OCTOBER 2021 (NEWSLETTER III)

TE WHAKAHEKE O TE WAI

A quarterly newsletter for stakeholders of the TWOTW Research Programme

Blue Spring, Waihou River (Mereana Wilson-Rooy, GNS Science)

FROM THE PROGRAMME LEADERS

Catherine Moore and Uwe Morgenstern

Kia ora and welcome to our third update for the TWOTW research programme. The aim of this update is to keep our stakeholders and collaborators informed of project progress and activities being undertaken.

In this newsletter we highlight the progress made on the numerical and statistical approaches being used in the national groundwater age model development. We've also made significant progress across the modelling and mātauranga components of the programme. The interweaving of mātauranga Māori, community observations, historical resources, and groundwater tracer data in the Bridge Pa case study is also progressing well. This will allow a better appreciation of the value of combining indigenous knowledge with western science, in terms of how it can be used to reduce predictive uncertainty. These work streams are discussed in more detail in this newsletter and much of this work is also being presented at this year's annual Hydrological Society Conference.

Over the last months, our water age and chemistry tracer work focused on assessment of regional data sets to provide understanding of groundwater dynamics and hydrochemical evolution on regional scales. We've completed the West Coast region and the Tasman and Gisborne regions are almost finished, with their data sets and age interpretation finalised. We are currently working with GWRC to collect samples throughout the Greater Wellington region to fill knowledge gaps not covered by historic data sets.

Thank you for all your support for this project so far. We are looking forward to sharing and discussing more of this emerging science with you.

Ngā mihi, Cath and Uwe.

METAMODELLING

[Conny Tschritter, Sapthala Karalliyadda, and Brioch Hemmings]

A metamodel is a surrogate model of a model. The metamodeling workstream in this project describes the development, testing and deployment of data-driven modelling workflows that draw on statistical relationships between observable and estimable predictor variables and (tracer/model- derived) estimations of groundwater age (responses). Our approach uses Gradient Boosted Regression (GBR), machine-learning algorithms to tease out these relationships and propagate to predictions of age, where only the predictor variables are available (i.e. no age model exists). We are exploring the application of these techniques using predictor variables with different data availability and coverage. These are chemical analytes and hydrophysical parameters.

The prediction of groundwater age distributions from sampled chemical analytes have shown promise. This is consistent with similar results using an alternative symbolic regression metamodeling approach (Daughney, 2020). Both methods are able to establish reasonable relationships between some components of groundwater chemistry and groundwater age, and support prediction of age distributions at other locations. However, the widespread use of a metamodel that relies on chemical analyte measurements may be limited by the relative sparsity of analyte sampling, particularly in previously under-studied systems.

Hydrophysical parameters include, relative location within a catchment, sampling depth (e.g. bore depth, screen depth), distance to streams, and even estimates of water table elevation and aquifer thickness. These hydrophysical metamodels are still limited by the availability of groundwater age estimates. However, they benefit from the availability of a larger training dataset and significantly greater potential predictive coverage. This is because many of the parameters are mappable from nationally and regionally available geographical information system (GIS) databases. Consequently, the hydrophysical parameter metamodels have the potential to support rapid and dense prediction of groundwater age distributions with inter-regional and national coverage.

Daughney C.J., and Morgenstern U, 2020. Use of symbolic regression to estimate groundwater age distributions from hydrochemistry, Heretaunga Plains. NZHS Conference 1-4 December 2020, Invercargill.

VISION MATAURANGA

[Amber Aranui]

Recently the focus of this workstream has been on gleaning information from the May/June 'TANK' (Tūtaekurī, Ahuriri, Ngaruroro and Karamū Catchments) hearings, Hawke's Bay. In particular, the team are focussed on gaining a better understanding from the community on the issues being faced in locations such as Bridge Pā, Omahu, and Pakipaki. Amber has also been focusing on collecting information around the changing environment based on community observations over time. These include aerial photographs, weather events (such as droughts and floods over time), and historically recorded changes. These observations have been able to provide important information for this project regarding hydrology of the Heretaunga Plains.

NATIONAL MODELLING

[Wes Kitlasten]

The national modelling component of TWOTW is developing national scale groundwater models using MODFLOW 6. These models incorporate nationally consistent datasets and are designed to incorporate uncertainty in hydraulic properties, boundary conditions, and inputs. These models provide a consistent starting point for finer scale models designed to address specific questions in areas around the country. Information gained from these finer scale models can be used to inform the national scale model and/or finer scale models in areas with sparse data.

For example, a finer scale model of the Wairau watershed was recently constructed from the national model and over 200 tritium observations collected over 60 years were used for parameter estimation through history matching. Tritium concentrations were calculated from travel times simulated by MODPATH. The Wairau model history matching processing revealed that models with relatively coarse resolution can still replicate the measured tritium data, provided the locations of the tritium data are represented at a finer scale and uncertainty in their exact location is considered. This insight will greatly reduce the computational burden associated with assimilating groundwater age data at the national scale.

