P corrections for Lake Tarawera Model & TLI Review
WQTAG 19 May 2020

Professor Troy Baisden

Bay of Plenty Regional Council Chair in Lake and Freshwater Science

and Chris McBride (Research Officer)

Lake Ecosystem Research New Zealand

@LakesProf
@NZLakes

@TroyBaisden
@NZLakes

Recap and Direction: Greater Lake Tarawera (*+ Rotorua)*

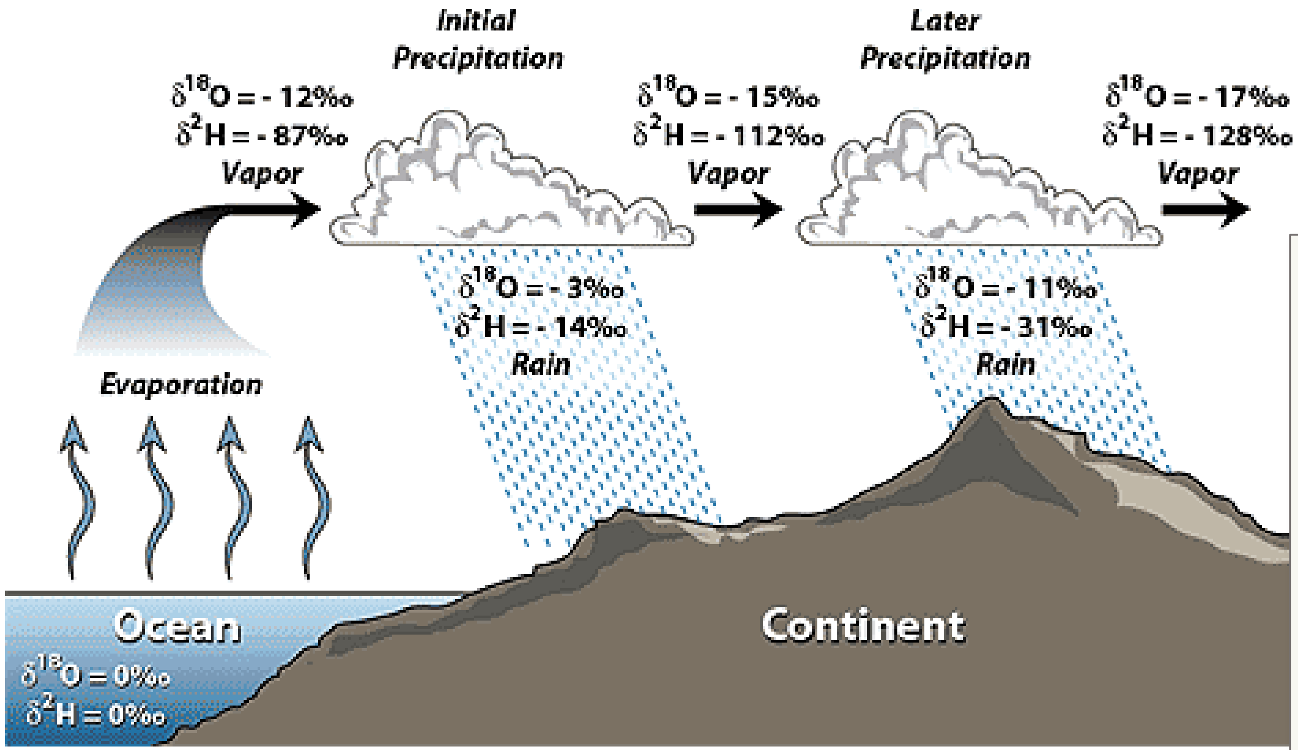
Interconnected catchments

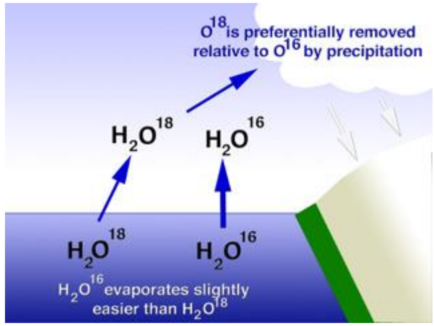
- Water budgets drive N & P loads to lakes
- Upstream lakes may be significant N & P sinks (attenuation)
- Need better constraints – fast.
- Water isotopes →

+ Rotorua

- 2022 and 2032 N reduction targets also have urgency

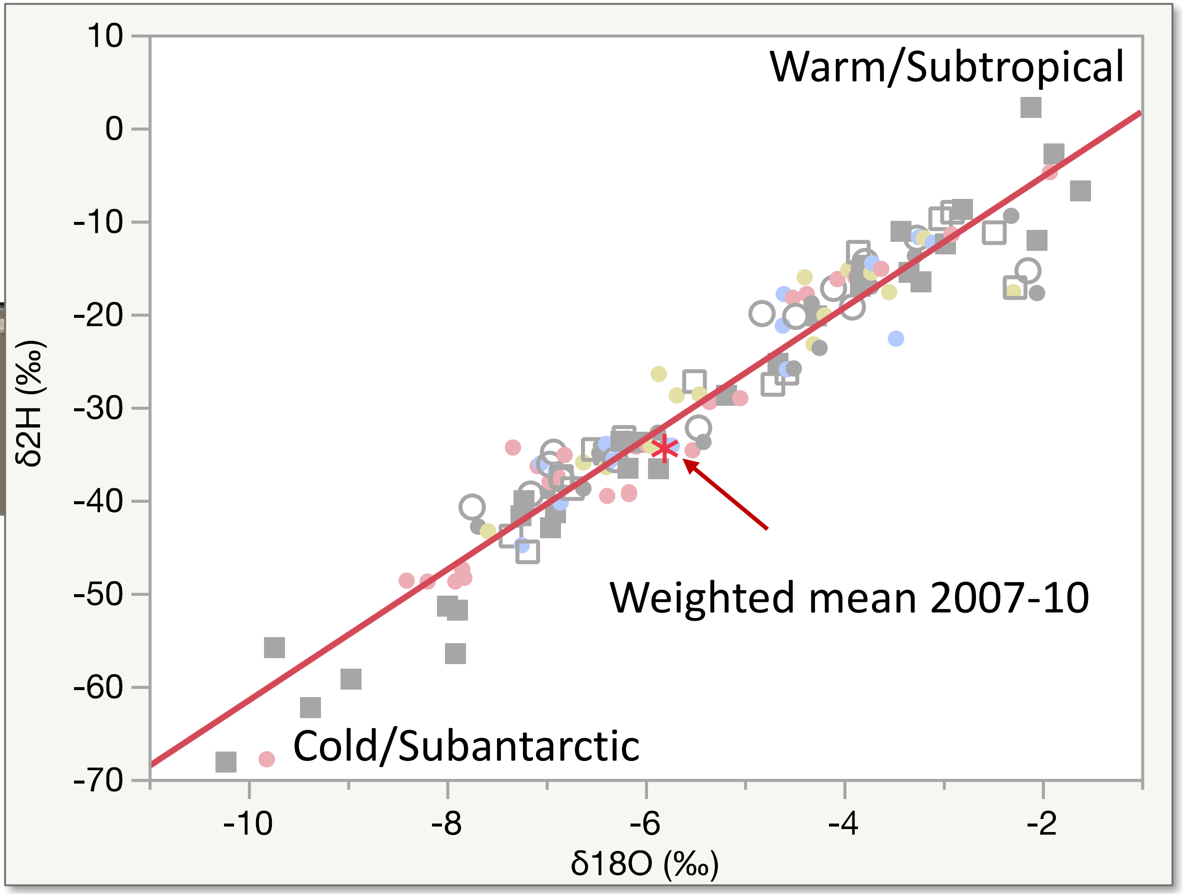
Water isotopes in rainfall:





Global: δ2H (‰) = 8 x δ18O + 10

Rotorua: δ2H (‰) = 7.03 x δ18O + 8.69



ISOTOPES IN ENVIRONMENTAL AND HEALTH STUDIES, 2016
http://dx.doi.org/10.1080/10256016.2016.1153472

