The New Zealand Water Model Isotopic Data Layers

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Introduction

The New Zealand Water Model Hydrology Project (NZWaM-Hydro) aims to develop hydrological understanding across the New Zealand landscape with a combination of data on surface water, soil, subsurface (geology), and groundwater. As part of this project GNS and NIWA are collecting tritium and stable isotope data from three test catchments in the Southland, Horizons, and Gisborne regions. The work aims to refine isotopic data layers to make them applicable for studies that estimate groundwater – surface water interaction at the catchment-scale.

Method

Sampling objectives are to capture seasonal and geographical variations in 1) stable isotope compositions (rainfall and river sites) to inform catchment transit times to surface waters; 2) tritium input to groundwater (river samples) to acquire data for use as a calibration target for the water age modelling.

Collection of both stable isotope and tritium data will enable the model to link relatively young and old water components. Both stable isotopes and tritium can be used to estimate transit time distributions in catchments by transforming input series of tracer concentrations in the recharge to match measured output concentrations in the stream. Faster and slower components in the catchment can be ascertained by the separate residence time distribution estimates from the different tracers.

Site Selection

Three catchment-scale case studies were selected to cover a range of hydrological (streamflow) data availability.

- A catchment with a relative data abundance (upper to mid-Mataura catchment in Southland; Figure 1).
- A catchment with a relative data shortage (Porewa stream catchment in the Horizons region; Figure 7).
- A catchment with limited data available (Taruheru catchment in Gisborne).

Data from the first two catchments are shown in this poster. Data collection for the Taruheru is ongoing.

Data collection

Monthly composite samples were collected from rainfall sites (Figures 6, 20-21) and monthly grab samples collected for river sites (Figures 2-5).

