The Lake Tarawera Catchments: Flows of Water and Nutrients

Professor Troy Baisden

Bay of Plenty Regional Council Chair in Lake and Freshwater Science

THE UNIVERSITY OF WAIKATO

Te Whare Wānanga o Waikato

The problem is in the lake; the solution lies in the landscape.

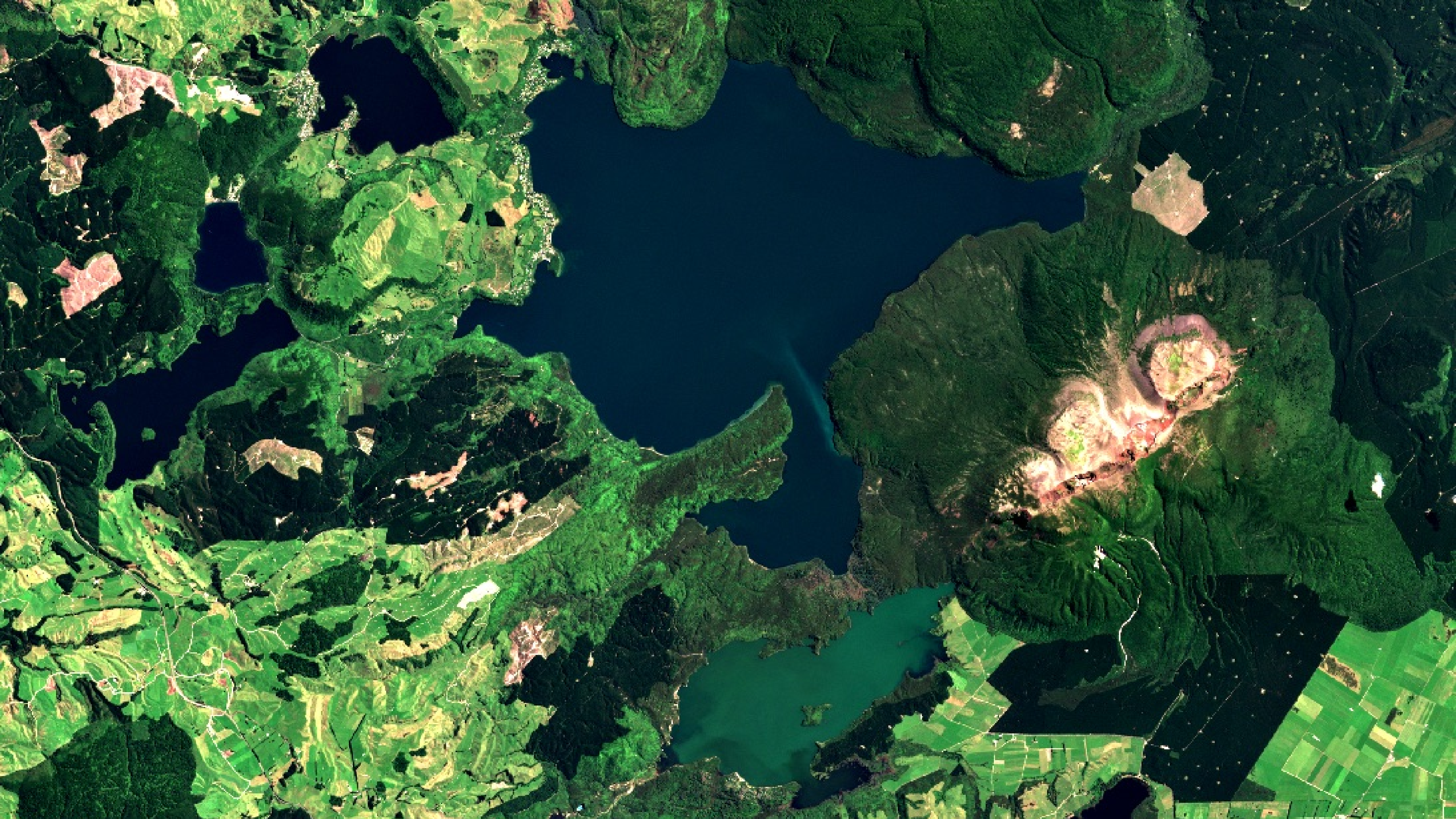
-Tony Petch

Te Pūnaha Matatini

Data ▪ Knowledge ▪ Insight

SCIENCE & ENGINEERING

TE MĀTAURANGA PŪTAIAO ME TE PŪKAHA



Valid, yet competing concepts:

“The first role of intelligent tinkering is to keep all the pieces.”