Taylor & Francis
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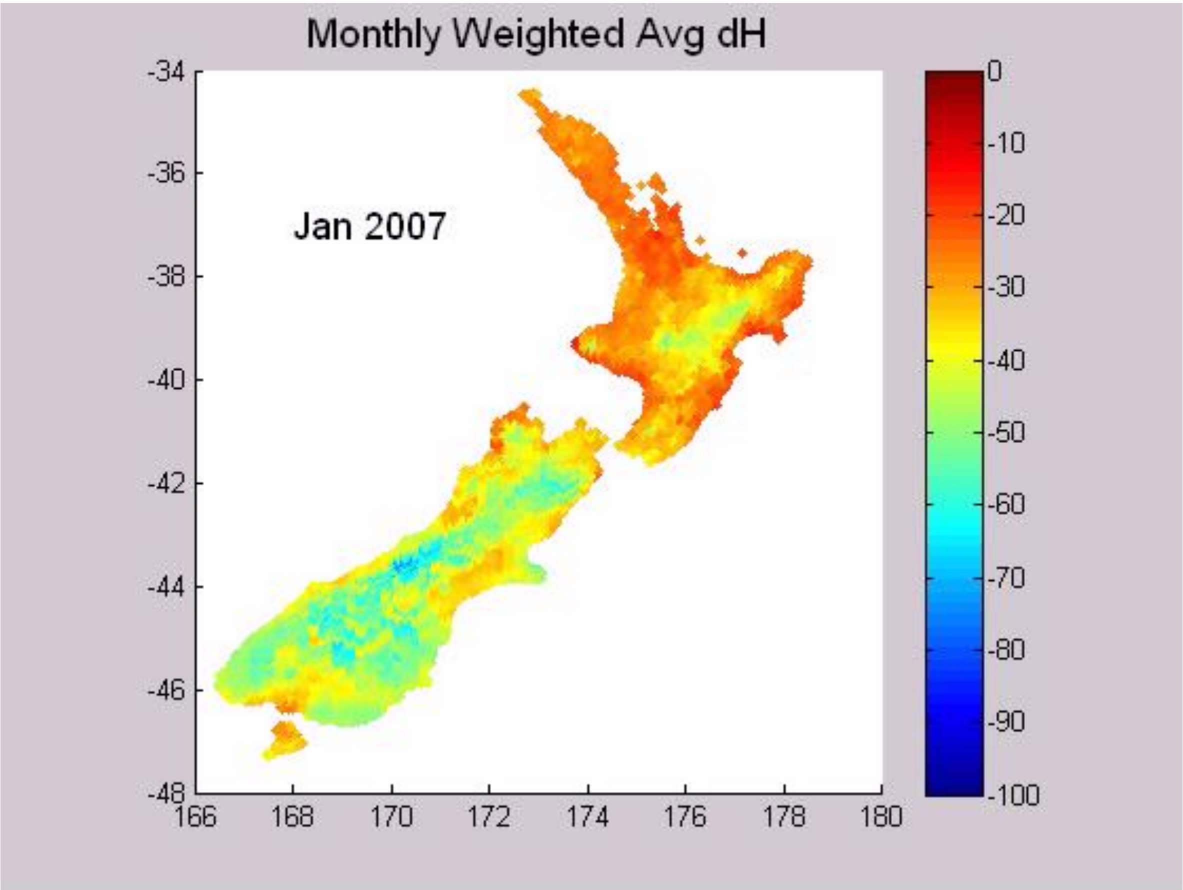
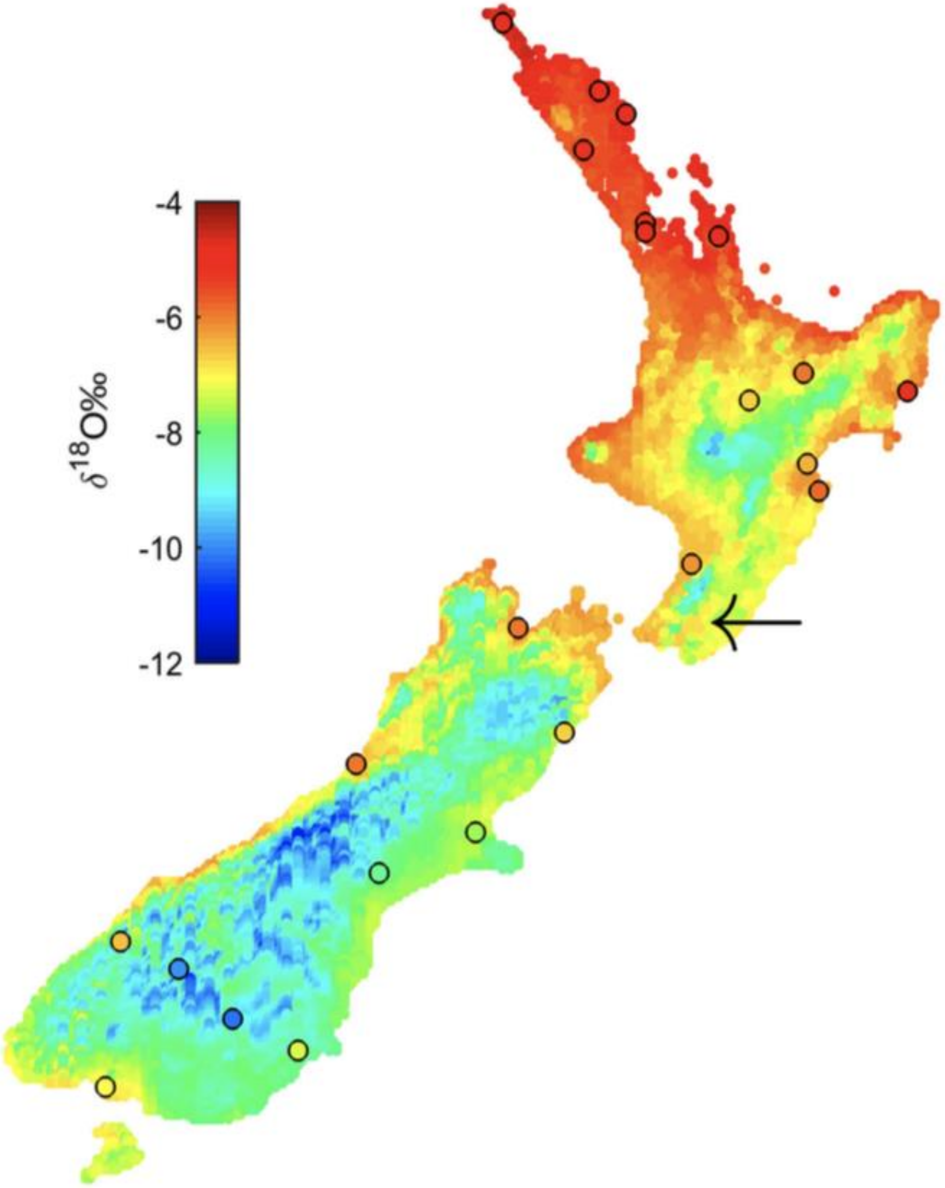
Precipitation isoscapes for New Zealand: enhanced temporal detail using precipitation-weighted daily climatology†

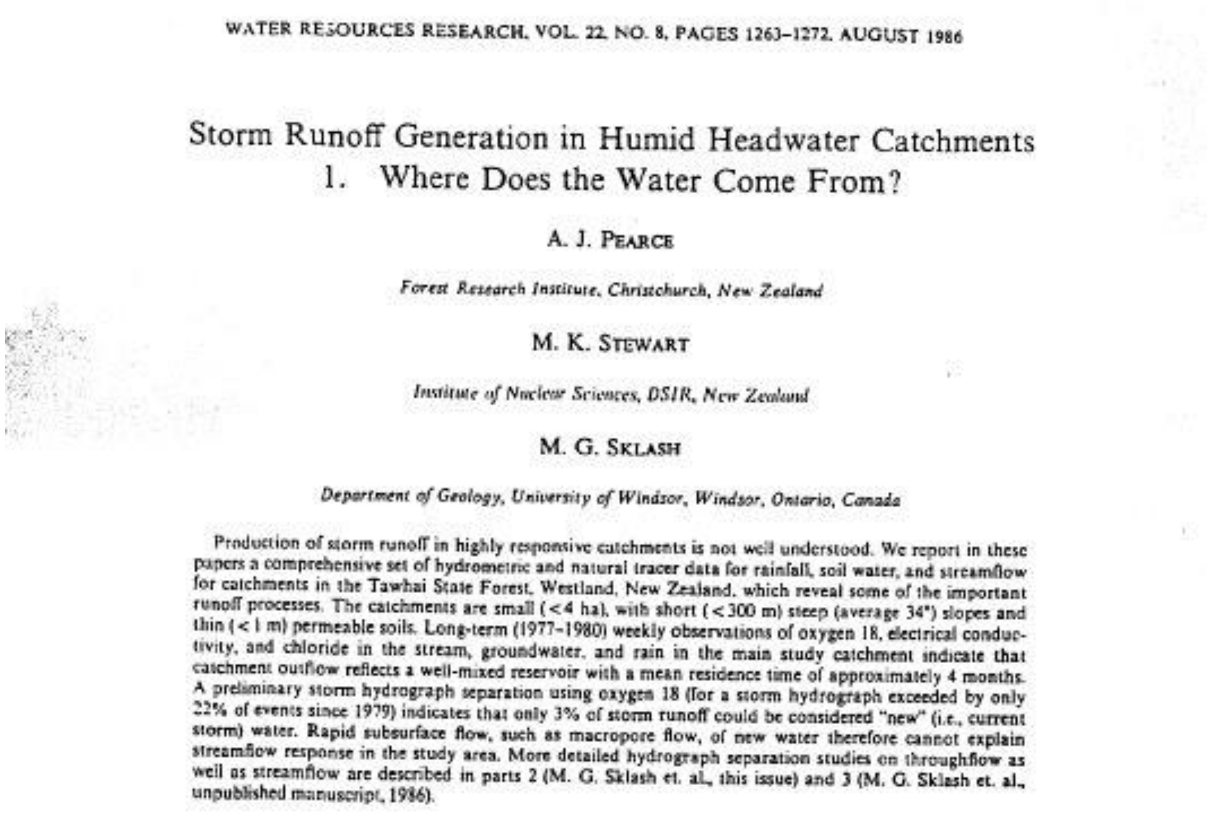
W. Troy Baisden[a], Elizabeth D. Keller[a], Robert Van Hale[b], Russell D. Frew[b] and Leonard I. Wassenaar[c]