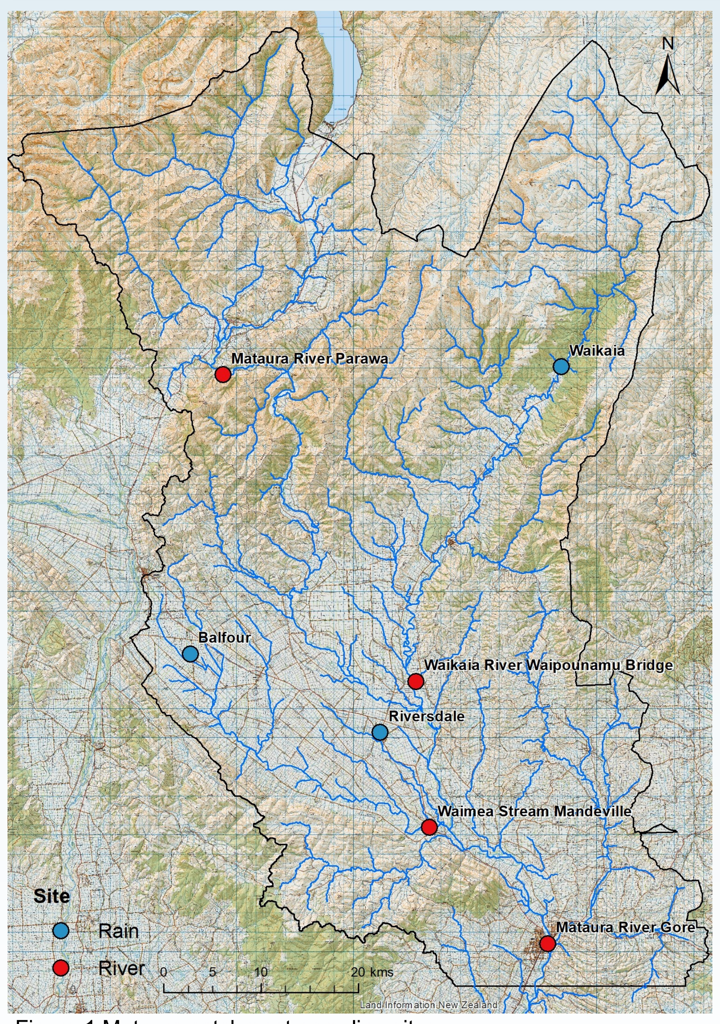

Figure 1 Mataura catchment sampling sites

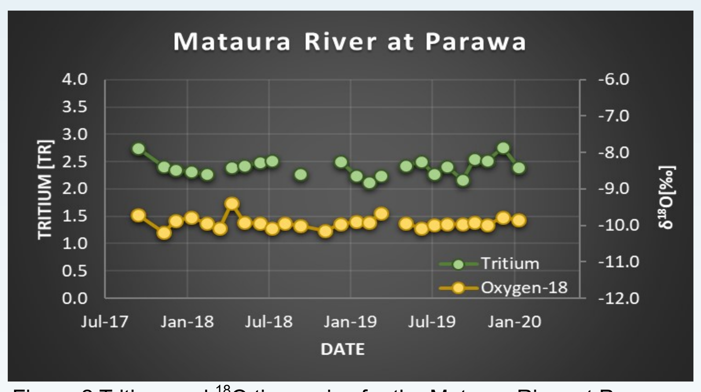

Figure 2 Tritium and ^{18}O timeseries for the Mataura River at Parawa.

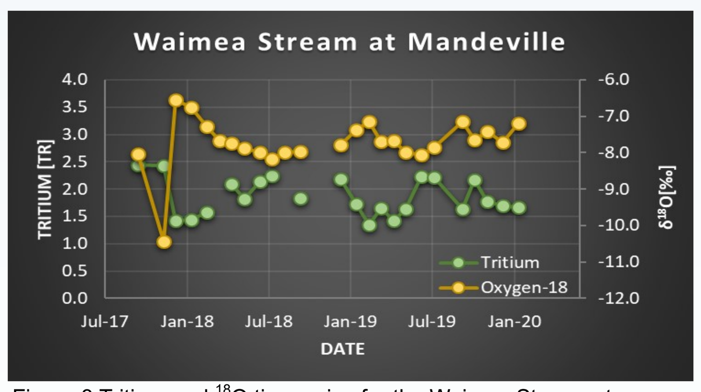

Figure 3 Tritium and ^{18}O timeseries for the Waimea Stream at Mandeville.


Figure 6. Stable isotope rain collector installed at Tututotara, Porewa.

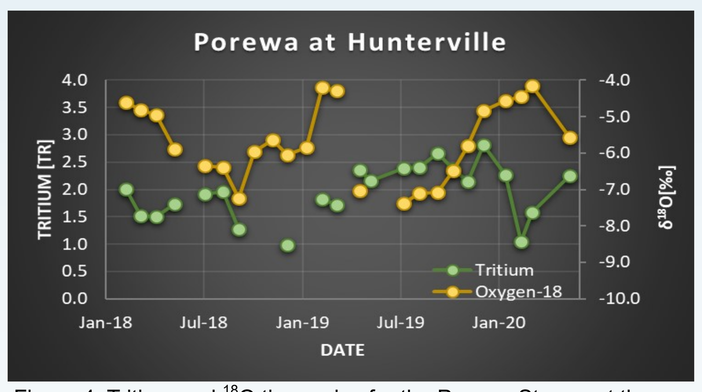

Figure 4. Tritium and ^{18}O timeseries for the Porewa Stream at the U/S Hunterville site.

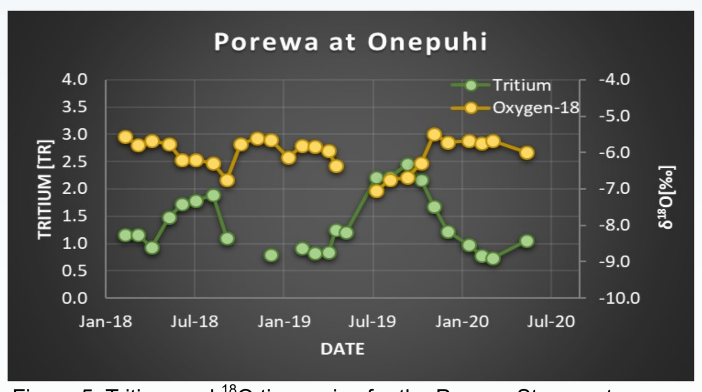

Figure 5. Tritium and ^{18}O timeseries for the Porewa Stream at Onepuhi Road.

