model, or they can be used to directly predict flows based on data about the previous weather and antecedent conditions. We will evaluate the performance of these models, focusing on extreme events and discuss their potential to enhance early warning for floods in Aotea oa New Zealand.

HALO-SOUTH – FLIGHT PLANNING FROM THE ANZ TEAM

Adrian McDonald [1], Daniel Morrish[1], and Marwan Katurji
[1] University of Canterbury

The latest Intergovernmental Panel on Climate Change report shows aerosol-cloud interactions are the largest single source of uncertainty in climate models, leading to biases in sea surface temperatures and errors in the position of the Southern Hemisphere storm track in our local vicinity. The goSouth2 umbrella campaign brings together three large research projects to address these uncertainties:

• HALO-South: an instrumented research aircraft campaign which will fly f om Christchurch International Airport in September–October 2025.
• ACADIA (2025–2027): A ground-based measurement campaign which will occur for 18 months at Invercargill and at the Tāwhaki National Aerospace Centre which overlaps with HALO-South.
• ACAROA (2027/2028): A research voyage into the Southern Ocean by the RV Sonne linked to the Antarctica Insync effort.

The broad range of cloud environments of interest, including low-level boundary layer clouds, cloud inflow and outflow egions, and high-level cirrus, and the wish to sample regions potentially associated with new particle formation offers a wide range of potential priorities for any individual flight plan. Combined with the ability to deploy dropsondes to quantify the influence of vertical velocity on clou processes, a range of atmospheric features a wide range of valid targets for sampling were identified. Flight operations also have to consider the possibility to complete overpasses over field site at Invercargill, Kaitorete Spit, and Taranaki, to enable coordinated in situ, remote sensing, and aircraft observations.

Given this wide range of priorities, cloud climatologies and statistical analyses of atmospheric features were used to identify the expected frequency and location of potential priority targets previous to the campaign period. After this review, environments near low-pressure centres, where aircraft positioning relative to the centre can allow sampling of a wide range of distinct in and out of cloud environments was highlighted as a particular focus for flight planning. ith the potential for airflows such as feeder airst eams, atmospheric rivers, and the warm conveyor belt offering opportunities to sample different thermodynamic and microphysical cloud properties. These features also provide opportunities to identify air masses that have recently interacted with cloud systems, particularly near dry intrusions, where conditions may favour new particle formation.

For operational planning, we will discuss the integration of local area model simulations to resolve fine-scale cloud structures, feature tracking from IFS and GFS forecasts to anticipate the evolution and position of target low pressure centres, and near-real-time Himawari-9 satellite imagery for cloud field monitorin and adjustments to flight paths. e will discuss how this structured approach worked and whether it allowed us to sequence targets by likelihood, adapt to evolving weather conditions, and maximise both data quality and scientific elevance during the HALO-South mission flight

QUANTIFYING FOREST HYDROLOGICAL PROCESSES & RESPONSES TO EXTREME EVENTS WITH TERRESTRIAL AND REMOTE SENSING MESUREMENTS

Meason, D.F.,[1] Corbett-Lad, P., [1] Villamor, G.B., [1] White, D.A., [1] Salekin, S., [1] Owens, J.,[1] Xue, J.,[1] Dudley, B., [2] Griffiths, J. [2] Yang, J., [2] Cassles, G.,[3] Bifet, A.,[3] Andreadis, K.,[4] Moller, D.,[5] Höck, B.,[6] Zhu, H.[7], Araki, R.[8] Corbet, J.[9], Azan, C.,[9] Palma, J.[10], and Matson, A.[11]

[1] Scion Bioeconomy Science Institute
[2] NIWA Earth Sciences New Zealand
[3] University of Waikato
[4] University of Massachusetts Amherst
[5] University of Auckland
[6] Candleford
[7] Shanxi Agricultural University
[8] San Diego State University
[9] Bordeaux INP
[10] MV Agroecology Research Centre
[11] Wageningen University

Aims
Land-use intensification and climate change a e increasing pressure on water availability and use around the world. Furthermore, the frequency and intensity of extreme rainfall events are increasing with climate change (Meason et al., 2019). Forests cover 31% of global land area and are crucial for storing and releasing precipitation, however, it is difficult to quantify fo est hydrology processes and transfer the learnings from one watershed to another.

Planted forests are increasingly seen in NZ as a competitor for freshwater resources, and regulations are being proposed to limit forestry (Meason et al., 2025). This could have a large impact on the New Zealand forestry sector that is dominated by Pinus radiata (D. Don). However, current knowledge about forest hydrology is based on studies from over 45 years ago. They relied heavily on a water balance 'black box approach' and are not suitable for answering today's questions (Meason et al., 2025). The Ministry of Business, Innovation & Employment (MBIE) Endeavour Forest Flows Programme (2019-2024) employed a fundamentally new approach using integrated terrestrial and remote sensing measurements to directly quantify tree water use, the amount of water stored and released in planted forest catchments, and the underlying drivers. Scientists from 23 institutions were involved from New Zealand and seven other countries.

Methods
Five primary research sites and four secondary sites were established with the primary sites established across a rainfall gradient ranging from 800 mm to 3,000 mm per year. All five catchments a e within commercially managed forests planted with P. radiata with contrasting geology, soil and topography. An intensive sensor network was installed in each of the five primary esearch sites to directly measure as many of the hydrological processes as possible. In total, 1,717 sensors across seven sites collected 360,000 measurements every 24 hours. This included three groundwater wells per site at a depth of 10m. New big data and machine learning algorithms were developed for analysing the big data (Cassles et al., 2025). With the integration with terrestrial and remote sensing measurements (airborne and satellite), Forest Flows was able to quantify forest hydrological processes on an unprecedented spatial and temporal scale and provide world-leading new insights. Local communities and iwi were engaged for their perceptions and knowledge requirements (Villamor et al. 2025), and the results were shared with them.

Results
The hydrological processes of almost 300 individual precipitation events per site were measured over 3.5-year period. This included measurements during the January 27th 2023 Auckland Flooding Event and Cyclone Gabrielle extreme weather events and long dry periods that impacted individual sites during the study period. Canopy interception was not the overriding factors for precipitation infiltration into the soil. Infiltration wa detected for low precipitation events as small as 1.4mm. The study found that across all five primary sites, a mean of 74% of all rainfall events infiltrated into the soil o a depth of 100 cm. Despite the differences in

climate, soil, and geology, the soil water dynamics during precipitation events had similarities. Lateral flow was a dominate process for soil water movement. Low precipitation events were detected reaching shallow groundwater (10m) even during summer. For the sites with lower annual precipitation, groundwater had a greater proportion of response to precipitation events than streamwater. Groundwater flux was insensitive to antecedent soil moisture conditions and for most sites insensitive to season. Soil macropore pathways were important for subsurface water movement to groundwater and surface water. At the catchment level, it was found that subsurface water movement is key for water release from planted forest catchments. Indeed, more than 50% of the annual precipitation left the catchment underground than it did with surface water for the three catchments with precipitation <1,600mm/yr. For large precipitation (>50mm) and extreme precipitation (>150mm) events, P. radiata catchments had a mean short-term retention rate of 60% of the precipitation, thus reducing downstream flooding. Baseflow during the summer months will be esented.

The results suggest that the water balance method overestimates evapotranspiration of P. radiata forests and such forests are more important than previously thought for precipitation storage and release, which will important regulatory implications. The integration of terrestrial and remote sensing and forest hydrological modelling will be discussed as well as future projects.

References

Cassales, G., Salekin, S., Lim, N., Meason, D., Bifet, A., Pfahringer, B. and E. Frank. 2025. A comparative study of four deep learning algorithms for predicting tree stem radius measured by dendrometer: A case study. Ecological Informatics, p.103014. doi.org/10.1016/j.ecoinf.2025.103014.

Meason, D.F., Baillie, B.S., Höck, B., Lad, P., and T. Payn. 2019. Planted forests and water yield in New Zealand's hydrological landscape – current and future challenges. New Zealand Journal of Forestry, 63: 33-39.

Meason, D.F., Griffiths, J., Mc illiams, V., Corbett-Lad, P. 2025. New insights into forest hydrology with Forest Flows Programme – radiata pine catchments' water use and release. New Zealand Journal of Forestry, 70: 25-32.

Villamor, G.B., van Noordwijk, M., Srinivasan, M.S., Clinton, P.W. and D.F. Meason. 2025. Trees and water: A survey of the perception and decisions of landowners in New Zealand. People and Nature, doi.org/10.1002/pan3.70012.

TOWARDS AN OPERATIONAL HIGH-RESOLUTION DATA-DRIVEN WEATHER PREDICTION MODEL FOR NEW ZEALAND

Meyers, T.[1]; Rio, Maxime[1]; Mason, G.[2]; Moore, S.[1]; Aide, J.[3]; Juntao, Y.[3]
[1] Earth Sciences New Zealand, Wellington
[2] Earth Sciences New Zealand, Auckland
[3] NVIDA AI Technology Centre (NVAITC), Singapore.

Machine-learned Weather Prediction (MLWP) using Neural Weather Models (NWMs) has matured to the point where they are considered accurate and reliable, even outperforming traditional numerical weather prediction (NWP) by some metrics, globally and within New Zealand. Leading forecasting centres now operate their own NWMs. However, these models typically run at coarse resolutions (≥0.25°) and offer limited output fields, making them unsuitable for use highly localised foreasting services.

A further challenge is how NWM architectures are implicitly global in scope. This complicates retraining or fine-tuning with the same networks on local data for limited area domains. Recent developments show promise, with local NWMs trained on high-resolution datasets and conditioned on coarse global forecasts, similar to how high-res NWP models use global models for boundary conditions.

Nevertheless, the computational demands of training such high-resolution models, which require dozens of GPUs or TPUs, remain a barrier for many centres. We present a prototype NZNWM: a high-resolution, data-driven forecasting model designed to produce operationally relevant fields for weather fo ecasting and downstream hazard modelling. This talk outlines the model's development, from architecture selection to training and initial results, and discusses future directions for localised MLWP in New Zealand.

HIGH-RESOLUTION MESOSCALE ATMOSPHERIC MOTION VECTORS FROM FY-4B GEOSTATIONARY SATELLITE FOR IMPROVED TYPHOON TRACK FORECASTING

Min Min,[1] Pan Xia,[1]
[1] School of Atmospheric Sciences and Guangdong Province Key laboratory for Climate Change and Natural Disaster Studies, Sun Yat-sen University and Southern Laboratory of Ocean Science and Engineering (Guangdong, Zhuhai), Zhuhai 519082, China

Atmospheric Motion Vectors (AMVs) derived from satellite measurements play a crucial role in improving Numerical Weather Prediction (NWP) models through data assimilation, with this study focusing on the development of high-resolution Minute-scale and Mesoscale Atmospheric Motion Vectors (MAMVs) using Fengyun-4B geostationary satellite high-speed imager (FY-4B/GHI) data at 3 km horizontal resolution and 1-minute temporal resolution to enable precise monitoring of mesoscale weather systems and their rapid dynamics, demonstrating high accuracy through validation against radiosonde data with a Speed Bias (SB) of 0.37 m/s, speed Root Mean Square Error (sRMSE) of 4.68 m/s, and direction Root Mean Square Error (dRMSE) of 26.35°, while significantly enhancing typhoon fo ecasting by providing valuable multi-layer wind field insights that educe 48-hour track forecast errors by nearly 50% and extend forecast accuracy to 72 hours when assimilated into NWP models, as evidenced by case studies of recent super typhoons that highlight MAMVs' potential to substantially improve tropical cyclone prediction.

FUTURE PROOFING GROUNDWATER: BUFFERING CLIMATE CHANGE EFFECTS ON WATER AVAILABILITY AND QUALITY

Catherine Moore[1] , Uwe Morgenstern[1], Zara Rawlinson[1], Wes Kitlasten[1], Nick Cradock-Henry[1]
[1] Earth Sciences New Zealand

Freshwater availability and quality in New Zealand is declining, and hotter and drier future conditions projected, the management challenges are only likely to increase. The Future Proofing G oundwater Endeavour programme will enhance understanding of the resilience of groundwater and connected surface water systems to drought and nitrate contamination under future climate and land-use stresses. We combine models, new geophysical data and tools with unique environmental groundwater tracers to provide understanding of complex groundwater flow systems and their limits (storage), and their ca acity to assimilate land-use nitrate loads.

At the national scale, spatial patterns of drought resilience combined with an understanding of current and future water demand and water availability, will be used to assess future hydrologic impacts of climate change in terms of groundwater levels and surface flows, c op production and economic outcomes. Furthermore, land-use and resilience patterns associated with nitrate contamination will be used to assess the combined impact of future land-use changes and climate pressures on ground- and surface water quality.

Within selected regions, interfaces between numerical modelling tools and dynamic adaptive pathways maps are being developed to navigate environmental, economic, social and cultural trade-offs, while accounting for increasing uncertainty and future changes in system states and understanding.

THE NEW ZEALAND REANALYSIS

Stuart Moore
Earth Sciences New Zealand

Through its membership of the Momentum Partnership, a collaboration of operational and research centres across the globe and led by the UK Met Office, Earth Sciences NZ (SNZ) has been contributing to the development and testing of a new Numerical Weather Prediction (NWP) modelling system called LFRic. Designed from the outset with a view to running large NWP models on next generation "exascale" HPC infrastructure at increasingly higher spatial resolutions, and featuring a new dynamical core, called Gung-Ho, ESNZ has contributed to technical work to optimise model performance on CPU architectures and scientific testing on domains that cover all of the challenges New Zealand can offer. This includes its complex terrain and varied landscape, proximity to the International Date Line and extreme weather events.

GROUNDWATER QUALITY MONITORING OPTIMISATION 2/2 – NATIONAL PROGRAMME REVISION IN THE WAIKATO

Moreau, M.,[2] Hadfield, J. [1] Wilson, N.,[1]
1 Earth Science New Zealand
2 Waikato Regional Council

This part two paper focuses on the review of the National Groundwater Monitoring Programme (NGMP) initially applied in the Waikato region. It is a pilot for wider application to consistently review regional and national programmes. It aims to address current shortcomings of environmental monitoring and limitations in our ability to use the acquired data to assess policy effectiveness (Parliamentary Commissioner for the Environment 2019; Etheridge et al. 2023). This pilot also intends to provide transparency on the necessary compromises between objectives, practical considerations and resources within monitoring programmes.

The joint review of Waikato's groundwater quality monitoring by Waikato Regional Council and Earth Science New Zealand was undertaken over multiple years, allowing for consultation with the Groundwater Forum Special Interest Group. It led to first the ag eement on common monitoring principles between councils, central government and former crown research institutes, and agreement on a core analytical suite in 2024 (Groundwater SIG 2024; Moreau 2024). These monitoring principles use a Surveillance (i.e. long-term state and trends) and Evaluative (i.e. management focused) framework, which is a departure from State of the Environment programmes.

To review the NGMP monitoring objectives and structure, these were compared to the agreed principles; current monitoring needs and, reporting requirements at the national scale (Environmental Reporting Act 2015; Ministry for the Environment and Statistics New Zealand 2016). Optimisation constraints included applicability at the national scale; use of national datasets; development of a consistent method enabling flexibility to eflect variations in hyd ogeological setting; unchanged collaborative operating model and fixed resourcing. The NGMP monitoring suite was evaluated simultaneously to that of WRC to identify overlaps and alignment opportunities. Site distribution and sampling frequency were reviewed using an index-overlay method to assess priority areas for groundwater monitoring, complemented with regional hydrogeology considerations. Optimisation variables (e.g. increasing spatial coverage using fixed site densities) we e tested by developing five options for the p oposed programme changes. Finally, the proposed change was selected to increase monitoring breadth and operational efficiencies, in consultation with egional experts.

In the Waikato, the NGMP network currently consists of 10 sites monitored quarterly for 17 variables. Samples are currently collected by WRC and analysed at the New Zealand Geothermal Analytical Laboratory. The monitoring objectives are to provide a nationally consistent, long-term perspective on the state and trends in groundwater quality suitable to inform national reporting, which fits under Surveillance Monitoring. No changes are proposed to the monitoring suite as it remains relevant to track hydrogeological processes and diversity of groundwater bodies. Operational efficiencies a e already in place e.g. low frequency of expensive variables such as dissolved metals and groundwater age tracers. The proposed network consists of 18 existing or planned regional monitoring sites representing all identified primary monitoring aquifers and a selec ion of secondary monitoring aquifers (Figure 1). Coordinating sampling between regional and national programmes allows for simultaneous data collection reducing both time and cost, while enhancing data coverage and maintaining sampling frequency. The proposed changes include data compilation to support freshwater national reporting to address data gaps.

It should be noted that monitoring programmes were developed in the early 1990s in response to the 1991 Resource Management Act. Over time, collected data enabled characterisation of aquifer systems, identified groundwater quality issues and informed sustainable management. Therefore, proposed changes regionally and nationally are modifications rather than a complete edesign. Regular reports to the Groundwater Forum were effective in ensuring clear communication, developing buy-in and leveraging expertise. The process involved iterative high level and practical considerations. Recommendations were provided to address current disconnects (e.g. linking data collection to reporting), which are the result of compartmentalized management. Addressing these challenges will be key to ensure enduring benefits f om this step change. This optimization focused on fit-fo -purpose data rather than data management. The index overlay method used could also be used to inform future groundwater level monitoring reviews. The overall approach is potentially transferable to other freshwater monitoring domains.

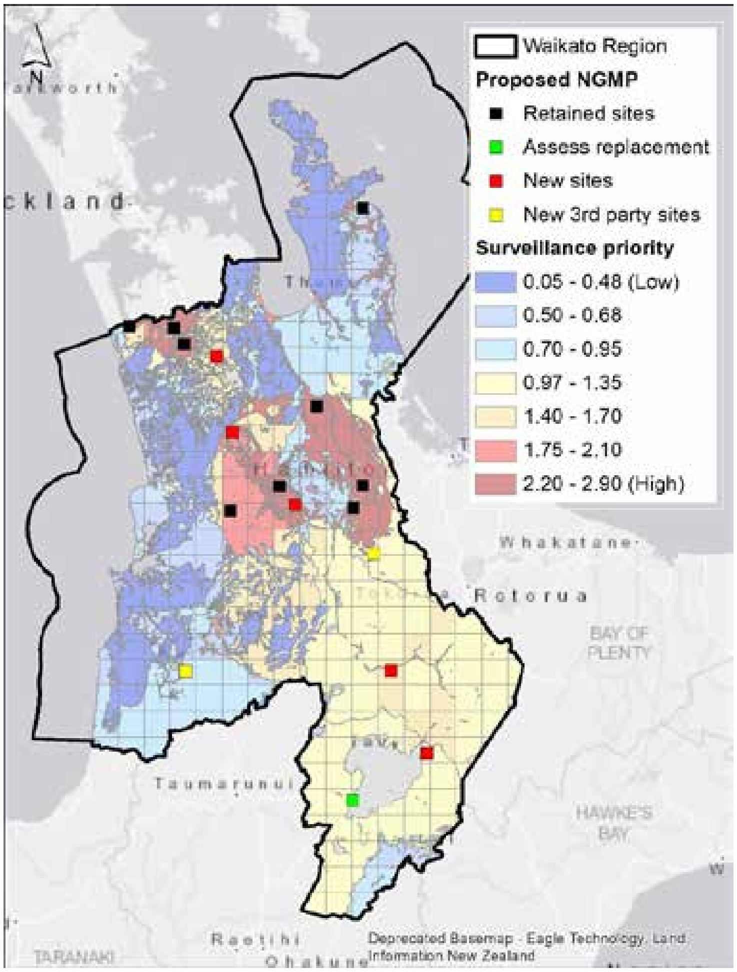


Figure 1: Current and proposed modifications to the national surveillance network in th Waikato. Note that some sites are to be shared with the Auckland region where aquifers extend beyond the regional boundary.

References

Groundwater Special Interest Group. 2024. Te Uru Kahika Groundwater Special Interest Group meeting minutes—25 November 2024.

Etheridge, Z.; Dumont, M.; Charlesworth, E. 2023. Water quality monitoring for management of diffuse nitrate pollution. Wairakei (NZ): Komanawa Solutions Ltd Science. Report No: Z22014_01. 51pp.

Environmental Reporting Act. 2015. https://www.legislation.govt.nz/act/public/2015/0087/latest/DLM5941105.html

Ministry for the Environment and Statistics New Zealand. 2016. Topics for Environmental Reporting. 11 p.

Moreau M. 2024. Development of a national framework for groundwater monitoring. Lower Hutt (NZ): GNS Science. 19 p. Consultancy Report 2024/56. Prepared for the Ministry for the Environment.

Parliamentary Commissioner for the Environment. 2019. Focusing Aotearoa New Zealand's environmental reporting system. Wellington (NZ): Parliamentary Commissioner for the Environment. 100 p.

Resource Management Act 1991. https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

BEYOND GLOBAL ESTIMATES: CLASSIFYING SEA-LEVEL RISE IMPACTS ON GROUNDWATER AT A NATIONAL-SCALE FOR NEW ZEALAND

Leanne Morgan[1], Amandine Bosserelle[1], Rogier Westerhoff[2]
[1] Waterways Centre, School of Earth and Environment, University of Canterbury
[2] Earth Sciences New Zealand

This presentation describes a national-scale classification of nea -surface unconfined coastal g oundwater systems in New Zealand, that predicts vulnerability to sea-level rise (SLR). Using high-resolution national datasets, a well-established water table ratio framework was applied to classify coastal catchments and their associated aquifers as either flux-cont olled (recharge-limited) or head-controlled (topography-limited). This distinction between flux-cont olled and head-controlled is important as they represent endmembers in terms of impacts from SLR. Flux-controlled systems are more vulnerable to water table rise while head-controlled systems are more vulnerable to seawater intrusion. The findings eveal that while flux-cont olled systems are more prevalent by catchment count along the New Zealand coastline (64% of catchments), head-controlled systems dominate in terms of land area (56% of coastal catchment area) and are characteristic of most low-elevation coastal zones (71%). In terms of length of coastline, the majority was flux-cont olled (60% of coastline length). This national-scale assessment significantly refines prior coarser global p edictions, which estimated that 75% of the NZ coastline was head-controlled. Location-dependent insights are essential for informing effective national water management and enhancing resilience to impacts of climate change on New Zealand's coastline.

SALINITY SURVEY IN THE ASHLEY-WAIMAKARIRI SHALLOW COASTAL AQUIFER USING WATER QUALITY AND GEOPHYSICS

Fiona Rodie,[1] Amandine Boserelle[1], Leanne Morgan[1]
[3] Waterways Centre, School of Earth and Environment, University of Canterbury

Coastal aquifers are vital freshwater resources that are increasingly vulnerable to salinisation from sea-level rise, land use pressures, and groundwater abstraction. Despite this, studies of spatial and temporal salinity dynamics in NZ's shallow coastal aquifers are limited. The goal of this study is to investigate the Ashley-Waimakariri coastal plain in North Canterbury by characterising shallow groundwater salinity and assessing effectiveness of electromagnetic (EM) geophysics methods compared to a water quality approach. An integrated approach was employed, combining continuous salinity monitoring using loggers in shallow piezometers at four sites (S1 and S2 at Pines Beach, S3 at Woodend, and S4 at Waikuku), along with EM and water quality surveys carried out in October 2024 and April 2025. Logger data revealed both short-term and seasonal variations in groundwater salinity, with high conductivity observed in the summer months. Surface water sites near the coast, including Kairaki Creek and Ashley Estuary, showed persistent high salinity (>10,000mS/cm, peaking ~39,000mS/cm). EM surveys identified zones of elevated apparent conductivity consistent with logger and water chemistry data, whilst loggers captured temporal changes. This study demonstrates the value of combining geophysics and continuous monitoring to better understand seawater intrusion processes and support groundwater management in low-lying coastal settings.

GROUNDWATER AND SURFACE WATER CONCEPTUAL FLOW FROM ENVIRONMENTAL TRACER SIGNATURES IN THE TASMAN REGION

Morgenstern, U.[1], Moreau, M.[1], Townsend, DB.[1], Stewart, MK.[1], Thomas, J.[2], Fenemor, AD.[3]
[1] Earth Sciences New Zealand
[2] Tasman District Council
[3] Landcare Research

In the Tasman District, groundwater is essential for drinking water supplies, for irrigation of crops for a large range of horticulture and agriculture practices, and for reliable industrial and commercial water supplies. Groundwater is also the resource that maintains base flows in the rivers and st eams throughout dry periods to enable healthy freshwater ecosystems.

Water quality is influenced by land use activities and by geolo ical factors. Groundwater in the Tasman District is generally of good quality, but elevated nitrate concentrations are an issue in some areas. In the Waimea Plains, groundwater and surface water bodies (groundwater fed springs) at times exhibit high nitrate concentrations above limits including the Drinking Water Standard of New Zealand maximum acceptable value of 11.3 mg/L NO_3-N and the NPSFM (2020) median nitrate toxicity limit of 2.4 mg/L NO_3-N.

Aquifers in the Tasman District include alluvial, karstic, and sedimentary rocks with a wide range of hydraulic conductivities and storage. Management of water resources in the district, regarding quantity and quality, requires understanding the water dynamics through these aquifers, including sources and rates of recharge, water transit times, storage, and interaction between surface water and groundwater. Understanding these dynamics also enables understanding of contaminant sources, spatial patterns, and temporal trends.

Age tracers provide information on flow rates, hyd ochemical evolution, and storage, while groundwater source tracers provide information on recharge sources, such as local rain, versus loss from higher altitude catchment rivers. Radon can be used to understand where groundwater discharges into rivers or where rivers lose water into aquifers.

We used these tracers, in combination with hydrochemistry, to address the following questions:

- What are the sources of recharge for aquifers and are they being actively recharged?
- Can we infer recharge and flow rates f om groundwater source and age data?
- Are there preferential flow paths
- Are the river systems connected to the aquifer via their gravel fans?
- What are the processes that control the hydrochemical properties (quality) of the groundwater?
- Are high nitrate concentrations caused by historic or current land use practices?
- Is there active denitrification occurring in the g oundwater systems?

This regional synthesis brings together newly acquired data, on-going monitoring data and site investigations.

HALO-SOUTH – FIELD CAMPAIGN AND DATA COLLECTION FROM THE ANZ TEAM

Daniel Morrish[1], Adrian McDonald[1], and Guy Coulson[2]
[1] University of Canterbury
[2] The Air Quality Collective

Model projections used to guide climate change adaptation in Aotearoa New Zealand (ANZ) carry significant uncertainties, particularly due to challenges in imulating cloud-aerosol interactions. The latest Intergovernmental Panel on Climate Change report shows these interactions are the largest source of uncertainty in climate models, leading to biases in sea surface temperatures and errors in the position of the Southern Hemisphere storm track. Most climate models are developed with data from the Northern Hemisphere, where cloud and aerosol datasets are more available compared with very sparse measurements over the Southern hemisphere, and particularly the Southern Ocean.
The goSouth2 umbrella campaign brings together three large research projects to address these uncertainties via focussed collaborative effort between New Zealand and German researchers. The three field e forts are:

- HALO-South: an instrumented research aircraft campaign which will fly f om Christchurch International Airport in September–October 2025.
- ACADIA (2025–2027): A ground-based measurement campaign which will occur for 18 months at Invercargill and at the Tāwhaki National Aerospace Centre which will start at the same time as HALO-South.
- ACAROA (2027/2028): A research voyage into the Southern Ocean by the RV Sonne.

This talk provides an overview of the ground-based measurements made from Invercargill and the Tāwhaki National Aerospace Centre during the HALO-South campaign. The focus will be on the complementary nature of the measurements made to those collected from the HALO aircraft.

DEVELOPMENT OF 3D FACIES MODELS OF COASTAL AQUIFER SYSTEMS FOR NEW ZEALAND

Narvaiza MA.[1], White P.[1], Moreau M.[1].
[1] Earth Science New Zealand

Aims

Coastal aquifer systems are key groundwater resources for New Zealand as they supply much of the country's drinking water and most of the groundwater used by the productive sector. Three-dimensional (3D) coastal aquifer facies models are developed for 175 coastal aquifer systems in New Zealand (Figure 1). These models represent facies in model cells (100 m*100 m*1 m) that combine surface and subsurface data to understand coastal hydrogeology.

The project is funded by the New Zealand Ministry of Business, Innovation and Employment Strategic Science Investment Fund Groundwater Research Programme (contract C05X1702) in collaboration with regional and district councils. The project aims to develop a consistent 3-D digital aquifer map of New Zealand.

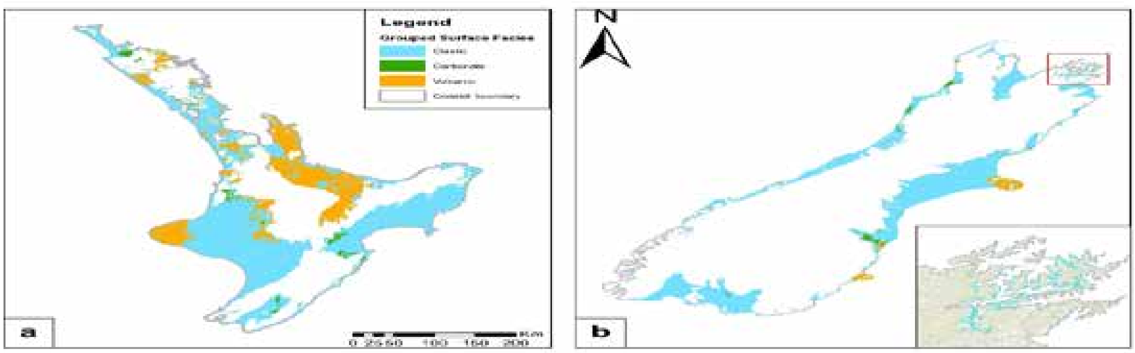


Figure 1: Coastal aquifer systems and surface facies distribution for: (a) North Island and (b) South Island.with zoom in Cook coastal aquifer system (Figure 2).

Method

The 3D facies models combine two publicly-available datasets: the 2D Hydrogeological System Map with broadly-consistent hydrogeological properties within general groundwater catchments (Moreau et al. 2019); and the Hydrogeological Unit Map (i.e., aquifers, aquitards, aquicludes and basement) mapped nationally, at a 1:250,000 scale in a consistent manner to illustrate geological layering (i.e., overlapping, stacked, polygons; White et al. 2019).

Models were developed by:

- estimating basement facies elevation within coastal systems by interpolating from the outcrop of Mesozoic geological formations.
- tertiary layers (i.e., Paleocene, Eocene, Oligocene, Miocene and Pliocene) were developed using the 1:250,000 geological maps (QMAP) cross sections and estimating the elevation of each layer.
- considering surface facies e.g., as identified in the QMA .
- calculating cell facies with borelog data supplied by regional and district councils. Boolean operators identified key markers in lithological logs (e.g., shell, peat, sand).

The models are used to calculate aquifer volumes and begin a new classifica ion of aquifer systems by facies types (surface and sub-surface). Earth Vision and ArcGIS software were used to develop these models. Model data is stored as comma separated values (.csv) files in Earth Science New   ealand databases.

Results

Coastal system models have produced new understandings of New Zealand's coastal aquifer systems. For example, this project identified the geometry of the 175 coastal aquifer system , many of which never been modelled before. Aquifer volumes calculated from these models can improve estimates of national groundwater volumes. The models have found uses across multiple research areas. For example, models are currently being used in numerous groundwater projects, e.g.: Wairau Plain (climate change and groundwater); Canterbury (geology, shallow aquifers and groundwater catchment boundaries); Kapiti (drilling potential); Southland Plains (shallow groundwater level assessment); Wairarapa (aquifer locations including gravel fans) and Pukekohe (groundwater heat source potential).

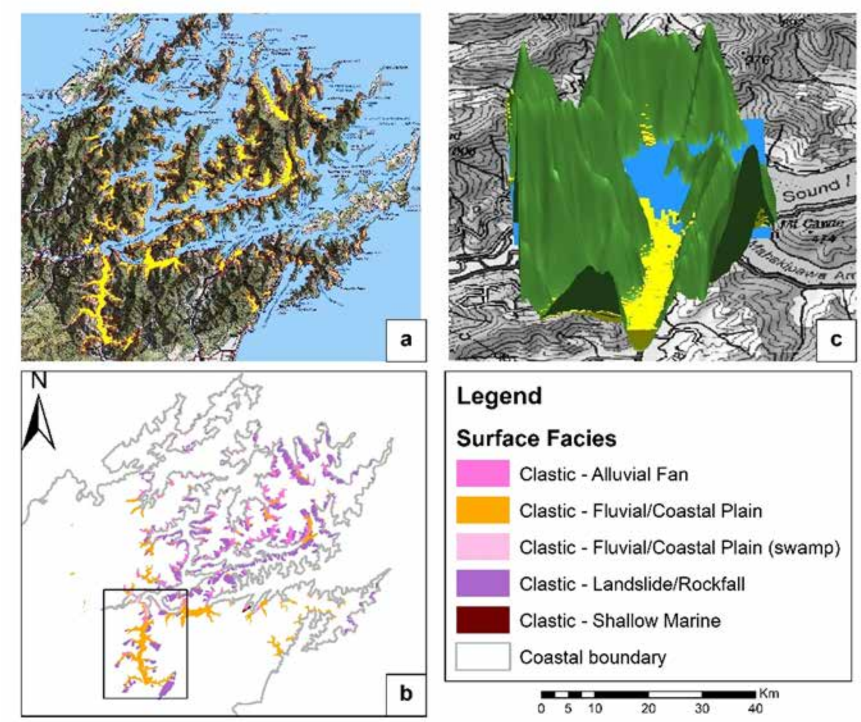


Figure 2: Marlborough Sounds with: (a) Cook South Island coastal aquifer system area (red polygon) with valley fill coastal aquifer systems (yellow); (b) surface geologic l facies; and (c) cross section of Kaituna River valley (looking North), valley fill coastal aquifer systems (y llow) as cells (100 m*100 m*1 m) and sea level (blue), the green colour shows an estimate of basement elevation within the coastal system.