[a]National Isotope Centre, GNS Science, Lower Hutt, New Zealand; [b]Department of Chemistry, Otago University, Dunedin, New Zealand; [c]Isotope Hydrology Laboratory, International Atomic Energy Agency, Vienna, Austria





Catchments respond quickly with old water … ?
And variable solute chemistry?



WATER RESOURCES RESEARCH, VOL. 22, NO. 8, PAGES 1263–1272, AUGUST 1986

Storm Runoff Generation in Humid Headwater Catchments
1. Where Does the Water Come From?

A. J. PEARCE

Forest Research Institute, Christchurch, New Zealand

M. K. STEWART

Institute of Nuclear Sciences, DSIR, New Zealand

M. G. SKLASH

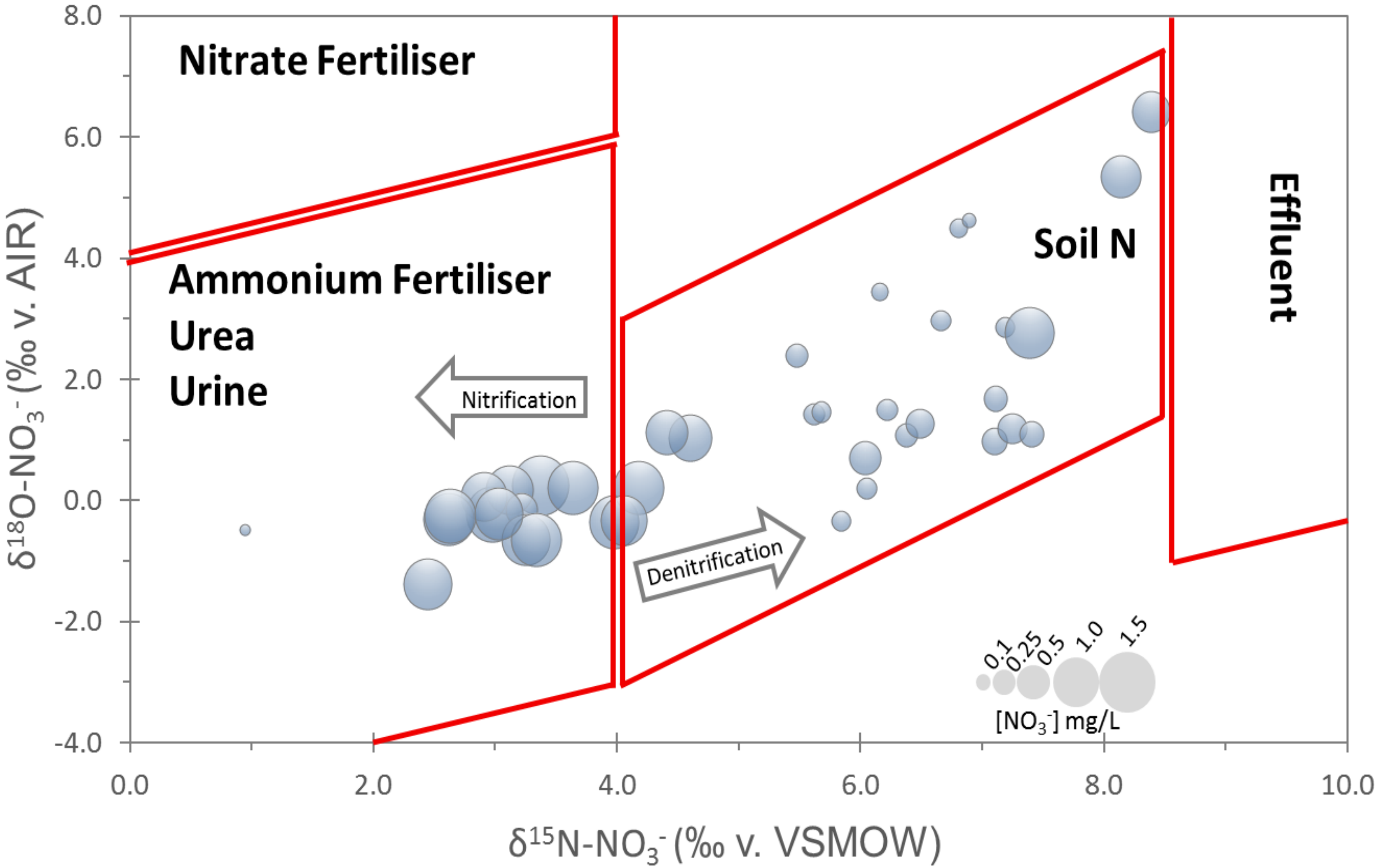
Department of Geology, University of Windsor, Windsor, Ontario, Canada

Production of storm runoff in highly responsive catchments is not well understood. We report in these papers a comprehensive set of hydrometric and natural tracer data for rainfall, soil water, and streamflow for catchments in the Tawhai State Forest, Westland, New Zealand, which reveal some of the important runoff processes. The catchments are small (<4 ha), with short (<300 m) steep (average 34°) slopes and thin (<1 m) permeable soils. Long-term (1977–1980) weekly observations of oxygen 18, electrical conductivity, and chloride in the stream, groundwater, and rain in the main study catchment indicate that catchment outflow reflects a well-mixed reservoir with a mean residence time of approximately 4 months. A preliminary storm hydrograph separation using oxygen 18 (for a storm hydrograph exceeded by only 22% of events since 1979) indicates that only 3% of storm runoff could be considered "new" (i.e., current storm) water. Rapid subsurface flow, such as macropore flow, of new water therefore cannot explain streamflow response in the study area. More detailed hydrograph separation studies on throughflow as well as streamflow are described in parts 2 (M. G. Sklash et. al., this issue) and 3 (M. G. Sklash et. al., unpublished manuscript, 1986).