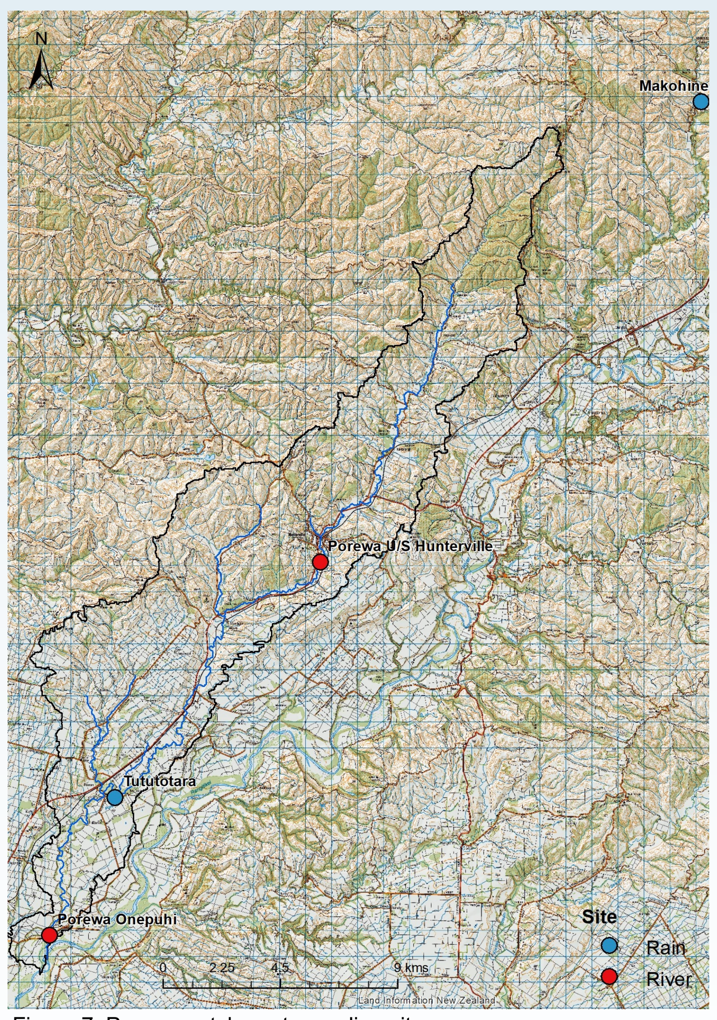

Figure 7. Porewa catchment sampling sites

Mataura Catchment, Southland

The Mataura catchment is the Southland region's second largest catchment, covering an area of 5400 km^2. Its main tributary is the Waikaia River, which joins the Mataura river east of Riversdale and contributes about half of the Mataura River flow. Extensive interaction (alternating losing and gaining reaches) occurs between the river and deposits along the riparian margin of both the Waikaia and Mataura Rivers, and between the river and alluvial gravel aquifers underlying the Mataura River. Rainfall over the catchment varies from 1000 mm/year in the upper catchment to less than 800 mm/year around Riversdale (mid-Mataura), increasing again to about 1150 mm/year in the lower coastal catchment area. The Mataura River median flow is roughly 70 m^3/s in its lower reaches.

Age of groundwater influxes into surface water

Tritium (^{3}H) is a component of the water molecule and thus forms an ideal tracer for surface and groundwater studies. Age-dating using tritium is based on radioactive decay of tritium after rainwater penetrates the ground during recharge. The half-life of tritium is 12.32 years. River waters and groundwater outflows such as springs are comprised of a mixture of water of different ages due to mixing of water from different length underground flow paths. Therefore, the water doesn't have a discrete age but has an age distribution. Mean residence times (MRT) are derived from tritium concentrations via lumped parameter models such as the exponential piston flow model [1].

Tritium concentrations, and thus the age of the water, show a relationship with stream flow in both catchments (Figures 8,10,13,15).

- In the Porewa catchment the mean residence time of the stream water in the upper reaches (Hunterville) is relatively young (<2 years) while the lower reach of the stream is dominated by influx of older groundwater at times of low flow (Figure 11). This relationship may have an effect on stream water quality, with higher conductivity in the older water (Figure 12).
- River water in the upper Mataura catchment is also dominated by younger water less than 2 years old, while in the Waimea Stream sub-catchment, the mean residence time varies with stream flow (Figure 16).

Porewa Catchment, Horizons

The Porewa Stream is a tributary of the Rangitikei River, covering an area of 153.7 km^2 and an elevation range from 600 m (north) to 100 m (south) above mean sea level. Rainfall over the catchment is approximately 1000 mm/year and mean flow is 130 L/s (10 year period) at Porewa at the "u/s Hunterville STP" site.