References

Moreau, M., White, P.A., Mourot, F., Rawlinson, Z., Tschritter, C., Cameron, S.G., Westerhoff R. 2019. Classification of New Zealand hyd ogeological systems. Lower Hutt (NZ): GNS Science. 28 p. (GNS Science report; 2018/35). doi:10.21420/42QW-MC74.

White, P.A.; Moreau, M.; Mourot, F.; Rawlinson, Z.J. 2019 New Zealand Groundwater Atlas: hydrogeological-unit map of New Zealand. GNS Science. 89 p. (GNS Science report; 2019/144).

ENSO AND SEASONALITY MODULATION OF TROPICAL CYCLONE GENESIS EVALUATED IN DOWNSCALED CLIMATE MODELS

Tolulope Emmanuel Oginni [1,2], James Renwick [1], Erik Behrens [2], Peter B. Gibson [2]
[1] School of Geography, Environment and Earth Sciences, Victoria University of Wellington
[2] The New Zealand Institute for Earth Science, Wellington, New Zealand

Tropical cyclone (TC) behaviour was evaluated from six CMIP6 models dynamically downscaled with the Conformal Cubic Atmospheric Model (CCAM) over the Southwest Pacific f r the historical period. To characterise coupled ocean – atmosphere variability, El Niño–Southern Oscillation (ENSO) phases are identified using the Coupled ENSO Index (CEI) and a e examined over three TC seasons: early (October – January), late (February – May) and full (October – May). We evaluate how tropical cyclone frequency, genesis spatial distribution, and subsequent intensity is modulated by ENSO across the models. Four of the six models underestimate total TC frequency, while two overestimate TC frequency in relation to observation. All models reproduce the overall ENSO modulation of TC frequency, with more TCs during El Niño; but a few models generate too many TCs during La Niña. Spatially, tropical cyclone genesis peaks north of 15°S near the dateline in observations, while most models have a slight westward genesis bias. In observations, the most intense TCs tend to preferentially occur during El Niño, but this relationship is generally not captured in the downscaled models. Despite these highlighted biases, the process-based evaluation presented here shows that the downscaled models can broadly capture several of the main ENSO-TC relationships in this region.

OPERATIONAL METHODS FOR REAL-TIME RIVER FLOW MEASUREMENT SYSTEMS FOR EFFICIENT WATER MANAGEMENT

Dongheon Oh, Eunjeung Shim, Chanwoo Kim, Sanguk Cho
Korea Institute of Hydrological Survey

As flood damage caused by climate change has inc eased in recent years, the Korean government has introduced AI-based flood fo ecasting as part of its flood cont ol policy. Furthermore, as the application of flood fo ecasting—previously focused on large rivers—expands to small and medium-sized rivers, the importance of producing highly reliable flow data has g own significantl .

Accordingly, the government is currently operating real-time river flow measu ement systems at 101 of the 223 AI flood fo ecasting points nationwide, with plans to expand to 75 additional locations by 2025.

In this study, the optimal installation locations and required number of velocimeters were derived through the analysis of flow rate and velocity data collected f om 106 sites in 2024 using an electromagnetic surface velocimeter. The study also confi med that measuring flow depth ac oss river cross-sections is a crucial factor when applying the surface velocity method. Based on these findi gs, a plan was proposed for installing flow meters that accounts for the longitudinal and cross-sectional hydraulic characteristics of rivers, as well as variations in flow depth

Through this case study on the operation of real-time river flow measu ement systems, the optimal installation methods and quantities for efficient water management— egardless of river size—were identified and applied to the planned expansion of 75 new locations in 2025. It is expected that this will lead to the production of more accurate and reliable flow data in the futu e.

GROUNDWATER INSIGHTS: A NEW TOOL FOR SUSTAINABLE WATER MANAGEMENT IN A CHANGING CLIMATE

Oluwunmi P.A.,[1] Cox S.C.,[1]
[1] Earth Sciences New Zealand

Groundwater is a resource that millions rely on for drinking water, agriculture, and industry. However, understanding the temporal variability of groundwater level in response to rainfall remains a significant challenge and uncertainty for water managers and researchers. A comprehensive analysis tool is being developed by Earth Sciences New Zealand to examine the relationship between groundwater levels and nearby rainfall across multiple monitoring wells. The tool offers innovative ways to visualise and analyse groundwater data, enabling scientists and water resource managers to identify key patterns, seasonal changes, and the impact of rainfall recharge on groundwater supplies. As climate change intensifies ext eme weather events, grasping how groundwater systems respond to evolving patterns of rainfall will be more crucial than ever. By providing clear visualisations and statistical analyses of change, this tool should empower decision-makers to manage water resources effectively during drought or heavy rainfall. Ultimately, the work aims to support sustainable groundwater management practices and enhance resilience against climate-related water challenges. It will enable technical and non-technical users to gain valuable insights into groundwater behaviour, fostering better water resource planning and environmental protection.

A REAL-WORLD DEMONSTRATION OF THE FORECAST PROCESS

Neal Osborne
MetService

The scale and duration of weather systems vary considerably, ranging from thunderstorms (typically a few kilometers in size and lasting only hours) to mid-latitude weather systems (typically thousands of kilometres in size and lasting multiple days). Mid-latitude systems are generally well forecast by Numerical Weather Prediction (NWP) models. In contrast, thunderstorms continue to present a significant challenge to NWP models and operational meteorologists, yet the impacts may be no less severe with the risk of localised torrential rain and flash floodin

In the lead up to Friday evening 18 April 2025, NWP models showed significant potential for seve e thunderstorms to develop over northern New Zealand, including Auckland. Along with the rainfall fields, which varied considerably from just a few showers to severe thunderstorms and torrential rain, there were other signals within the NWP models of the looming risk.

During the late evening, satellite imagery, radar imagery and weather observations were essential for diagnosing and monitoring the situation as it developed.

This talk will review the above meteorological information available both prior to and during this event. Further, it demonstrated the limitations of NWP models and highlights how operational meteorologists, with the correct interpretation and conceptual models, can add considerable value.

RECORDED FLOOD DATA SHOULD WE BE CONCERNED

Lennie Palmer,[1]
[1] Riley Consultants Limited

Overview. Hydrological records, where available, are used to derive flood estimates. Flow ecords are typically derived from level measurements transformed via level to flow ratings. Flow gauging info mation is typically used to define these ratings. For flood equency analysis, statistical distributions are fitted to the flood fl maxima series. The large floods influence the selection of best fit statistical distr tions and hence the design flow estimates dete mined from this information.

Aim. This presentation will highlight potential inaccuracies assocaited with the high stage flow ratings and the influence this can have on design flood estimate

Method. The flow series used in several ecent flood f equency analyses are assessed, including the flow ratings and the gaugings available to define these ratings. The focus will be on the high stage rating. A rating developed based on limited high stage gaugings is compared to a flow rating dete mined by a hydraulic model.

Results. Several of the series investigated, had large "outlier" floods, typically the la gest on record. There was very little gauging data to define the upper rating, and m ny of the highest flow gaugings we e undertaken many years ago. The comparison of high stage rating, extrapolated well past the highest gauging, to the rating defined by a hydrualic model, identified consider le divergence from mid to high stage levels. At the highest measured levels, the "gauged rating" flows we e over 20% higher than determined by the hydraulic model.

With the importance of flood data to dete mine design estimates for critical infrastructure, the accuracy of the recorded flood data should be fully conside ed.

RISK ASSESSMENT OF DEWATERING-INDUCED SEAWATER AND CONTAMINANT INTRUSION AT TE MAUNGA WASTEWATER TREATMENT PLANT, TAURANGA

Rocky Parsons
Beca

To accommodate growing residential development in the Mount Maunganui–Papamoa area, infrastructure upgrades are requireddae Te Maunga Wastewater Treatment Plant.cSignificant dewatering activities we e undertaked to enable simultaneous construction of additional clarifier and bio eactor structures.tThe site is approximately 600 metres froorRangataua Bay and is adjacent to a closed landfil,, meaning ewatering activities greatly increasd the risk of saline intrusion and contaminant migration
A groundwater monitoring programme was implemented to assess potential impacts of dewaterins on groundwater quality and quantitg. Samples were collected from a network of piezometers with measured hydrochemical parameters includingddissolved ions, p, and Electrical conductivity. Saline front migration was indicated by groundwater samples displaying similar Sodium to chloride ratior to that recorded in seawate,tantrincreasing concentrationsycloser to the coast. In addition, A strong correlation between total ammoniacal nitrogen and boron, two analytes commonly found in landfill leachate, was obse ved between the site and theycoast An in-depth baseline water quality study was not completed prior to dewatering, meaning it is i possible to determine if dewatering alone hay caused saline and contaminant intrusion or simply exacerbated pre-existing conditione. Continual monitoring is suggested to better inform future contaminationtassessments at the site.

PRECIPITATION DOWNSCALING TO KM AND SUB-HOURLY SCALE USING GENERATIVE AI: DEMONSTRATING WORLDWIDE APPLICABILITY

Julius Polz
Karlsruhe Institute Of Technology

High-resolution precipitation data is critical for hydrological modeling, flood p ediction, and climate impact assessment, yet current global reanalysis products lack the spatial and temporal resolution needed to capture extreme rainfall events. Data-driven methods rely on accurate high-resolution reference data, which is not available for most parts of the globe. This limitation raises a key research question: Are deep generative models capable of generalizing to different rainfall regimes? We present spateGAN-ERA5, a deep learning-based global precipitation downscaling method that transforms ERA5 data from 24 km/1-hour to 2 km/10-minute resolution using generative adversarial networks.

Our results demonstrate that generalization works much better than expected. Despite training exclusively on German weather radar data, the model shows remarkable performance across climatically diverse regions, including continental US, subtropical Australia, and tropical northern Australia, successfully adapting to fundamentally different precipitation dynamics from mid-latitude to tropical convective processes. The model reconstructs realistic precipitation patterns, extreme value distributions, and convective structures completely absent in original ERA5 data.

SpateGAN-ERA5's computational efficiency enables ensemble generation for unce tainty quantification while being orders of magnitude faster than traditional dynamical downscaling. This breakthrough provides unprecedented access to high-resolution precipitation reconstructions, potentially spanning ERA5's full historical record (1940-present), enabling improved hydrological modeling, climate impact studies, and extreme weather analysis globally.

DEVELOPING A NATIONWIDE SOIL MOISTURE DATASET FOR HYDROLOGICAL APPLICATIONS IN AOTEAROA NEW ZEALAND

Porhemmat, R.,[1] Westerhoff, R.,[1] Zammit, C.,[1] Rajanayaka, C.[1]
[1] Earth Sciences New Zealand

Aims
Soil moisture is a critical variable in hydrology, influencing infiltration, run f generation, evapotranspiration, and slope stability. In New Zealand, the fragmented nature of soil moisture information, collected across multiple platforms, agencies, and spatial scales, limits its integration into hydrological models and risk assessments. This project aims to develop a harmonised, national-scale ensemble soil moisture dataset for New Zealand by combining in-situ observations, remote sensing products, and reanalysis data. The goal is to support a wide range of hydrological and environmental applications, including landslide forecasting, drought assessment, and flood modelling

Method
The first step in this work involves compiling and eviewing all available soil moisture datasets across Aotearoa New Zealand. We are using data from four major sources:

• In-situ observations from NIWA's climate station network, Fire and Emergency New Zealand (FENZ), regional councils, and other monitoring partners (Figure 1);
• Satellite-derived products, including NASA's Soil Moisture Active Passive (SMAP) Level 3 and Level 4 dataset, the European Space Agency's Climate Change Initiative (ESA CCI) soil moisture product, and the Advanced Scatterometer (ASCAT) surface soil moisture product from EUMETSAT's MetOp satellites;
• Climate reanalysis outputs such as the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5-Land dataset; and
• Modelled soil moisture data from (initially two) hydrological models.

The project is developing workflows to standa dise, quality-control, and intercompare these datasets. A key aim is to identify spatial and temporal gaps, inconsistencies in measurement methods, and uncertainties across the datasets. We are assessing approaches for downscaling, bias correction, and data fusion, with the intention of producing an ensemble product that represents the best-available estimate of near-surface soil moisture across New Zealand. The ensemble approach will allow for uncertainty quantification and flexibilit for different end-users.

A core focus of the project is identifying spatial and temporal gaps in current soil moisture observations and recommending strategies to address them. By combining datasets using ensemble and data fusion techniques, we aim to develop a high-resolution soil moisture product that is suitable for operational and research use and includes uncertainty estimates. As a first applica ion, this dataset will directly support the Landslide Watch Aotearoa programme, which requires robust soil moisture inputs to forecast rainfall-induced landslides under different climatic and soil conditions.

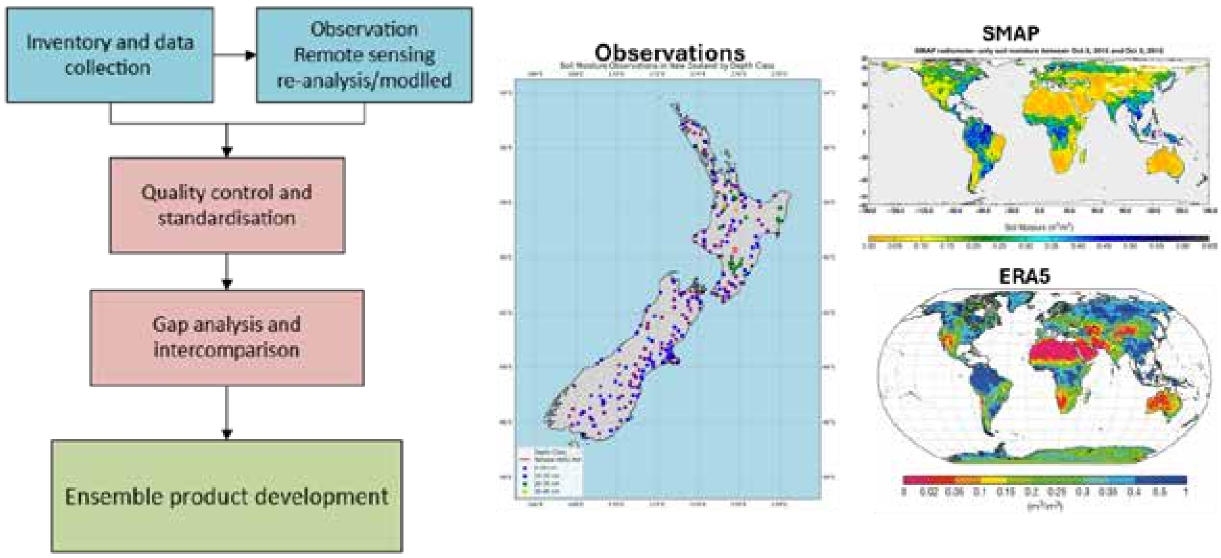
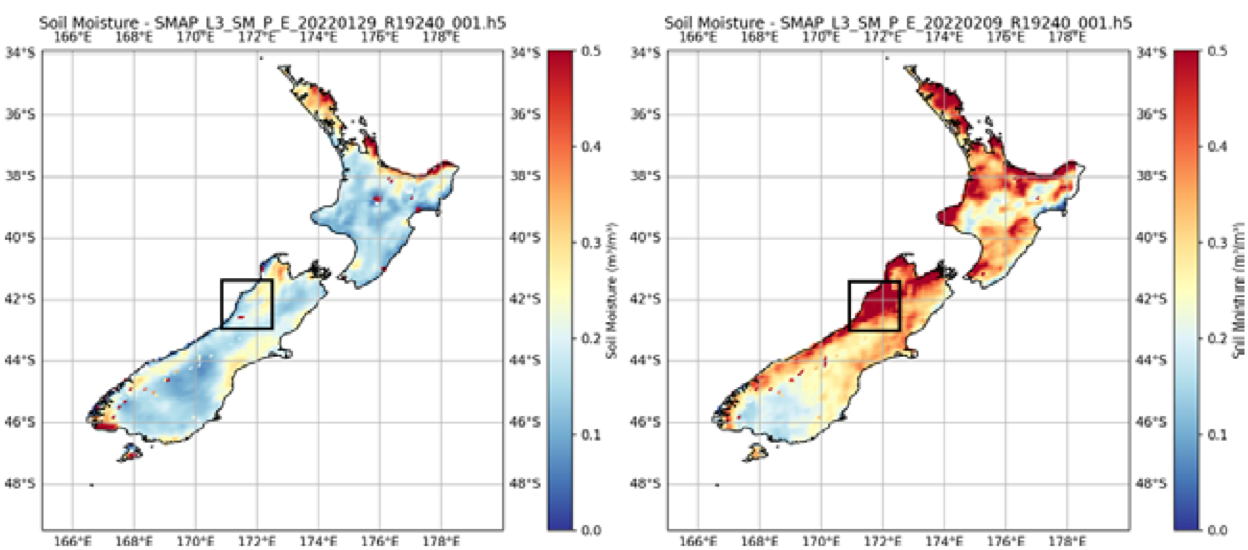


Figure 1. Overview of the methodology and data sources used to develop a harmonised ensemble soil moisture dataset for New Zealand. The left panel shows the workflow st ps from data collection to ensemble product development. The top right show examples of observational data coverage across New Zealand, global soil moisture products from SMAP and ERA datasets.

Results

As an early demonstration of the datasets being integrated in this study, we present examples from NASA's SMAP Level 3 satellite product and ERA5-Land reanalysis data to illustrate their potential for capturing soil moisture dynamics during extreme weather events. Figure 2 (top) shows SMAP-derived surface soil moisture before and after the February 2022 flood event on the est Coast of the South Island, highlighting a substantial increase in moisture across the affected region. Figure 2 (bottom) presents ERA5-Land soil water content (SWVL1 and SWVL2) at a given point, showing two sharp increases in soil moisture associated with the Auckland Anniversary floods in late January and Cyclone Gab ielle in mid-February 2023. These examples illustrate how remote sensing and reanalysis datasets can help detect antecedent wetness and soil response to extreme rainfall-demonstrating one of the key hydrological applications of the harmonised soil moisture product being developed in this project.



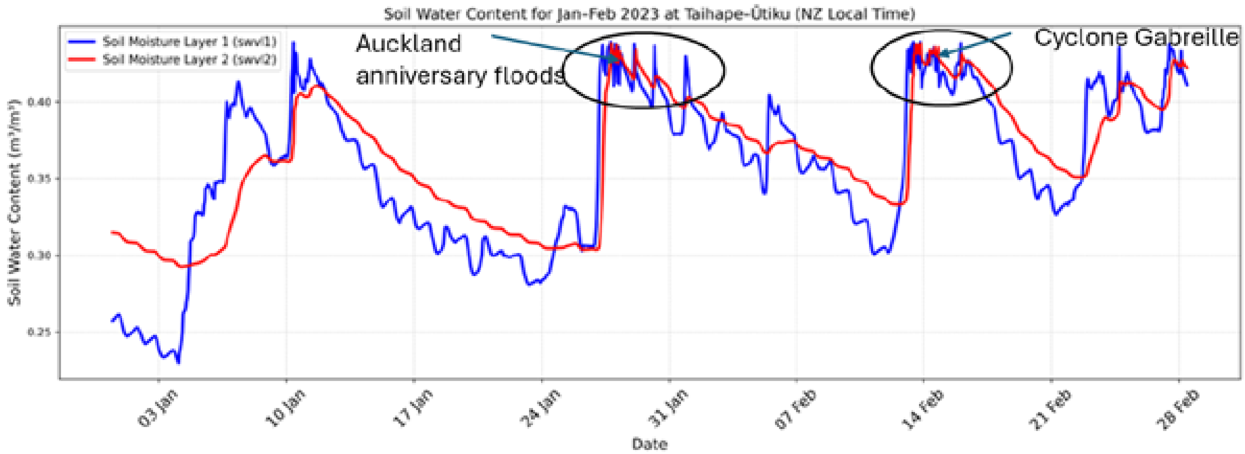


Figure 2. (Top) SMAP L3 soil moisture (surface layer) over New Zealand showing conditions before (left) and after (right) the February 2022 West Coast flood event. The black box highlights the a fected region. (Bottom) ERA5-Land reanalysis time series of soil water content at Taihape–Utiku for January-February 2023, displaying soil moisture in Layer 1 (0–7 cm, swvl1) and Layer 2 (7–28 cm, swvl2). Two major rainfall events (Auckland Anniversary floods and Cyclone Gabrielle) a e highlighted, both resulting in marked increases in soil moisture levels.

HIGH-FLOW HARVESTING FRAMEWORK IMPLEMENTATION: IDENTIFYING OPPORTUNITIES AND BARRIERS

Rajanayaka, C.,[1] Booker, D.,[1] Franklin, P.,[1] Stoffels, R.,[1] Murphy, P.,[2] Osbaldiston, S.,[3] Gonah, T.[3]
[1] Earth Sciences New Zealand
[2] Gisborne District Council
[3] Northland Regional Council

Aims

Many catchments in Aotearoa New Zealand are fully or over-allocated under low-flow egimes, limiting water availability for economic development and ecological resilience. High-flow harvesting (HFH) o fers an alternative water allocation strategy by enabling water abstraction during elevated river flows, the eby reducing ecological stress during low-flow periods. The app oach is particularly relevant in regions like Gisborne and Northland, where drought frequency is increasing and conventional water sources are constrained. Building on previous work by Hickford et al. (2023) and Booker & Rajanayaka (2023), which outlined the rationale for a multi-band water allocation system (Figure 1), this study explores the opportunities and barriers for implementation of HFH within environmental constraints. The proposed framework aligns with national policy directives, including the National Policy Statement for Freshwater Management (NPS-FM), and prioritises environmental health while enabling adaptive and equitable water use.

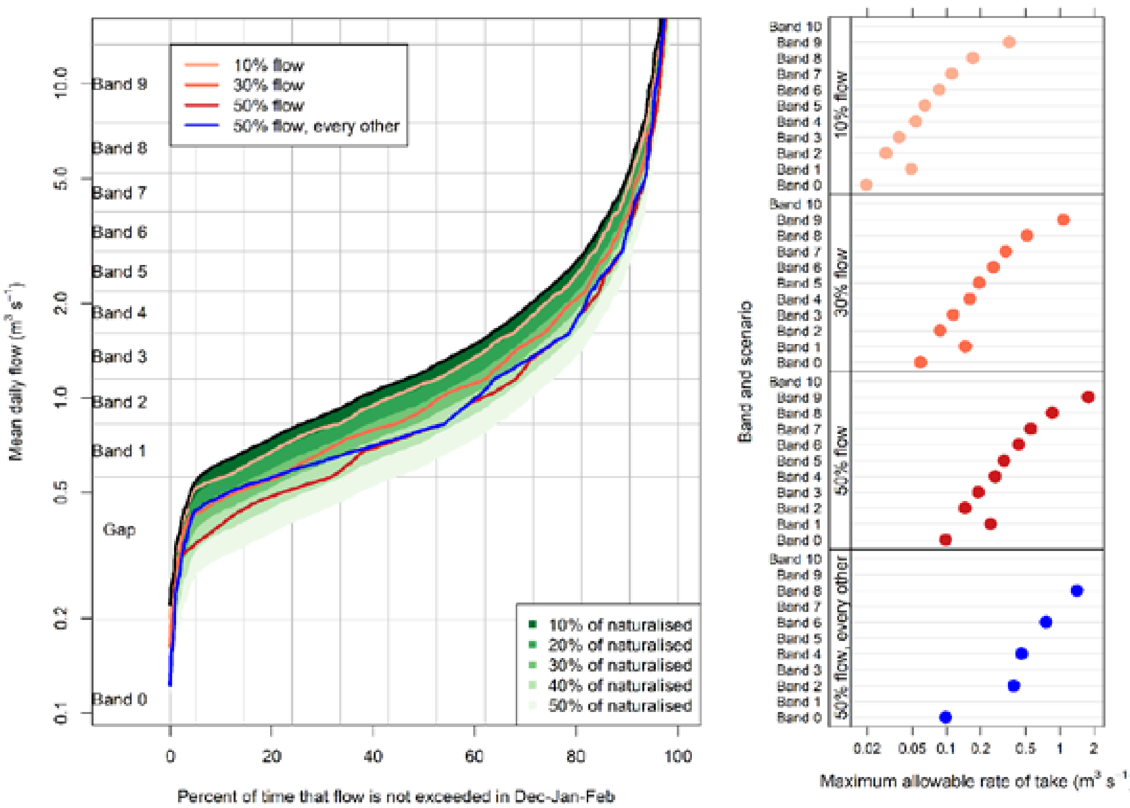


Figure 1: The potential impacts of different water allocation rules for a small Northland river. Deviation of summer mean daily flow f om a naturalised state (left panel) is controlled by varying allowable rates of take within flow bands (right panels).

Gisborne District Council (GDC) and Northland Regional Council (NRC), in collaboration with Earth Sciences New Zealand, initiated a multi-stage project to develop a regionally adaptable HFH framework. Stage 1 focused on identifying opportunities and barriers to implementing a multi-band HFH allocation system that enables water abstraction during elevated river flows while saf guarding environmental values.

This work presents an overview of the multi-band HFH allocation system and outlines an approach to, and findings f om, identifying opportunities and barriers to its practical implementation.

Method

Stage 1 of the HFH implementation project employed a collaborative methodology, including stakeholder workshops with representatives from regional councils (GDC, NRC, ORC, ECan, GWRC), central government agencies (MfE, MPI), and technical experts. Participants brought expertise in hydrology, environmental science, policy planning, and resource consenting. The workshop featured presentations on international and domestic HFH allocation strategies, including flow-sharing models, banded allocation systems, and adaptive licensing frameworks. A key activity involved participants ranking the top five barriers to practical implementation of a multi-band HFH system. Responses were analysed under four guiding principles: practical operationalisation, environmental sustainability, water efficienc , and spatial adaptability. A noted limitation of Stage 1 was the absence of direct engagement with water users (e.g., iwi, irrigators, industry representatives, and community groups), which has been identified as a priority for futu e stages.

Results

The study identified the potential of HFH, particularly when p ired with off-stream storage, to:

- Unlock water in fully allocated catchments.
- Support economic development.
- Give water users, such as irrigators, a greater total allocation by spreading the impact across a broader flow spectrum rather than concentrating it at the low-flow end
- Improve environmental outcomes by reducing pressure on low flows
- Enhance climate resilience through adaptive allocation.

Workshop participants broadly supported the multi-band framework for its flexibilit , transparency, and alignment with national policy. However, several implementation barriers were identified

- High infrastructure costs (e.g., storage and flow monitoring)
- Limited availability of real-time flow data
- Administrative complexity and resource constraints.
- Uncertainty in ecological responses to high-flow abstraction

The study also recognised that many of the challenges and system requirements for implementing HFH, such as the need for adaptive management, ecological validation, and robust monitoring, are not unique to HFH and are equally relevant to low-flow allocation systems.

The study findings p ovide a strong foundation for advancing to the next stage, which will focus on co-developing and testing allocation options using a structured decision-making framework. A stepwise decision tool was also developed to help regional councils assess readiness for HFH implementation.

To support successful implementation, the study recommends:

- Investing in monitoring infrastructure and data systems.
- Embedding adaptive management principles from the outset.
- Aligning HFH frameworks with national freshwater policies.
- Fostering cross-regional collaboration to share methodologies and lessons.
- Supporting ecological validation of flow bands th ough modelling and monitoring.

References

Booker, D.J., Rajanayaka, C. 2023. High-flow harvesting Part 2: guida ce for devising water allocation rules with examples from Northland and Gisborne. Report prepared for AIA/NRC/GDC/GNS. 120pp. https://www.nrc.govt.nz/media/alabvcjf/high-flow-harvesting-part-2-guidance-f r-devising-water-allocation-rules-with-examples-from-northland-and-gisborne.pdf

Hickford, M.J.H, Booker, D.J., Greenwood, M., Haddadchi, A., Hoyle, J., Kilroy, C., Lam-Gordillo, O., Measures, R., Woodward, A. 2023. High-flow harvesting Part 1: The potential e fects of high-flow harvesting on in-stream values in New Zealand. NIWA Client report prepared for AIA/NRC/GDC/GNS/MBIE-Envirolink. 88 p. https://www.nrc.govt.nz/media/5cdc1zhg/high-flow-harvesting-part-1-influence- -new-zealand-in-stream-values.pdf

Acknowledgements

We acknowledge the valuable support and contributions from: Gemma Wadworth, Yuki Ochiai, and Maya Speers (Access to Experts); Andy Hicks and Kohji Muraoka (MfE); M.S. Srinivasan (MPI); Jason Augspurger (ORC); Dan Clark (ECan); Mike Thompson (GWRC); Justin Murfitt a d Katie McGuire (NRC); and Pippa Steele, Rachel Ainsworth, and Sarah Thompson (GDC).

INTEGRATED MODELLING OF CLIMATE CHANGE AND SLR FOR COASTAL GROUNDWATER RESILIENCE IN INVERCARGILL

Rajanayaka, C.,[1] Chambers, L.,[1] Kitlasten, W.,[1] Yang, J.,[1] White, P.,[1] Moore, C.,[1], Kees, K.,[1] Cameron, S.,[1] Stephens, S.,[1] Lovett, A.,[2] Rodway, E.[2]
[1] Earth Sciences New Zealand
[2] Environment Southland

To support climate resilience planning in Invercargill City, Environment Southland (ES) and Earth Sciences NZ have developed a fit-fo -purpose groundwater–surface water model to assess the impacts of climate change, including sea-level rise (SLR) and vertical land movement (VLM), on groundwater systems, infrastructure, and flood haza ds. A 3D facies model of the Southland Plains coastal system, built from ES well logs, underpins a MODFLOW 6 model with 100 m × 100 m resolution. The model simulates steady-state and transient groundwater conditions, capturing groundwater–surface water interactions and coastal boundary influ nces. Initial sensitivity analyses identified critical data gaps limi ing robust adaptation planning for key infrastructure such as the Invercargill Airport and hospital. Scenario testing, aligned with IPCC SSP climate pathways, highlights inland propagation of SLR impacts, inundation risks, and changing groundwater–surface water dynamics. The modelling outputs inform flood haza d mapping, infrastructure resilience planning, and future monitoring priorities, providing ES with a credible basis for integrated hazard assessment. This collaborative, future-ready framework is designed for ongoing refinement, ensuring long-te m value as a decision-support tool for managing climate change impacts in low-lying coastal environments.

DOWNSCALING WITH AI REVEALS LARGE ROLE OF INTERNAL VARIABILITY IN FINE-SCALE PROJECTIONS OF CLIMATE EXTREMES

Neelesh Rampal[1,2,3], Peter B. Gibson[1], Steven C. Sherwood[2,3], Laura Queen[1], Hamish Lewis[1,4] Stephen Stuart[1], Gab Abramowitz[3].
[1]National Institute of Water and Atmospheric Research (NIWA), New Zealand
[2] ARC Centre of Excellence for Weather of the 21st Century, University of New South Wales, Sydney, Australia. [3] Climate Change Research Centre, University of New South Wales, Sydney, Australia
[4] Te Aka Mātuatua School of Science, University of Waikato, Hamilton, New Zealand

Regional Climate Models (RCMs) simulate fine scales, but their computational cost limits ensemble sizes, making it difficult to isolate fo ced climate responses from internal variability or assess extremes. We developed a cost-effective RCM emulator to generate over 15,000 years of daily precipitation and temperature simulations for New Zealand at 12-km resolution from 20 climate models, including two large ensembles. The emulator replicates RCM skill, capturing historical variability and future changes in extremes when applied to unseen climate models. At fine scales, the forced component of precipitation and temperature extremes for future periods (2080-2099) is spatially smoother than changes in individual simulations and locally smaller. Unpredictability from internal variability dominates model uncertainty and, for precipitation, exceeds the variance across emission scenarios by sixfold for annual and tenfold for decadal extremes. Fine-scale changes in future precipitation are nearly unpredictable and require much larger ensembles to assess reliably than changes at coarser scales.