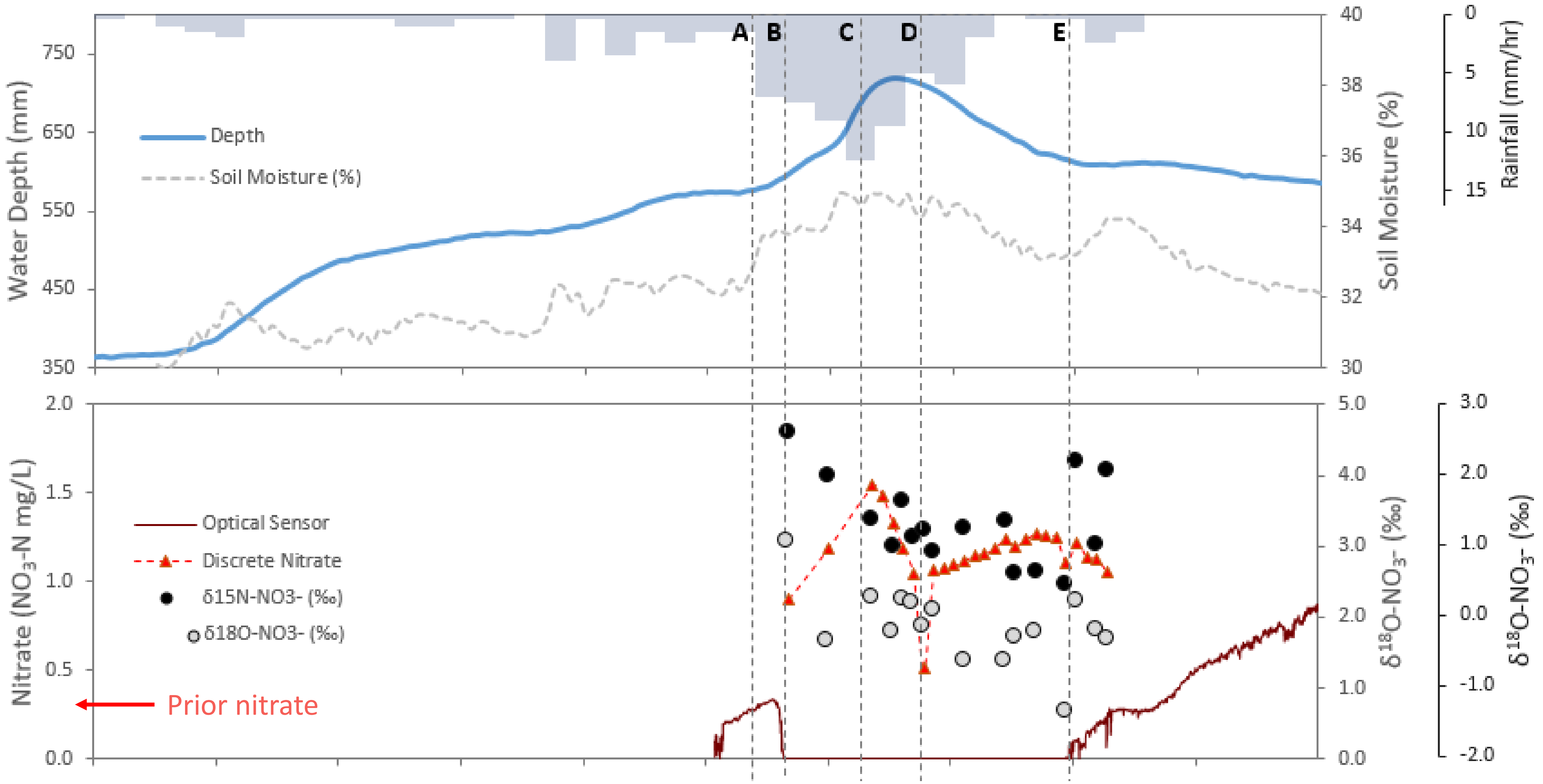
Jeff McDonnell, Maimai

Isotope tracers at Lake Ōkaro

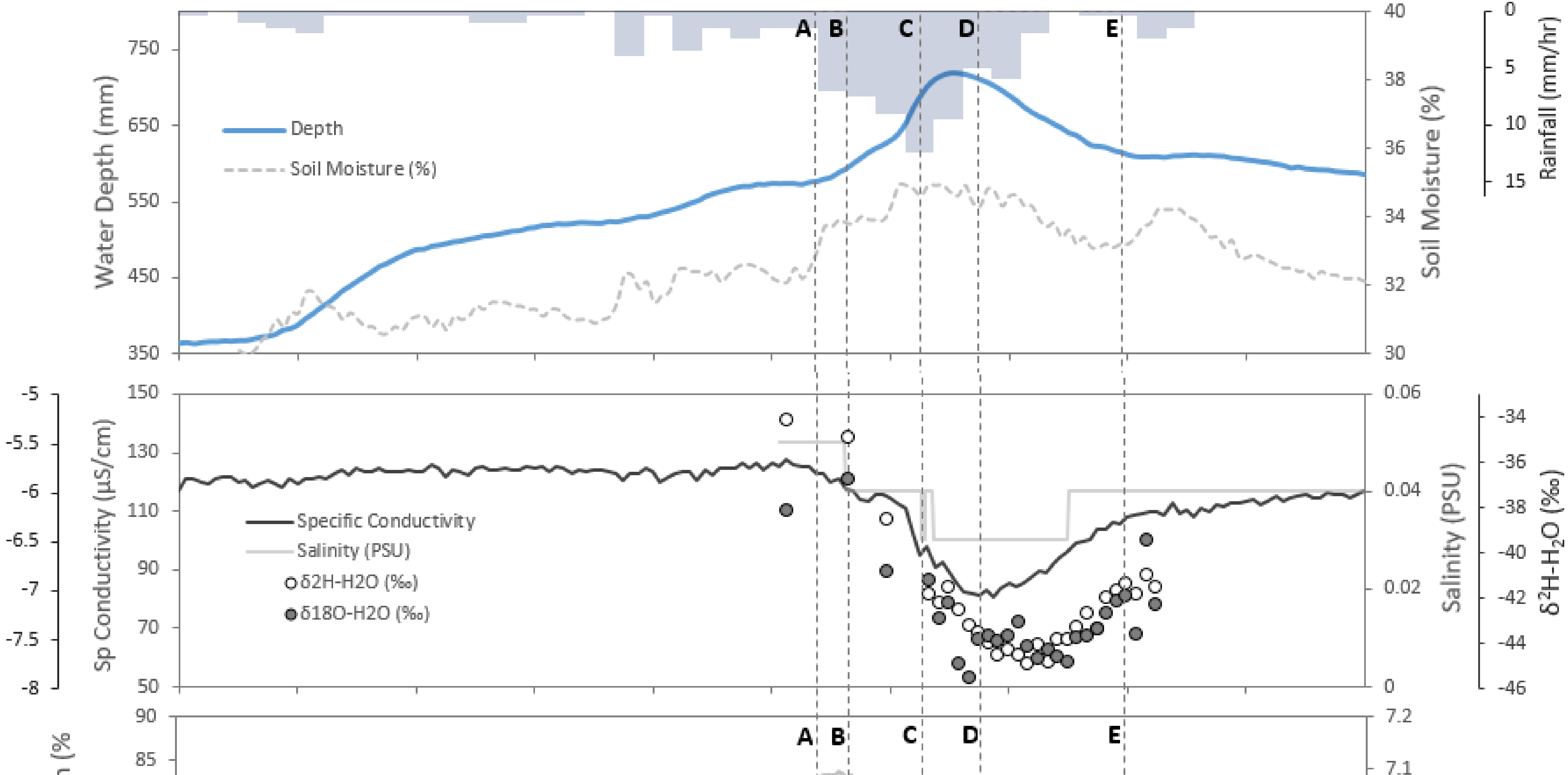
Claire Eyberg
MSc student

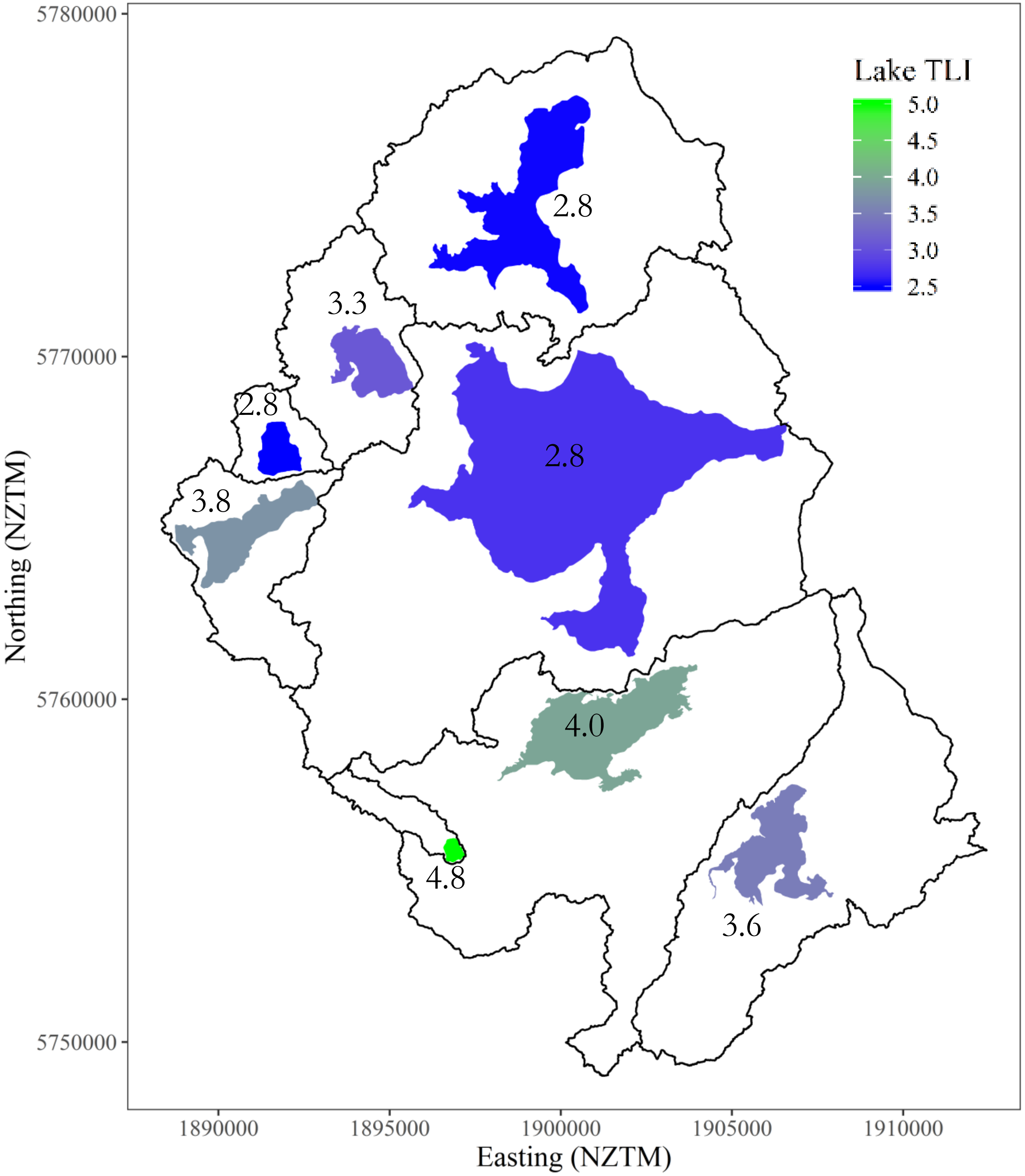


Isotope tracers at Lake Ōkaro



Isotope tracers at Lake Ōkaro



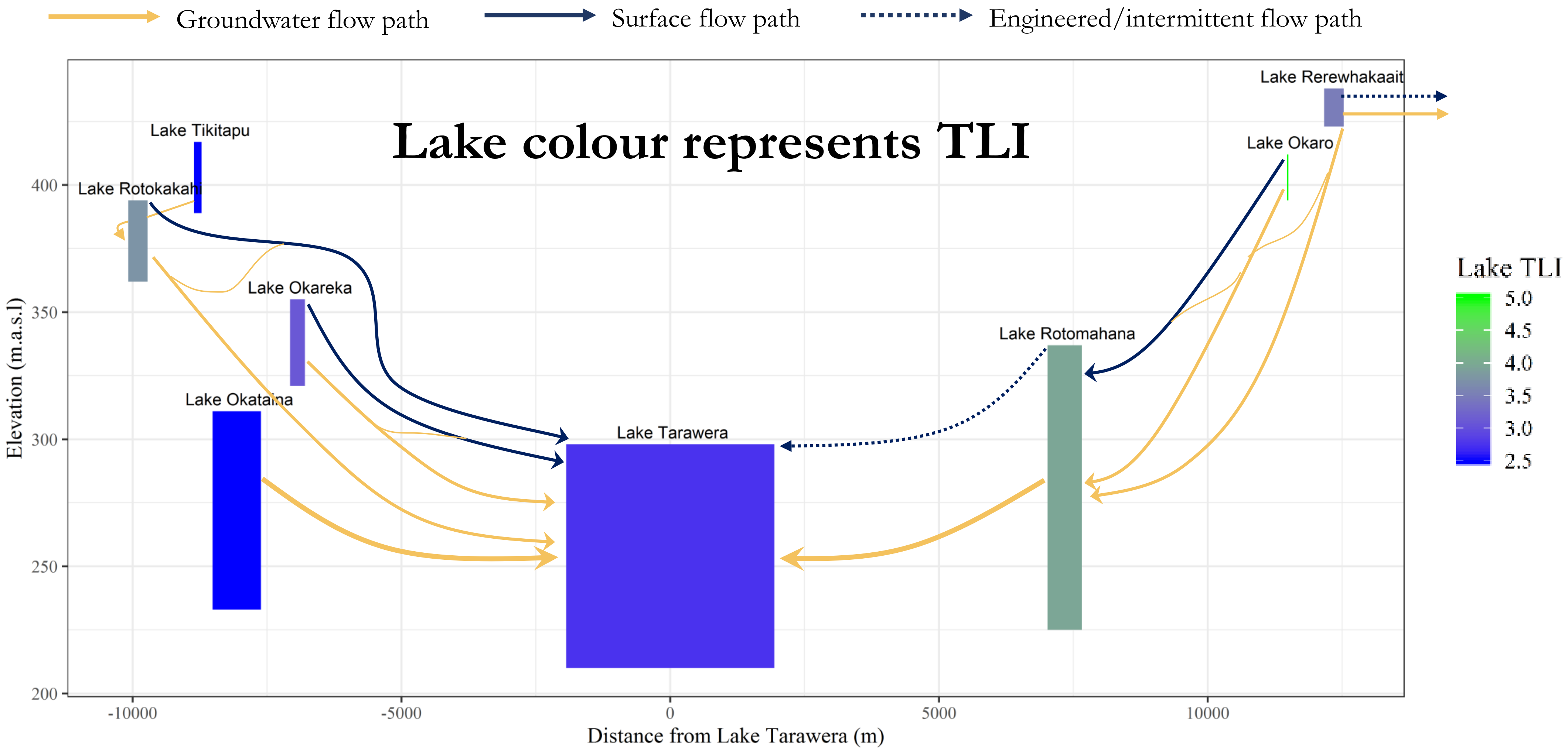


Water quality of 'connected' lakes

Trophic Level Index	Lake Type
Less than 2	Very good water quality (microtrophic)
2 – 3	Good water quality (oligotrophic)
3 – 4	Average water quality (mesotrophic)
4 – 5	Poor water quality (eutrophic)
Greater than 5	Very poor water quality (supertrophic)