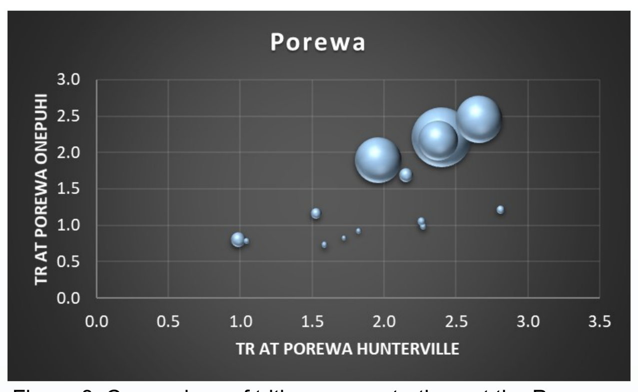

Figure 8. Comparison of tritium concentrations at the Porewa Stream sites. Points are weighted by stream flow.

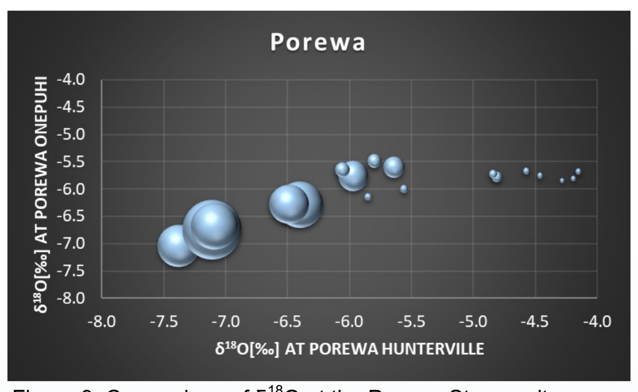

Figure 9. Comparison of δ^{18}O at the Porewa Stream sites. Points are weighted by stream flow.

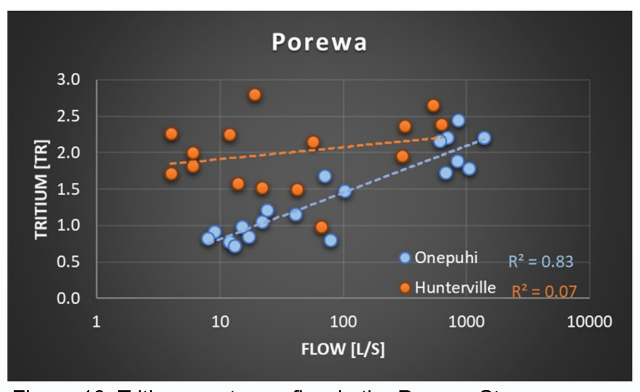

Figure 10. Tritium vs stream flow in the Porewa Stream.

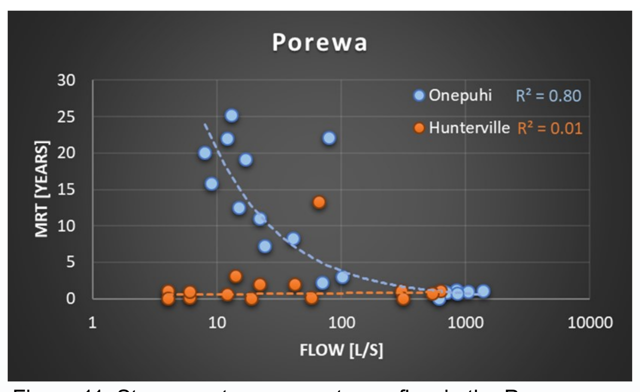

Figure 11. Stream water age vs stream flow in the Porewa Stream.

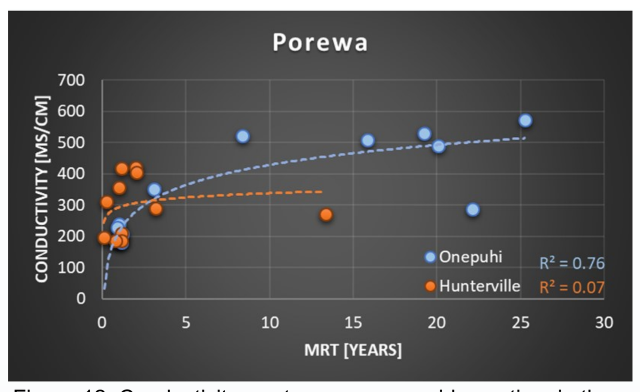

Figure 12. Conductivity vs stream mean residence time in the Porewa Stream.