RAPID REVIEW OF RADAR QUANTITATIVE PRECIPITATION ESTIMATION FOR URBAN MODELING

Radar Quantitative Precipitation Estimation (QPE) provides vital gridded rainfall boundary conditions for urban stormwater and wastewater catchment modelling. However, significant ca e to correctly treat and merge radar and rain gauge observations is required. Naively prepared radar QPE (as offered by MetService using the radar manufacturer's bundled software) can result in poorer quality data than realised with gauges alone, significantly comp omising model build and increasing rework costs.

Auckland Council and Watercare Services Limited have invested heavily in robust data processing methods to ensure high-quality QPE. Complete control of the operational framework allows continuous improvement, where deficiencies can be rapidly identified, understood and co ected. The structured assessment of gridded QPE, combining prompt manual quality checks by scientists with twice-monthly targeted reviews, ensures robust data for immediate use in flow monitoring, calibration an model development across multiple Strategic Management Areas (SMAs). Thereby, accelerating the delivery and reliability of rainfall data for Watercare's Network Performance Measurement and Modelling (NP2M) programme.

Rapid QPE improvement during catchment flow monitoring supports an assembly line of urban network model development, supporting NP2M's goal of delivering high-quality planning tools at pace. Lessons learned from the NP2M context are also being applied across other Auckland Council initiatives.

AQUIFER DRINKING WATER FOR CENTRAL OTAGO COMMUNITIES

Jens Rekker
Kōmanawa Solutions

Novel aquifer types were investigated for exploitation as community water supplies for the Ranfurly and Roxburgh in Central Otago. At Ranfurly in the Māniatoto basin, a sequence of semi-confined wate -bearing layers in Miocene era terrestrial sediments have shown promise for providing sufficient volume and water quality for the community, currently supplied with creek water along an 18 km pipeline. The groundwater system north of the township was encountered in regional council investigations, including a pumping test. Subsequent drilling studies have widened the focus to reveal greater extent and depth of the prospect.
At Roxburgh, the use of surface water from the Clutha River / Mata Au from gallery wells has presented water quality issues and risks. Mineral exploration north of the township revealed the presence of a buried paleochannel aquifer, which is inferred to be a former channel of the Clutha cut into basement schist. This long, slender, and perched aquifer system presented opportunities for the community. Staged drilling, aquifer testing, and water quality investigations have been undertaken to confi m the utility of the groundwater resource for a replacement water supply. Investigations at Ranfurly and Roxburgh are ongoing.

THE LIFE AND TIMES OF ZONAL WAVE THREE

James Renwick
Victoria University of Wellington-Te Herenga Waka

Zonal wave three has long been known to be a major component of the wintertime atmospheric circulation, exhibiting three positive and three negative anomalies in the zonal eddy field a ound the Southern Hemisphere, with maximum amplitude over the Southern Oceans. Using ERA5 data, this presentation will describe the form of ZW3 and trends in its behaviour. Over the past 60 years, the amplitude of ZW3 exhibits significant upwa d trends throughout the year but most prominently in summer (Dec-Feb). Such trends are related to increasing meridional temperature gradients and to trends in eddy activity in general and to trends in poleward energy fluxes. Implications for surface climate temperatu e and precipitation extremes will be outlined.

ADVANCING HYDROLOGICAL DATA ASSIMILATION WITH PARTICLE FILTERS AND DYNAMICAL METEOROLOGICAL ENSEMBLES IN NEW ZEALAND

Rio, Maxime[1]; Cattoën, Céline[2]
[1] Earth Sciences New Zealand, Wellington
[2] Earth Sciences New Zealand, Christchurch

Flood forecasting in New Zealand is challenged by steep-terrain, fast-responding catchments, and chaotic atmospheric processes. Data assimilation (DA) has transformed weather forecasting but remains underused operationally in hydrology, where unobserved water states, limited real-time data, and multiple uncertainty sources complicate implementation. Our current operational Retrospective Ensemble Kalman Filter (REnKF) struggles with the non-linear, non-Gaussian behaviour typical of floods in complex topograph .

We investigate particle filters as an alte native DA strategy, applying them with real dynamical meteorological ensembles (NZEns, 18 members) as model forcing, rather than perturbed rainfall inputs. Particle filters c n better handle nonlinearity and non-Gaussianity, but their integration with real ensemble forecasts is rare in hydrology and poses new challenges in coupling meteorological and hydrological uncertainties.

We performed experiments in the Buller catchment using NZEns and streamflow observations, with assimilation to evaluate both short-term and extended lead times. Initial experiments indicate improved performance during high-precipitation events, with sensitivity to hydrological regime and parameter settings. Ongoing work includes hyperparameter tuning, site-specific obse vation noise calibration, and testing up to five-day fo ecasts to assess persistence.

This research advances DA methods that support more robust operational flood fo ecasting frameworks.

DEPLOYING LLMS FOR FORECASTING: WHY EVALUATION COMES FIRST

Rio, Maxime[1]; Meyers, Tristan[1]; Brandolino, Chris[2]; Fedaeff, Nava[2]
[1] Earth Sciences New Zealand, Wellington
[2] Earth Sciences New Zealand, Auckland

Large Language Models (LLMs) are increasingly valued for generating fluent, context-awa e text from structured and unstructured data. Their ability to synthesize complex information from diverse sources makes them especially attractive for use in producing text-based weather forecast, potentially enabling tailored, data-driven communication that meets specific user needs ac oss regions and applications. However, it is known that LLMs can falsify details, use meteorologically incorrect terminology, or misinterpret data. So, without proper validation, they risk producing forecasts that misrepresent key details and fall short of meteorological standards.

In this project, we explored the application of LLMs to generate accurate, readable weather forecasts by integrating multiple data streams, including numerical weather prediction (NWP) model outputs, climatology records, real-time weather station observations, and official wa nings. A custom dashboard was also developed to support real-time experimentation, allowing forecasters to test various types of LLMs and prompting strategies while comparing to ground-truth data.

To evaluate reliability, we conducted targeted assessments across specialised use cases, including early trials for park-specific text fo ecasts with the Department of Conservation (DOC) and a pilot with MetService forecasters. These evaluations revealed both strengths and limitations in how LLMs represent underlying data, informing practical guidelines for future implementation of user-focused LLM-generated forecasts.

FUTURE CHANGES IN HYDRO-CLIMATE EXTREMES ESTIMATED USING LARGE ENSEMBLES OF COUPLED CLIMATE-HYDROLOGY MODELLING

Christian ZAMMIT[1] and Suzanne ROSIER[1]
[1]Earth Sciences New Zealand

The future outlook for climate/weather extremes and their associated effects on regional hydrology in New Zealand are investigated using large ensembles of coupled climate-hydrology modelling. Climate outputs from the 'weather@home/ANZ' experiment have been used to drive the TopNet hydrology model, creating multi-thousand-member ensembles of river flow simulations for selected locations. Some interesting, and perhaps counterintuitive, results are found. It is not always the case that the most extreme rainfall directly drives the most extreme river flows; other mechanisms, including antecedent conditi ns, clearly have an important role to play. Whilst the non-stationary generalised extreme value (GEV) method appears useful for estimating rainfall extremes in a changing climate, it may not be entirely adequate for describing the associated changes to hydrological extremes. Further research, particularly for translating this usefully to operational forecasting, is clearly required.

CHANGING RAINFALL EXTREMES WITH CLIMATE CHANGE IN NEW ZEALAND

ROSIER, Suzanne[1], Greg BODEKER[2], Peter GIBSON[1], Trevor CAREY-SMITH[1], Shalin SHAH[2], Luke HARRINGTON[3], David FRAME[4], Daithi STONE[1]
[1]Earth Sciences New Zealand
[2]Bodeker Scientifi
[3]University of Waikato
[4]University of Canterbury

Extreme rainfall in New Zealand, and its expected changes as the climate warms, is investigated using three atmosphere models (CAM5.3, CCAM and weather@home/ANZ), all slightly different in complexity, detail and size of dataset. All have been run at various stages of global warming, ranging from a pre-industrial climate, through the present day, to a range of warmer futures.
The models agree that extreme rainfall generally intensifies with wa ming: by about 9%/deg (CAM5.3 and CCAM), and nearer 6%/deg (weather@home/ANZ). CAM5.3 and CCAM have greater increases at higher elevations. Small changes, or even a reduction of extreme rainfall amounts, however, occur in eastern regions. The largest increases in intensity occur in Northland, with notable increases also in Southland. Hourly data from CCAM indicate that rainfall intensity increases most for hour-long events, least for week-long events, and by intermediate amounts for intermediate durations.
Non-stationary GEV analysis using the very large weather@home/ANZ ensembles indicates that allowing location and scale, but not shape, parameters to vary linearly with warming improves rainfall estimates over a stationary approach whilst minimising the GEV model complexity. This represents a useful approach when estimating rainfall extremes with datasets of similar size to the typical lengths of observational record.

MANAGING GROUNDWATER, STORMWATER, AND SEAWATER INTERACTIONS AT A COASTAL AIRPORT

Helen Rutter[1] Michelle Duncan[2,]
[1] Lincoln Agritech Ltd
[2] Hawkes Bay Airport Ltd

History of the Airport
Hawkes Bay Airport is located on land that was uplifted by the 1931 earthquake, previously known as the Ahuriri Lagoon (Figure 1). The earthquake caused a major shift in the landscape, with land uplift of up to two metres. This transformed what was previously swampy land into a more solid foundation for development though area still presented significant challenges elated to water drainage and flooding, given its low-lying nature and proximity to the estuary.

Figure 1. Map of the pre-1931 airport area (as displayed at Napier Airport)

The area is very low-lying, particularly to the west of the airport itself. It is bounded to the west by the "Outfall Channel" a large channel that acts as a drain for the hills to the west. The channel curves eastward to the south of the airport site and empties into the estuary to the east of SH2. The site is bounded to the east by sand dunes (with residential development) and then the coast. There are wetlands in the southeast of the area. The runways are elevated above the land level.

Current drainage is extensive across the airport and land to the west. There is a network of drains and a pump stations, which effectively manage stormwater, ensuring the runway and terminal remain operational, even during major events such as the devastating Cyclone Gabrielle in February 2023.

Future-proofing the Airpor
The Airport has installed monitoring across the site to investigate the role of groundwater in stormwater management, recognising (a) the need to understand and characterise the complex interaction between groundwater, stormwater and the coast, and (b) how this could change with climate change and sea level rise. Initial monitoring has revealed that groundwater responses across much of the site are predominantly driven by tides, with this dominating over land surface recharge responses across much of the site. Conductivity monitoring also revealed relatively high salinity across much of the site. The outfall channel/estuary also has elevated conductivity as expected.

Overall, the hydraulic gradient appears to be influenced by pum ed drainage, the gradient being approximately northeast to southwest. It is possible that the drainage and change in gradient has resulted in some saline intrusion from the coast.

Through conceptualising the area and developing predictive groundwater models, the airport aims to assess potential management and adaptation strategies aimed at controlling flooding, p eventing contamination, and enhancing resilience.

This paper will outline the findings at the Airport as well as future investigations that may be needed to inform strategies to ensure resilience.

ASSESSING DRINKING WATER SECURITY USING A MULTI-FACETED EVIDENTIAL APPROACH

Helen Rutter [1], Brent Gilpin [2], Julian Weir [3] Louise Weaver [2]
[1] Lincoln Agritech, Lincoln
[2] PHF Science, Christchurch
[3] Aqualinc Research Ltd, Christchurch

Introduction
Ensuring the microbial quality of drinking water is critical for public health. We present some examples from a multifaceted approach used in Christchurch to evaluate the safety of drinking water at groundwater sources based on evaluation as to whether source water was likely to be greater than a year old. Several methods were evaluated to assess water safety and the age of drinking water, providing valuable insights.

These included:
- Age dating
- Variability in chemical composition
- Local hydrogeology
- Groundwater modelling
- Molecular techniques to detect viral pathogens

Reliance on a single tool is always less desirable than if several lines of evidence lead to the same conclusion. Using multiple lines of evidence to understand drinking water sources is a proactive approach to determining source water risks.

Method
Various approaches can be used to assess whether source water may contain young water. Approaches that were used within Christchurch included:
- Assessment of the local hydrogeology, which is the first step in assessing likely sou ce water safety. We considered factors such as presence or absence of a confining laye , vertical hydraulic gradients and any aquifer test data.
- Analyses of a bore's water chemical composition, including variability in parameters such as pH, dissolved oxygen, and nutrient levels. These can provide insight into the hydraulic connection with the land surface (and therefore source security).
- Groundwater modelling, which is another important and useful tool to assess groundwater source security. By simulating the flow of water within and between aquifers, mo els can predict how contaminants move through a groundwater system and enable a conservative calculation of the travel time, thereby providing an assessment as to whether or not the water at a specific bo e is more than a year old. However, models can be difficult to build accuratel , expensive to construct, and have inherent uncertainties. We stressed the calibrated model in various ways to provide additional confidence in the esults. These included modifying the model to include:
    - Local aquitard punctures to allow greater vertical connection;
    - The presence of leaky bores; and
    - Reduced spatial extent of the coastal confining layers

- Age determination of drinking water is an approach that can also inform microbial risk assessments. These techniques are used to estimate the time water has spent in the aquifer and provide additional evidence as to whether groundwater is likely to pose a microbial risk.
- New research has also led to the evaluation of viruses in source waters to indicate the bore's source security. Viruses, particularly enteric viruses, can survive for extended periods in groundwater and potentially pose health risks, even at low concentrations. Advanced molecular techniques, such as polymerase chain reaction (PCR), can be used to detect viral pathogens with high sensitivity. Though this approach was used to evaluate virus risks, results can also be used to support other lines of evidence regarding the age of groundwater.

We present some examples showing how the different approaches added confidence to the assessment of age (and hence water safety), and also some examples where results were ambiguous.

Results

We found that the results were generally consistent between methods, and the use of multiple lines of evidence increased confidence in the conclusions drawn about water safet . Together, these approaches offered a robust and comprehensive framework for evaluating the safety of drinking water.

In general, the different approaches agreed with each other and provided consistent results. Where there were conflicting esults, the local scenarios could be investigated in greater detail.

THE CHRISTCHURCH ARTESIAN SYSTEM: A HISTORICAL TREATISE

Len J. Brown[1], Lee F. Burbery[2*], Helen K. Rutter[3], Michael K. Stewart[4] and John H. Weeber[5]
[1] Independent researcher, Queensland, Australia
[2] Independent researcher, Christchurch
[3] Lincoln Agritech Ltd., Lincoln, Christchurch
[4] GNS Science (now Earth Sciences New Zealand), Lower Hutt
[5] Independent researcher, Golden Bay

The Christchurch Artesian System (CAS) is one of Aotearoa New Zealand's most significant f eshwater resources. Since artesian water was discovered by European settlers beneath Christchurch in 1858, generations of well-drillers, water managers, and scientists have worked collectively to investigate, monitor, and characterise this important groundwater system, upon which the people of Ōtautahi / Christchurch depend.

Len Brown and John Weeber, collectively amassed a great deal of knowledge about the development of our understanding of the CAS, resulting (after a prolonged gestation period) in the publication of "The Christchurch Artesian System: a historical treatise" (Brown et al., 2025). This contribution to the Journal of Hydrology (NZ)'s Special Publication in 2025 presents a concise history of the collective endeavour of investigators over the decades. The paper traces the development of scientific investigation, drilling techniques, the roles of key individuals and organisations, and the growth of long-term monitoring and data curation that underpin today's understanding of the CAS. It brings together decades of hydrogeological research and institutional memory, highlighting the unique efforts of some of Aotearoa New Zealand's hydrogeologists who have devoted their careers to understanding this resource.
The work not only documents the scientific and technical jou ney that has shaped knowledge of the CAS but also looks forward. It identifies challenges such as scientific collaboration, intaining robust monitoring networks, managing anthropogenic stresses on the CAS, and the importance of raising public awareness of the CAS, to ensure the enduring protection of this vital asset.

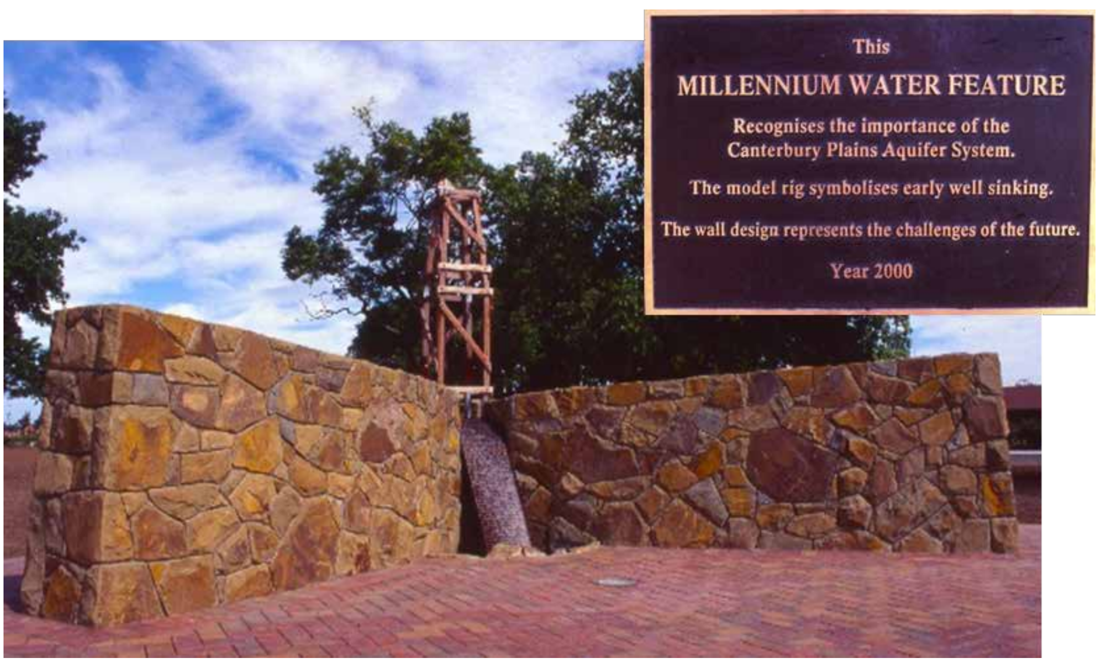


Figure 1 – The Millenium Water Feature, Leeston – a commemorative memorial to pioneering well-sinker Job Osborne who resided at Doyleston and whose drilling innovations and meticulous record keeping contributed greatly to our understanding of the CAS (Photo supplied by John Weeber).

References
Brown, L. J., Burbery, L. F., Rutter, H. K., Stewart, M. K. and Weeber, J. H. 2025. The Christchurch Artesian

System: a historical treatise. Journal of Hydrology (NZ) Special Publication.

HYDROGEOLOGICAL MAPPING IN THE RUAMĀHANGA CATCHMENT, WAIRARAPA VALLEY

Sahoo, TR.,[1] Kellett, RL.,[1] Kirkby, AL.,[1] Berhe, DT.,[1] Lee, JM.,[1] Herpe, M.,[1] Scadden, P.,[1] Sanders, F.,[1] Boyes, AF.,[1] Van Der Raaij, R.,[2] Gyopari, M.,[2] Annear L,[2] Poole, R[3], White, P.[1]
[1] Earth Science New Zealand (GNS Science)
[2] Greater Wellington Regional Council
[3] TetraTech Coffey

Aim

Existing numerical groundwater flow models for the airarapa Valley are based on conceptual hydrogeological models derived from geological interpretations and surface mapping of Quaternary sediments (e.g. Gyopari and McAlister 2010, Begg et al. 2005). These hydrogeological models, primarily represent shallow aquifer systems to a depth of approximately 50 meters. Deeper aquifer structures and their connectivity remain poorly understood. To enhance groundwater resource assessment and support the development of next-generation 3D flow models, this study empl ys airborne electromagnetic (SkyTEM) surveying. The aim is to refine the spatial delineation of aquifers and imp ove groundwater potential mapping across the Ruamāhanga Catchment in the Wairarapa Valley. This study was part of the Ruamāhanga Airborne Aquifer Mapping Project jointly funded by Kānoa, Greater Wellington Regional Council (GWRC), Masterton District Council, Carterton District Council and South Wairarapa District Council.

Method

A hydrogeological framework was developed for the Wairarapa Valley using an integrated analysis of SkyTEM resistivity models and supporting data (e.g. boreholes, surface geology, digital elevation model (DEM), geological cross-sections, seismic data, and gravity models). The SkyTEM smooth resistivity model was primarily used to map boundaries between hydrogeological units, as it provides finer detail of lateral resistivity changes caused by lithological variations compared to the SkyTEM sharp resistivity model. The sharp resistivity model was used as a supporting reference to assist in mapping vertical hydrogeological boundaries with reduced uncertainty, particularly in areas with subtle resistivity variations and complex structures. In structurally complex areas (e.g. near basement highs and within narrow valleys), and in locations where resistivity data have a shallow depth of investigation (DOI) or are missing due to cultural noise, surface geology, borehole lithology, and DEM data provided regional topographic and structural information to support hydrogeological boundary delineation.

The top of the hydrogeological model is defined by a 100 m DEM e-sampled from a 10 m DEM (LINZ, 2011). The model was extended to a depth of 500 m below sea level to encompass the DOI of the SkyTEM data and the likely hydrogeological basement. Hydrogeological boundaries were interpreted and mapped based on the features including 1) sharp changes in resistivity with depth, 2) lateral continuity of resistivity, 3) major lithological changes in boreholes, 4) mapped faults, and 5) surface geology.

An aquifer potential model was developed using the hydrogeological model and resistivity thresholds derived from statistical analysis of SkyTEM resistivity and lithology data. This model provides a qualitative assessment of the likelihood that each model cell contains aquifer material, ranging from low to high potential.

Results

To understand the spatial variability of resistivity in the study area, we developed a hydrogeological framework that divides the stratigraphy into four hydrogeological units: HU-1, HU-2, HU-3, and Basement (Figure 1).

HU-1 is the uppermost hydrogeological unit, representing Holocene and Late Pleistocene deposits (mainly Q1–Q4), including gravel and fine-grained age equivalents. HU-2 comprises older Quaternary deposits (Q5 to eQ), also consisting of gravel and fine-grained equivalents. HU 3 includes consolidated rocks from the Early Quaternary to Miocene, such as conglomerate, sandstone, mudstone, and limestone. Beneath HU-3 lies the

Basement unit, composed of Mesozoic greywacke rocks, which are considered highly compacted and of low aquifer potential.

The most likely lithologies to host aquifers are coarse gravel beds within HU-1 and HU-2, which exhibit resistivity values greater than 180 ohm·m and have the highest aquifer potential. Sandy to fine gravel layers within the same units, with resistivity ranging from 60 to 180 ohm·m, represent the next most favourable aquifer materials. As silt and clay content increases, aquifer potential decreases. Within the consolidated section (HU-3), limestone and sandstone beds are the most likely to contain aquifers, with resistivity values ranging from 60 to 350 ohm·m. Siltstones and mudstones in this unit are expected to have lower aquifer potential. Additionally, anomalously high resistivity values (>350 ohm·m) in the consolidated units may indicate low water content, resulting in reduced aquifer potential. In this study, the Basement unit is assumed to have low aquifer potential due to its high degree of compaction.

The current model provides a strong foundation for the development of hydrogeological flow models to support groundwater management in the region. Finally, the models were published as web maps with a 2D cross section viewer to enable broad user access to them. See the web map link below. https://data.gns.cri.nz/mapservice/embed/embed.html?map=skytem_ruamahanga&key=R1dSQzpOWiBUcmFuc3ZlcnNlIE1lcmNhdG9yOlk6WTpZ

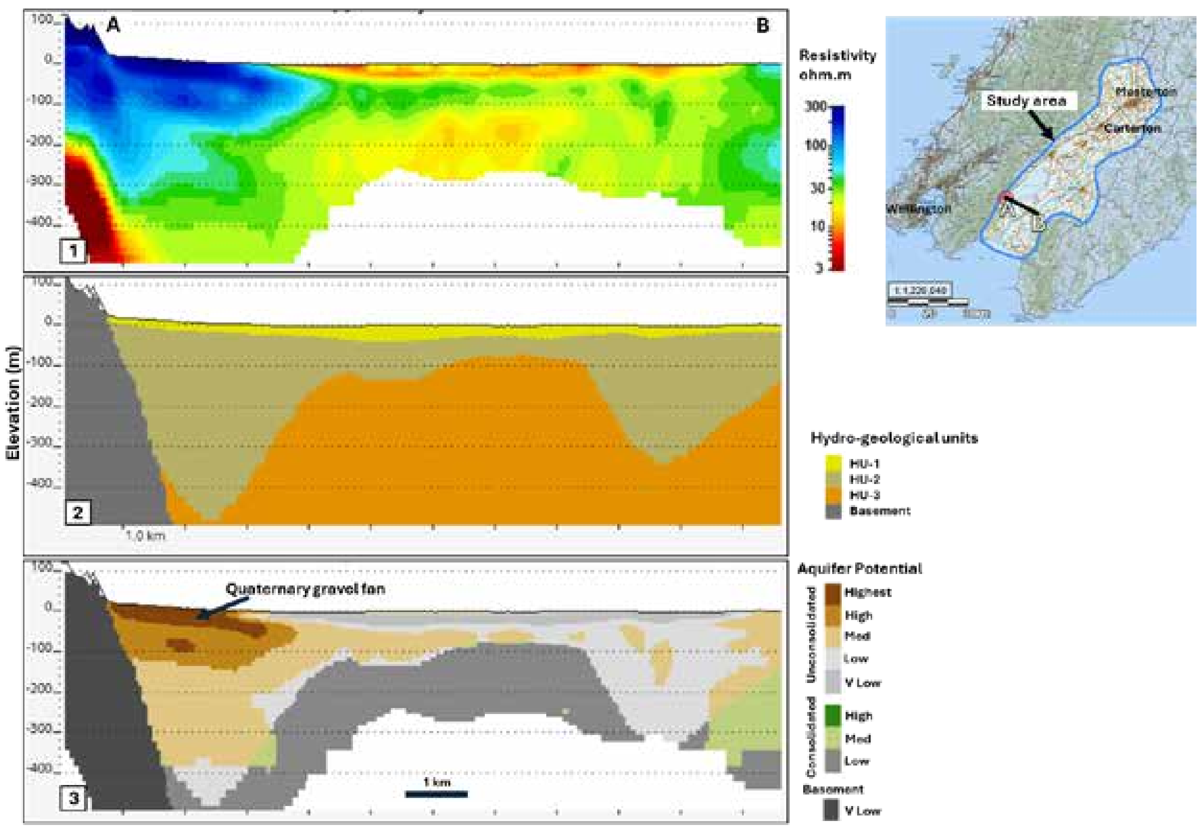


Figure 1: A NW-SE profile showing 1) SkyTEM esistivity, 2) mapped hydrogeological units and 3) aquifer potential. The inset map in the top righthand corner shows the location of the profile. The ed circle in this inset map show the location of Quaternary gravel fan.

References

Begg JG, Brown LJ, Gyopari M, Jones A. 2005. A review of the Wairarapa geology – with a groundwater bias. Lower Hutt (NZ): Institute of Geological & Nuclear Sciences. 34 p. Client Report 2005/159. Prepared for Greater Wellington Regional Council.

[LINZ] Toitū Te Whenua Land Information New Zealand. 2011. NZ Topo250 maps. Wellington (NZ): LINZ; [updated 2024 Mar 20; accessed 2024 Jun]. https://data.linz.govt.nz/layer/50798-nz-topo250-maps/

Gyopari MC, McAlister D. 2010. Wairarapa Valley groundwater resource investigation: Upper Valley catchment hydrogeology and modelling. Wellington (NZ): Greater Wellington Regional Council. 303 p. (Technical publication; GW/EMI-T-10/74).

3D FACIES MODELLING AND HOLOCENE MARINE INCURSION IN COASTAL AQUIFERS IN THE COROMANDEL PENINSULA

Sahoo, TR.,[1] White, P.,[1] Narvaiza, M.,[1] Koh, S.,[2] Moreau, M.[1]
[1] Earth Science New Zealand (GNS Science)
[2] Waikato Regional Council

Aim

The Coromandel Peninsula of New Zealand contains several small valley-fill coastal aquifer systems that serve as vital freshwater resources for local communities. These coastal aquifer systems are mainly composed of Quaternary sediments. The groundwater resource potential of many of these aquifers remains poorly understood due to limited borehole data and insufficient subsurface facies info mation.

This study developed a three-dimensional facies model of the coastal aquifers in the Coromandel Peninsula by integrating multiple datasets, including surface geology, hydrogeological system polygons, Digital Terrain Model (DTM), and borehole records. In areas with limited data, facies development concepts are applied using insights from analogue areas. The Pauanui area in the east and the Hauraki Plains in the west of the Coromandel Peninsula serve as key analogue areas where borehole data are available and can be used to inform regional facies development and aquifer characterisation. Holocene marine sediments, that play an important role in understanding the extent of marine incursion and facies development in these coastal systems, are also analysed.

Methods

The development of 3D facies models in these coastal aquifers involves two main steps:
• construction of 3D facies models in the Pauanui area and the Hauraki Plains.
• application of facies development patterns and concepts derived from these analogue areas to regions with limited or no borehole data.

The majority of the Coromandel region is underlain by volcanic rocks that are poorly fractured and yield small volumes of groundwater (Hadfield, 2001). In this stud , these rocks are considered the hydrogeological basement, bounding the Quaternary coastal aquifer systems. The hydrogeological system polygons (Moreau et al. 2019) define the geographical boundaries of these coast l aquifers. Surface geology data (Heron, 2014) have been used to delineate areas covered by volcanic rocks and those covered by Quaternary sediments. The DTM over the Quaternary sediment areas was used to define the top of the 3D facies model. o define the base of the 3D facies model, the DTM overlying the volcanic rocks was projected downward beneath the Quaternary sediment cover, generating a basement surface. The facies development process in the analogue areas followed steps outlined below.

• Facies identification at bo ehole locations using Boolean operators and well log descriptions.
• Assignment of facies code values to identified units
• Analysis of lateral and vertical facies distribution using well data.
• Creation and resampling of borehole facies property data.
• Development of a 3D facies model based on borehole facies data.
• Clipping of model data that falls below the basement surface or above outcrop elevations.
• Analysis of the 3D facies model, including facies development patterns and identification of Holocene marine incursion events.

Assuming regional tectonic conditions have remained consistent across the coastal aquifers of the Coromandel Peninsula, the facies layering patterns observed in the analogue areas were subsequently applied to other Coromandel valley-fill coastal aquifer systems

We have mainly used EarthVision 3D modelling software and ArcGIS to generate 3D facies model and suitable maps.

Results

Seven facies categories were defined to epresent borehole lithologies in the Pauanui area, namely: basement, overbank, swamp, shallow marine, estuary, beach, and braid-plain/fluvial fan. Bo ehole data and the 3D facies models suggest that the overbank facies are widely distributed and spatially dominate (Figure 1A). These facies are primarily composed of sands and silts, with minor occurrences of mud. The hydraulic conductivity of these coastal sand aquifers is generally around 15 m d^{-1} (Hadfield, 2001), and they are considered the main aquifer units in the Pauanui area. The lateral distribution of swamp, shallow marine, beach, and braid-plain facies is limited. In the central part of the Pauanui area, layering of estuary facies is observed, indicating sea level fluctuations during the Quate nary period. A distinct Holocene marine incursion has been identified at an elevation of app oximately –10 m in borehole records.

The 3D facies model and borehole data from the Hauraki Plains also reveal lithological layering and the presence of Holocene marine sediments (White et al. 2018; Figure 1B).

In general, coastal aquifers that extend below –10 m elevation have a higher likelihood of preserving terrestrial sediments, suggesting greater aquifer potential. The outcomes of this research will contribute to a better understanding of the subsurface architecture and hydrogeological behaviour of coastal aquifers in the Waikato region, supporting improved groundwater management and resilience planning in response to climate-induced sea level changes.