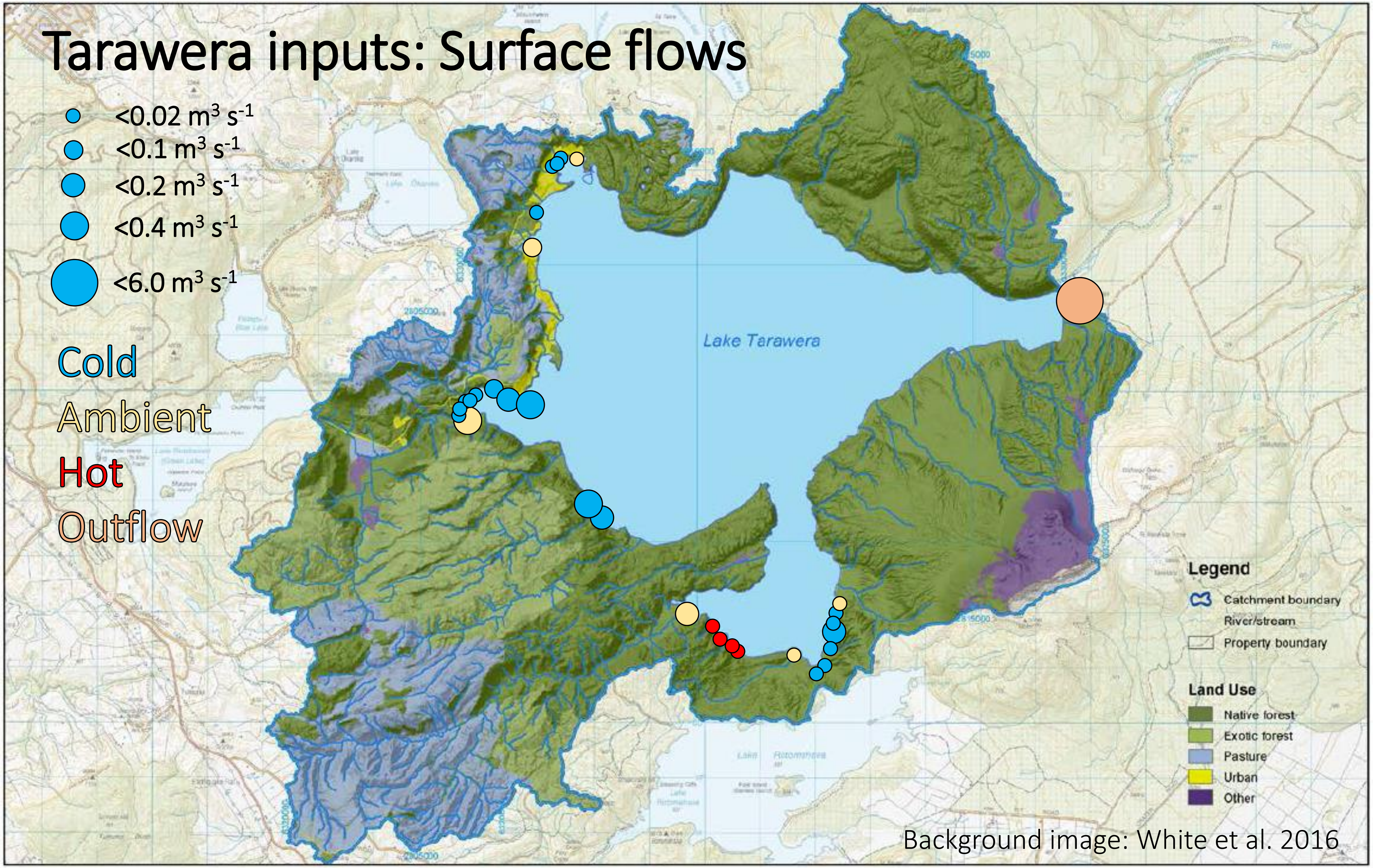
Tarawera conceptual model

Arrows show flow paths between lakes and into Tarawera

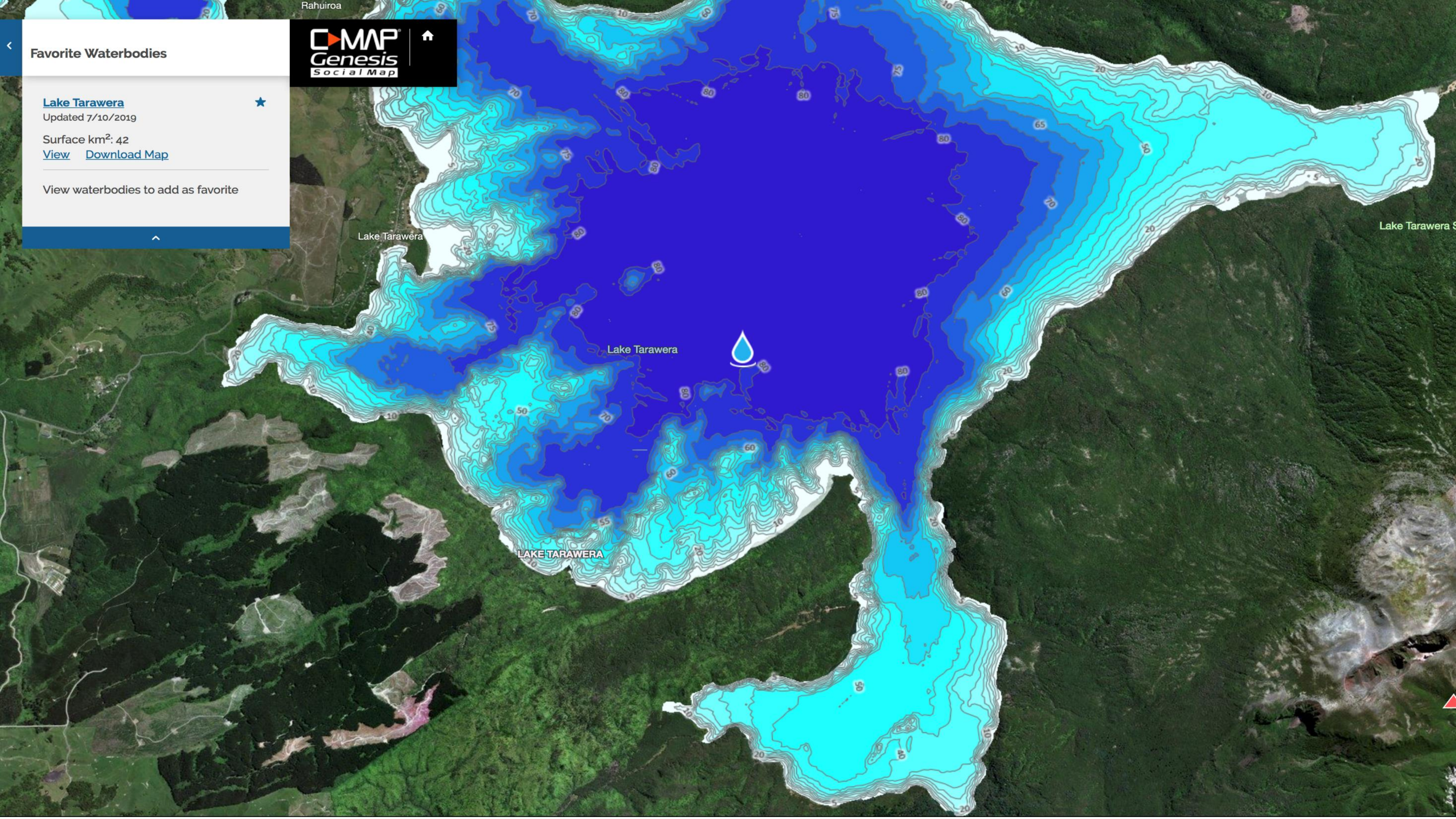


More information on hydrological connections: White et al. 2016 (GNS report)

Tarawera inputs: Surface flows



Background image: White et al. 2016


Rahuiroa
Favorite Waterbodies
Lake Tarawera
Updated 7/10/2019
Surface km^2: 42
View
Download Map
View waterbodies to add as favorite
C-MAP
Genesis
Social Map
Lake Tarawera
Lake Tarawera
LAKE TARAWERA

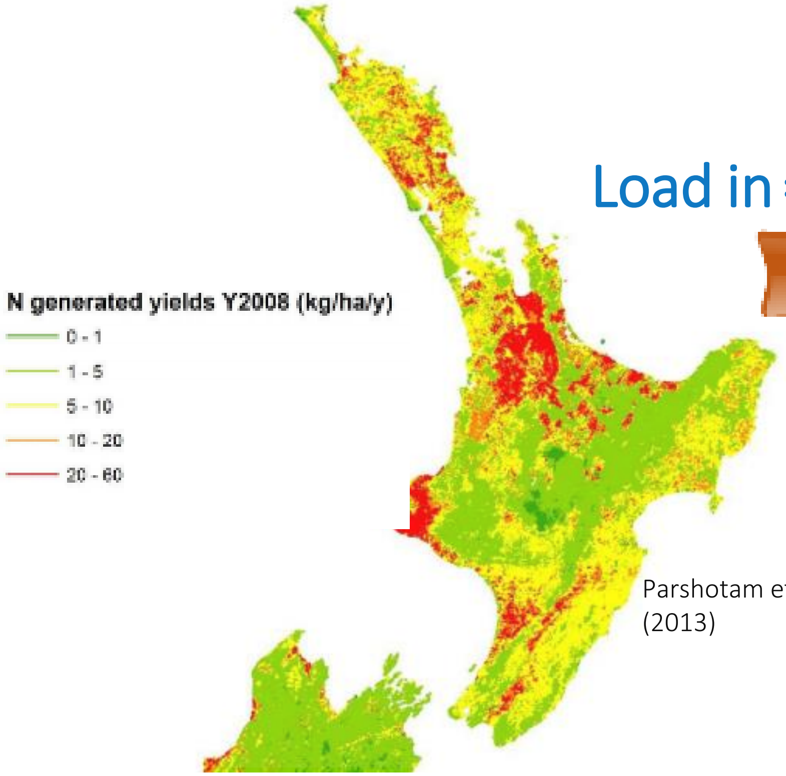
Isotope to improve …

Mass balance lake models

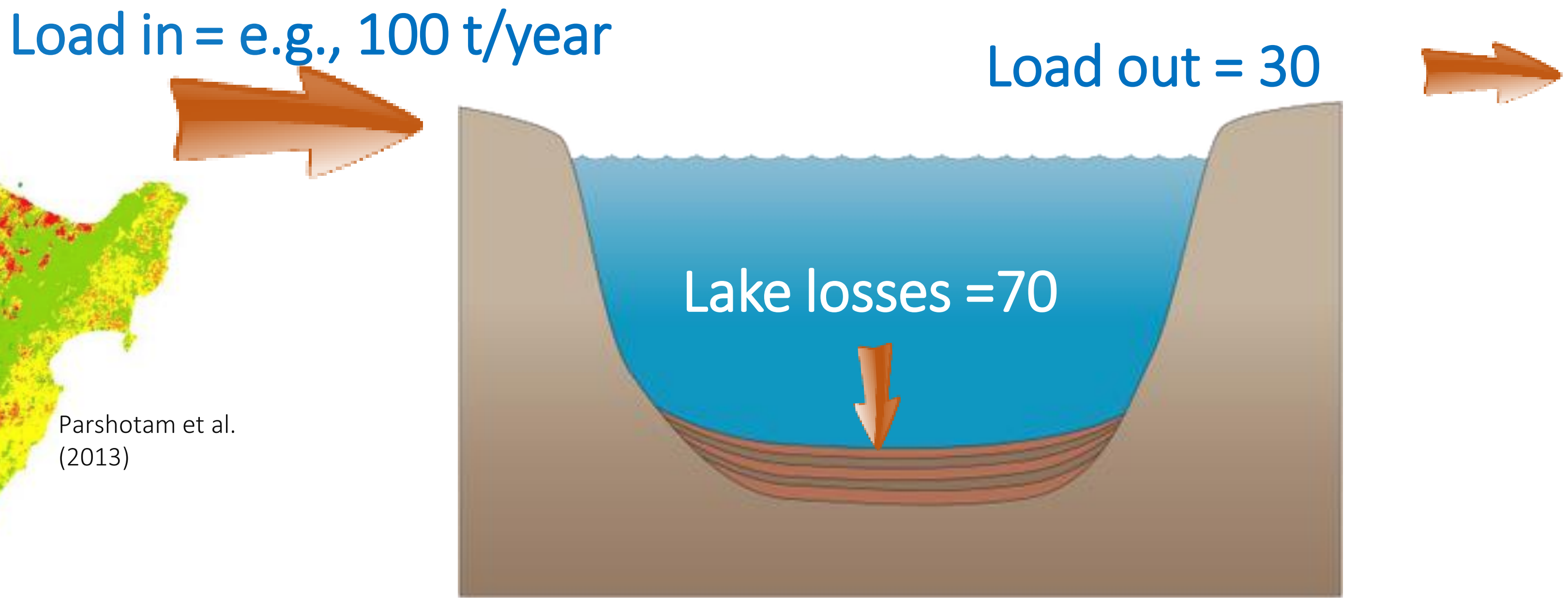
(e.g. Vollenweider models developed during 1960s and 1970s)