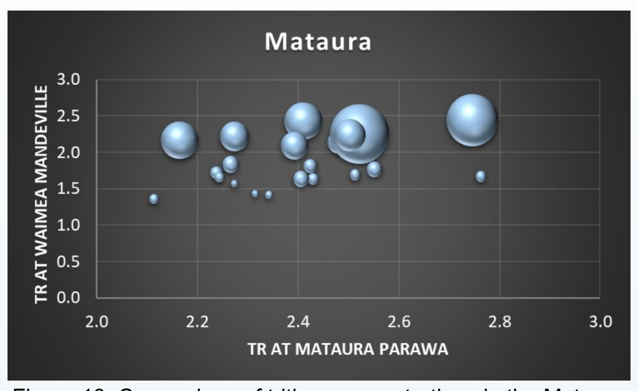

Figure 13. Comparison of tritium concentrations in the Mataura River and Waimea Stream. Points are weighted by stream flow data for the Waimea Stream.

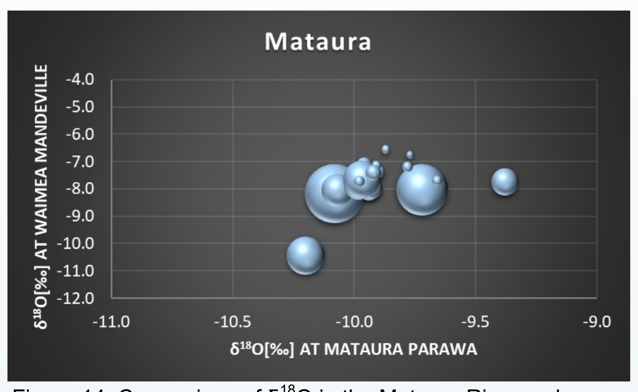

Figure 14. Comparison of δ^{18}O in the Mataura River and Waimea Stream. Points are weighted by stream flow data for the Waimea Stream.

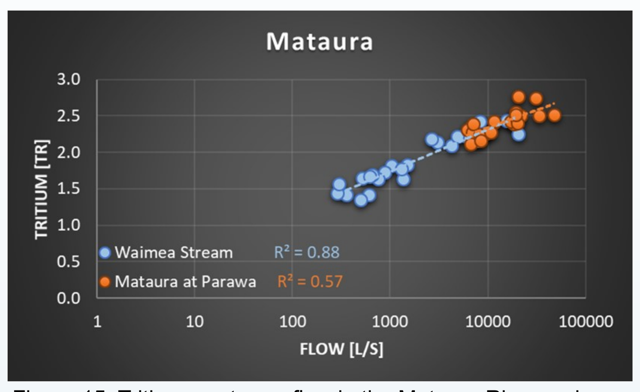

Figure 15. Tritium vs stream flow in the Mataura River and Waimea Stream. .

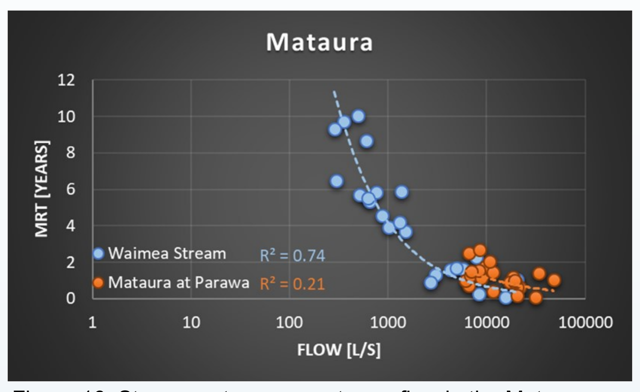

Figure 16. Stream water age vs stream flow in the Mataura River and Waimea Stream.

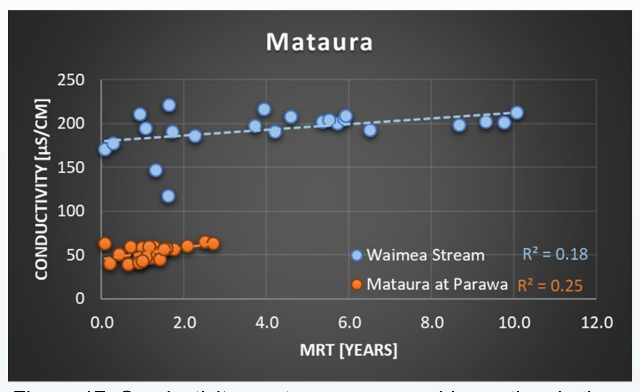

Figure 17. Conductivity vs stream mean residence time in the Mataura River and Waimea Stream.