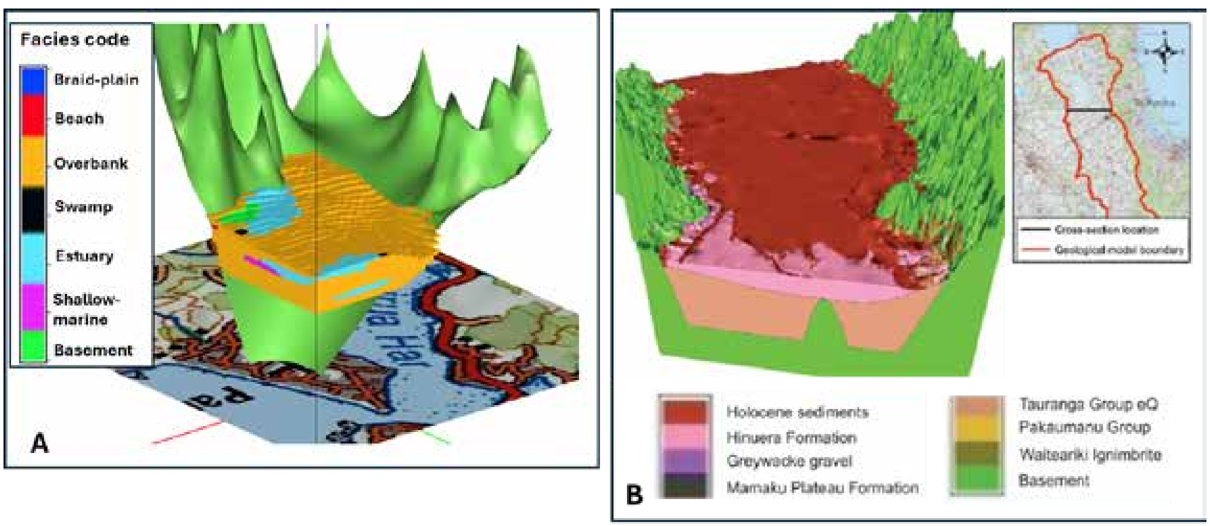


Figure 1: A) 3D facies model in the Pauanui area where most wells take groundater from overbank sediments and B) 3D geological model of the Hauraki Plains area; commonly, groundwater is sourced from the Hinuera Formation (White et al. 2018).

References

Hadfield, J. 2001.   aikato. In Groundwaters of New Zealand, M.R. Rosen and P.A. White (eds). New Zealand Hydrogeological Society Inc., Wellington: 315-326.

Heron, D. W., (Ed). 2014. Geological Map of New Zealand 1:250 00, 1DVD containing digital vector data + all 21 QMAP texts as PDFs, GNS Science, Lower Hutt.

Moreau M, White, P. A., Mourot, F., Rawlinson, Z., Tschritter, C., Cameron, S. G., Westerhoff, R. 2019. Classification of New Zealand hyd ogeological systems. Lower Hutt (NZ): GNS Science. 28p. (GNS Science report; 2018/35).

White, P. A., Raiber M., Tschritter C. 2018. Geological model and water budget of the Hauraki Plains, Waikato region. Wairakei (NZ): GNS Science. 63p. (GNS Science consultancy report).

NEW ZEALAND AND SURROUNDING OCEANS SURFACE TEMPERATURE TRENDS : 1870 - 2024

M. J. Salinger[1]
[1] School of geography, Environmental and Earth Sciences,Victoria University of Wellington,
P.O.Box 600, Wellington

Aims

Trends and variability in homogenised series of mean air temperature averaged over New Zealand (NZ) for the period 1870 – 2024 are compared with surrounding sea surface temperatures (SST) over the country's Exclusive Economic Zone (EEZ). As well as the anthropogenic warming signal, influences f om decadal and interannual variability – the Interdecadal Pacific Oscillation (IPO) with the ElNiño/Southe n Oscillation (ENSO), and the shorter time period Southern Annual Mode (SAM) explosive volcanic events are investigated. NZ temperatures are updated from Salinger et. al (2020).

Methods

For the land surface, issues arise because artificial changes c n be introduced, such as variations in the exposure of thermometers, alterations in observing methods and times and changes in the environment surrounding climate sites. Procedures were used to homogenise the data after Rhoades and Salinger (1993) to produce the NZ land temperature series NZT. Sea surface temperature data have also suffered from artificial changes because of methods of observation. Adjustments used methods of Folland and Parker (1995). Trends and variability in NZT are combined with the Extended Reconstructed Sea Surface Temperature version 5 (ERSST, Huang et al. 2017) for the NZ region to produce a combined temperature series NZEEZT on annual to multidecadal time scales. The land area (NZT) is only 1/15th of the EEZ so NZT and ERSST combined in proportions representative of their total areas. For the area of study, the uncertainties in SST were less than 0.4°C from 1854-1900, in the range of 0.2°C from 1900-1950, and less than 0.2°C from 1950 to the present. Finally, explosive volcanic eruptions (Kelly et al. 1996) cause climate impacts for up to 30 months. Examination of six eruption events (Krakatau (1883); Tarawera (1886), Pele, Soufrire and Santa Maria (all 1902); Agung (1963); El Chichon (1982) and Pinatubo (1991)) found good agreement between the spatial patterns of temperature anomalies associated with these events.

CMIP5 experiments with coupled atmosphere-ocean global climate models, used the average of all suitable CMIP5 model simulations for 1900-2015 which had Anthropogenic Global Warming (AGW) and natural variability (NAT) runs with 13 CMIP5 models suitable, using the methodology of Flato et al. (2013). These simulations show the magnitude of the AGW warming signal compared with NAT over time. Relationships with atmospheric teleconnections of variability, using actual and linearly detrended data, were examined as follows: (1) major volcanic eruptions; (2) the SAM for both trends and annual periods; (3) the Southern Oscillation Index (SOI) for interannual periods, and (4) the IPO for decadal periods. Bivariate correlations were used to identify relationships between both forcing of temperature by AGW, and teleconnections with SAM, SOI and the IPO. Multiple linear regression was used to explore multivariate relationships between NZEEZT and these four factors

Results

Table 1. Serial correlations between atmospheric indices, regional circulation indices and regimes with New Zealand temperature anomalies. Bolded italicized values are significant at the 1% confidence level and bold a the 5% level.

		SAM	SOI	IPO	AGW	NZEEZT-AGW
	ERSST	***0.49***	***0.38***	***-0.43***	***0.47***	***0.85***
	NZT	***0.55***	***0.34***	***-0.32***	***0.54***	***0.71***
	NZEEZT	***0.51***	***0.38***	***-0.42***	***0.50***	***0.84***
	N Z E E Z T smoothed	***0.58***	0.04	***-0.43***	***0.70***[1]	***0.47***

	ERSST	***0.23***	***0.47***	***-0.45***	-0.14	
	NZT	***0.28***	***0.47***	***-0.32***	-0.05	
	NZEEZT	***0.23***	***0.48***	***-0.44***	-0.14	

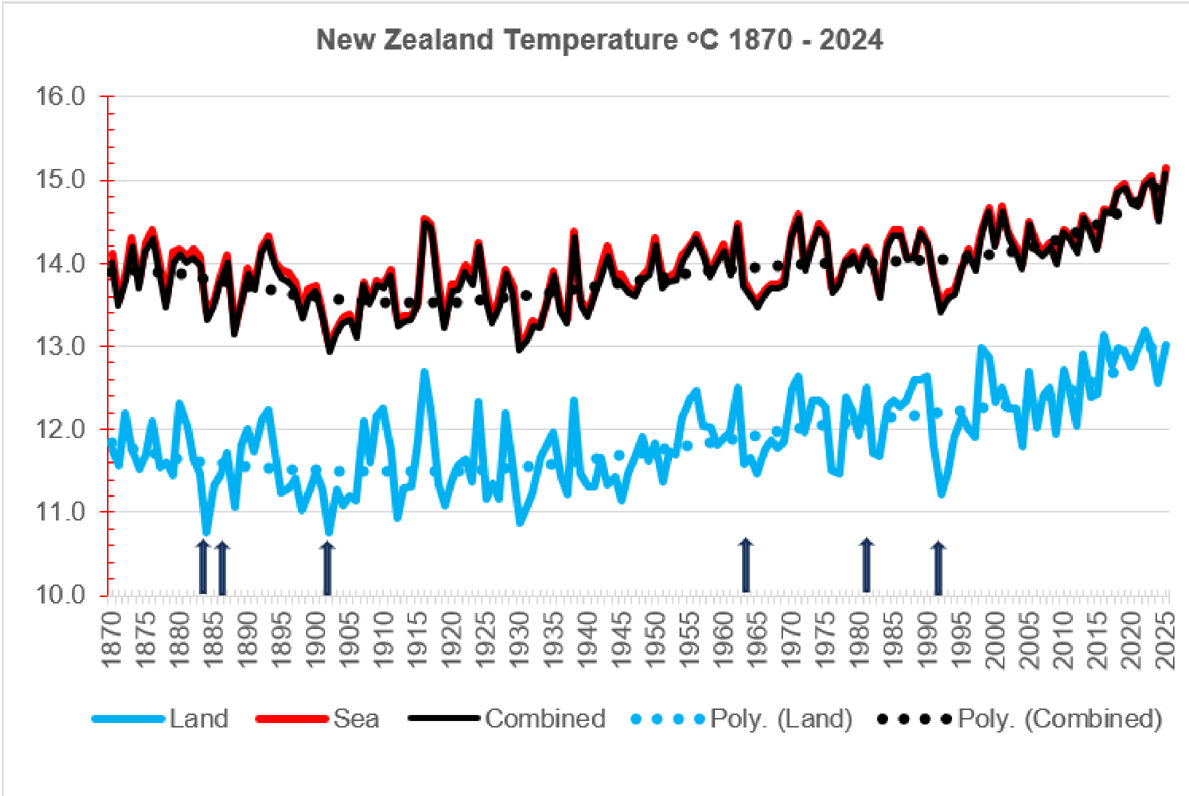


Figure 1. New Zealand temperature 1870-2024 (°C). NZT(blue), ERSST (red) and NZEEZT (black). The arrows indicate dates of major volcanic eruptions that affected New Zealand climate.

The New Zealand regional temperature signal, NZEEZT, shows a highly significant wa ming trend of 1.6°C for the 155-year period ($p<0.01$) from 1870 –2024. Multivariate analysis shows the importance of the climate teleconnections of SAM, IPO and SOI forcings with AGW. Table 3 shows the order of importance in affecting NZEEZT is AGW, followed by the SAM, IPO, and the SOI. The SOI measures the El Niño/Southern Oscillation between El Niño (cooler) and La Niña (warmer) phases.

From 1870-1895 mean NZEEZT was 13.8°C, then decreased to 13.0°C in the early 1900s (Figure 1). It decreased to a similar value (around 13.0°C) in the early 1930s; both these periods being the coolest in the temperature record. During the 1910s, 1920s and 1940s mean NZEEZT was 13.7°C. Temperatures increased to around 14.0°C in the1950s, 1970s and 1980s, with brief cooler excursions to 13.6°C in the 1960s and early 1990s owing to significant volcanic eruptions. NZEEZT then inc eased rapidly to 14.5°C to 2010 and 15.0°C by 2024.

This study has shown the importance of AGW forcing as depicted by CMIP5 simulations and the SAM in determining long-term warming in the NZ. The IPO and SOI give the decadal/interannual variability.

References

Huang, B., Thorne, P. W., Banzon, V.F., Boyer T., Chepurin, G., Lawrimore, J. W., Menne, M.J., Smith, T.M., Vose, R.S., Zhang, H-M. 2017. Extended Reconstructed Sea Surface Temperature version 5 (ERSSTv5), Upgrades, validations, and intercomparisons. Journal of Climate 30: 8179-8205. https://doiorg/ 10.1175/JCLI-D-16-0836.1.

Folland, C. K. and Parker, D. E. 1995.Correction of instrumental biases in historical sea surface temperature data, Quarterly Journal of the Royal Meteorological Society 121: 319-367. https://doi.org/10.1002/qj.49712152206.

Flato G, Marotzke J, et al. 2013. Climate Change 2013: Evaluation of Climate Models. The Physical Science Basis. Working Group 1 of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. http:// cmip-pcmdi.llnl.gov/cmip5/.

Kelly, P.M., Jones, P.D. and Jia Pengqun, 1996. The spatial response of the climate system to explosive volcanic eruptions. International Journal of Climatology 16(5): 537- 550.
Rhoades, D. A. and Salinger, M. J. 1993. Adjustment of temperature and rainfall records for site changes. International Journal of Climatology 13: 899-913. https://doiorg/ 10.1002/joc.3370130807
Salinger, M.J., Diamond, H.J, Renwick, J.A. 2020. Surface temperature trends and variability in New Zealand and surrounding oceans: 1871-2019. Weather & Climate 40(1): 32-51.

WHEN THE RAIN FALLS MAINLY ON THE PLAIN
EXPLORING MECHANISMS OF EXTREME RAINFALL IN UNUSUAL PLACES

Mark Schwarz[1]
[1] MetService

Many of Aotearoa's mountain ranges accumulate several metres of rainfall per year, with Warning levels occurring on a monthly or even weekly basis. When things get messy is where this occurs in less expected places, such as in low-lying, coastal or urban environments. Extreme rainfall in these cases often requires organised convective systems in order to produce the high rainfall rates sustained over several hours. But sometimes there are neither mountains nor obvious convection.

This study investigates cases of extreme rainfall over relatively low terrain in the absence of significant convection, with the aim of identifying the mechanisms involved. Recent examples include heavy rain events affecting the Nelson/Tasman region this year, where in some cases the coastal plains received more than 100mm in 6 hours, comparable to that of the mountains inland. Another notable case is that of Esk Valley during Cyclone Gabrielle, where the modest hills and valley catchment received up to 400mm in 12 hours - twice the rainfall recorded for the same period on the slopes of the Kaweka range immediately inland.

Numerical models typically fail to accurately capture the distribution of rainfall in these cases, instead placing the emphasis on the higher terrain. It is difficult for fo ecasters to add value when unsure what features of an event may cause a model to struggle, and without a conceptual framework in which to interpret the models and observations.

By identifying the mechanisms involved, improvements can be made to both forecast practice and the numerical modelling of rainfall.

HOW LOW CAN WE GO? GROUNDWATER NUTRIENTS IN A FARMED HIGH COUNTRY AREA, CANTERBURY

<u>Scott, L.C.</u>[1]

[1] Environment Canterbury

Aims

Waitaha/Canterbury's long-term groundwater monitoring data generally comes from areas where groundwater is used widely, both for drinking water and irrigation. Not as much attention has been paid where there is less pressure on the resource – areas with few wells and low groundwater abstraction. But even where groundwater resources are less developed, groundwater is important for its role in transporting contaminants through the landscape to receiving waterbodies.

In this study (Scott et al., 2024) we wanted to investigate nutrient concentrations and speciation in groundwater and rivers in one of Canterbury's less intensively farmed intermontane basins, Lees Valley. We aimed to find out mo e about how groundwater interacts with the wetlands and streams in the valley and how it carries nutrients to the Ashley River/Rakahuri that flows ou from Lees Valley through Ashley gorge.

We also wanted to see how nitrate concentrations in Lees Valley groundwater compared with groundwater quality from other high country farmed areas. This could help give some context to what it might mean for farming land use when communities concerned about drinking-water quality and ecological effects are calling for groundwater nitrate be reduced to concentrations of <1 mg/L.

Methods

Water samples from two existing wells, seven purpose-drilled piezometers and ten river sites in Lees Valley were analysed for a suite of major ions, various nutrient species (nitrogen, phosphorus and carbon), and indicator bacteria. Water quality data were used as natural tracers to assess the influences of geolog , soils and drainage on the groundwater composition and the cycling of nutrients affected by farming land use.

Results

Dissolved nitrogen and phosphorus concentrations were all below 0.5 mg/L, but concentrations were several times higher in groundwater than in the surface water samples. Groundwater contributes to the relatively elevated nitrate concentrations in the tributary stream across the southern sub-basin and increasing nitrate concentrations between up- and downstream sites on the Ashley River (Fig 1).

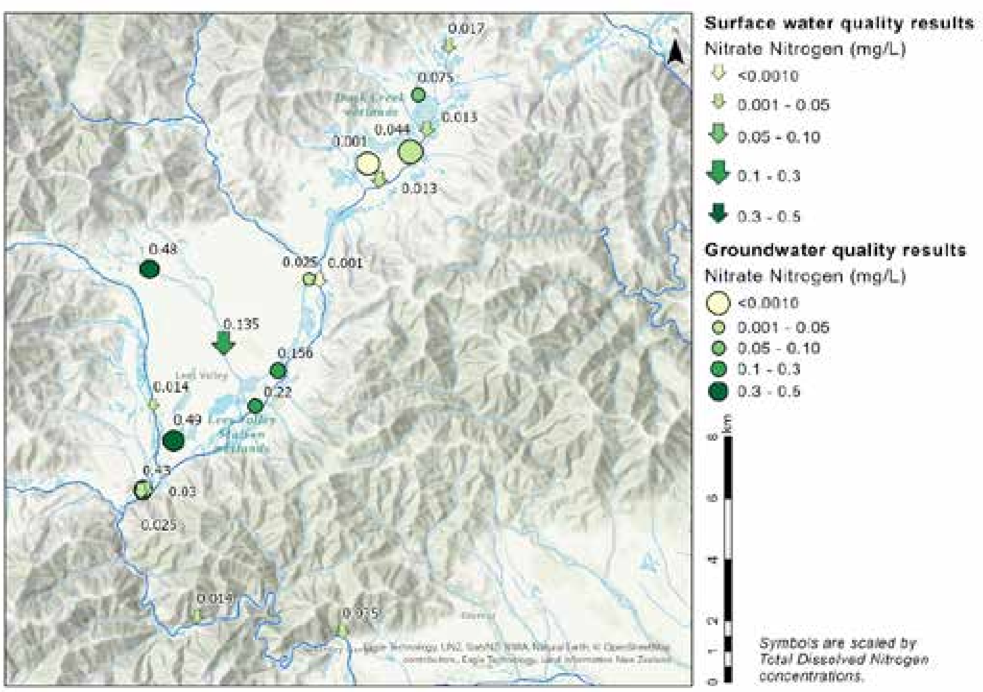


Figure 1: Nitrate N results from the Lees Valley investigation in April 2023

Dissolved nitrogen in groundwater was highest near wetland areas, but the dominant form varied from ammoniacal and organic nitrogen in the poorly drained (low oxygen) northern wetland area to nitrate nitrogen near the spring-fed southern wetlands.

The northern wetland areas also had higher concentrations of dissolved reactive phosphorus in groundwater and as a result, the Duck Creek tributary stream was contributing dissolved phosphorus to the Ashley River/Rakahuri. Dissolved organic nitrogen and phosphorus were the dominant forms of the nutrients in all the river samples and could be contributing to downstream periphyton growth observed at a popular swimming site below the gorge.

In Table 1, the investigation results are compared with other inland basin areas in Canterbury, ranked by increasing intensity of farming land use. Data for low intensity farmed areas aligns well with reported national reference concentrations for minimally impacted groundwater (Daughney et al., 2023). If any nitrogen leaching from the extensively grazed sheep and beef farmland in Lees Valley is contributing nitrate to the groundwater, this is resulting in lower concentrations than Daughney et al.'s (2023) reference levels. Under any more intensive land use, such as we see in the Ahuriri, Cass and Hanmer Basins, even extensive sheep and beef grazing, or relatively small areas of dairy or dairy support grazing, can easily result in median groundwater nitrate concentrations exceeding 1 mg/L.

Table 1: Summary of nitrate N concentrations in groundwater from Canterbury areas with lower land use intensity

Location	Nitrate N concentration			Number of sites	Number of samples	Analysis period	Data source
	Median	80th %ile	90th %ile				
Oxic groundwater							
Ōtūwharekai	0.15	0.24	0.5	9	47	2022 - 2023	1
Tekapo Basin	0.21	0.27	0.3	2	78	2009 - 2023	2
Lees Valley	0.29	0.49	0.54	7	9	2023	1, 2
Twizel Basin	0.48	1.4	2.1	12	466	2009 - 2023	2
Ahuriri Basin	1.0	1.6	2.2	7	316	2009 - 2023	2
Cass Basin	1.1	2.4	5.3	4	32	2023 - 2025	4
Hanmer Basin	3.7	5.0	5.6	5	68	1987, 2012-2023	1, 2
NZ Reference	*0.76 ± 0.09*	*1.65 ± 0.12*	*1.97 ± 0.14*	*approx. 20*	*NR*	*2000 - 2019*	*3*
Anoxic groundwater							
Ōtūwharekai	0.014	0.043	0.093	3	29	2022 - 2023	1
Lees Valley	0.081	ID	ID	2	2	2023	1
Ahuriri Basin	0.08	ID	ID	1	3	2009 - 2023	2
Hanmer Basin	<0.05	0.3	0.627	4	70	1987, 2012-2023	1, 2
NZ Reference	*NR*	*0.04 ± 0.01*	*0.16 ± 0.01*	*NR*	*NR*	*2000 - 2019*	*3*

Data sources: 1 = ECan investigation, 2 = ECan SoE monitoring, 3 = NGMP, Daughney et al., 2023. 4. Consent monitoring data supplied to ECan, NR = not reported, ID = insufficient data to compute statistic

Acknowledgement
Thank you to Dave Evans and Tom Johns for piezometer installation and undertaking the groundwater sampling and to David Ashby-Coventry for the surface water sampling.

References

Scott, L., Evans, D. and Johns, T. 2024. Lees Valley Water Quality Investigation. Environment Canterbury Science Summary Report No. R24/16

Daughney, C. J., Morgenstern, U., Moreau, M., & McDowell, R. W. 2023. Reference conditions and threshold values for nitrate-nitrogen in New Zealand groundwaters. Journal of the Royal Society of New Zealand, 55(1), 1–31.

CUSTOMISED E. COLI MODEL AND ECONOMIC ASSESSMENT SHOWS RELATIVE BENEFITS OF CURRENT MITIGATIONS IN TARANAKI

Annette Semadeni-Davies[1], Sandy Elliott[1], Yvonne Matthews[1,2]
[1] Earth Sciences New Zealand Ltd (formerly NIWA)
[2] NIWA / Concept Consulting Group Limited

Aims

Current-state E. coli levels for most of the streams in pasture areas of Taranaki are estimated to be in the National Objective Framework (NOF) D or E bands for the E. coli attributes for Human Contact (Whitehead et al. 2022). The Taranaki Regional Council (TRC) engaged NIWA (now Earth Sciences New Zealand) to undertake modelling of E. coli mean annual loads to inform their regional plan development to improve water quality in the region. This work required a regional customisation of the Catchment Land Use for Environmental Sustainability (CLUES; Elliott et al. 2016) E. coli model and scenario applications representing mitigation programmes that are already planned for the region. In addition to CLUES modelling, we also undertook economic analysis to estimate the effectiveness and cost of these mitigations.

CLUES calibration and customisation

CLUES is a catchment-scale, steady-state, mass budget model that estimates mean annual loads of TN, TP, sediment and E. coli for each segment in the Digital River Network version 2.5. For each stream segment, E. coli loads from diffuse sources are estimated as the product of the source area and a calibrated source yield. These loads are modified by delivery factors epresenting soil drainage, annual rainfall and temperature before delivery to the stream network. Any point sources are added to the instream load for the respective segment. The instream load is routed downstream and is subject to both instream attenuation and losses in lakes and reservoirs.

The CLUES E. coli model was calibrated in a joint project for TRC and Horizons Regional Council (Semadeni-Davies et al. 2023) against mean annual E. coli yields estimated from water quality and flow data f om sites located in both regions. A previous national calibration for E. coli was done in 2014. The new regional calibration was done to make use of new data not available in 2014 and to remove possible bias from other regions. We used a bootstrapping approach to estimate E. coli loads, which allowed us to determine the uncertainty associated with the estimates. Sites with high load estimate uncertainties were discarded from the calibration. In all, load estimates were available for 58 monitoring sites. Calibration was carried out using yields (i.e., loads / upstream area) rather than loads to normalise for catchment area. Calibration is an iterative process whereby the model fit, parameter uncertainty and collinearity dete mined for a calibration run (which undertakes non-linear least squares parameter optimisation) are used to guide the parameter set-up for the next run. The model fit was dete mined in log-space to counter the wide range of yields between sites and to make the distribution of model errors closer to a normal distribution. The final calibration esulted in a coefficient of dete mination (R^2) and Nash-Sutcliffe Efficiency of 0.689, and a Root Mean Squa e Error of 0.567.

Initial use of the model for TRC showed that the model gave unreasonably high load estimates for streams flowing f om Taranaki Maunga. This area was not represented by any of the data available for calibration. The high load estimates were an artefact of the calibrated rainfall parameter (which has an exponential form) that did not account for orographic rainfalls on the mountain's slopes. Water quality data taken within and just outside the boundaries of Taranaki National Park, that were not available or suitable for calibration, showed near pristine water quality. To counter this issue, we use a maximum value of 3 m/y mean annual rainfall in the model's rainfall factor. The rainfall limit roughly corresponds to an elevation of 500 masl and the national park border. While the customisation had a profound effect of the yields estimated in the national park and its surrounds, it had minimal impacts on downstream water quality estimations as forested land gave way to pasture. This is because the area affected is small compared to the region as a whole. The relatively small change in estimated loads at the calibration sites meant that we did not fully recalibrate the model after the adjustment. The subsequent customisation of the CLUES E. coli model shows the value of evaluating and adjusting calibrated model parameters using other sources of knowledge where there are known sources of uncertainty.

Scenario Modelling
We ran two mitigation scenarios for TRC representing planned mitigations already underway in the region (Semadeni-Davies et al. 2024):

- Scenario 1 Completion of currently planned fencing and riparian planting for stock exclusion, which is represented by reducing pastoral source yields. The impacts of stock exclusion already in place was not assessed.
- Scenario 2 Land disposal of farm dairy effluent (FDE) cur ently discharged to streams. Which is represented by removing estimated FDE loads as E. coli point sources.

The outputs of the load modelling were used to adjust the estimated current E. coli NOF attributes using a simple delta-change technique, whereby attribute state concentration metrics are adjusted in proportion to the change in load. We used the same method as Semadeni-Davies et al. (2018); model outcomes were represented as the length of higher order (≥4) streams in each band..

We conducted a cost-effectiveness analysis (CEA) and benefit-cost analysis (BCA) for ach scenario, applying lifecycle costing (LCC). The costs (updated to 2025) and assumptions for fencing, riparian planting and FDE removal were primarily sourced from technical reports commissioned by the Ministry for Primary Industries and the Ministry for the Environment and validated against other published sources. Costs included installation, maintenance and loss of profits f om productive land over a 50-year period. We present the total annualised costs, cost-effectiveness and net benefit outcomes. Cost-e fectiveness was calculated by multiplying the median concentration (C50) in each segment by the segment's stream length (km) and summing across segments, yielding a metric in $/C50/km/year, referred to as the cost per unit concentration reduction. Net benefits we e calculated by including non-market values for water quality improvement.

With no mitigation included in the model, the estimated regional mean annual load delivered to the coast is 99.5 peta organisms per year. Neither scenario results in significant changes to the length of higher o der streams estimated to be in each of the NOF E. coli attribute bands.

Scenario 1 would result in a 17% increase in the length of streams with new or improved stock exclusion. With a medium level E. coli removal by stock exclusion (Muirhead 2019), the scenario achieved only a 3% reduction in E. coli loads across the region. The estimated cost of the additional fencing and planting would be around $14.3 million / year and the cost effectiveness is around 64.1 $/C50/km/year. In contrast, Scenario 2 resulted in an 11% reduction in E. coli loads regionally. This scenario has a very high cost-effectiveness (2.4 $/C50/km/year) due to its low cost (0.7 $million/year).

Acknowledgements: We would like to thank Thomas McElroy, Angela Collins and Jeremy Wilkinson at TRC for their support and allowing us to present this work.

References
Elliott, A.H.; Semadeni-Davies, A.F.; Shankar, U.; Zeldis, J.R.; Wheeler, D.M.; Plew, D.R.; Rys, G.J. and Harris, S.R. (2016) A national-scale GIS-based system for modelling impacts of land use on water quality. Environmental Modelling & Software, 86: 131–144. http://dx.doi.org/10.1016/j.envsoft.2016.09.011

Muirhead, R.W. (2019) The effectiveness of streambank fencing to improve microbial water quality: A review. Agricultural Water Management, 223: 105684. https://doi.org/10.1016/j.agwat.2019.105684

Semadeni-Davies, A.; Elliott, S. and Matthews, Y. (2024) Modelling E. coli to support implementation of the NPS-FM: Stage 2 Technical Report, reissue with Addendum, NIWA client report prepared for Taranaki Regional Council, 2023207AK.

Semadeni-Davies, A.; Elliott, S. and Yalden, S. (2023) Calibration of the CLUES E. coli model for the Taranaki and Manawatū-Whanganui Regions: Stage 1 Technical Report, Client report prepared for Tanaki and Horizons Regional Councils, NIWA report: 2023064AK.

Semadeni-Davies, A.; Yalden, S.; Sukias, J. and Elliott, S. (2018) Appendix E. National E. coli modelling: Supplementary material to support setting draft regional targets for swimmable rivers. Regional information for setting draft targets for swimmable lakes and rivers. Published by the Ministry for the Environment on behalf of a joint taskforce of central and local government representatives. http://www.mfe.govt.nz/publications/fresh-water/regional-information-setting-draft-targets-swimmable-lakes-and-rivers

Whitehead, A.; Fraser, C. and Snelder, T. (2022) Spatial modelling of river water quality state: Incorporating monitoring data from 2016 to 2020, NIWA client report prepared for the Ministry for the Environment, 2021303CH. https://environment.govt.nz/assets/publications/spatial-modelling-river-quality.pdf

PARADIGM SHIFT TOWARD SMART HYDROLOGICAL SURVEYS FOR CLIMATE RESILIENCE: THE ROLE OF KIHS IN KOREA

Eunjeung Shim, Dongheon Oh, Chanwoo Kim, Geumyoung Lee
Korea Institute of Hydrological Survey

The frequency and intensity of water-related disasters such as floods and d oughts have been exacerbated by the climate crisis, revealing the limitations of traditional, labor-intensive, and intermittent hydrological observation methods. Korea has also experienced frequent floods and d oughts, highlighting the growing need for a systematic hydrological survey framework to enhance water resource management efficienc .

This study reviews the transition of the Korea Institute of Hydrological Survey (KIHS)—the nation's sole institution dedicated to hydrological observation under the Ministry of Climate and Environment—toward a non-contact, automated, and continuous data production systemsince its establishment in 2017, and presents its outcomes and future directions. Focusing on the Revised Second National Hydrological Survey Plan (2020–2029)(updated in 2025), this paper examines strategies to improve data reliability, customized quality management, AI-based flood fo ecasting, and the joint utilization of hydrological observation networks.

Field applications of cutting-edge technologies, including drones, unmanned boats, PAVO (remote-controlled devices), ultrasonic and radar current meters, and automatic sediment measurement instruments, have significantly enhanced accuracy and safet . The Smart Hydrological Data Information Management System (SHDIMS)has established a real-time framework for data collection, processing, and dissemination. Additionally, the implementation of the national hydrological data certification system, localization of measurement equipment, and expansion of international cooperation and training programs have strengthened Korea's overall hydrological survey capacity, leading to a paradigm shift from flood-focused to integrated water management.

Future developments in hydrological observation will focus on expanding automation and non-contact measurement technologies, such as Microwave Surface Velocity Meters, Space-Time Image Velocimetry, satellite-based analysis, and AI-driven prediction systems. The Korean Water Resources Satellite, scheduled for launch in 2027, is expected to further enhance the spatial resolution of hydrological observations.This paper highlights KIHS's leadership in modernizing Korea's hydrological survey system and proposes future directions for smart hydrological observation and managementin response to the climate crisis.

FLOW SIMULATION MODEL APPLICATION TO FLOODS IN AN URBAN DISTRICT

Jaehyun Shin[1]
[1] Department of Civil and Environmental Engineering, Gachon Univeristy, Republic of Korea

The frequency of extreme rainfall events is increasing due to urbanization and climate change. This study applies rainfall scenarios to urban flooding simulations to qua tify safety-related risk levels in an actual district. It integrates a former hydraulic experiment which is reproduced in OpenFOAM, a 3D flow simulation model which would be applied to a realistic urban district flood scenario. A cont olled flash-flood experiment wit variable inflow discha ges over a simplified urban layout was used to verify the model This showed the model's ability to reproduce observed flow dynamics even with complex flow patt ns inside the urban layout before extending it to conditions in an actual urban environment.

For application to an urban district, rainfall scenarios were generated using frequency-based design rainfall. Then the scenarios were translated into time-varying discharge boundary conditions for the flow simulation. The areas that were flooded in the urban district we e then assesed for pedestrian safety. The impact of rainfall intensity changes per return periods applied to urban flooding we e analyzed, and total risk areas were estimated. This integrated approach shows how urban flood simulations can be used with design ainfall scenarios for conducting flood risk assessment

QUANTIFYING UNCERTAINTY IN THE PERCEIVED RISK OF UNPRECEDENTED RAINFALL: A NEW ZEALAND CASE STUDY

Muhammad Fikri Sigid,[1] Luke J. Harrington,[1] Suzanne Rosier,[2] Hamish Lewis[1,3]
[1] Te Aka Mātuatua School of Science, University of Waikato, Hamilton, New Zealand
[2] National Institute of Water and Atmospheric Research, Christchurch, New Zealand
[3] National Institute of Water and Atmospheric Research, Auckland, New Zealand

Abstract

As global temperatures increase, extreme rainfall events are expected to become more frequent and intense. However, their irregular occurrence and high variability can obscure long-term trends at local scales. Current assessments of extreme rainfall, including in New Zealand, largely rely on limited historical records, yet the severity (or absence) of past events can strongly influence pe ceived risk of unprecedented rainfall.