– Aldo Leopold

“Perfection in anything at all is achieved not when there is no longer anything to add, but when there is nothing left to take away.”

– Antoine de Saint-Exupéry

Valid, yet competing concepts:

“Everything should be made as simple as possible but no simpler.”

– Albert Einstein

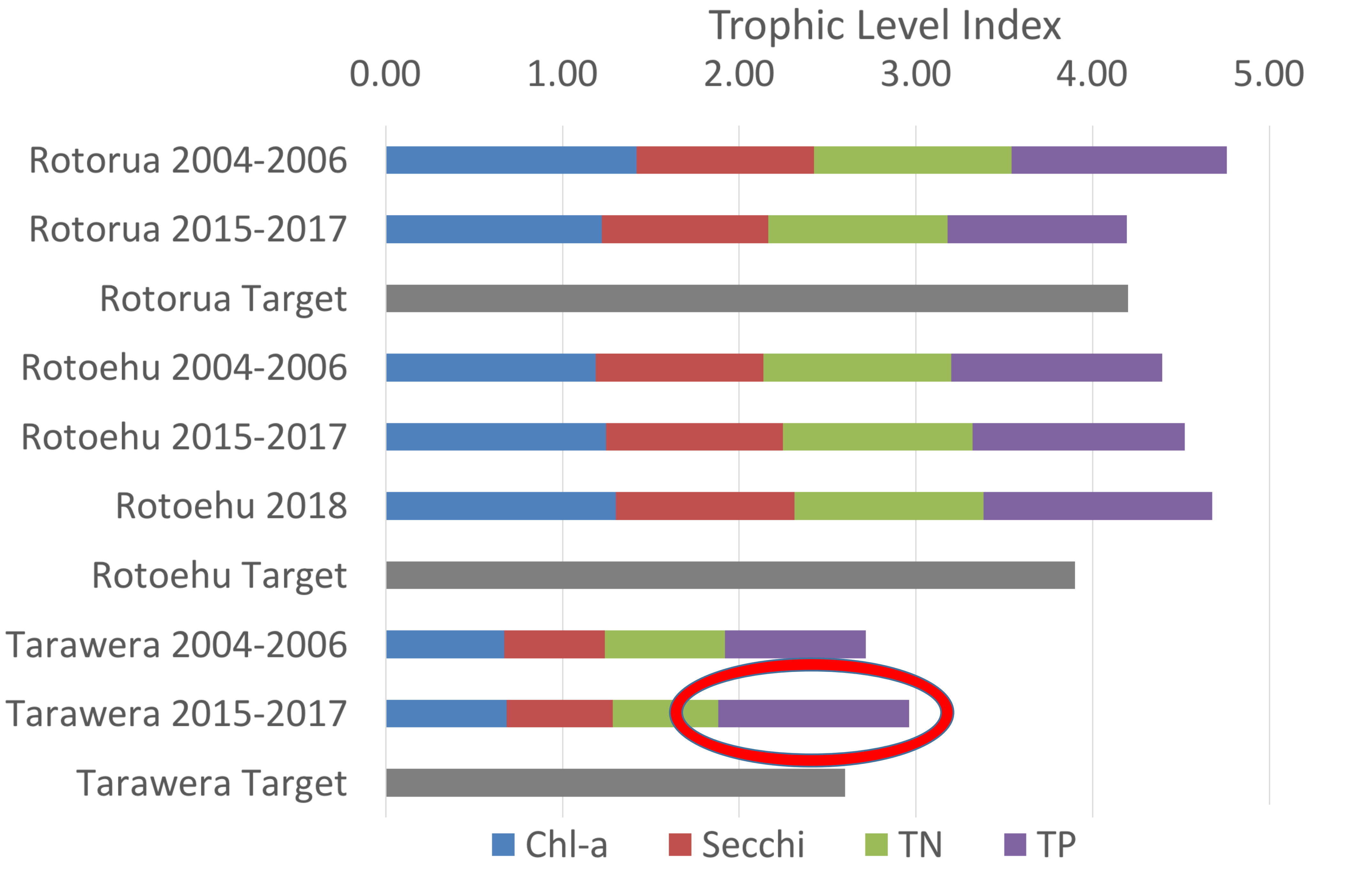
- Science in the face of complexity tends toward complication.
- Mid-20th-century paradigms develop science as a body of knowledge separated from its application.
- Excellence in Post-Normal science evaluates information and uncertainty with direct focus on decisions and risk.

Why might simplicity be just what we need?

- Load = flow x concentration
- Simple models of lake loads used since the 1960s and 1970s
- If you can understand it, you can manage it?

Why might simplicity be difficult?