Stable Isotopes

Precipitation has considerable seasonal variability in isotopic signature (Figures 20-23). During infiltration mixing processes such as dispersion and dispersion smooth out variations in δ values, such that the variability is considerably smoothed by the time it reaches the groundwater zone (Figures 2-5, 22-23). This dampening can be used to estimate the transit time distribution through the catchment [2].

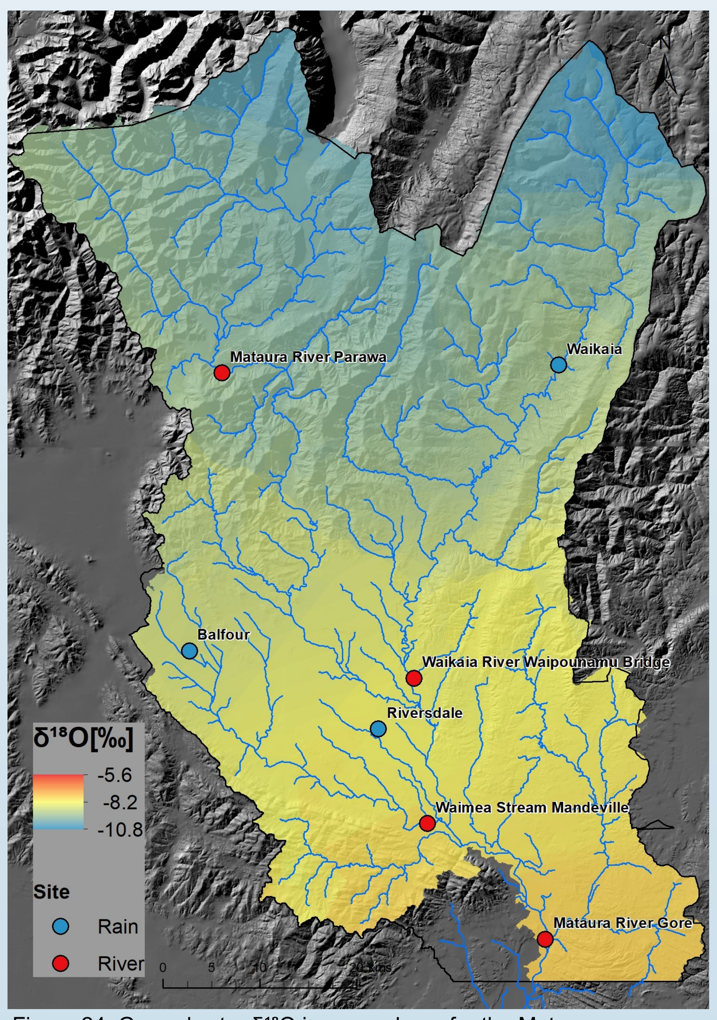

Figure 24. Groundwater δ^{18}O isoscape layer for the Mataura catchment.

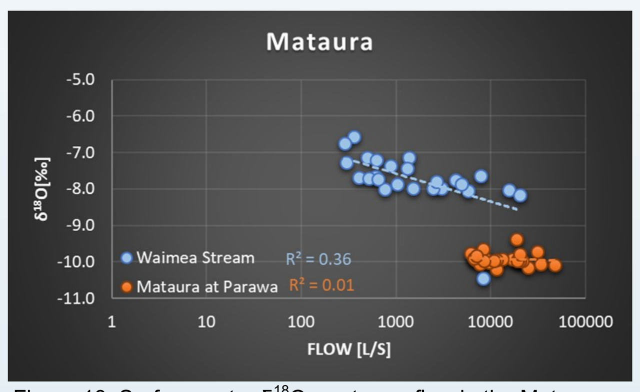

Figure 18. Surface water δ^{18}O vs stream flow in the Mataura River and Waimea Stream.

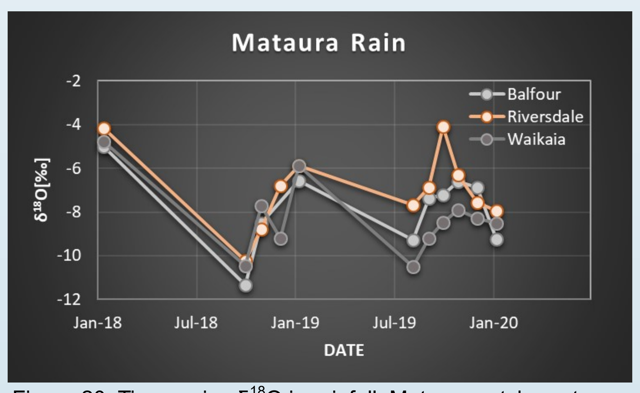

Figure 20. Time series δ^{18}O in rainfall, Mataura catchment.