Using over 3,200 years of high-resolution (~50 km) atmosphere-only model simulations for a quasi-stationary climate resembling the early 2010s, we quantify uncertainty in the perceived risk from extreme rainfall due to randomness of past observations. We repeatedly sample 100-year subsets from the model, identify the most extreme “worst-in-memory” (WIM) event in each, and assess its rarity and intensity.

WIM intensities ranged from 70% to more than twice the “true” 1-in-100-year event. Their return periods varied by over a factor of 200, with a 1% chance of experiencing only a 1-in-25-year event over a century, and a 1% chance of exceeding 1-in-5000-year rarity. The most extreme simulated events were linked to plausible large-scale weather systems. These findings highlight la ge sampling uncertainty in estimating extreme rainfall rarity and intensity, stemming from their highly stochastic nature, potentially leading to misleading risk assessments.

LEVERAGING HISTORICAL OBSERVATIONS TO CONTEXTUALISE RECENT RECORD-SHATTERING RAINFALL EVENTS: A NEW ZEALAND CASE STUDY

Muhammad Fikri Sigid,[1] Luke J. Harrington,[1] Trevor Carey-Smith[2]
[1] Te Aka Mātuatua School of Science, University of Waikato, Hamilton, New Zealand
[2] New Zealand Institute for Earth Science Limited (Earth Sciences New Zealand), 301 Evans Bay Parade, Greta Point, Wellington, New Zealand

Abstract
Record-shattering rainfall is intensifying and projected to occur more frequently in a warming climate, primarily via changes in extreme rainfall variability. However, dominant internal variability at local scales is a limitation in quantifying these historical extremes. New Zealand has experienced record-breaking rainfall events, including the January 2023 Auckland floods, exceeding 2 -hour records by 60% in four hours. Yet, it remains unclear whether these are New Zealand's most severe on record and whether extreme rainfall becomes more frequent.

Using daily rainfall data from 307 weather stations (>70 years), we examine long-term trends in extreme rainfall and assess past events' relative severity across New Zealand. To circumvent challenges in fitting GEV distributions to quantify past events' return periods, we standardize rainfall extremes into "sigma anomalies" using standard deviations of the RxNday distribution (N=1:5). The extreme events' relative frequency shows no clear historical trend. Notably, +4□ events were most prominent during 1921–1940, potentially reflecting decadal variability. The most extreme occurred in May 1923, delivering over 600 mm in two days (+8□) to the South Island's east coast. Other record-shattering events unseen since include February 1971 (Taranaki) and January 1984 (Invercargill), while King Country and Central Otago showed statistically modest extremes.

INFERRING ALPINE RIVER RECHARGE OF GROUNDWATER USING PRINCIPAL COMPONENT ANALYSIS WITH INORGANIC CHEMISTRY

Matt Silver[1] and Lisa Scott[1]
[1] Environment Canterbury Regional Council, Groundwater / Water Quality Science Team

Aims

Groundwater in alluvial gravels in Canterbury may be recharged by land surface infiltration, alpine rivers (losing streams) or a combination of both. While land surface infiltration can result in high levels of nutrients being carried to groundwater, alpine river recharge represents a relatively low-nutrient source of groundwater recharge. Understanding the relative proportions of recharge sources and whether they vary over time could improve our insight into aquifer dynamics and inform better management of groundwater abstraction and land use. In this work, we use major ion and silica groundwater chemistry data from Environment Canterbury's state of the environment (SoE) groundwater monitoring to infer relative amounts alpine river recharge in wells across most of Canterbury.

Major ion and silica composition of major alpine rivers in Canterbury is dominated by alkalinity and calcium, with very low concentrations of chloride, potassium and magnesium (Jacobson et al., 2003). Both alpine river water and water infiltrating th ough the land surface, from rainfall or irrigation, are likely to have capacity to dissolve minerals along their subsurface flow paths However, any differences in major ion and silica concentrations from the two types of groundwater recharge may be subtle. We have used principal component analysis (PCA) to investigate these subtle differences in water quality.

Methods

A subset of SoE monitoring wells deemed to represent typical alluvial gravel Canterbury aquifers was selected with a requirement for availability of at least one set of groundwater quality data in at least four years out of a five-year period. For these 303 wells, five-year median concent tions were calculated for eleven groundwater quality parameters (excluding nitrogen and phosphorus). PCA was then conducted in an iterative process: the first PCA iteration used all eleven g oundwater quality parameters, with judgement applied viewing the results to drop one variable, often the water quality parameter with the shortest loading vector, for the next iteration. To aid with the judgement applied in variable reduction, PCA biplots were symbolised with groundwater mean age estimates and oxygen 18 data, where available. Additionally, a limited number of ion ratios/sums that may be meaningful to the overall purpose were considered. After several iterations, three variables were selected: alkalinity divided by total anionic charge, reactive silica, and the sum of potassium and magnesium molar concentrations. Then, the PCA was refined once further by d opping wells that appeared as outliers at the end of the first ound of PCA, as these were considered unlikely to be representative of typical aquifer mineralogy and hydrogeologic setting.

Results

Figure 1 shows the PCA biplot from the second-round PCA, with data points for all 295 included SoE wells, coloured by mean groundwater age where available. More negative PC1 values combine high alkalinity / total charge with low silica concentrations, showing similarity to alpine river water with a possibility of water dissolving more silica along groundwater flow paths. Positive values of PC1 have high K + Mg, otentially reflecting echarge through soils with exchangeable cations. Based on these considerations, we suggest that PC1 reflects a continuum f om predominantly alpine river recharge at the more negative values to mainly land surface recharge at the more positive values of PC1.

Figure 2 shows the same PCA loadings but only plots a subset of wells located outside of irrigated areas (irrigation water is often sourced from alpine rivers) for which oxygen 18 data are available. We suggest that the 18O* (delta 18O deviation from expected based on land elevation, see figu e caption) values help to provide verification, using a di ferent data source, of the interpreted meaning of PC1. In particular, many of the more negative 18O* (< -1.5 ‰) values (indicating alpine river recharge) occur at negative PC1 values, and many of the higher 18O* (> -0.5 ‰) values (indicating land surface recharge) occur at positive values of PC1. While groundwater age does not directly identify a recharge source, some clustering of younger ages at PC1 values less than -1 and PC2 between about 0.2 and -1.1 is apparent. We suggest that this area of the plot reflects elatively recent (less than about 20 years) alpine river recharge.

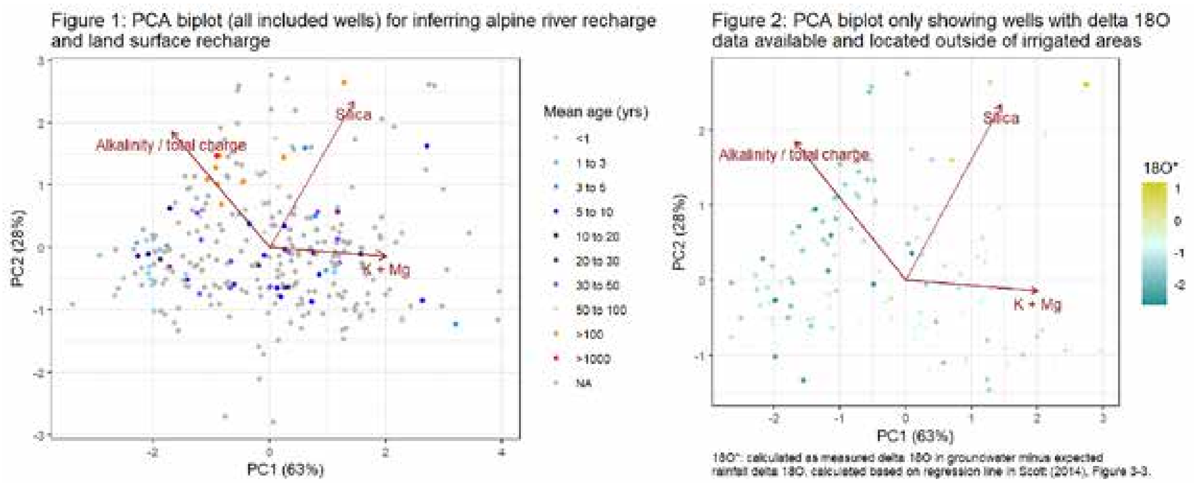


Figure 1: PCA biplot (all included wells) for inferring alpine river recharge and land surface recharge

Figure 2: PCA biplot only showing wells with delta 18O data available and located outside of irrigated areas

References

Jacobson, A.D., Blum, J.D., Chamberlain, C.P., Craw, D. and Koons, P.O. (2003). ‘Climatic and tectonic controls on chemical weathering in the New Zealand Southern Alps’, Geochimica et Cosmochimica Acta, 67(1), pp.29–46.

Scott, L. (2014). ‘Review of Environment Canterbury’s groundwater oxygen-18 data’, Environment Canterbury Technical Report No. R14/128, record number PU1C/8206-1.

FLOOD FREQUENCY ANALYSIS USING ENVELOPE CURVES FOR EXTREME FLOODS

Shailesh Kumar Singh[1], George A Griffith [1]; Alistair I. McKerchar[1]
[1] Earth Sciences New Zealand, Christchurch

Abstract

Accurate estimation of return periods for extreme flood peaks is critical for hyd ological design, infrastructure planning, and risk management. However, flood ecords are often short, contain outliers, or lack sufficient data for reliable flood f equency analysis and extrapolation for extreme flood. This study add esses these limitations by developing straightforward, transferable methods for constructing envelope curves applicable throughout New Zealand. The aim is to provide designers and planners with a practical tool for quickly verifying estimates of flood peak magnitude or eturn period, particularly for rare and extreme events where conventional methods are uncertain.

The approach involves plotting dimensionless annual maximum flood peak magnitude against return period, with logarithmic scales employed to linearise the relationship and facilitate analysis. The resulting upper bounds, or envelope curves, are modelled using power laws, which can be applied to regional, regional extreme value, and site-specific flood equency relationships. At the site level, an updated predictive equation is introduced that links dimensionless flood peak magnitude to both eturn period and the average annual number of floods. This allows extension of flood equency curves beyond observed data, adjustment of fitted curves, and imp oved estimation of the return periods of statistical outliers.

The method offers a rapid, reliable, and consistent means of cross-validating extreme flood estimates for both preliminary checks and detailed assessments, supplementing traditional statistical analyses and supporting more robust decision-making.

IMPACTS AND MANAGEMENT OF HAZARDOUS FLOWS IN ICELAND

G.M. Smart,[1]
[1] Earth Sciences New Zealand

Aim

Iceland sits on active, divergent tectonic plates, leading to significant volcanic and geoth rmal activity. More than a tenth of Iceland is covered with glaciers. Volcanic activity beneath glaciers creates enormous outburst floods (jökulhlaups). Basaltic lava f equently flows f om ground fissu es and inundates land, infrastructure, homes and people. We herein use Iceland examples to inform NZ of potential impacts and management options for future hazardous flows that could occur he e. Iceland's land area is just over one third of that of New Zealand and the population density is one fifth. wo-thirds of the population live in the capital, Reykjavik.

Method

We start with examples of geohazard flows in Iceland. Jökulhlaups a e caused by subglacial geothermal lakes, meltwater from volcanic eruptions and bursting of glacier-margin, ice-dammed lakes. The extreme flood flow reshape the landscape by erosion of large upstream canyons and transport and deposition of sediments over outwash plains. The jökulhlaup floods can last over weeks and ischarge several cubic kilometres of water. Recent glacial outburst floods occur ed in in 2010 and 2021. The size and power of these floods is illustrated in the talk.
Fig. 1 shows a scour hole in the vast alluvial plain caused by a glacier outwash flood. The scour hole occur ed around a large block of ice which then melted following the flood

Fig. 1 A scour hole in the vast plain caused by a glacier outwash flood. Note the scale f om the car at top right. Photo: G. Smart.

Lava flows a e not conventionally considered under hydrology but many hazard management options offer solutions similar to what may be considered for flood haza ds in NZ. Furthermore, flows of this type a e likely to occur in NZ in the future, particularly in Auckland. Fig. 2 shows basaltic lava flows e tering the town of Grindavik in south Iceland. The flows occur ed in January and March 2024, and again in April and July of 2025 requiring evacuation of the town on three occasions. Large rock diversion walls (stopbanks) were built in an attempt to protect assets and deflect lava flows away om the town.

Fig 2. Two fresh fissu es extrude lava in January 2024. Lava from the closest fissu e is entering the town of Grindavik. Photo: Grindavik town information display.

Results

Iceland's preparedness and monitoring systems help mitigate the impact of these events. Children are normalised to think of such disasters as "natural" - which helps reduce panic during an event. The potential for glacial outwash floods is monito ed by the Icelandic Meteorological Office and danger wa nings are issued by the Department of Civil Protection. One sign of potential volcanic-induced jökulhlaups, is an increase in electrical conductivity and turbidity in glacial outflow st eams. Roads are then closed in high hazard areas and the public is warned. Nevertheless, severe damages and deaths do occur, with tourists being stranded and roads cut until they can be reformed and bridges rebuilt. Minimal infrastructure exists in the high hazard zones. Planning essentially comprises hazard monitoring, zone avoidance and early warning, but this is complicated as jökulhlaups can avulse and re-route entire river systems.

The Grindavik 2024 lava inundation event unfolded as follows. On January 14 sirens at 3 am warned that magma was rising under the town and the 3400 residents were evacuated. Five hours later lava flowed out from a 1 km fissu e just north of the town. Around 12:30 pm a smaller fissu e opened closer to the town's northeastern edge. The defensive stop banks initially deflected lava to th west of the town until the fissu e undercut the walls and lava flowed into Grindavík s outskirts. Several houses were destroyed.

The Iceland national disaster fund (funded by taxes) pays for houses which are destroyed by natural hazard. In Grindavik, the government offered to buy-back around 1000 houses considered too dangerous to live in while the eruption phase continues. Affected house owners have the first right to buy back their hous when it is deemed safe. Most Grindavik residents accepted the market price buy-back offer. Residents had to remove all belongings from houses when they were sold. Subsequently, some houses have started deteriorating from neglect. House prices have risen in the rest of Iceland because of the sudden demand. This year previous owners of around 50 of the houses have been allowed to reoccupy their house for the 2025 summer (3 months).

More details on the impacts and management of these severe inundation hazards are given in the talk.

Reference

Björnsson. H. (2017). Jökulhlaups in Iceland: prediction, characteristics and simulation. Annals of Glaciology ,

Volume 16 , Cambridge University Press. pp. 95 - 106

CLIMATE CHANGE AND WATER RESOURCES: MODELLING FUTURE RISKS AND RESPONSES

Rachel Smith, Doug Booker, Jing Yang, Channa Rajanayaka, Peter Davidson, Jamie Sigmund

Climate change is expected to alter both the availability of and demand for water across Aotearoa New Zealand via effects on linked surface water–groundwater systems. These changes challenge the effectiveness of current water allocation frameworks and highlight the need for adaptable strategies to ensure future resilience. We present a nationally applicable modelling workflow to assess clim te-driven impacts on water availability and demand for both surface water and groundwater resources. The workflow incorporates multiple global circulation models (GCMs), shared socio-economic pathways (SSPs), crop types, allocation rules, and irrigation strategies. Applied to the Wairau Plains in Marlborough—an area with increasing irrigation demand from both rivers and aquifers—the model quantifies potential chan es in water availability, cease-to-take thresholds, and allocation limits. It identifies whe e and when climate adaptations may be needed to maintain supply reliability, protect environmental flows, and support p oductive land use. This work demonstrates the compounding effects of climate change on the balance between water demand and availability, and provides a practical foundation for assessing the performance of current allocation limits and informing the development of climate-resilient water management strategies.

EXPLORATION OF QUANTITATIVELY FORECASTING PINUS RADIATA POLLEN IN NEW ZEALAND

Eveanjelene Snee
Metservice

Forecasts of pollen concentration can be valuable for a range of stakeholders, for example empowering allergy sufferers to reduce allergic reactions by timing outdoor activities and their intake of preventive medication. To forecast the airborne concentration of pollen as a function of space and time, we need to couple pollen emission schemes with atmospheric dispersion models. Emissions can be characterised through empirical models to predict the release flux of pollen in a given a ea. This can then be used as an input to numerical dispersion models that predict the subsequent atmospheric transport.

Here, we present a case study forecasting pollen concentration from Pinus Radiata in New Zealand. We use an empirical model to determine the emission flux of pollen ac oss during the 2024 pine pollen season, then couple this to the dispersion model HYSPLIT to predict the spatio-temporal distribution of pollen based on the meteorological conditions. We examine the modelled pollen concentration at major population centres across New Zealand to examine how much pine pollen is reaching these communities and identify trends throughout the season. Thoughts are presented on the challenges of verifying the results within New Zealand and a discussion on the uncertainty related to pollen forecasting.

WHEN SURFACE FLOW DISAPPEARS BELOW: MAPPING DRY RIVER REACHES USING FIELD OBSERVATIONS AND SATELLITE IMAGERY

Somerville, L.,[1] Gabites, S.,[1] Clark, D.,[1] Topélen, J.[1]
[1] Canterbury Regional Council (Environment Canterbury)

Aims

Canterbury Regional Council (Environment Canterbury) monitors river flow ac oss the region using a network of 157 water level recorders alongside manual gauging at spot sites. It is not uncommon for surface flow to become disconnected, particularly during the summer. The sections of riverbed where surface flow goes subsurface are known as dry reaches and their presence is often not fully captured by Canterbury's point-based hydrometric network. Information on the spatial extent and temporal variability of dry reaches is crucial to understanding catchment dynamics, enabling informed decision making in water management. To address this, a dry reach mapping programme has been operating each summer since 2020, using a combination of field observations and satellite imager .

Method

Throughout the mapping season, field data is collected using A cGIS Field Maps during repeat visits to rivers. While walking and/or driving down a riverbed, Field Maps is used to map the hydrological status of a river as 'Flowing,' 'Intermittent,' or 'Dry.' Points of interest are recorded as the river changes hydrological status, including photographs and relevant notes. Field observations are compared to the hydrological status recorded from Planet Explorer satellite imagery at the closest available date, and the relevant discharge measurements are also recorded. To date, dry reach data has been collected for 61 rivers across Canterbury.

Results

The dry reach dataset has confi med understanding of catchment dynamics in some locations and provided new insight in others. For rivers where hydrological status results have been consistent between satellite imagery and field observations, satellite imagery can now be elied upon to determine hydrological status. The programmes' results are documented in a science summary report at the end of each mapping season (Somerville, 2024). This foundational dataset is now beginning to support further investigation into spatial and temporal dry reach trends and their potential environmental drivers. A case study on the Waitohi River in North Canterbury is currently being developed. The dry reach dataset shows increasing dry reach frequency, extent and duration along this river. With a new application to take the last remaining water for allocation in the catchment, understanding the environmental drivers of dry reaches in the river is essential. An analysis of surface flo , groundwater levels and abstraction data aims to identify any commonalities in conditions leading to dry reach formation. Additionally, an adapted method from Di Ciacca et al., (2025) using satellite-derived data to estimate transmission losses will help to assess how water storage capability varies alongside the other variables. The continued development of this monitoring programme and analysis of the dry reach data alongside relevant catchment characteristics will work to strengthen regional hydrological insight and support proactive decision making in water management across Canterbury.

References

Di Ciacca, A., Knight, L.G., Brand, M., Durney, P., Wilson, S. and Wöhling, T. 2025. Transmission losses and groundwater recharge from ephemeral rivers in the Canterbury Plains (New Zealand): Historical reconstruction and environmental implications. Journal of Hydrology: Regional Studies, 59, p.102317.

Somerville, L. 2024. Dry Reach Mapping 2023 - 2024. Environment Canterbury Science Summary Report, No. R24/31. Canterbury Regional Council (Environment Canterbury).

REGIONAL ANALYSIS FOR THE PURPOSES OF DESIGNING A REFERENCE CLIMATE STATION NETWORK IN NEW ZEALAND

Raghav Srinivasan[1], Trevor Carey-Smith[1], Andrew Harper[2], Nicolas Fauchereau[3], Sam Dean[1]
[1] Earth Sciences New Zealand, Wellington.
[2] Earth Sciences New Zealand, Christchurch.
[3] Earth Sciences New Zealand, Hamilton.

The aim of this study is to contribute to the design of a reference climate station network that captures regional variability in the climate and climatology of New Zealand (NZ).

We performed our analysis using the New Zealand Reanalysis (NZRA), which is a high resolution (1.5km) convection-permitting atmospheric regional reanalysis dataset spanning ~30 years (Pirooz et al., 2023), and a selection of CMIP6 global climate models downscaled using CCAM (Gibson et al., 2024, Gibson et al., 2023). We analysed the former dataset to identify climate regions that are co-varying and/or have similar climatology while the latter was used to find egions having a similar response to climate change. The same clustering methodology was used to determine region boundaries for all three-climate metrics. Self-Organising Maps were used to reduce the dimensionality of the data and then K-means clustering was applied with the Gap Statistic used to find the optimal clusters. Firstl , monthly anomalies from NZRA were used to determine regions that were co-varying. Secondly, daily climatologies, also from NZRA, were used to isolate regions with similar climate. Finally, we clustered the differences between present daily climatology with respect to the future climatology using the downscaled CMIP6 projections to identify the regions which are likely to have similar climate change signals. We also present a method to analyse the robustness of regions identifie

Using the regions derived, we present a method to optimally select a reference network representing the components of covariance, climatology and climate change.

REFERENCES

- Pirooz, A., Moore, S., Carey-Smith, T., Turner, R., & Su, C.-H. (2023). The New Zealand Reanalysis (NZRA): development and preliminary evaluation. Weather and Climate, 42(1), 58–74. https://doi.org/10.2307/27226715
- Gibson, P.B., Stuart, S., Sood, A. et al. Dynamical downscaling CMIP6 models over New Zealand: added value of climatology and extremes. Clim Dyn 62, 8255–8281 (2024). https://doi.org/10.1007/s00382-024-07337-5
- Gibson, P. B., Stone, D., Thatcher, M., Broadbent, A., Dean, S., Rosier, S. M., et al. (2023). High-resolution CCAM simulations over New Zealand and the South Pacific for the detection and attribution of weather extremes. Journal of Geophysical Research: Atmospheres, 128, e2023JD038530. https://doi.org/10.1029/2023JD038530

ELUCIDATING WATER CHEMISTRY AND ECOSYSTEM CHANGE THROUGH HIGH-FREQUENCY MONITORING

Hartland, A.,[1] Stenger, R.,[1] Lang, J.,[1] Clague, J.,[1] Moorhead, B.,[1], Park, J.[1,] McBride, C.[2]
[1] Lincoln Agritech
[2] LimnoTrack Ltd

Aims

The "Safeguarding Te Mana o te Awa o Waikato from Emerging Climatic Pressures" programme (ECP) investigates the impacts of rising atmospheric CO_2 on the Waikato River's water chemistry (pH, dissolved nutrients, and carbonate saturation), phytoplankton dynamics, and mollusc populations (e.g., kākahi). High-frequency monitoring informs a mechanistic model to predict CO_2-driven changes in freshwater ecosystems.

Methods

Multi-parameter sondes were deployed for high-frequency monitoring at four sites along an approximately 35 km stretch of the Waikato River, including two sites within Lake Karāpiro (Fig. 1). The Aniwaniwa site, located furthest upstream, has been operational since late July 2024, followed by the Karāpiro and Cambridge sites in October 2024, and the Mystery Creek site in March 2025. Three sondes, installed along the shoreline, record data at 15-minute intervals at a depth of approximately 25 cm, while a buoy near the Lake Karāpiro dam enables vertical profiling at 4-hourly intervals down to a depth of 22 m.

Figure 1: Locations of four high-frequency monitoring sites between upper Lake Karāpiro and Hamilton City.

Recorded physicochemical parameters include water temperature, dissolved oxygen, CO_2 partial pressure (pCO_2), pH, oxidation-reduction potential, specific conductance, turbidit , and a proxy for dissolved organic matter. Biological measurements include chlorophyll-a, phycocyanin fluo escence, and tryptophan fluo escence. Complementary fortnightly analyses include nutrient measurements (phosphate, ammonia, and nitrate) and trace element bioavailability assessments using diffusive gradients in thin films (DGT) p obes.

Results

High-frequency monitoring reveals pronounced seasonal and diurnal variability in Waikato River water chemistry. Photosynthesis and respiration cycles and mixing processes driven by the dam operation result in very wide pCO_2 (from ≈ 0 to 3,500 ppm) and pH fluctuations (5-11) in surface wate and more subdued dynamics at greater depth. Dissolved oxygen exhibits corresponding diurnal and seasonal patterns. Preliminary data suggest that CO_2-driven pH changes influence nutrient and trace metal mobilit , with reduced calcium levels potentially associated with golden clam (Corbicula fluminea) activity and diminished efficiency in water t eatment processes. Chlorophyll-a and phycocyanin fluo escence indicate algal biomass variability tied to nutrient availability; however, further analysis of DGT data is required to elucidate mechanistic links. Historical data from the Waikato Regional Council show multi-decadal declines in pH alongside increases in dissolved reactive phosphorus and chlorophyll-a, suggesting CO_2-enhanced nutrient availability and algal growth.

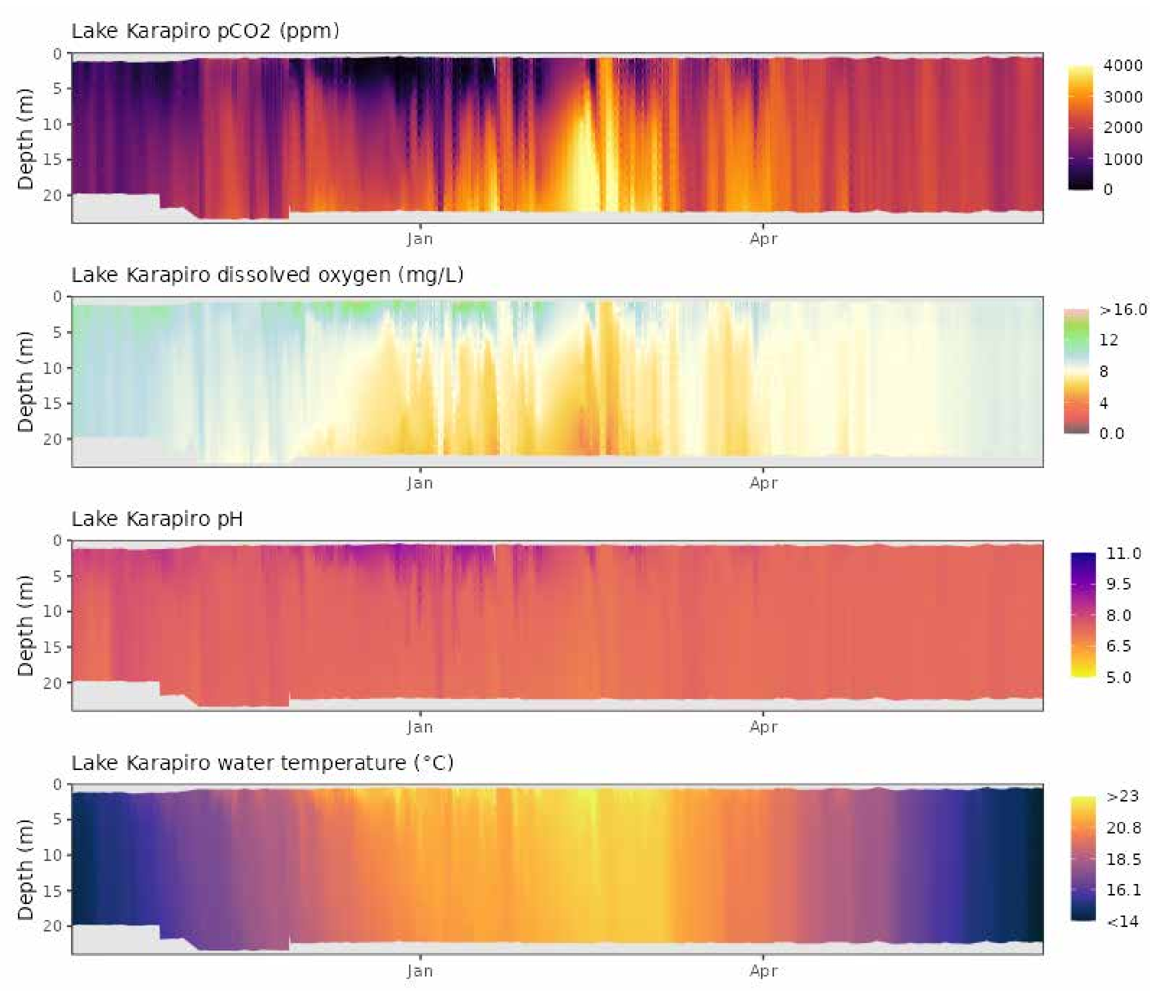


Figure 2: Heat maps of depth-resolved pCO_2 (ppm), DO (mg/L), pH and temperature (°C) high-frequency data from the Lake Karāpiro profiler buo .

This work provides significant benefits to stakeholders in the aikato catchment by addressing two critical issues beyond the scope of the ECP programme. First, preliminary data analysis indicates that the spread of the invasive golden clam (Corbicula fluminea) can be tracked th ough our monitoring efforts. Second, analysis of DGT probes for arsenic species, combined with water chemistry data (total arsenic and calcium), has clarified the easons for observed changes in arsenic removal efficiency at water t eatment plants along the Waikato River in late 2024.

SEA WATER INTRUSION AT TE WAIKOROPUPŪ SPRINGS

Stewart, M[1], Thomas, J[2], Morgenstern, U[1], Mourot, M[1]
[1]Earth Sciences NZ
[2]Tasman District Council

Aims

The aims of this work are to understand the nature of the water components and the mechanism of seawater intrusion supplying the slightly brackish Te Waikoropupū Springs (TWS) Main Spring waters. Seawater intrusion in karst has special features due to flow being in conduit networks below sea level, very ifferent from seawater inflow to po ous aquifers (Fleury et al., 2007). Three mechanisms of seawater intrusion in karst have been hypothesised (venturi suction effect, head balance process, and freshwater dilution of a constant brackish water flo , Arfib & Charlie , 2016). This work proposes a fourth mechanism at TWS Main Spring – constant freshwater flow with inc easing brackish water flow as spring discha ge increases following rainfall in the catchment.

Method

The study uses chemical and tritium measurements on Main Spring water samples between1970 and 2025, and Main Spring discharge (flow) measu ements by TDC at the time of sampling from 2000 to 2025.

Results

The chloride concentration of TWS Main Spring ranges between 30 and 135 g/m^3 depending on the spring flow (Figs 1a,b). The cor esponding sea water flow f om the spring is shown in Fig 1c. Two water components, freshwater (FC) and brackish water (BC), combine to produce the springs' outflo . FC is purely freshwater and BC is a mixture of freshwater and sea water (Stewart et al., 2024). At low flow the ischarge is almost all FC, then flow and sea water content inc ease as BC is added. Chemical data over 50 years show that the FC contribution to the flow and the sea water content of BC have not changed in that time.

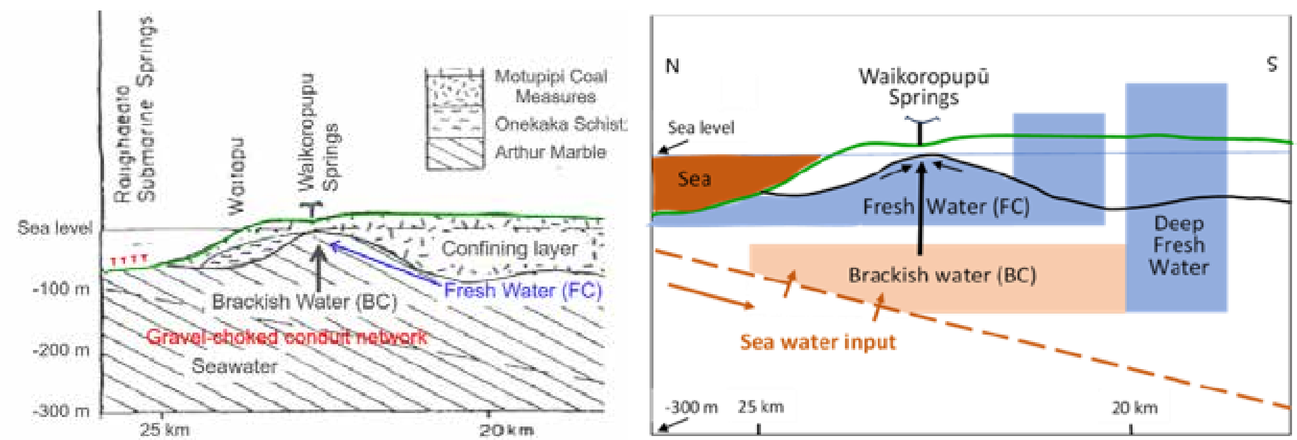


Figure 1a, b, c. Chloride-flow and sea wate -flow elationships in Main Spring outflo .