Catchment model → Lake ‘retention’ → Outflow load

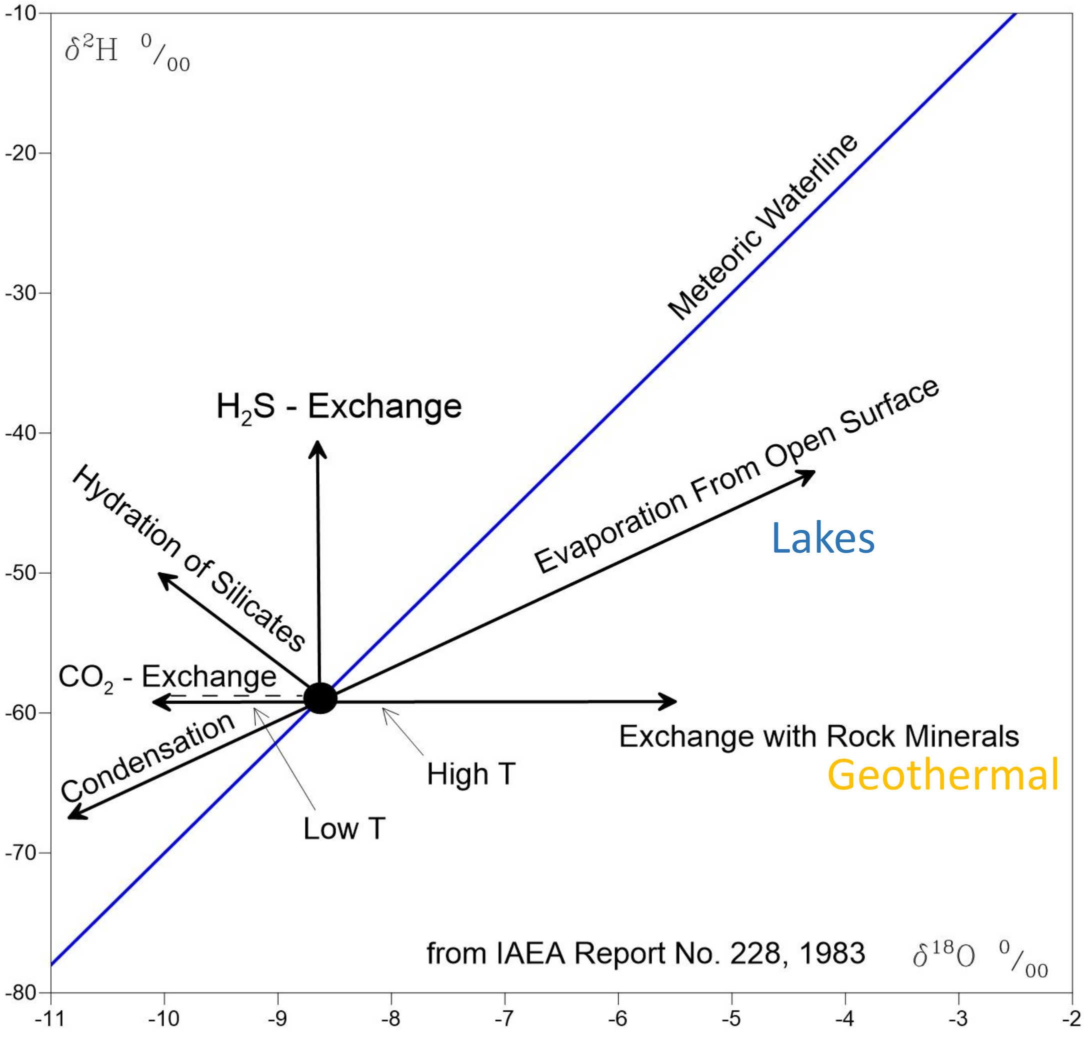
Lake TP Concentration = (Load out)/(Flow out)

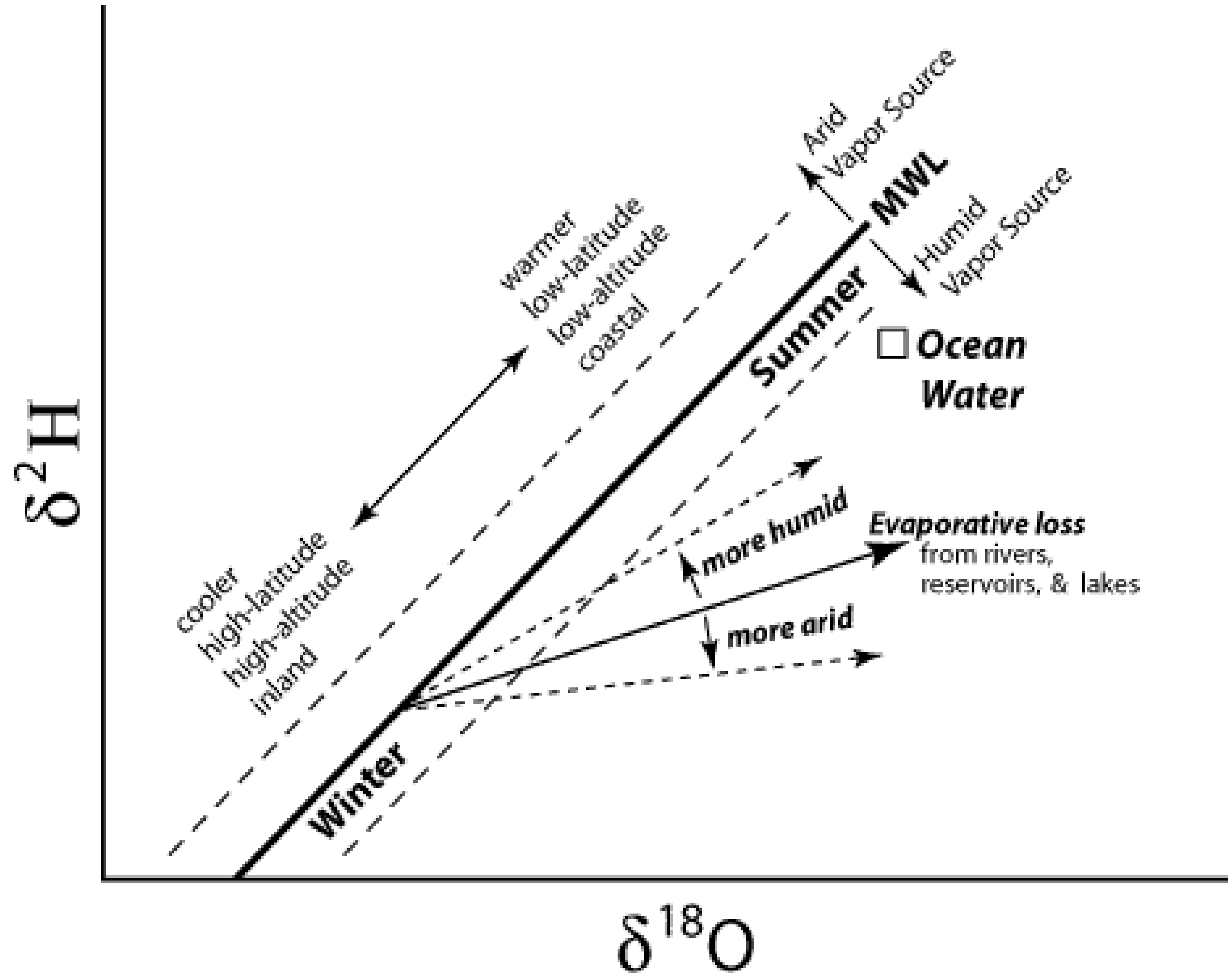


Parshotam et al. (2013)



Isotope effects: expect (mainly) evaporation





Isotope theory:

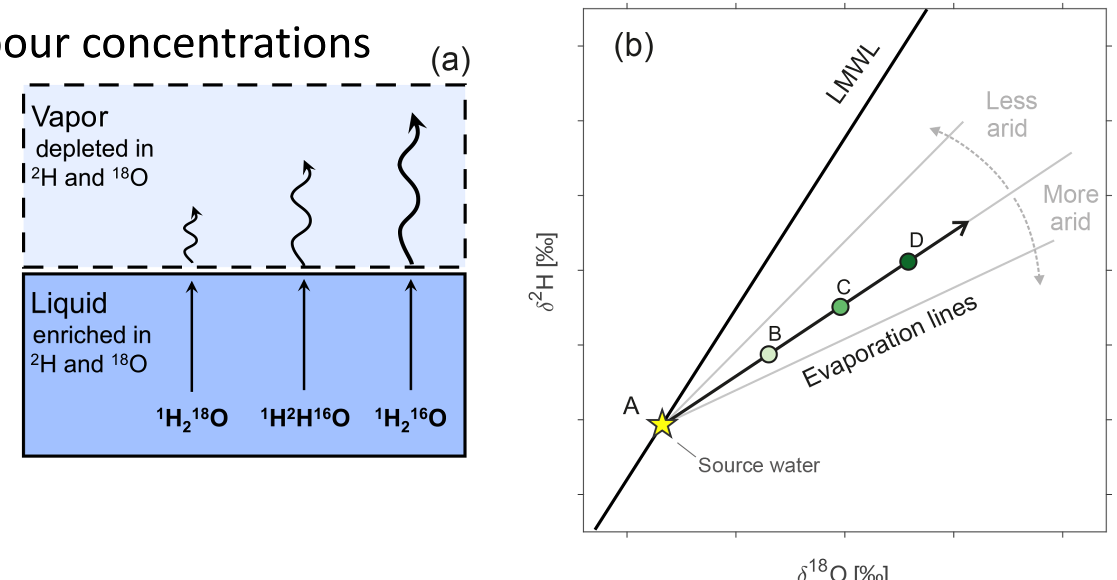
evaporation involves kinetic & equilibrium fractionation

The isotopic value of evaporating water, δ_E, was estimated using the Craig–Gordon model for open-water evaporation (Craig and Gordon 1965):

$$\delta_E = \frac{(\delta_L - \varepsilon^+)/\alpha^+ - h\delta_A - \varepsilon_K}{1 - h + \varepsilon_K} \qquad (6)$$

Diffusion: vapour concentrations

Equilibrium isotope fractionation



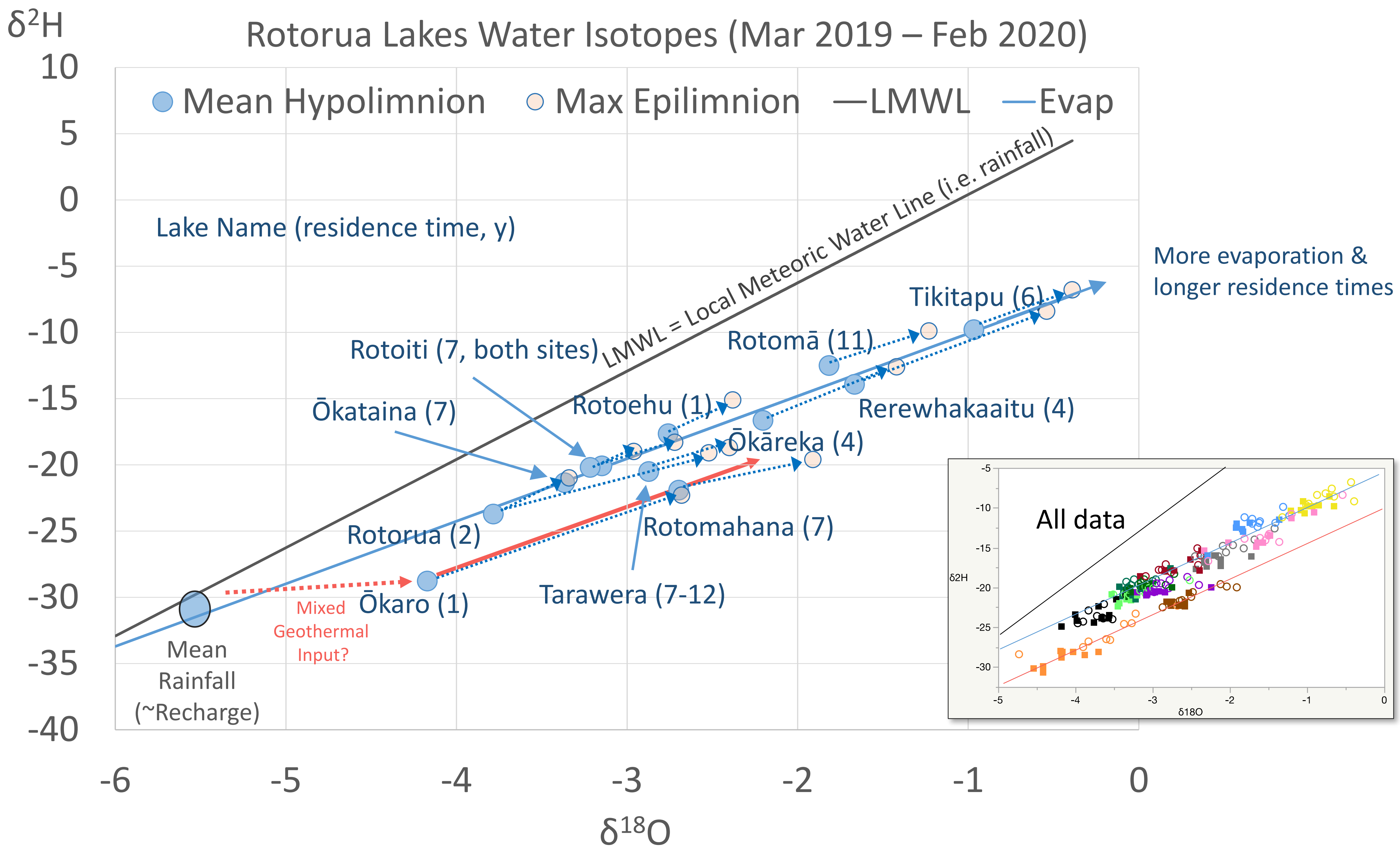
Getting E/I → τ

Combining Eqs. 4 and 6 and substituting Q_L with $I_L - E_L$, we derive the following equation for lake $E:I$ (Gibson and Edwards 2002; Gibson and Reid 2010):

$$\frac{E_L}{I_L} = \frac{\delta_I - \delta_L}{m(\delta^* - \delta_L)} \tag{7}$$

$$\tau = \left[\frac{E}{I}\right] \frac{V}{E} \tag{8}$$

where V is lake volume. We used the method described by



Rotorua Lakes Water Isotopes (Mar 2019 – Feb 2020)
δ²H
δ¹⁸O
Mean Hypolimnion
Max Epilimnion
LMWL
Evap
Lake Name (residence time, y)
LMWL = Local Meteoric Water Line (i.e. rainfall)
More evaporation &
longer residence times
Tikitapu (6)
Rotomā (11)
Rotoiti (7, both sites)
Rotoehu (1)
Rerewhakaaitu (4)
Ōkataina (7)
Ōkāreka (4)
Rotorua (2)
Rotomahana (7)
Tarawera (7-12)
Ōkaro (1)
Mixed
Geothermal
Input?
Mean
Rainfall
(~Recharge)
All data
δ2H
δ18O
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-6
-5
-4
-3
-2
-1
0

Key points on water isotopes (and other tracers)

- Lakes show evaporation signal, particularly long-residence time lakes with small catchments.
- Groundwater (which looks like winter precipitation unless from another lake) ‘throughflow’ probably explains lakes that show less evaporation than expected based on residence times
- Tarawera, Rotoiti and Ōkataina show a surprising lack of evaporation, presumably a result of hidden groundwater ‘throughflow’.
- Ōkaro and Rotomahana are on a different evaporation line, presumably reflecting geothermal inputs from Waimangu. This was not expected at Ōkaro. Comments?
- Rotoehu perhaps has less throughflow (and if so less catchment area) than expected.
- So far, these conclusions are qualitative but can be firmed up and explored in detail as a key focus for a postdoc and proposals.
- There’s lots of signal to work with and opportunities to look at detailed mechanisms, timing, mixing, including where water turns up down the hill from the lakes.

Related projects

- Complete current seed project on Tarawera Catchment As
  - Geochemical fingerprinting of groundwater and geothermal
  - Nitrate and related tracers (isotopes)
  - Database and dataflow infrastructure (invisible to you)
- Advance prototypes for citizen-science monitoring collaboration
  - Builds on Terry Beckett (LTRA) inflow monitoring for Tarawera

John Mering (Nov 2019 – May 2020)

Dr. Rachel Murray

Chris Eager (until Nov 2019)

Claire Eyberg

Meti Yulanti

Chris McBride

Dr Mat Allan (thru Feb 2020)