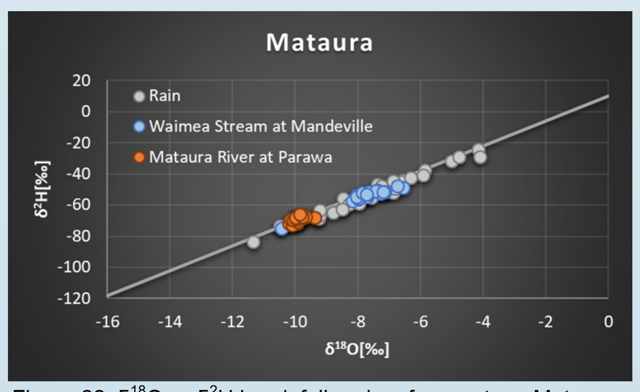

Figure 22. δ^{18}O vs δ^2H in rainfall and surface waters, Mataura catchment. The meteoric line is $\delta^2H = 8x\ \delta^{18}O+10$

Catchment scale isoscape GIS layers of groundwater stable isotope values have been created using historic data [3,4]. The isoscape layers can be used to predict average isotopic values for groundwater in the target catchments (Figures 24-25), allowing for comparison to the measured data.

While both the upper and lower Porewa catchment sites have isotopic values close to those expected for the catchment (Figure 25), there is greater variation observed at the upper Hunterville site (Figure 5), indicative of a high fraction of young water overall in streamflow at this site. The variation is related to both stream flow (Figure 19) and the seasonal variation observed in precipitation (Figure 21). At the Onepuhi site the variation is more muted reflecting the greater influence of older water at this site at low stream flows.

In the Mataura catchment surface water isotopic values reflect the difference between higher altitude (upper catchment) and lower altitude (mid-catchment) precipitation and groundwater values (Figure 24). The seasonal signal in the upper Mataura catchment is very dampened (Figure 2), indicating a well-mixed catchment reservoir contributing to the river flow.

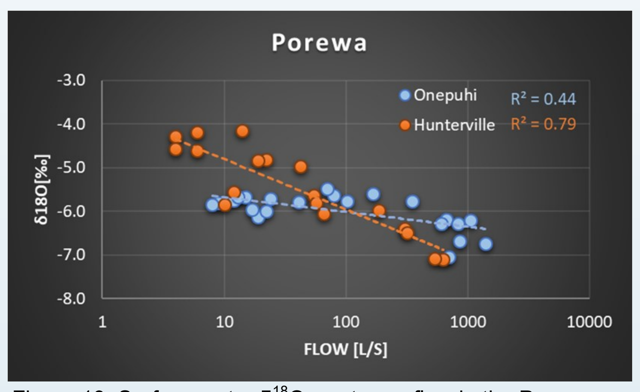

Figure 19. Surface water δ^{18}O vs stream flow in the Porewa Stream catchment.

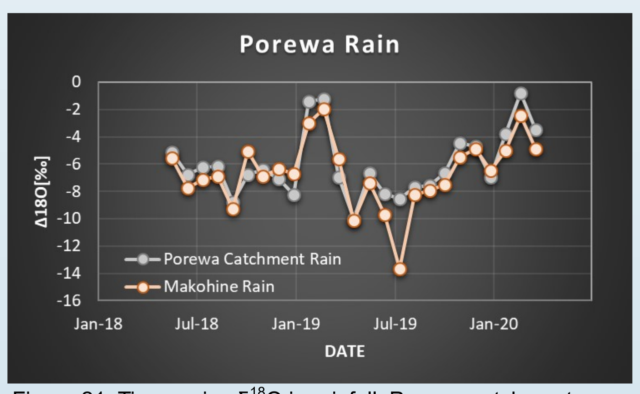

Figure 21. Time series δ^{18}O in rainfall, Porewa catchment.