Tritium measurements between 1966 and 2020 show that the average residence time of the spring water is 8 years. Further tritium measurements are being made to determine the MRTs of the FC and BC waters. One possible MRT solution is shown in the last column of Table 1 - other solutions are possible depending on the results to be obtained.

Table 1. Mean residence times of flow components based on the observed M T of average flows (8.0 years)

Quantity	Total flow m^3/sec	FC fraction	BC fraction	MRT yr
FC	5.88	1.00	0.00	6.0
Minimum flow	6.30	0.93	0.07	6.3
Average flow	9.95	0.59	0.41	8.0
Maximum flow	13.87	0.41	0.59	8.9
BC	230.00	0.00	1.00	10.8

Fleury et al., 2007 classed the TWS coastal karst aquifer as Type 3 (i.e. 'a system with well-developed karstification below sea level, partially or totally closed to he sea'). This is illustrated by the relatively slight brackishness of the spring water and no clear offshore freshwater outlets, although it is clear that freshwater escapes to the sea. Gravel-choked conduits below sea level probably limit the exit of freshwater/access of sea water. A North-South cross section and conceptual model of the system are given below (Figs. 2a, b).
Figure 2a,

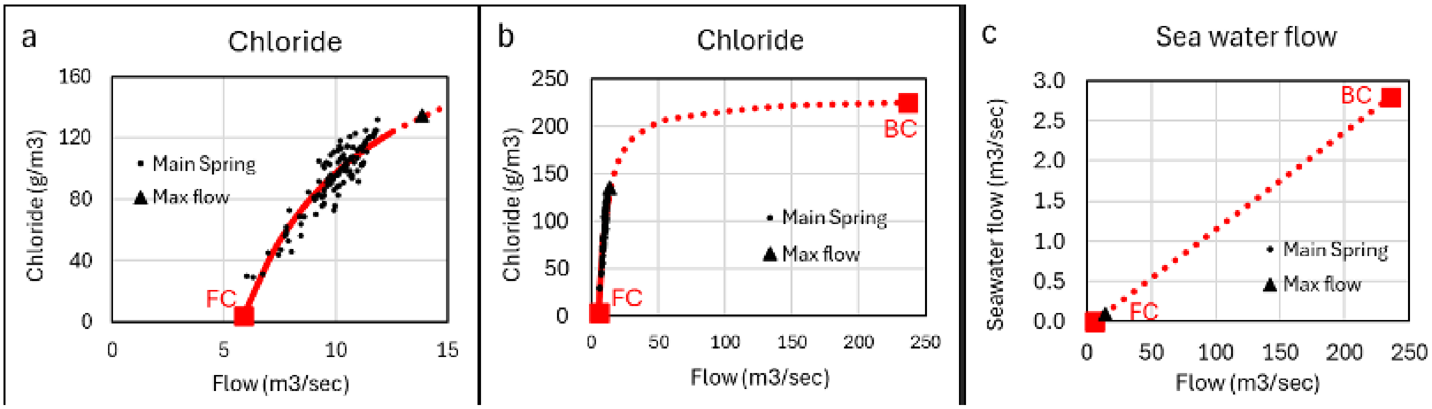


Figure 2a, b. Northern part of N-S cross section and conceptual model of TWS Main Spring.

Conclusion: Consideration of all relevant data to 2025 shows that the water in Te Waikoropupū Springs is composed of two components, one of which contains no sea water (the Fresh Component) and the other 2.8% sea water (the Brackish Component). Mixing models show constant fresh water (FC) with increasing brackish water (BC) contributions as flow inc eases in TWS Main Spring. This is why salinity increases with flow (i.e. it is not due to the venturi e fect). The disposition of the two components in the subsurface is schematically shown in Fig. 2.

References

Arfib, B., Charlie , J.-B. 2016. Insights into saline intrusion and freshwater resources in coastal karstic aquifers using a lumped rainfall–discharge–salinity model (the Port-Miou brackish spring, SE France). Journal of Hydrology 540, 148–161..

Fleury, P., Bakalowicz, M., de Marsily, G. 2007. Submarine springs and coastal karst aquifers: A review. Journal of Hydrology 339, 79–92.

Stewart, M.K., Moreau, M., Morgenstern, U., Thomas, J. 2024. Two water components feed Te Waikoropupu Main Spring. New Zealand Hydrological Society 2024 Symposium, Blenheim, 26-29 Nov.

Stewart, M.K., Thomas, J.T. 2008. A conceptual model of flow to the   aikoropupu Springs, NW Nelson, New Zealand, based on hydrometric and tracer (O-18, Cl,H-3 and CFC) evidence. Hydrology and Earth System Sciences 12(1), 1-19.

PROJECTIONS OF FUTURE HOURLY PRECIPITATION EXTREMES IN NEW ZEALAND

Stephen Stuart[1], Peter Gibson[1], Sam Dean[1], Trevor Carey-Smith[1], Daithi Stone[1]
[1]Earth Sciences New Zealand, Wellington

Extreme rainfall is expected to increase across much of the world as the atmosphere warms in response to increased concentrations of greenhouse gases. This may increase the risk of flooding in many egions but uncertainty remains around the magnitude of future intensification of short-duration rainfall. e compare hourly precipitation extremes in gauge-based observations against three regional climate models, and evaluate future intensification in the latest high- esolution (12 km) climate projections for New Zealand based on dynamical downscaling of global models from the Coupled Model Intercomparison Project Phase 6 (CMIP6). Initial results show increases in hourly rainfall extremes of approximately 7-15% per degree of warming. Improved representation of observed rainfall extremes in convection-permitting simulations highlights their value in complementing larger multi-model downscaling efforts.

STRENGTHENING WATER RESOURCE PLANNING USING CLIMATE MODELLING

Shane Sullivan
Watercare Services Limited

Watercare's Integrated Source Management Model (ISMM) is a bespoke software tool supporting strategic water resource planning by balancing operational costs with hydrological risk. In 2022/23, the scope of ISMM was extended to include climate change assessment, incorporating new hydrological datasets and enabling dynamic scenario analysis aligned with the then established climate models (CMIP5).

Initial assessments revealed significant uncertainty in yield p ojections, ranging from a 60MLD loss to a 1MLD gain, highlighting the need for more representative data.

The updated climate scenarios (CMIP6) include socio-economic factors alongside precipitation and evapotranspiration, improving predictive accuracy. Watercare has also included its own rainfall data record into Earth Sciences NZ's Virtual Climate Station Network (VCSN) and extended the climate record to include up to the year 2024. This enhanced data refines downscaled global climate models and looks to imp ove yield assessments across Watercare's catchments.

The results of the assessment are to ensure resilient and informed decision-making for Watercare's future water supply infrastructure.

ADVANCING PRECIPITATION MONITORING: THE OPERATIONAL QPE SYSTEM AT METSERVICE

Lu Sun,[1] Ulrich Ebling,[1] Annick Terpstra,[1] Gregory Pearson[1] Ellorine Carle[1]
[1] Meteorological Service of New Zealand Ltd

Reliable rainfall estimation is critical for weather forecasting, hydrological modelling, and hazard management, serving as a foundation for timely, informed decision-making. The next generation Quantitative Precipitation Estimation (QPE) system at MetService combines radar, rain gauge, satellite, and model data into a unified, high-resolution depiction of precipitation nationwide. Designed for flexibility and speed, it perates on both local infrastructure and cloud platforms, delivering near real-time updates to support operational and research needs. A key advancement is a robust ensemble modelling framework that merges multi-source precipitation inputs and applies bias corrections informed by long-term observation records. This enables more accurate real-time estimates and improves detection of high-impact rainfall events. The system incorporates 95 observation sites from Earth Sciences New Zealand (previously NIWA) in addition to the existing rain gauge network from MetService, councils, FENZ et al., expanding coverage and enhancing data density. A dedicated feedback mechanism will integrate insights from major weather events, ensuring continuous calibration and optimisation. Results show significant gains in spatial consist ncy and event detection, particularly during severe weather. This presentation will provide a concise overview of the system, technical approach, and examples of value for forecasting and resilience planning in New Zealand.

BETTER VOLUME ESTIMATES USING THE RDI HYDROLOGICAL MODEL FOR THE PORT HILLS CATCHMENTS IN CHRISTCHURCH

Antoinette Tan,[1] Peter Christensen,[2]
[1] DHI Water & Environment
[2] Storm Environmental

Aims
The Port Hills, overlooking Christchurch City, contribute to flooding in the downst eam city and rural catchments, including the Heathcote River, Halswell River and Sumner Main Drain. Of primary interest to Christchurch City Council (CCC) is the volume of water entering the Upper Heathcote storage basins which are actively managed during a flood event to educe flood peaks downst eam. Of particular relevance for this study are the basins directly downstream of the Hoon Hay and Cashmere catchments which are the Te Kuru Wetlands, Cashmere Valley Dam and the Cashmere-Worsley Basins. These basins have a combined storage volume of over 1.5 million cubic metres.

Significant work has been done over the years by CCC and its va ious consultants to model and understand the runoff response of the loess soil-dominated Port Hills. This has proven to be a challenge due to the high variability in the response to antecedent soil conditions, as well as the significa t difference in runoff response between adjacent gauged catchments. The most recent RORB modelling of the Port Hills was shown to produce a substandard estimation of the runoff volume. To improve the rainfall runoff predictions for input into the CCC hydraulic models a more detailed rainfall runoff model has been developed.

Method
This rainfall runoff model uses the MIKE+ RDI module, formerly known as NAM, to simulate the rainfall runoff response. RDI is a continuous simulation model that is made up of a series of reservoirs that connect via hydrological processes. This includes accounting for surface and rootzone storage, groundwater, interflo , groundwater leakage and surface runoff response. Throughout the continuous simulation, the model keeps track of the soil moisture as the root zone storage fraction, which means there is no need for assigning antecedent conditions as a simulation parameter. This is particularly important for the Port Hills, as this area shows a vastly different runoff response in dry periods versus wet.

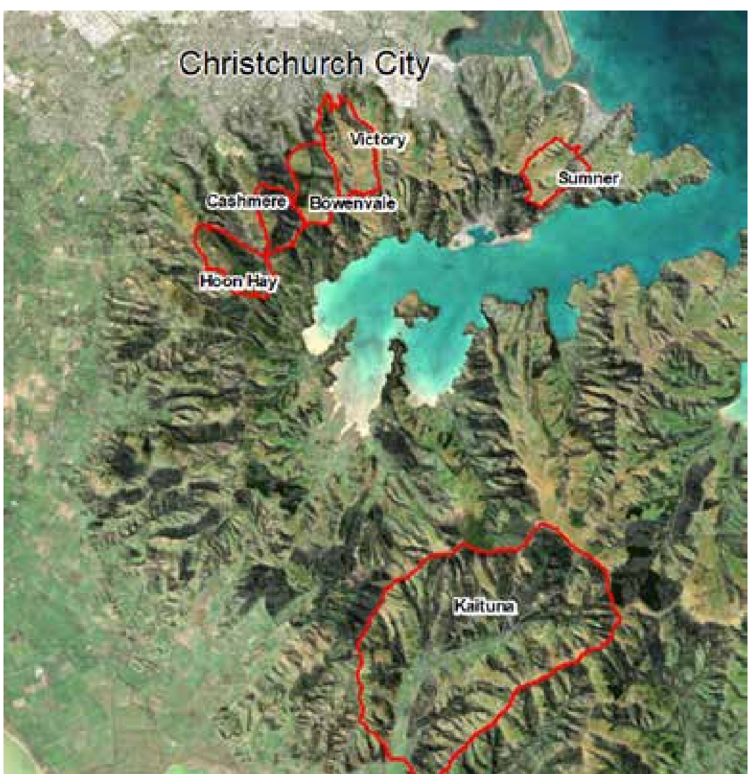


Figure 1: Study area location showing key gauged catchments

The model was developed to initially cover only the catchments in the Port Hills with rated water level recorders. These were the Hoon Hay, Bowenvale, Cashmere, Victory, Kaituna and Sumner Catchments, Figure 1.

This simplified model was calibrated using the RDI autocalibra ion feature to determine the RDI parameter sets. This was then further calibrated via manual adjustments. The model was then expanded to cover the full breadth of the Port Hills, so that the rainfall runoff results could be used in the CCC hydraulic models. In order to allocate representative parameter sets to the ungauged catchments, it was necessary to align the parameters, where possible, to the physical characteristics of the catchments. A correlation of key parameters was found by assessing the sensitivity of the parameters within the calibration to the physical characteristics of vegetation, soil drainage type and rootzone depth. This also included assessing the impacts of the Port Hills fi es, which occurred in 2017 and significantly changed the vegetation (and the efore the rainfall runoff response) in the Hoon Hay catchment.

Results

The final calibration p oduced good results where the data was reliable. This is particularly true of the Bowenvale catchment, which has two rain gauges within, as well as a long and reliable flow ecord and soil moisture recordings. Where the calibration was not as good this was generally due to uncertainty in the input rainfall data or the flow ecords. Post calibration a validation has been done on the recent May 2025 flood event with no changes made to the model parameters; exam le results of the modelled vs measured discharge at Bowenvale are shown in Figure 2.

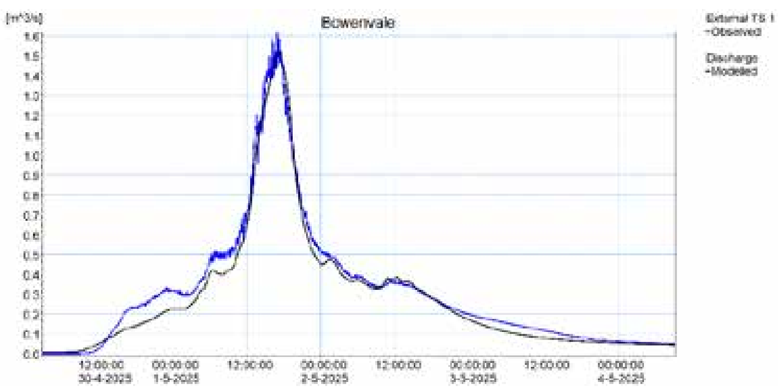


Figure 2: Bowenvale modelled vs observed runoff response

During the May 2025 flood event, the new Cashme e Valley Dam was purposefully closed during the event for testing purposes. This was a good opportunity to validate the flow in the Cashme e Valley catchment. The closure of the dam allowed for volumetric data to be derived that was used to validate and improve the flow rating at the Cashmere Adventure Park drain.

This study has highlighted the challenges of calibrating a rainfall runoff model to a wide range of events. A total of nine events have been assessed in detail as part of this study, which cover the period between 2000 and 2025. The study outcomes include:

• Calibrated NAM datasets that can be used throughout the Port Hills for a range of events
• An improved match to the runoff volume than was achieved with the previous RORB modelling
• An improved understanding of the impact of vegetation on the runoff response
• The ability to associate the model parameters with the soil moisture records and use this to develop appropriate initial conditions for use in design events
• Further the understanding of the Port Hills hydrology and catchment response to rainfall for different soil moisture conditions

References

DHI Water & Environment (2025). NAM continuous modelling of the Port Hills prepared for Christchurch City Council.

THE HAO MOANA WRF HINDCAST: LONG-TERM DYNAMICAL DOWNSCALING IN NEW ZEALAND

Annick Terpstr, Gregory Pearson
MetService, NZ

We present the Hao Moana New Zealand Hindcast, a high-resolution historical weather dataset generated using the Weather Research and Forecasting (WRF) model. The hindcast spans 54 years, covering the wider New Zealand maritime region with a configuration closely matching the cur ent operational WRF setup at MetService. This consistency makes the dataset particularly valuable for forecast verification, diagnosing model biases, and placing operational events in a climatological context.
We summarise initial findings on long-te m climatologies, seasonal variability, and large-scale climate influences. Model perfo mance is assessed across land, ocean, and complex terrain, with particular attention to high-impact events such as extreme wind gusts and heavy rainfall. Comparisons with reanalyses and observations highlight strengths and systematic biases, offering insights for both operational forecasting improvements and broader research applications.
We highlight how the hindcast supports operational forecasting by integrating climatological context into Forecast Room practices. Historical distributions of temperature, precipitation, and wind help benchmark current forecasts, gauge anomaly magnitude, and assess event rarity. This enhances situational awareness for regional and severe weather forecasting, improving impact anticipation and risk communication.

SULFUR-35 FOR YOUNG GROUNDWATER DATING

Vanessa Trompetter[1] Reuben Rodricks[1]
[1] GNS Science
[2] GNS Science

Aims

Naturally occurring radiosulfur (35S) has been shown to be a useful tracer for young groundwater in the Northern Hemisphere. The Water Dating Laboratory has developed a method for measuring 35S by Liquid Scintillation Counting (LSC). 35S has a half-life of 87.4 days making it useful for investigating residence times of $^{35}SO_4^{2-}$ in shallow groundwater on time scales of up to 1.5 years. We present sample collection and handling procedures for high-sensitivity determination of cosmogenic 35S using a low-level liquid scintillation spectrometer. Laboratory experiments using diluted 35S standards (with activities of <5 disintegrations per minute) showed a 35S recovery percentage of 95%, demonstrating a relatively small deviation from the true value. Using this method, we successfully measured 35S in 10L of groundwater samples collected in the Hutt Valley region. Methodology and recent results for mean residence time determination are presented. This tracer adds to the Water Dating Lab's current repertoire of water dating techniques and to the robustness of our young groundwater dating methodology.

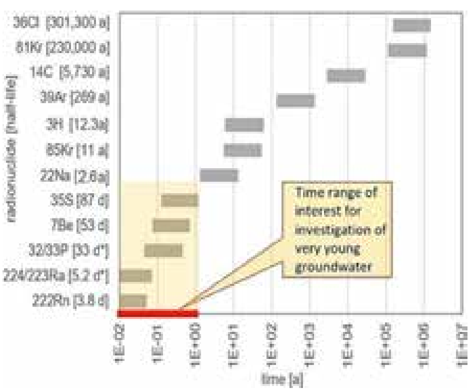


Fig1. Time range of interest for S35. (Schubert, et al. 2024 Graphical Abstract).

Methods

Sulfate is extracted from groundwater samples by adding an anion-exchange resin Amberlite IR67 to 10 litres of sample, using a batch method, and shaking the samples for several hours. The $^{35}SO_4^{2-}$ is then eluted off the resin by adding ammonium hydroxide, again shaking for several hours. The eluate is then dried and the remaining precipitate hydrated counted by LSC in Quantulus 1220.

Results

Results to date show the recovery percentage for sulfate extraction experiments, and Bq/L for standard counting experiments. Initial results for mean residence time of Hutt Valley water will be presented. This tracer technique will be offered to commercial clients in the near future.

References

Brothers, L.A., Dominguez, G., Abramian, A., Corbin, A., Bluen, B., Thiemens, M.H., 2010. Optimized low-level liquid scintillation spectroscopy of S-35 for atmospheric and biogeochemical chemistry applications. Proc. Natl. Acad. Sci. USA 107, 5311–5316.

Clark, J.F., Uriostegui, S.H., Bibby, R.K., Esser, B.K., Tredoux, G., 2016. Quantifying apparent groundwater ages near managed aquifer recharge operations using 35S as an intrinsic tracer. Water 8. https://doi.org/10.3390/W6061826.

Kralik, M., Vergnaud, V., Uriostegui, S.H., Esser, B., 2016. Multi-tracer approach (18O, 3H/3He, CFC, SF6, 35S) to find the best eme gency drinking water supply, Vorarlberg, Austria. Geophys. Res. Abstr. 18, EGU2016–14354. https://meetingorganizer.co pernicus.org/EGU2016/EGU2016-14354.pdf.

Schubert, M., Kopitz, J., Taeglich, S., Bibby, R., Copia, L., McGuire, B., Wangari, S., Harjung, A. 2025. Radiosulfur (35S) as stort-term residence time tracer – Step by step instruction for sample preparation and LSC setup. Journal of Environmental Radioactivity, 282 https://doi. org/10.1016/j.envrad.2025.107627.

Schubert, M., Kopitz, J., Knoller, K., 2020. Low-sulphate water sample preparation for LSC detection of 35S avoiding sulphate precipitation. J. Environ. Radioact. 213, 106153. https://doi.org/10.1016/j. jenvrad.2019.106153.

Uriostegui, S.H., Bibby, R.K., Esser, B.K., Clark, J.F., 2015. Analytical Method for Measuring Cosmogenic 35S in Natural Waters. Anal. Chem. 87, 6064–6070.

CARBONWATCH-URBAN: GRANULAR CO_2 EMISSIONS INFORMATION FOR EVERY TOWN AND CITY IN NEW ZEALAND

Jocelyn Turnbull[1], Gordon Brailsford[1], Perry Davy[1], Lydia DiCaprio[1], Lucas Domingues[1], Jack Drummond[1], Leigh Fleming[1], Sally Gray[1], Timothy W. Hilton[1], Liz Keller[1], Daemon Kennett[1], Haeyoung Lee[1], Erika Macapagal_Taluban[1], Sara Mikaloff Fletcher[1], Vanessa Monteiro[1], Rowena Moss[1], Stijn Naus[1], Peter Sperlich[1], Hayden Young[1], Scott Graham[2], John Hunt[2], Johannes Laubach[2], Adam Tipper[3], Nancy Golubiewski[4], Andrea Brandon[5], Jessica Hiscox[6], Mingjing Dong[7], Selena Sheng[7], Le Wen[7]

[1]Earth Sciences New Zealand
[2]Bioeconomy Science Institute
[3]StatsNZ
[4]Climate Change Commission
[5]Ministry for the Environment
[6]Ngāti Whātua Ōrākei
[7]University of Auckland

Urban areas produce most fossil fuel CO_2 emissions, and to play their part in the transition, detailed information about urban emissions and offsetting potential is needed to focus efforts where they will have the most impact to deliver meaningful, measurable change. CarbonWatch-Urban is a multi-tiered approach that provides fine-scale C $_2$ emissions and sink information for all New Zealand's urban areas. First, we established a high resolution bottom-up inventory of Auckland's fossil fuel CO_2 emissions , and optimised the UrbanVPRM land surface model to estimate the Auckland region biogenic CO_2 budget. We use atmospheric observations of carbon dioxide, radiocarbon-in-carbon-dioxide, carbon monoxide, carbonyl sulphide and black carbon to partition Auckland's CO_2 emission sources, and an atmospheric inversion to rigorously validate and improve the bottom-up flux estimates. e leverage the Auckland experience to expand the bottom-up emission modelling framework nationally, incorporating the improvements identified in Auckland, and validate the models using mobile laboratory observations across towns and cities spanning New Zealand's climates, topographies and urban forms. This combined approach provides the most accurate estimates of New Zealand's urban emissions, with granular information in both space and time.

WHAT IF GABRIELLE HAD HIT AUCKLAND: SENSITIVITY OF TRACK, RAINFALL AND WIND TO TERRAIN SHIFTS?

Richard Turner[1], Nava Fedaeff, Stuart Moore, Cyprien Bosserelle, Glen Reeve, Jorge Bornemann, Daryl Hook
Earth Sciences New Zealand[1]

Gabrielle was the costliest weather disaster to have ever affected Aotearoa/New Zealand and was particularly devastating in the Hawke's Bay. Insurance costs alone were over NZD$2.2 billion, while overall losses likely topped NZD$13 billion. While Auckland did experience strong winds, rainfall, flooding and landslides, it was fortunate to largely escape the worst of the storm. Here we present results of an effort to explore plausible outcomes for the Auckland region as if Gabrielle had taken different tracks by re-simulating the storm passage multiple times but with slight shifts each time to assess the plausible range of extreme wind, heavy rainfall, storm surge, and flood inundation on Auckland and its sur oundings.

An initial set of simulations saw the heaviest rainfall (up to 600mm) now occurring over the Coromandel and Kaimai ranges. This placed Auckland in a rain-shadow with reduced rainfall, though still receiving around 100 mm. Additional shift scenarios saw areas of higher rainfall over central Auckland and greater storm surge over the Waitemata harbour but with somewhat weaker extreme gusts.

There are still additional areas that could be explored. Future studies could focus on flood risks during high tide events and a method to do this was identified during the w rk.

NATIONAL-SCALE GEOSPATIAL MODELLING OF RECOMMENDED RIPARIAN BUFFER ZONE WIDTHS

Uuemaa, E.,[1] Kull, E.,[1] Mõisja, K.,[1] Mander, Ü.,[1] Nurm, H.I.,[1] Guaman Pintado, P.,[1] Kmoch, A.[1]
[1] Department of Geography, University of Tartu

Aims
Determining optimal riparian buffer zone widths, especially considering landscape spatial heterogeneity, is challenging, often relying on computationally demanding hydrological simulations with scale limitations. Empirical nomographs, linking terrain, soil, and slope, offer a more tractable alternative. The aim of the current study is to scale localised buffer strip efficiency knowledge to b oader regions and create national-level mapping of recommended riparian buffer zone widths while explicitly incorporating critical local variations in flow patte ns, soil, and terrain.

Method
This study focuses on the Republic of Estonia, a Northern European country bordering the Baltic Sea, Latvia to the south, and Russia to the east. Riparian buffer strip width is determined by the soil and elevation of the adjacent landscape, which can be derived from the digital elevation and soil data. We used a nomograph developed by Mander et al. (1997) and Mander and Kuusemets (1998) developed a formula for dimensioning riparian buffer strips in Estonia based on slope and soil conditions. The nomograph calculates the recommended buffer strip's width based on three parameters: specific slope length, slope, and soil textu e class. All these were calculated based on geospatial layers.

- Specific slope length was originally acco ding to Mander and Kuusemets (1998) aimed to represent combination of slope length and the high flow accumulation a eas on slopes. To obtain that based on geospatial data, we calculated LS-factor, flow accumulation and flow length based on 5m elevation model
- Slope (in degrees) was according to Mander and Kuusemets (1998) mean slope of elementary watershed which we transformed into slope of the pixel and it was calculated from 5m elevation model using QGIS 3.28.
- Soil texture class was obtained from EstSoil-EH dataset (Kmoch et al. 2021) where local texture has been already reclassified into USDA classification. For the nomograph, we eclassified USDA textu e classes into soil classes specified in the nomograph

National-level processing was achieved by dividing Estonia into 22 overlapping zones. The overlap between these zones was strategically designed to maintain spatial dependencies essential for flow path length and accumulation calculations. To address potential edge effects and ensure hydrological continuity across zone boundaries, a 5 km buffer was incorporated into each processing unit. This buffering strategy prevented artificial interruptions in flow pathways. After ocessing, the zones were clipped to their original boundaries and merged.

Following the processing of three geospatial input layers for the nomograph, its angular relationships were applied pixel by pixel using Python NumPy's trigonometric functions and implemented as a Python script in QGIS. This resulted in a continuous raster layer representing recommended riparian buffer widths for each pixel. However, to obtain buffer strips specifically along rivers and to avoid ambiguity from pixel-based widths, we performed a final vectorisation of the raster laye . We utilised data on natural water bodies and drainage ditches to identify waterbodies requiring protection zones, as mandated by the Estonian Water Act.
We categorised the calculated recommended riparian buffer strip widths into five classes. These estimates were used to represent the pollution risk: a potential risk of non-point source pollution (nutrients, pesticides) may reach the water body via surface runoff. Pollution risk within the scope of this work does not indicate how sensitive the buffer strip itself is to pollution, but only shows the potential risk of pollution reaching the water body: if a water body borders land under agricultural use, then it is necessary to consider establishing a buffer strip of appropriate width, and the buffer strip width depends on the risk of pollution reaching the water body, i.e., the pollution risk.

Results
There was no significant di ference in pollution risk between natural water bodies and drainage ditches, resulting in similar recommended riparian buffer widths (Figure 1). Nearly 50% of both have a very low

pollution risk, and another 34-38% have a low risk, requiring only a 1 to 10 m buffer. These are mainly in flatter areas (Figure 2). Streams and ditches with medium pollution sensitivity make up 14% and 11%, respectively, while those with high to very high risk are below 5%, mostly found in Southern Estonia's uplands (Figure 2).

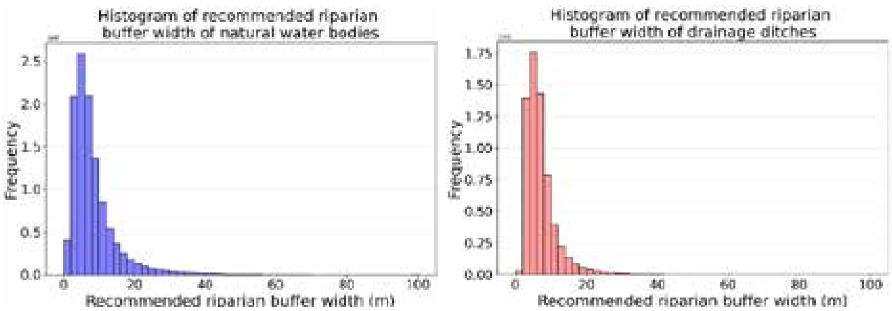


Figure 1. Histograms of recommended riparian buffer widths calculated for natural water bodies and drainage ditches. The frequency calculation is done based on 5 m buffer segments.

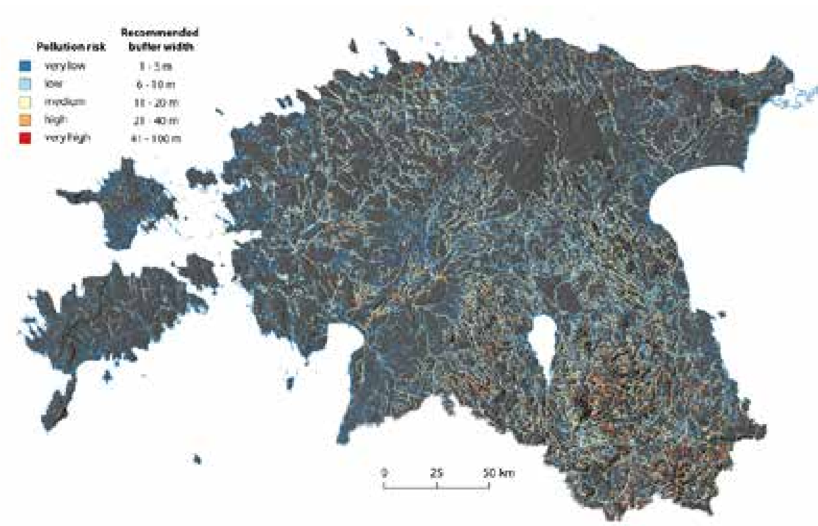


Figure 2. Pollution risk and recommended riparian buffer strip width for natural water bodies and drainage ditches in Estonia. The recommended riparian buffer strip width is also available at https://geokuup.ee/estonia/water-management/map?

When looking at the presence of vegetation higher than 2 m across different pollution risk classes, it becomes clear that in areas with very high pollution risk, the riparian bank is covered by vegetation in 78.4% of natural water bodies and 54.0% of drainage ditches. In a comparison of the two water body types, drainage ditches consistently show less vegetation cover across almost all pollution risk classes.

This research demonstrates the feasibility of national-scale riparian buffer width optimisation using geospatial modeling approaches, providing a valuable tool for evidence-based water protection policy development. The methodology's computational efficiency and spatially explicit outputs o fer significant advantages over traditional approaches, though validation and regional adaptation remain important next steps for broader implementation.

References

Kmoch, A., Kanal, A., Astover, A., Kull, A., Virro, H., Helm, A., Pärtel, M., Ostonen, I., Uuemaa, E., 2021. EstSoil-EH: A high-resolution eco-hydrological modelling parameters dataset for Estonia. Earth System Science Data 13. https://doi.org/10.5194/essd-13-83-2021

Mander, Ü. and Kuusemets, V. 1998. Non-point pollution control by riparian buffer strips: Dimensioning and efficiency assessment, in: P oceedings of the 3rd International Conference on Diffuse Pollution. Edingurh, pp. 136–143.

Mander, Ü., Kuusemets, V., Lõhmus, K., Mauring, T., 1997. Efficiency and dimensioning of riparian bu fer zones in agricultural catchments. Ecological Engineering 8, 299–324. https://doi.org/10.1016/S0925-8574(97)00025-6

A GROUNDWATER QUALITY MULTI-TRACER SITE INVESTIGATION

Van Soest, M.C.,[1] Moreau, M.,[1] Houghton, K.M.,[1] Northcott, G.,[2] Hadfield, J. [3] Gibson, N.[4]
[1] Earth Sciences New Zealand
[2] Northcott Research Consultants Limited
[3] Waikato Regional Council
[4] Tūwharetoa Māori Trust Board - Waitiaki

Aims:
Sustainable groundwater resource management requires improved understanding and characterisation of groundwater quality contaminants, both regulated/monitored (e.g. nitrate) and less understood/monitored (e.g. contaminants of emerging concern or CECs). Although regulated contaminants present an immediate threat, it remains important to prioritise the less understood ones as they may pose significant human ecosystem impacts (Lapworth et al. 2023). In addition, some contaminants, such as CECs can be used as groundwater tracers (e.g. Erostate et al., 2019).