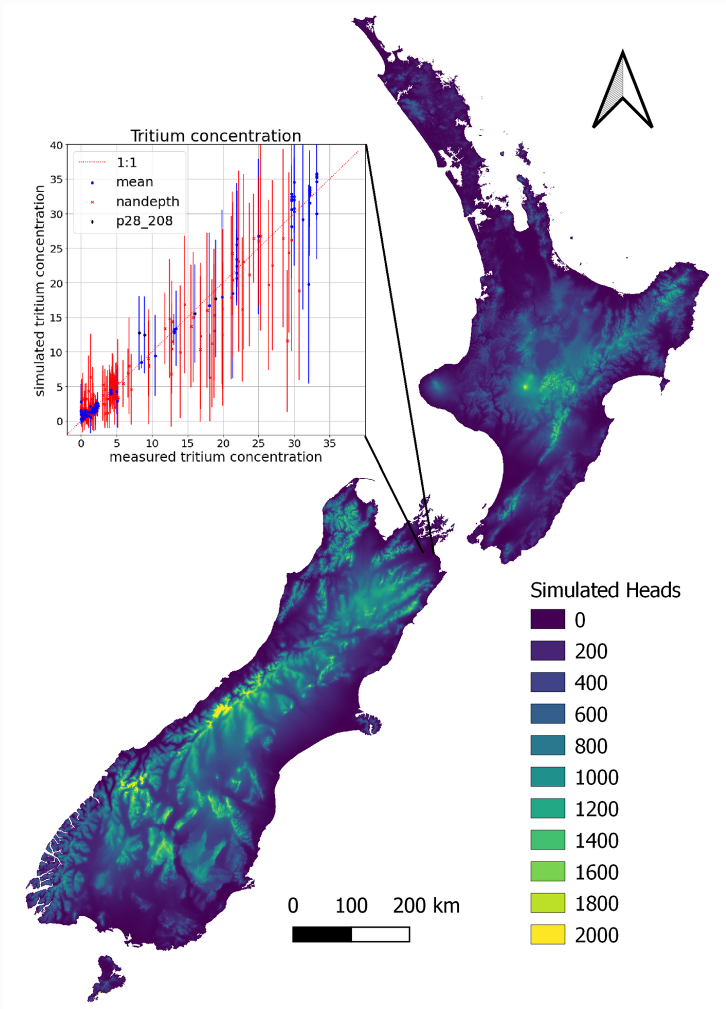

Figure 1: National MODFLOW 6 Groundwater Model" and/or "National Groundwater Model used to Simulate Tritium in the Wairau Watershed,

Recent work in the national modelling component includes:

- addition of a surface water network to simulate surface water-groundwater interactions
- ability to represent observation locations more precisely in MODPATH
- calculation of water age based on simulated particle travel times
- history matching to tritium data using a highly parameterized watershed scale model.

INTRODUCING OUR TEAM

Each newsletter we will be gradually introducing you members of our team so that you can get to know us better. This quarter we will introduce members of the meta-modelling team. See below for more information on Conny, Brioch, and Sapi.

Constanze Tschritter: Conny is a senior groundwater scientist who has been with GNS Science for 12 years, based in Taupo. She is leading GNS' groundwater Strategic Science Investment Funding research programme. Her main research interests include hydrogeological and geological data analysis, 3D modelling and visualisation; machine learning; and remote sensing for hydrogeological applications. In the Te Whakaheke o te Wai programme, Conny is working together with Brioch and Sapi on the Metamodelling workstream.

Brioch Hemmings: Brioch is a groundwater modeller with a background in geophysics and volcanology. His work focus is on the construction and application of highly parameterised groundwater models to provide water resource and land-use management decision-support. This involves development and deployment of state-of-the-art numerical techniques for model uncertainty quantification and data assimilation for real-world management problems.

Sapthala Karalliyadda: Sapi is a research data scientist with a geophysics background. She is part of the Artificial Intelligence (AI) and Advanced Analytics Team at GNS Science and provides research groups across GNS Science with data driven solutions to geoscience research problems. Sapi's current research focuses on application of machine learning/deep learning algorithms for predictive modelling, such as boosting machines, CNN, and surrogate modelling.

TWOTW PROGRAMME SUMMARY

The Te Whakaheke o Te Wai (TWOTW) is a five-year research programme funded by MBIE's Endeavour Fund and led by GNS Science. Multiple national and international organisations and stakeholders are involved in the collaboration. Primary collaborators of the research programme include NIWA, ESR, Te Tai Whenua O Heretaunga, Victoria University of Wellington, and Watermark Numerical Computing. Hawke's Bay Regional Council support the major case study area, the Heretaunga Plains. Other regional councils and other organisations also contribute to the research project, including with co-funding.

The TWOTW programme aims to better support water management based on improved understanding and integration of flow sources, pathways, water travel time, and cultural knowledge and values in New Zealand. The research is underpinned by the concept and defining of 'Te Whakaheke o Te Wai' of groundwater throughout the main catchments and aquifers in New Zealand. The 'Te Whakaheke o Te Wai' of groundwater - our largest freshwater resource - is largely unknown, yet stakeholders recognise that this knowledge is urgently needed to protect and sustainably manage groundwater and the rivers and streams it feeds. Outputs from this research are to provide decision-makers with much needed knowledge for improved water management at national, catchment, and local scales. Outputs from the research will be publicly available and benefit people and institutions involved in water management.

The programme is currently developing the world's first nationally continuous maps of groundwater age, origin and flow paths. A technical foundation of the research project is the development of new modelling technologies. This project builds on the current knowledge and implementation of data assimilation and uncertainty quantification commonly expected and often required in modelling projects. This research is evolving modelling capability from simply understanding uncertainty (which is now generally accepted in modelling), to the design of novel models with an ability to reduce that uncertainty. This includes combining mātauranga Māori and mōhiotanga Māori with aquifer models to reduce this uncertainty. This is a unique combination of western science and indigenous knowledge that demonstrates the importance of combining the two knowledge systems. New stochastic approaches for source protection zone modelling (SPZ) are also being developed.