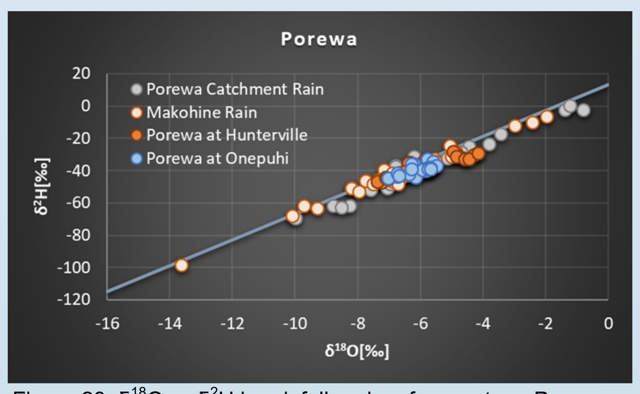

Figure 23. δ^{18}O vs δ^2H in rainfall and surface waters, Porewa catchment. The meteoric line is $\delta^2H = 8x\ \delta^{18}O+13$

In contrast the Waimea stream catchment shows greater variation (Figure 3), related to both the precipitation seasonal signal (Figure 20) and the influence of older groundwater inflow at low stream flows.

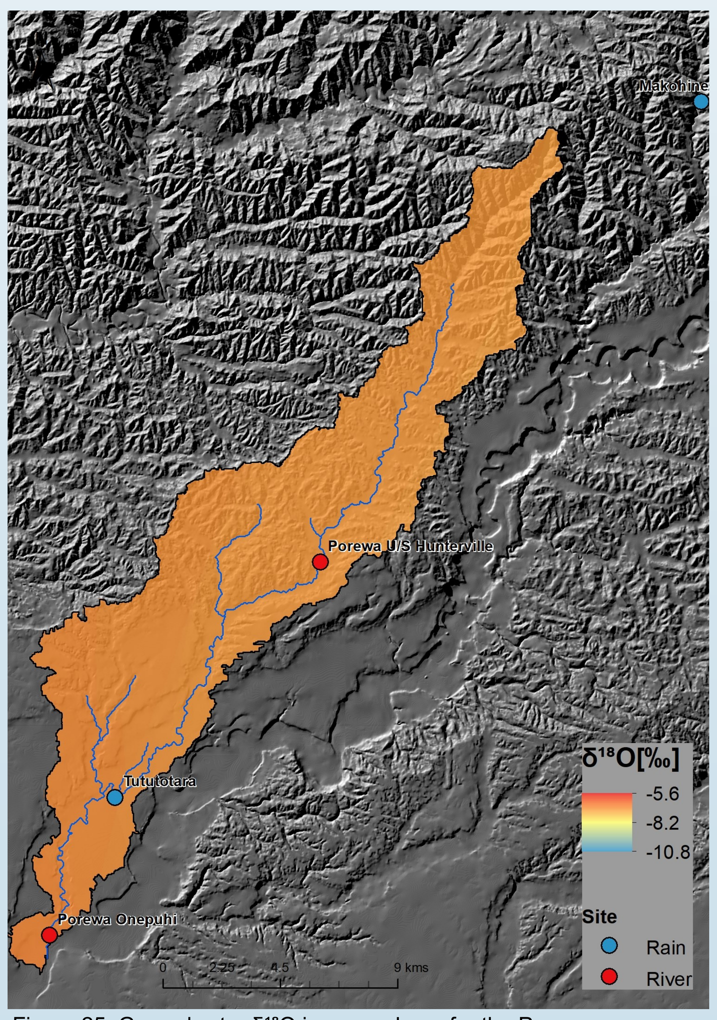

Figure 25. Groundwater δ^{18}O isoscape layer for the Porewa catchment.

References

1. Małoszewski P, Zuber A. 1982. Determining the turnover time of groundwater systems with the aid of environmental tracers. Journal of Hydrology. 57(3-4):207-231.
2. Stewart MK, McDonnell JJ. 1991. Modelling base flow soil water residence times from deuterium concentrations. Water Resources Research. 27(10):2681-2693.
3. van der Raaij, R.W.; Trompetter, V. 2019 Creating a groundwater isoscape for New Zealand. p. 171 IN: NZ Hydrological Society Conference 3-6 December 2019, Rotorua, NZ : oral abstracts. [Wellington, N.Z.]: New Zealand Hydrological Society
4. van der Raaij RW, Moreau MF, Westerhoff RS. 2018. The refinement of isotopic data layers for three catchment-scale studies in the Southland, Horizons, and Gisborne regions: activities between May 2017 and May 2018. Lower Hutt (NZ): GNS Science. p. (GNS Science report; 2018/18). doi:10.21420/G2R34G

NZ Hydrological Society, Rivers Group and Freshwater Science Society Joint Conference, Invercargill,1–4 December 2020