Two site investigations are currently underway in the Taupo area to quantify in-situ denitrification p ocesses using ground water dissolved gas analysis while also assessing insights gained by combining CECs with groundwater age tracers.

Methods:
Groundwater samples were collected in April 2025 (Figure 1) at two waste-water treatment application sites where historical data was available (n=7 and n=8, including control sites). Treated wastewater was also sampled at each site. Samples are currently being analysed for inorganic chemistry, stable isotopes, groundwater age tracers, nitrogen, nitrous oxide, and noble gas abundances, microbial DNA, pesticides and CECs including PFAS, pharmaceuticals and personal care products.

Figure 1: Field sampling for noble gases using a copper tube.

Microbial DNA sequencing will be used to characterise microbial community diversity and predict potential metabolic functions and ecosystem services provided by microbes.

Nitrogen and noble gas abundance analysis of the ground water samples will be used to measure the amount of non-atmosphere derived nitrogen in the sample, and therefore to quantify the amount of denitrification that has taken place. Nitrous oxide is an intermediate product in the denitrification p ocess and will help inform on whether denitrification is active or is incomplete at the ite.

Results:
Field parameters and chemistry data clearly indicate reducing conditions at each site along the flow path. Initial results indicate the presence of excess nitrous oxide and nitrogen in many of the samples implying that denitrification is occurring in the g oundwater and the presence of a significant CFC12 contaminant plume at one of the wastewater sites. These results will be complemented with more results as analysis progresses.

References:
Erostate, M.; Huneau, F.; Garel, E.; Vystavna, Y.; Santoni S.; Pasqualini V. 2019. Coupling isotope hydrology, geochemical tracers and emerging compounds to evaluate mixing processes and groundwater dependence of a highly anthropized coastal hydrosystem, Journal of Hydrology,578: 123979.

Lapworth, D.; Boving, T.; Brauns, B.; Dottridge, J.; Hynds P.; Kebede S.; Kreamer D.; Misstear, B.; Mukherjee, A.; Re, V.; Sorensen, J.; Ruz Vargas, C. 2023. Groundwater quality: global challenges, emerging threats and novel approaches, Hydrogeology Journal,31:15–18.

FILL, SPILL, BURN, REPEAT: EVOLUTION OF RUNOFF GENERATION IN PEATY BOREAL SHIELD ROCK BARRENS CATCHMENTS

Furukawa, A.K.,[1] Sutton, O.F., [1] Waddington, J.M. [1]
[1] McMaster University

Aim

Wildfi e is a part of natural succession of Canada's Boreal Shield landscape, a mosaic of shallow wetlands, deep peatlands, conifer forests, granite rock barrens (with thin organic soil mats), and deciduous forest valley hydrological response units (HRU). These HRUs have differing storage capacities and function follow the 'fill and spill' runoff conceptual model. Wildfi e burn severity (depth of burn of organic soils) is varied across the landscape with highest soil combustion losses on rock barrens and shallow wetland HRUs due to their greater susceptibility to drying (Moore et al., 2019). In contrast, deep peatlands are generally considered wildfi e refugia with no soil loss (Tekatch et al., 2025). Nevertheless, the differential loss of soil can result in dramatic changes to HRU storage capacity and runoff contributing area and by extension the rainfall-runoff response. Moreover, differential peat accumulation across HRUs following wildfi e results in differing rates of decline in HRU capacity (until the next wildfi e). This study aims to characterize how wildfi e impacts the controls on runoff generation on the Boreal Shield rock barrens landscape at the hillslope and plot scale. We hypothesized that organic soil depth and HRU were the primary controls.

Method

We hydrometrically instrumented four Boreal Shield rock barrens hillslopes during the summers of 2022 and 2023. Detailed ground and lidar surveys were conducted to characterize these micro-catchments, of which 23-46% were rock and lichen with minimal to no storage capacity and highly variable soil depth (8.3 ± 7.5 cm). We also measured water table dynamics in ten burned and unburned shallow wetlands (HRU with greatest burn severity) from 2019 to 2024 to better understand how wildfi e impacts storage capacity.

Results

Across 30 rainfall events, mean runoff coefficients we e lowest (0.08) on the hillslope with the shallowest soil and least amount of forested rock barren coverage. Hillslopes with greatest forested rock barren coverage had the highest mean runoff coefficient (0.33). Storage capacity inc eased post-fi e at burned shallow wetlands, altering the storage threshold for runoff from this HRU. These findings have implications for wildfire-affected rock barrens which tend to lose both soil and tree cover to combustion and may adversely impact burned catchments' ability to supply water to adjacent peatlands. We suggest that to understand the evolution of runoff dynamics in this landscape that is necessary to model post-fi e organic soil development through time and present a framework that couples watershed hydrology with peatland carbon dynamic models.

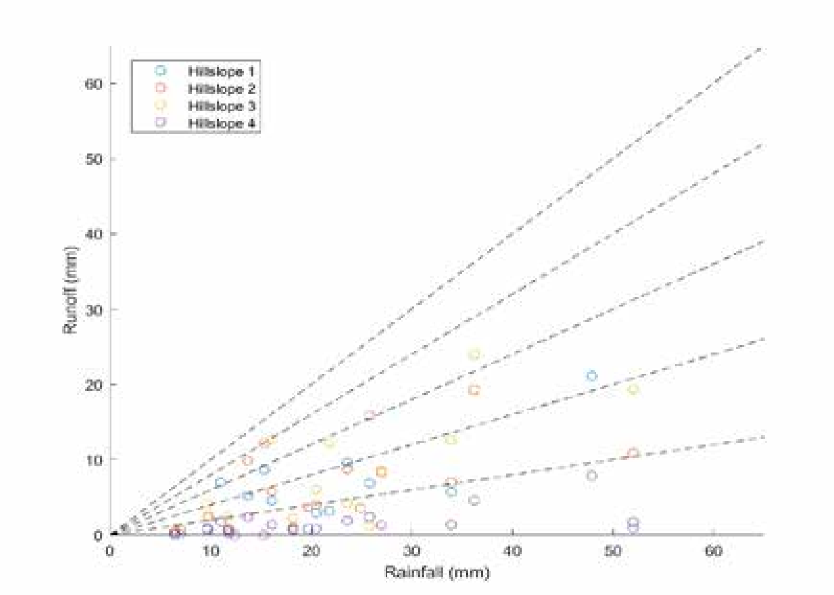


Figure 1: Runoff measured at the outlets of four rock barrens hillslopes across 30 rainfall events, including 8 hours post rain cessation. Dashed lines indicate runoff ratios of 0.2 to 1.0 by 0.2 increments.

Reference List

Moore, P.A., Smolarz, A.G., Markle, C.E., Waddington, J.M. 2019. Hydrological and thermal properties of moss and lichen species on rock barrens: Implications for turtle nesting habitat. Ecohydrology, 12: 1–8.

Tekatch, A.M., Markle, C.E., Wilkinson, S.L., McCarter, C.P.R., Moore, P.A., Waddington, J.M. 2025. Ecohydrological drivers of Boreal Shield peatland fi e refugia. Ecohydrology, 18: e70075.

MICROBIAL METABOLIC POTENTIAL IN NEW ZEALAND GROUNDWATERS: REGIONAL PATTERNS AND IMPLICATIONS FOR CLIMATE-RESILIENT MANAGEMENT

Weaver L*1, Webber J1, Abraham P1, Bolton A1, Sitthirit P1, Masterton H1, McGill E1, Sarris T1
1 Institute for Public Health and Forensic Science (PHF Science)

Aims

This study aims to elucidate the physicochemical, geological, and land use drivers that influence bacterial and archaeal community structures and their predicted functional capabilities across New Zealand's diverse aquifer systems.

Introduction

Groundwater provides over 40% of New Zealand's drinking water and supports agriculture, industry, and ecosystems (White, 2001). Microbial communities within aquifers mediate essential processes such as nutrient cycling, redox transformations, and contaminant degradation (Griebler et al., 2019, Fillinger et al., 2023). However, their metabolic capacity and sensitivity to environmental change remain poorly understood.

Recent studies have shown that microbial metabolic versatility in aquifers could buffer against environmental stressors and contribute to climate resilience (UNESCO and UN-Water, 2020, Griebler et al., 2019, Mammola et al., 2019, Dahlke et al., 2018, Lipczynska-Kochany, 2018).

This study aims to characterise the microbial metabolic potential of New Zealand's groundwater ecosystems, identify regional and lithological patterns, and assess implications for climate-resilient water management. By linking microbial function to aquifer characteristics and land use, we provide a framework for integrating microbial indicators into groundwater monitoring and policy.

Methods

The study was undertaken across eight regions in the North and South Islands of New Zealand. Regions were selected to represent a range of hydrogeological settings, different land uses, and climatic gradients.

Water samples were collected from 99 existing wells across the eight regions between 2013 and 2024. Physicochemical parameters were measured in the field and by Hill Labs. Environmental (e) DNA was concentrated in the field by pressure filtration and sequenced using Illumina MiSeq (Dong et al., 2017).

Bioinformatic analysis included ASV collation (using DADA2 (Callahan et al., 2016)), taxonomic assignment (using SILVA v138.1), diversity metrics analysis (PhyloSeq v1.50.0, McMurdie and Holmes, 2013), and functional inference (PICRUSt2 v2.5.2, Douglas et al., 2020). Analysis of the data was undertaken in R Studio using PhyloSeq and vegan packages. Canonical Correspondence Analysis and indicator species were used to identify the environmental (including climate related) drivers and corresponding identifying taxa present.

Results

Fractured basalt aquifers (e.g., Auckland) exhibited the highest predicted metabolic activity, while coarse sand aquifers (e.g., Hawke's Bay) showed the lowest. Urban and industrial land uses were associated with elevated microbial functional potential, suggesting anthropogenic influence on microbial ecosystem services. Canonical Correspondence Analysis identified temperature, pH, DOC, ammonia, and potassium as key predictors of microbial function.

From Figure (1) we can draw key observations: Auckland and Tasman show the highest overall metabolic potential across all pathways, especially for methane metabolism and denitrification. This aligns with their volcanic and marble aquifers and urban/industrial land use for Auckland region and agricultural activity in Tasman region, which likely contribute to elevated nutrient and organic carbon inputs. There is potential for metabolic activity to remove these inputs, as the microbial diversity present and their metabolic function show clear alignment to activity in these key processes. Canterbury and Southland exhibit lower metabolic activity, consistent with alluvial aquifers and pastoral land use, suggesting more oligotrophic conditions and low metabolic activity to remove contaminants or nutrients present.

The results demonstrate that two key drivers are land use and lithology. The data also showed an influence on key environmental conditions that will likely be important as we experience more impacts from climate change. Key environmental drivers observed were temperature, pH and ammoniacal nitrogen.

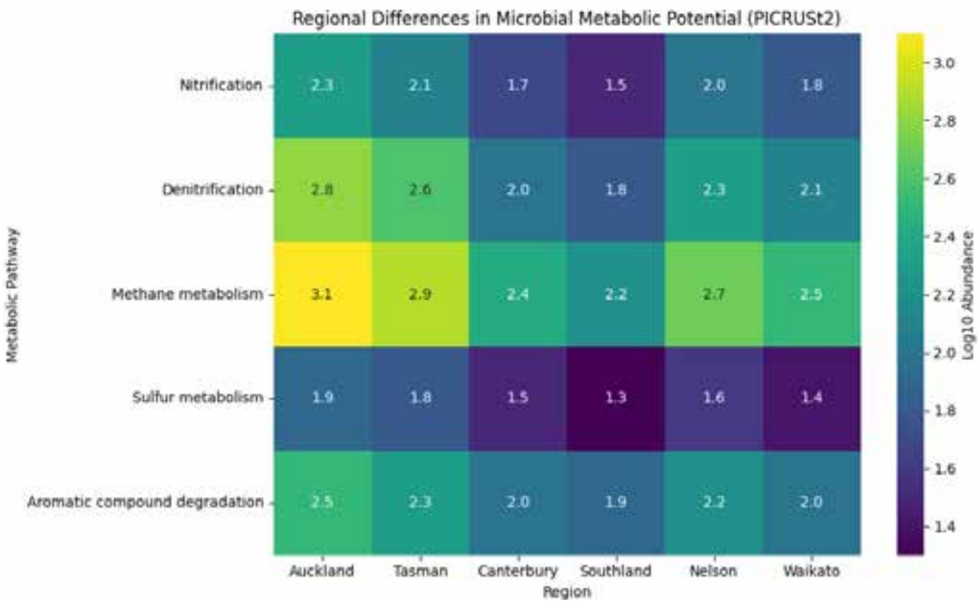


Figure 1 Heatmap summarising differences in microbial metabolic potential through PICRUSt2) analysis. This heatmap visualises the log10-transformed mean abundances of five key microbial metabolic pathways across six New Zealand regions. These pathways were inferred using PICRUSt2 from 16S rRNA gene sequencing data and represent core biogeochemical functions in groundwater ecosystems.

These findings highlight the need to integrate microbial indicators into groundwater monitoring and management frameworks, especially under climate change scenarios that may alter aquifer recharge, redox conditions, and nutrient fluxes. Ongoing work is exploring seasonal dynamics, microbial activity rates, and integration with hydrological models to support sustainable groundwater governance.

References

CALLAHAN, B. J., MCMURDIE, P. J., ROSEN, M. J., HAN, A. W., JOHNSON, A. J. & HOLMES, S. P. 2016. DADA2: High-resolution sample inference from Illumina amplicon data. Nat Methods, 13, 581-3.

DAHLKE, H. E., LAHUE, G. T., MAUTNER, M. R. L., MURPHY, N. P., PATTERSON, N. K., WATERHOUSE, H., YANG, F. & FOGLIA, L. 2018. Managed Aquifer Recharge as a Tool to Enhance Sustainable Groundwater Management in California: Examples From Field and Modelling Studies. Advances in Chemical Pollution, Environmental Management and Protection. Elsevier.

DONG, X., KLEINER, M., SHARP, C. E., THORSON, E., LI, C., LIU, D. & STROUS, M. 2017. Fast and

Simple Analysis of MiSeq Amplicon Sequencing Data with MetaAmp. Frontiers in Microbiology, 8.
FILLINGER, L., GRIEBLER, C., HELLAL, J., JOULIAN, C. & WEAVER, L. 2023. Microbial diversity and processes in groundwater. Groundwater Ecology and Evolution. Elsevier. GRIEBLER, C., AVRAMOV, M. & HOSE, G. 2019. Groundwater Ecosystems and Their Services: Current Status and Potential Risks. In: SCHRÖTER, M., BONN, A., KLOTZ, S., SEPPELT, R. & BAESSLER, C. (eds.) Atlas of Ecosystem Services: Drivers, Risks, and Societal Responses. Cham: Springer International Publishing.
LIPCZYNSKA-KOCHANY, E. 2018. Effect of climate change on humic substances and associated impacts on the quality of surface water and groundwater: A review. Science of The Total Environment, 640-641, 1548-1565.
MAMMOLA, S., CARDOSO, P., CULVER, D. C., DEHARVENG, L., FERREIRA, R. L., FIŠER, C., GALASSI, D. M. P., GRIEBLER, C., HALSE, S., HUMPHREYS, W. F., ISAIA, M., MALARD, F., MARTINEZ, A., MOLDOVAN, O. T., NIEMILLER, M. L., PAVLEK, M., REBOLEIRA, A. S. P. S., SOUZA-SILVA, M., TEELING, E. C., WYNNE, J. J. & ZAGMAJSTER, M. 2019. Scientists' Warning on the Conservation of Subterranean Ecosystems. BioScience, 69, 641-650.
McMURDIE, P. J. & HOLMES, S. 2013. phyloseq: an R package for reproducible interactive analysis and graphics of microbiome census data. PloS one, 8, e61217.
UNESCO & UN-WATER 2020. United Nations World Water Development Report 2020: Water and Climate Change. Paris, France: UNESCO.
WHITE, P. A. 2001. Groundwater Resources in New Zealand. In: ROSEN, M. R., WHITE, P. A. (ed.) Groundwaters of New Zealand. Wellington: New Zealand Hydrological Society Inc.

GRAVITY WAVES AS PRECURSORS TO MESOSCALE WARMING EVENTS IN ANTARCTICA

Marwan Katurji, Sam Walls[1], Eva Nielsen, Marte Hofsteenge, Tamara Pletzer, Peyman Zawar-Reza
University of Canterbury[1]

A new data product, AntAIR ICE, now allows for continental-scale mesoscale weather and climate analysis in Antarctica. Developed using satellite surface brightness temperature regressions against numerous automatic weather station records, AntAIR ICE provides daily, high-resolution (1 km) data on near-surface air temperature. We've confi med AntAIR ICE effectiveness in detecting Foehn wind-induced warming in coastal glaciated valleys and for analysing the extreme atmospheric river event of March 22 in the Ross Sea region. We also successfully used a self-organized map to identify meteorological drivers of temperature variability, combining data from ERA5, regional climate simulations, and AntAIR ICE.
Our new research suggests that atmospheric gravity waves, triggered by coastal topography, could serve as a precursor for detecting extreme warming events like Foehn winds. We've tested this using ERA5 data and AntAIR ICE temperature anomalies, offering the first opportunity for Anta ctic-wide detection of such events. This work could advance our understanding of how gravity waves change in a warming world and how these changes connect to localized warming, which impacts glacial melt and water availability for bacterial life.

EFFECTIVE GROUNDWATER MODELLING: TIPS FROM EXPERIENCE

Julian Weir
Aqualinc Research Limited

Introduction

Modelling is a key tool for projecting future conditions or reconstructing the past. Models are intended to represent our world mathematically, but as our world is so complex (and our understanding so limited), we need to apply simplifications and app oximations. And none more so than for models of groundwater systems, which are largely unseen and difficult to epresent.

Some Experiences

The following tips are drawn from experience developing numerical groundwater models across a range of aquifer systems in New Zealand. While focused on groundwater, many principles also apply to other hydrological modelling.

Understand the conceptual model before building the numerical model. A sound numerical model begins with a robust conceptual understanding, informed by as much data as possible. Know what drives the system, for example:

- Is the groundwater system heavily influenced by surface water and the co st? (e.g. Westport, Hector, 2025)
- Is surface water driven by groundwater? (e.g. coastal Canterbury, Weir, 2018)
- Do rivers provide a relatively steady ‘base’ groundwater level, with dynamic responses largely driven by land surface recharge and pumping? (e.g. inland Canterbury, Weir, 2018)

Figure 1: Ruataniwha Plains model domain

Is there a complex system of rivers interacting with groundwater as they weave over the catchment? (e.g. Ruataniwha Plains, Hawkes Bay, Weir, 2024) (Figure 1)

Define the modelling purpose and scale. Models must be built o answer specific questions, whether local, catchment-wide, or regional. However, changing the purpose doesn’t require starting over: models can be refined and epurposed with (for example) improved resolution, new monitoring data, or targeted calibration (e.g. Weir, 2022; Weir & Setiawan, 2024).

Data is foundational. Defensible models are data-hungry (Weir, 2016). Long-term data collection, QA, and management by skilled hydrologists (with a long-term vision) are essential. Tasman District Council (TDC)’s hydrology team exemplifies this app oach (Figure 2), contributing to successful modelling outcomes (e.g. Waimea Plains, Weir, 2025).

Think long-term, particularly for publicly-funded studies that feed into plan changes and subsequent revisions. Again, a good example is TDC's Waimea Plains model (Figure 2), which has been progressively developed for over four decades. This long-term vision, with a clear management purpose, has enabled an ongoing cycle of model development that feeds into plan changes, monitoring targeted at the questions being asked, subsequent model updates, and adaptive management. The cycle continues.

Stage development to manage complexity. Breaking down tasks and developing models in stages, while building up the complexity only to a level needed to answer the questions, helps avoid being overwhelmed. This allows for constructive review, and enables changes to the direction of development, if needed. Even well-planned studies may need to change focus.

Don't let uncertainty analysis become a substitute for good conceptualisation and model build, but do use it to inform what isn't known. Decisions need to be made, and they often can't wait until we have 'enough' data. Therefore, quantifying what we don't know is essential in the decision-making process (e.g. Weir, 2024).

A useful technique to employ is the use of models to predict <u>changes</u> between scenarios. This reduces overall errors associated with predicting absolute values. This rationale is echoed in the Australian Groundwater Modelling guidelines (Barnett et al., 2012). Should absolute values be needed, then these can be derived by adding the modelled change onto a measured baseline.
'Conservative' scenarios, designed to avoid an undesirable outcome, can also be used to counter unknows, but this requires careful judgment to balance precaution with realism.

Don't model by committee. Excessive input can derail progress and burn out modellers. Model development is a marathon, not a sprint. Seek targeted expertise, stay focused on the key aspects (relevant to model purpose), and choose modellers who are committed for the long haul (Weir & Dudley Ward, 2023).

Treat models as assets. Like infrastructure, models require ongoing maintenance to remain relevant. While the model itself doesn't change, new data (targeted to the model's purpose), software, techniques, and evolving objectives mean models can become outdated and must be actively managed to ensure they are ready and defendable when needed for critical decisions.

Groundwater models are important decision-support tools, but their strength lies in a clear purpose, robust data, and sound conceptualisation. When developed collaboratively and treated as long-term assets, they bridge engineering, science and policy, adapt to evolving needs, and support informed, defensible decisions.

References

Barnet, B; Townley, LR; Post, V; Evans, RE; Hunt, RJ; Peeters, L; Richardson, S; Werner, AD; Knapton, A; Boronkay, A (2012): Australian Groundwater Modelling Guidelines. Waterlines Report. Published by the Australian National Water Commission, Canberra. June 2012.

Hector, R (2025): Westport Groundwater Model: Model Documentation and Scenarios. Prepared for West Coast Regional Council. RD24001. 4 July 2025. Aqualinc Research Ltd.

Weir, J (2016): Using Best-Available Data for Robust Groundwater Model Development: An Example. Abstract. New Zealand Hydrological Conference. Queenstown, November 2016; p 143.

Weir, J (2018): Canterbury Groundwater Model 3: Model Documentation. Prepared for MBIE Wheel of Water Research. C15066-11. 17 August 2018. Aqualinc Research Ltd.

Weir, J (2022): Drinking Water Supply Security: Groundwater Bore Security Modelling. Prepared for Christchurch City Council/ WL19031. 17 March 2023. Aqualinc Research Limited.

Weir, J; Dudley Ward, N (2023): Some Practicalities of Groundwater Modelling for Decision Making. Poster. New Zealand Hydrological Conference. Auckland, November 2023.

Weir, J (2024): Ruataniwha Basin Tranche 2 Groundwater Modelling (Appeal). Prepared for Te Awahōhonu Forest Trust and I&P Farming. WL18045. 31 May 2024. Aqualinc Research Ltd.

Weir, J; Setiawan, I (2024): Upper Selwyn Huts Climate Impact Assessment. Te Waihora Levels and Groundwater Flooding. Prepared for Selwyn District Council. AQ25031. 20 December 2024. Aqualinc

Research Ltd.

Weir, J (2025): Waimea Plains Integrated Groundwater-surface Water Model. Model Documentation and Scenarios. Prepared for Tasman District Council. AQ25127. 27 June 2025. Aqualinc Research Ltd.

ESTIMATING SHALLOW GROUNDWATER: AIMING FOR 'ONE SOURCE OF TRUTH' FOR DECISION MAKERS

Rogier Westerhoff[1], Matt Dumont[2], Leanne Morgan[3], Scott Stephens[1], Patrick Durney[21]
[1] Earth Sciences New Zealand; [2] Komanawa Solutions; [3] University of Canterbury

Aims

Low-lying coastal areas, i.e., areas lower than 10m above current mean sea level, are of vital importance for Aotearoa New Zealand's (NZ) prosperity and wellbeing. Most of NZ agriculture is taking place in the fertile low-lying land and it is where one-third of the population resides (StatsNZ, 2025).

Shallow groundwater can impact the resilience of communities in low-lying coastal areas. Expected sea level rise (SLR) will aggravate this situation more. Therefore, a reliable spatial layer of shallow groundwater, at present and with SLR, will be of vital importance for sustainable management of freshwater and infrastructure.

Models that simulate depth to shallow groundwater are uncertain. That is mostly because shallow groundwater data is sparse: water level is mostly observed from wells that target the investigation of deeper groundwater levels.

Three different models currently exist that could be used to simulate shallow groundwater levels. From a scientific perspective that is good news, since p omising developments are advancing leading to better future models. However, using different models will end up in diverging model outcomes; which might lead to different decisions being made.

Method

A 'one source of truth' that allows continuous model development is found in the form of a weighted model average between three nationwide models:

1) A categorical depth to water model (Durney et al, in submission), a data-driven machine-learned model that predicts whether a given location has groundwater shallower than a given threshold (e.g., < 1m below ground level).
2) The National Water Table Model by Westerhoff et al. (2018), as a simple steady-state groundwater flow model ac oss New Zealand as "a solution to obtain a nationwide overview of groundwater that bridges the gap between the (too-)expensive advanced local models and the (too-)simple global-scale models"
3) Kitlasten et al. (2022) developed a nationwide application of a MODFLOW6 model. The intention of this model to function as a high-level prior framework, i.e., a reproducible workflow that can be used as a starting point for smaller-scale model.

The weighting of those averages consists of a combination between statistical tests and expert judgement.

Result

We present nationwide estimates of weighted averages at high resolution that can be used for decision at any scale required (Figure 1). We also present strengths and weaknesses and recommendations for further research.

References

Durney et al., Categorical Model Description, in submission.

Kitlasten, W., Moore, C.R., Hemmings B. 2022. Model Structure and Ensemble Size: Implications for Predictions of Groundwater Age. Frontiers in Earth Science, 10: 972305. doi:10.3389/feart.2022.972305.

StatsNZ. 2025. New Zealand Estimated Resident Population Grid 250 metre. URL: https://datafinde .stats.govt.nz/layer/119709-new-zealand-estimated-resident-population-grid-250-metre/. Accessed 20 June 2025.

Westerhoff, R., White, P., Miguez-Macho, G. 2018. Application of an improved global-scale groundwater model for water table estimation across New Zealand. Hydrology and Earth System Sciences, 22 (12): 6449–

1 Currently working at Lincoln Agritech

6472. Doi: 10.5194/hess- 22-6449-2018.

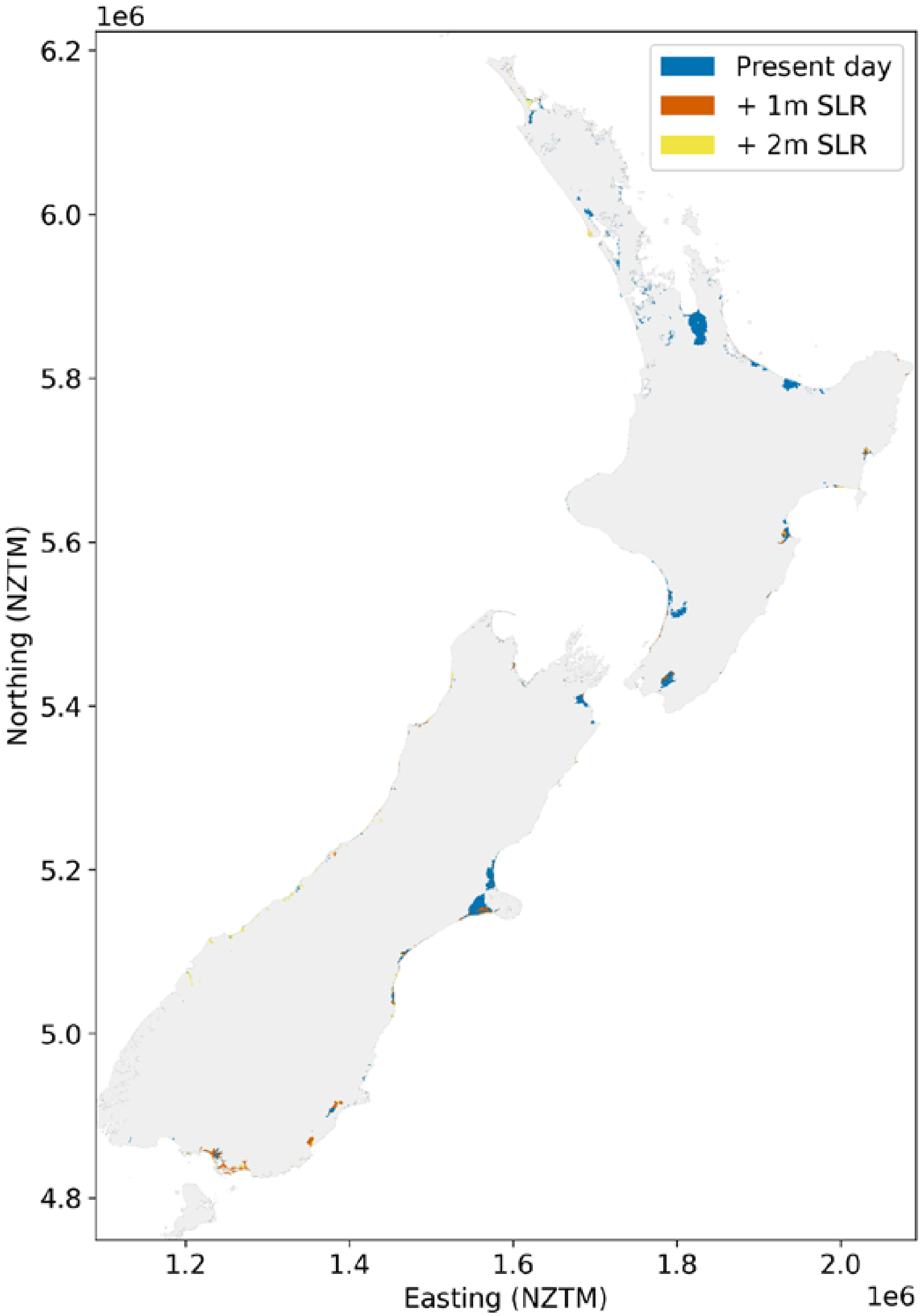


Figure 1: Low-lying coastal areas of NZ where groundwater depths are shallower than 1 metre below ground level for present day (blue) and increments of 1 m (orange) and 2m (yellow) of SLR

TOWARD EFFICIENT MULTIOBJECTIVE OPTIMIZATION IN APPLIED GROUNDWATER MODELING

Jeremy White
INTERA Inc

The decision-support utility of multi-objective optimization (MO) cannot be overstated. Directly estimating the shape of the trade-off between economic and environmental interests helps decision makers and stakeholders understand what is plausible and leads to more equitable compromises. Unfortunately, solving the MO problem usually involves a (very) large number of model evaluations, which can make this power analysis intractable in settings where the computational demand of the model is high.

In this talk, we will show how data-driven model emulation can be used within an MO analysis to greatly reduce the computational requirements to a level that makes these power analyses possible in settings where it was previously not. We will demonstrate application and usage of emulation-based MO using free and open-source software in a classic setting where environmental and economic considerations can compete with each other: mine dewatering with artificial echarge, where the goal is to protect nearby groundwater-dependent ecosystems while also allowing economically important mine-related activities to proceed. The results of this demonstration show that emulation-based MO can achieve similar results to simulation-based MO, but at a fraction of the computational cost.

CHRISTCHURCH CITY GROUNDWATER CATCHMENT AND THE WAIMAKARIRI COASTAL AQUIFER SYSTEM: SHALLOW HYDROGEOLOGY AND CATCHMENT BOUNDARY

P.A. White,[1] C. Tschritter,[1] G. Clark[1]
[1] Earth Sciences New Zealand.

Introduction

The Christchurch City groundwater catchment, part of the Waimakariri coastal aquifer system, provides baseflow to all urban spring-fed rivers and st eams and is the source of all the City's urban water supply. Important hydrogeological units in the urban area include aquifers, i.e., Holocene Springston Formation (HSF) and Late Pleistocene Riccarton Gravel (RG); and an aquitard, i.e., Holocene Christchurch Formation (HCF). This paper develops two-dimensional (2D) digitally filte ed LiDAR digital terrain models (DTMs) to map the groundwater catchment boundary of the system and to identify surface features of shallow groundwater flo , e.g., relic surface channels (RSCs), urban gravel lobes, gravel fans and swamps and wetlands mapped in 1856. Three-dimensional models (3D) of depositional facies identify characteristics of shallow hydrological units, e.g., the distribution and groundwater transfers between HSF, HCF and RG. Lastly, an urban groundwater budget is calculated to assess groundwater budget components (i.e., inflows, outflows and transf s).

Methods

Groundwater catchment features were identified by digitally-filt ed LiDAR digital terrain models, sedimentary facies calculated from an 1856 map of the urban area before urbanisation, well logs, 3D facies models, and an urban groundwater flow budget

The groundwater catchment area was mapped: north of the Waimakariri River bed, including Late Pleistocene Q2 gravel relict surface channels (RSCs) that strike towards the urban area; the Waimakariri River bed; and south of the river bed including Holocene RSCs that strike towards the urban area.

The groundwater budget considered catchment inflows (e.g., land surface echarge, Waimakariri River and water-supply channels) and outflows (e.g., g oundwater pumpage for irrigation, stockwater and municipal uses; the Waimakariri River bed; spring-fed rivers and streams; wetlands and swamps; and coastal outflow)

Results

The groundwater catchment area was mapped: north of the Waimakariri River bed; the Waimakariri River bed itself; and south of the river bed including the urban area.

Inflow to the catchment is la gest from the Waimakariri River bed (12.9 m^3/s). South of the river, this recharge is transported into the urban area by groundwater in RSCs and gravel lobes, for example the Yaldhurst gravel lobe that crosses South Christchurch.

Pathways of groundwater outflow in urban-a ea spring-fed rivers and streams, wetlands and swamps include, at least, the HSF and RG aquifers and the HCF aquiclude (Figure 1).

Outflow f om the catchment is mostly via spring-fed river and streams (-12.4 m^3/s). Other outflows include: Waimakariri River bed (1.8 m^3/s). wetlands and swamps; groundwater use; and the coastal boundary (-0.9 m^3/s, -5.2 m^3/s, and -3.9 m^3/s, respectively). Groundwater transfers from north of the Waimakariri River bed to the urban area (2.9 m^3/s); this transfer is the main reason for outflow ac oss the coastal boundary that is larger than published.

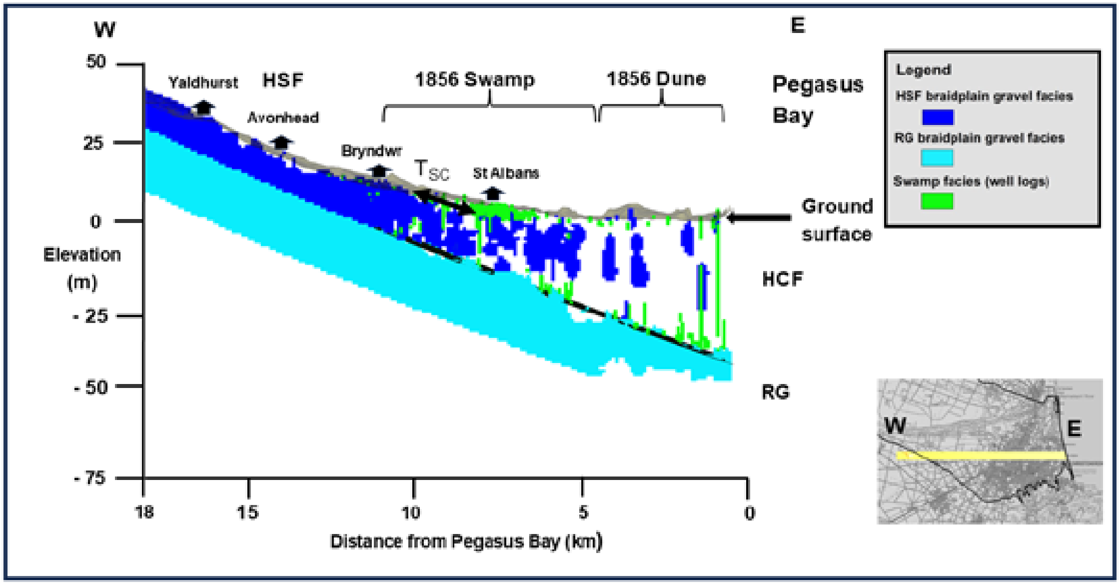


Figure 1: North-south cross section with: HSF and RG braidplain gravel facies; the HCFaquiclude with swamp facies; and features of the 1856 map.

STANDARDISATION - HAVE WE GONE TOO FAR?

Thomas Wilding
Waikato Regional Council

In a changing climate, is the increasing standardisation in science moving us forward or obstructing learning? There are many great examples of standards working to progress learning. For example, SI - the international standards of units - enables cross-border sharing of information. With all of us measuring precipitation in mm and the volume of water in m^3, we can reduce the mistakes of converting inches, gallons or barrels. Arguably, we know enough about length and volume to agree on a standard and abide by that indefinitel . The same cannot be said for how we measure flow in st eams. Standard methods are a poor match with the non-laminar flow and poorly defined bed in small, weedy s eams. When our understanding of the system is lacking, and there is conflicting advice on the best methods, an easy way out is to adopt a standard. However, the virtues of standardisation come into question if the motivation is simply to avoid a difficult decision or disregard the complexity of the natural world. Focusing on advances in water management, I will explore the useful limits of standardisation.

UNDERSTANDING AOTEAROA'S GROUNDWATER VULNERABILITY BY CHARACTERISING DYNAMIC RESPONSES

Wilson S[1], Durney P,[1]
[1] Lincoln Agritech

Aims
Aotearoa's diverse landscapes and hydrological settings give rise to variety of dynamic groundwater responses. This study aims to identify and compare groundwater response types across Aotearoa, to better understand their hydrological drivers. By doing so, we can enhance our understanding of groundwater vulnerability to water management practices and climate change.

Method
Groundwater hydrographs were obtained from across the motu from regional council databases and the Komanawa NZ Depth to Water database (Durney et al. 2024). A histogram was used to find the period of greatest daily data coverage, which was 2012-2017. Sites with >95% data availability within that period were then selected and trimmed so that the time series aligned. After filtering out some sites with unusual behaviour, close to 450 time series remained.

To compare the dynamic responses at different sites requires a normalisation of the data to remove the influence of the absolute elevation of each site. This was achi ved by subtracting the median value of each time series to create median-centred water levels. The resulting hydrographs show variation around the median rather than absolute water level elevations.

Exceedance probability distributions were then created for each site. The advantage of this is that it smooths the data, which enables a functional data analysis approach to be applied. Curves were fitted to each exceedance probability distribution using B-spline basis functions. Principal Components Analysis was then performed on the coefficient vectors epresenting the weights of the B-spline functions fitted to each probability distribution. Finally, K-means clustering was applied to the functional PCA scores to identify the main types of response patterns. The response types (clusters) were then mapped to understand their position in the landscape and hydrological setting.

The same approach was applied to time series by averaging the normalised groundwater levels of each site for each day of the year (i.e. day 1 to day 366). This approach enables B-spline basis functions to account for event driven fluctuations, and esults in a slightly poorer curve fit. Howeve , the advantage is that fitting to a time series includes time lags in the functional data analysis.

Results
The results for functional data analysis on both the exceedance probability and day of the year approaches show that most of the monitoring sites are influenced by head boundaries or a e in confined aquifers. Exceedance probability distributions are very similar for these sites because the annual variability is very small. Sites influenced by head boundary conditions a e particularly susceptible to water management practices, such as river and drainage engineering. Sites reliant on ephemeral streams or land surface recharge show the greatest variability, and significant time lags compa ed to head-controlled sites. These sites are most likely to be impacted by climate change. Additionally, some sites currently controlled by head boundaries may shift to the ephemeral category if stream flows significantly declin

These findings suggest that drainage, river and st eam management may have a more substantial impact on groundwater resources than climate change in many areas. They also highlight the need to increase monitoring in areas dependent on ephemeral streams or land surface recharge. These areas are most at risk of climate change and are under-represented in regional monitoring networks.

Reference List

Durney, P., Charlesworth, E., & Dumont, M. (2024). Developing a national groundwater level dataset for New Zealand. Journal of Hydrology (NZ), 63(1), 51-68

WELLS AOTEAROA NEW ZEALAND: BUILDING AND MAINTAINING A NATIONAL GROUNDWATER WELLS DATABASE

Paul Kennett,[1] Nicola Wilson,[1]
[1] Waikato Regional Council

Wells Aotearoa New Zealand https://wellsnz.teurukahika.nz/ is a collaborative national initiative led by Te Uru Kahika – Regional and Unitary Councils Aotearoa – to centralise and standardise data on wells, geothermal bores, and galleries across the motu. This publicly accessible database supports statutory functions under the Resource Management Act 1991 and serves as a vital resource for regional councils, scientists, consultants, drilling companies, and well owners.

The platform aggregates detailed records on well location, construction, geology, and aquifer test data, enabling users to search, view, and export data for planning, consenting, compliance, and scientific analysis. As regional councils progressively onboard and contribute their datasets, Wells Aotearoa NZ is evolving into a comprehensive national repository, enhancing transparency and data-driven decision-making in water resource management.

This presentation will provide an overview of the database's functionality and its role in supporting groundwater governance. It will also outline current council membership, onboarding procedures for new contributors, and the ongoing maintenance and stewardship of the system. Finally, it will explore future opportunities for integration, data quality improvement, and stakeholder engagement as the system scales.

GROUNDWATER QUALITY MONITORING OPTIMISATION 1/2 – WAIKATO PROGRAM REVISION

Hadfield, J. [1] Wilson, N.,[1] Moreau, M.,[2]
[1]Waikato Regional Council
[2]Earth Science New Zealand

Groundwater quality monitoring in the Waikato Region has been revised to ensure it is achieving objectives and addresses critique in respect to national consistency and transparency. State of environment (SOE) monitoring undertaken since the 1990s has evolved in an ad-hoc fashion, although it has provided very useful information to inform management of the resource to date. This collaborative review has involved wide consultation, with the proposed approach supported by regional councils, relevant CRIs and government departments.

An initial literature review resulted in proposed differentiation of Surveillance and Evaluative monitoring. The former involves more passive characterisation of groundwater quality state and trends. The latter is a more targeted approach notably to assess the efficacy of policies

An index-overlay method was used to assess priority areas for groundwater monitoring using a 10 km by 10km grid overlaid by hydrogeologically defined polygons . The combination of weights and ratings to mappable units provided the basis for informed decisions on the design of the monitoring network – using a consistent monitoring site density approach, whereby higher priority areas were assigned greater densities The index factor weightings were varied for Surveillance and Evaluative purposes and may be changed in a transparent fashion.

The existing monitoring program comprises a SOE network (110 wells) and a 'Community' network of rural schools (~80 wells). These were reviewed in respect to their spatial location, hydrogeological characteristics, availability of information, access, sampling logistics and notably their power to detect change. The power of detection of the current SOE network in respect to detecting changes in nitrate concentrations was found to be generally low, similar to other region's monitoring networks (Dumont and Charlesworth, 2024). This assessment assists in selecting wells for the revised program.

A standardised base suite of chemical parameters was agreed by regional councils for national consistency through the Groundwater Forum (SIG group) in 2024 (Groundwater SIG, 2024). This base suite includes major ions for groundwater characterisation, some nutrients (e.g. nitrate), various calculated parameters (e.g. hardness) and field parameters (e.g. temperatu e). It sets out the minimum expectations for surveillance/SOE monitoring of groundwater quality, but many councils choose to monitor additional parameters (e.g. arsenic) for a variety of reasons.

The review of surveillance monitoring involved comparison of the existing monitoring well distribution and characteristics with the index mapped priority areas. Various adjustments were required involving rationalising some existing sites while also adding some new monitoring wells (Figure 1). The latter involved some field confi mation of suitability. Some of the additional sites involve collaboration with a third party, typically District Council monitoring of drinking water supplies.

Evaluative groundwater quality monitoring is designed to assess the efficacy of management of the resource through policy. In the Waikato this includes initiatives for the protection of water quality in the Lake Taupo catchment. Also, evaluation of management to protect aquifers in the Coromandel from sea-water intrusion.

Extensive stakeholder engagement was undertaken throughout this process, with the aim of developing an approach that could be applied to similar initiatives in the future. A key outcome of the consultation was the recognition that transparency is critical, particularly given the influence of subjectiv   design choices on the final monitoring p ogramme. The process also demonstrated that meaningful improvements require iterative refinement, balancing strategic objectives with practical implem ntation considerations.

The reviewed network design is constrained by the intention to maintain the same level of overall investment in cost and logistics. Where higher frequency Evaluative monitoring is justified, automation is p oposed to mitigate costs. To achieve national consistency, the optimisation of groundwater quality monitoring in the Waikato region involved the consideration of national monitoring, notably as part of the National Groundwater Monitoring Program. This is the subject of the second related groundwater quality monitoring optimisation paper.

References

Dumont, M., & Charlesworth, E. 2024. The ability of the current monitoring network to detect nitrate changes, Waikato, NZ. Report prepared for Waikato Regional Council (Z24008WDP.1).

Groundwater Special Interest Group. 2024. Te Uru Kahika Groundwater Special Interest Group meeting minutes—25 November 2024.

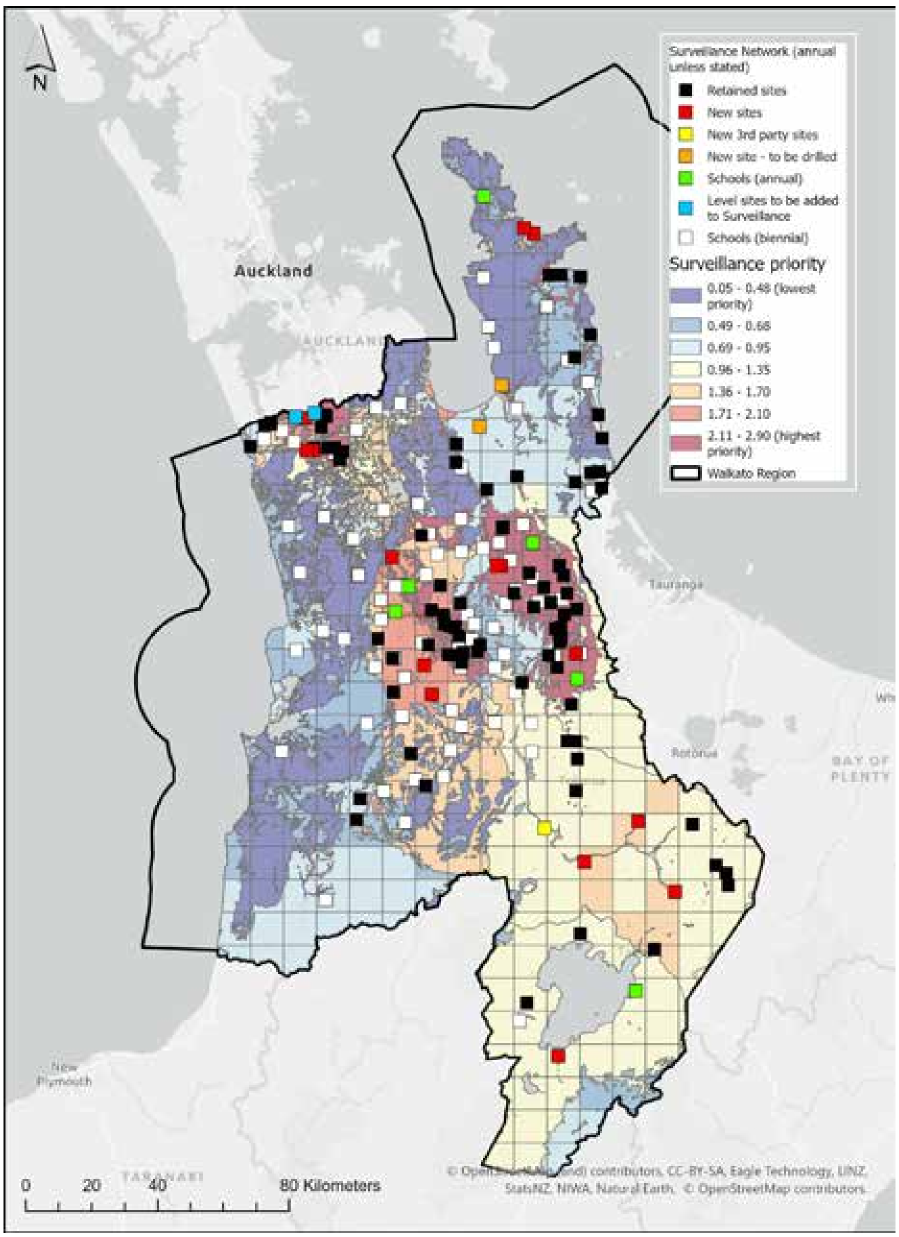


Figure 1: Proposed modifications to the egional surveillance (i.e. SOE) network in the Waikato

AQUIFERWATCH RELOADED: (NEAR) REAL-TIME VIZUALIZATION OF WAIRAU AQUIFER STORAGE

Wöhling T.[1,2], Davidson P.[3]
[1] Chair of Hydrology, Dresden University of Technology TUD, Dresden, Germany
[2] Lincoln Agritech Ltd, New Zealand
[3] Marlborough District Council (MDC), Blenheim, New Zealand

1. Aims

Groundwater levels in the highly conductive Wairau Aquifer exhibit a strong seasonality but also a long-term trend which has been discussed in previous studies (e.g., Wöhling et al., 2018, Morgenstern et al. 2019, Wöhling et al. 2020). Due to the non-stationarity of the groundwater system, the management with stationary groundwater level and stream flow th esholds is currently revised (Wöhling 2025) to explore alternative management options for the new Marlborough Environment Plan. Several studies have been conducted to better understand the physics of the groundwater system and its interactions with the Wairau River, which is the main contributor of aquifer recharge. For this purpose, groundwater flow models we e developed that represent the complex river-aquifer system and were used for scenario simulations (Wöhling et al, 2018, 2020, 2025). However, decision makers need simple tools that are easy to read and interpret, yet encapsulate the scientific knowledge gained by these complex models.

2. Methods

An initial attempt to develop a tool for Wairau Aquifer storage was AquiferWatch (Wöhling & Burbery 2020) which uses eigenmodels to relate Wairau River flow and estimates of land-surface echarge to groundwater levels at several locations in the aquifer. In a second step, aquifer storage was then estimated by assuming a (linear) groundwater surface. This study takes a different approach by predicting storage directly from observable quantities of the Wairau system. For this purpose, a Long Short-Term Memory model (LSTM) was utilized. The LSTM was trained with aquifer storage that has been simulated by a recently developed, integrated srface water - groundwater flow model (MODFLOW) of the enti e Wairau Plain (Wöhling et al. 2025), thereby incorporating the physical dimensions and the state of knowledge about the aquifer system. Predictive uncertainty of the complex groundwater flow model as well as of the model drivers a e propagated through the proposed modelling approach by LSTM ensembles.

3. Results

The LSTM models serve as a quick and computationally efficient substitute for the 3D numerical MODFLOW model when simulating Wairau Aquifer storage. Results demonstrate satisfactory accuracy to simulate historic system states as well as states that fall outside the training data set. Potential effects from overfitting cannot be excluded, but at this stage are not apparent from a set of numerical experiments performed with the model.

The new modelling approach has been integrated into AquiferWatch to simulate on a daily basis the percentage of currently available Wairau Aquifer storage. Results are displayed through a web interface and automatically updated daily. The tool provides a quick reference for water users and managers alike on the current state and trends of Wairau Aquifer storage.

4. References

Morgenstern, U., Davidson, P., Townsend, D. B., White, P. A., van der Raaij, R. W., Stewart, M. K., et al. (2019). From rain through river catchment to aquifer: the flow of water th ough the Wairau hydrologic system. Lower Hutt, NZ-WGN: GNS Science. 83. doi:10.21420/7125-ST46

Wöhling T, Burbery L (2020). Eigenmodels to forecast groundwater levels in unconfined rive -fed aquifers during flow ecession. Science of the Total Environment, 747, 141220, doi: 10.1016/j.scitotenv.2020.141220.

Wöhling, T., Gosses, M., Wilson, S., Wadsworth, V., Davidson, P. (2018). Quantifying river-groundwater interactions of New Zealand's gravel-bed rivers: The Wairau Plain. Groundwater doi:10.1111/gwat.12625

Wöhling T, Wilson SR, Wadsworth V, Davidson P. (2020). Detecting the cause of change using uncertain data: Natural and anthropogenic factors contributing to declining groundwater levels and flows of the airau Plain Aquifer, New Zealand. Journal of Hydrology: Regional Studies, 31, 100715, doi: 10.1016/j.ejrh.2020.100715.

Wöhling, T., Crespo Delgadillo, OA, Kraft, M., Guthke, A. (2025). Comparing and combining physics-based, conceptual and machine-learning models to predict groundwater heads using Bayesian Model Averaging. Groundwater, doi.org/10.1111/gwat.13487.

Wöhling, T. (2025). Assessing Groundwater Abstraction Scenarios with the Wairau Plain Surface Water – Groundwater Flow Model. Report 1053-08 R2, provided for the Marlborough District Council, Lincoln Agritech Ltd., Lincoln, Christchurch, New Zealand.

THE COMPOUND FLOOD DURING EX-TC GABRIELLE COULD HAVE BEEN FORECASTED WITH OPERATIONAL FLOOD MODEL

Xu, Z.[1]
[1] Earth Sciences New Zealand

Aims

The extensive flooding due to the ex- ropical Cyclone Gabrielle in 2023 has devastated Hawke's Bay and Gisborne. Although heavy rainfall was issued before the event, the extent of flooding was unknown, which hindered flood esponse and evacuation. To enable fast response to extreme flood events in the futu e, we are developing a real-time compound flood fo ecast system for New Zealand.

Methods

We force the hydrodynamics model BG-Flood (Bosserelle et al., 2021) with high-resolution numerical weather prediction (NZCSM) (Turner and Moore, 2017), which produces 48 hours weather forecasts. Using the rain-on-grid technique, the compound flooding in the enti e Waipaoa Catchment in Gisborne was simulated. The storm surge was obtained from Earth Sciences New Zealand's storm surge forecast model and applied at the coastal boundary.

Results

With the weather forecast input, our flood model can obtain at least 80% accuracy f r "predicting" the maximum flood depth (>10 m) 24 hours befo e the flood peak during ex-TC Gabrielle. Although the maximum flood depth was unde estimated at some river level gauges, it still gives the magnitude and impact of the event and leaves plenty of time for evacuation and preparation if the flood fo ecast model were operational before the event. We are working to make such a flood fo ecast system operational to prepare New Zealanders for future extreme flood events

References

Bosserelle, C., Lane, E.M., Harang, A., 2021. BG-Flood: A GPU adaptive, open-source, general inundation hazard model, in: Australasian Coasts & Ports.

Turner, R., Moore, S., 2017. An analysis of three years of Convective Scale Numerical Model diagnosed gusts over New Zealand, in: 9th Asia Pacific Confe ence on Wind Engineering, APCWE 2017.

A SMART WEBTOOL FOR EFFICIENT IRRIGATION WATER MANAGEMENT

Yang, J.,[1] Rajanayaka, C.,[1] Zhou, C.,[2] Shi, L.[2], Smith, R.[1], Booker, B.[1]
[1] Earth Sciences New Zealand
[2] Lincoln University

With most rivers and groundwater resources in New Zealand fully or over-allocated, there is a pressing need for water resource management that safeguard ecosystem requirements while meeting growing demands from agriculture, industry, cultural and recreational activities, and domestic use. In summer, irrigation accounts for approximately 80% of consumptive water use. To support efficient water management, we developed a web-based tool that enhances usability of ESNZ's irrigation demand model, IrriSET. The tool enables users to dynamically assess crop water requirements at plot or catchment scale, based on unique combinations of soil type, weather data, crop type, and crop management practices (e.g., planting and harvesting dates, irrigation strategy). It integrates four components: (1) Pre-processing – GIS operations to divide the study area into unique combinations; (2) Modelling – adjustable setups (e.g., simulation period) and parameters (e.g., soil type, crop type); (3) Visualisation – interactive display of inputs and outputs, such as rainfall, irrigation, drainage, and soil water; and (4) Automated reporting – user-friendly reports with figu es, tables, and narratives, integrated with a generative AI platform. The tool has been successfully tested in both New Zealand and Fiji, demonstrating its adaptability for diverse agricultural and climatic contexts.

UPDATE ON CLIMATE CHANGE IMPACT ON RIVERINE FLOODING INVESTIGATIONS UNDER CMIP6

Wybrig, Bakker[1], Christian Zammit,[1]

[1] Earth Sciences New Zealand

Aims

Flooding is the most frequent weather related natural hazard in New Zealand. As climate change intensifies rainfall extremes, the frequency and magnitude of floods are expected to increase and result in larger economic, environmental and cultural losses. However, uncertainties remain regarding how flood extremes will evolve under warming climate.

New Zealand's most recent hydrological projections were published in 2020 (Collins 2020). These were based on the Coupled Model Intercomparison Project version 5 (CMIP5) climate projections, downscaled for New Zealand (using a six-member Global Circulation Model (GCM) ensemble) (Ministry for the Environment 2018). At the time, climate change impacts on floods were represented by change in Mean Annual Flood metrics, and no guidance was provided in regards of change in flood magnitude for less frequent return periods.

The release in June 2024 of the CMIP6 climate projections (derived from the six members GCM ensemble) reflects several significant science and modelling advances compared to the CMIP5 projections. Among those is the ability of those projections to help characterise change in future riverine flood risk. Leveraging work completed as part of the Ministry for the Environment funded "Pilot CMIP5-CMIP6 hydrological projections intercomparison study "(Zammit et al, 2024), the project aims to characterise change in riverine flood magnitude for 15 headwater catchments in New Zealand. Application of the methodology to larger North-Island catchments (Uawa River (Gisborne District Council), Esk River and Wairoa River (Hawkes Bay Regional Council) and Wairoa River (Northland Regional Council)) will be discussed as part of the presentation.

Method

15 representative natural surface water catchments (one per administrative region) were defined as test catchments using Booker and Woods (2014) natural flow station dataset. Hydrological simulations were performed using one version of the surface water models within the New Zealand Water Modelling Framework (NZWaM, Zammit et al submitted). The model is referred as the nationally parameterised TopNet-KI model, developed as part of Mā te Haumaru ō te Wai project, which is conceptually Earth Sciences New Zealand's national flood awareness system model (NFAS) (Cattoën et al. 2022) bit which incorporates an improved parameterisation of infiltration excess processes.

A simple bias correction of the climate-hydrology modelling chain was developed to match observed annual daily flood frequency generated over the period 1995-2014. The simple correction method enables potential application at ungauged locations using New Zealand's most recent Flood Frequency Tool (Henderson et al. 2018).

A three parameter General Extreme Value analysis (GEV) was completed at each sites using stationary and non-stationary assumptions to assess how flood frequency is expected to change through time under warming. As part of the analysis the non-stationarity is represented as a linear relationship with the air temperature.

Results

The simple bias correction was found to perform adequately across all locations for return periods up to 1:20years Annual Recurrence Interval (ARI). Extrapolation of the Flood Frequency to less frequent events (i.e. up to 1:100 year) was found to be satisfactory for most of the locations considered and GCM driven historical simulations (see Figure 1).

Intercomparison with water resource bias correction developed as part of the project “Pilot CMIP5-CMIP6 hydrological projections intercomparison study “(Zammit et al, 2024), indicates that flood metrics representation is improved.

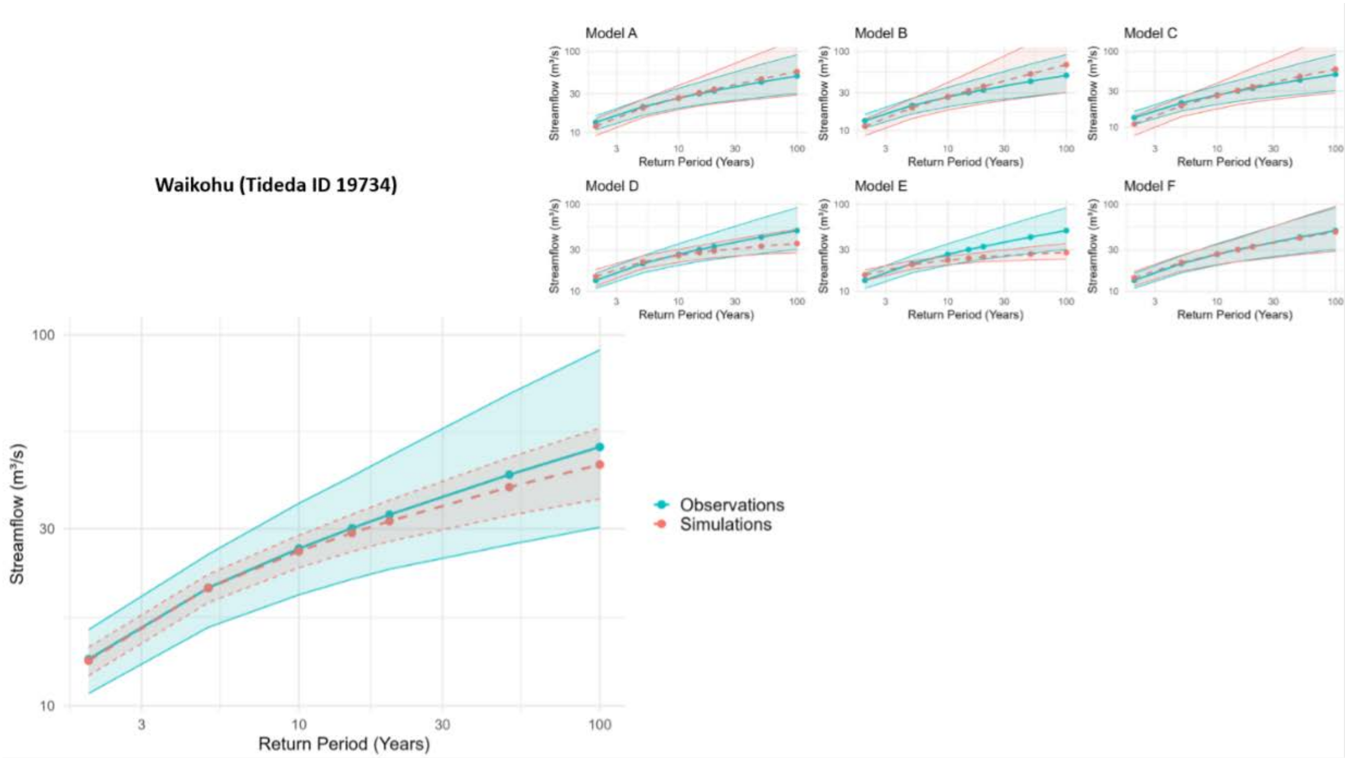


Figure1: Intercomparison of the observed and simulated annual daily flood frequency for Waikohu streamflow gauging station. Intercomparison is provided for each GCM driven historical simulations and pooled historical simualtions.

GEV analysis indicates that non-stationary GEV models generally perform better at representing the distribution of the magnitude of annual floods under warming scenarios. Specifically, the location and scale parameters exhibit a linear relationship with air temperature. This is not the case for the shape parameter, as non-stationary GEV models using constant shape parameter outperformed non-stationary and stationary GEV models. However, it is important to note that the value of the shape parameter can vary by up to 100% through time and warming scenario.

References

Bakker, W. (2025) Characterisation of climate change impacts on flood metrics in New Zealand. MSc internship report. Hydrology and Environmental Hydraulic Group, Wageningen University & Research

Booker, D. J., and Woods, R. A. (2014) Comparing and combining physically-based and empirically-based approaches for estimating the hydrology of ungauged catchments. J. Hydrol., vol. 508, pp 227-239. http://dx.doi/org/10.1016/j.hydrol.2013.11.007

Cattoën, C., Conway, J., Fedaeff, N., Lagrava, D., Blackett, P., Montgomery, K., Shankar, U., Carey-Smith, T., Moore, S., Mari, A., Steinmetz, T., Dean, S. (2022). A national flood awareness system for ungauged catchments in complex topography: The case of development, communication and evaluation in New Zealand. Journal of Flood Risk Management https://doi.org/10.1111/jfr3.12864

Collins, D. 2020. New Zealand river hydrology under late 21rst century climate change. Water, 12, 2175; doi:10.3390/w12082175

Henderson, R.D., Collins, D.B.G., Doyle, M., Watson, J. (2018) Regional Flood Estimation Tool for New Zealand Final Report Part 2. NIWA Client Report, 2018177CH for Envirolink Tools (MBIE): 44.

Zammit, C., Gibson, P., Shiona, H., Ren, J. (2024) Pilot CMIP5-CMIP6 hydrological projections intercomparison study. NIWA report 2024323CH prepared for Ministry for the Environment.

Zammit, C., Griffiths, J. A., Larned, S. , Lin, Y-J. , Shankar, U., Wilkins, M. , Yang, J., Porhemmat, R., Dudley, B., Walter, K.,, Rajanayaka, C., Kees, L., Kitlasten, W., Taves, M., Westerhoff, R. and Lilburne, L. Hydrological modular modelling framework for water management in Aotearoa New Zealand. Submitted to Water Resource Research (May 2025)