- Load = flow x concentration
  - Concentration measurements difficult/inconsistent
  - Flow varies with land cover and climate
  - Loads adjust slowly after land use change (legacies)
- Simple models of lake loads used since the 1960s and 1970s
  - Simple models may have bias and error
  - Complex models look “way more flash”
- If you can understand it, you can manage it?
  - Yeah, right!
  - Actually yes, but we need to get scientists and stakeholders to agree.



Trophic Level Index
0.00
1.00
2.00
3.00
4.00
5.00
Rotorua 2004-2006
Rotorua 2015-2017
Rotorua Target
Rotoehu 2004-2006
Rotoehu 2015-2017
Rotoehu 2018
Rotoehu Target
Tarawera 2004-2006
Tarawera 2015-2017
Tarawera Target
Chl-a
Secchi
TN
TP

Tarawera Outlet: How much water?

Data: NIWA portal

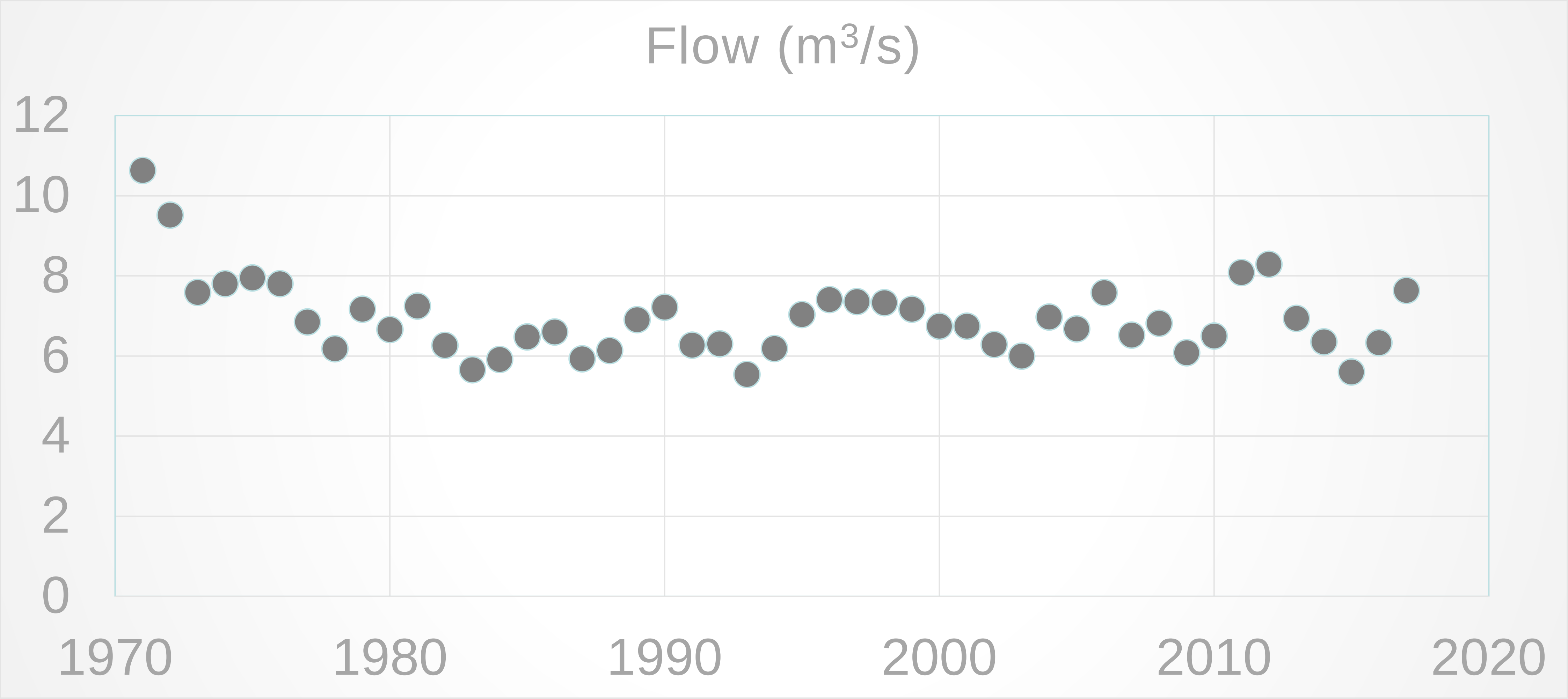


Figure 9. The NIWA NRWQN dataset from the Tarawera Outflow for TN (above) and TP (below). Ruapehu eruptions generating ashfalls are shown as red lines.

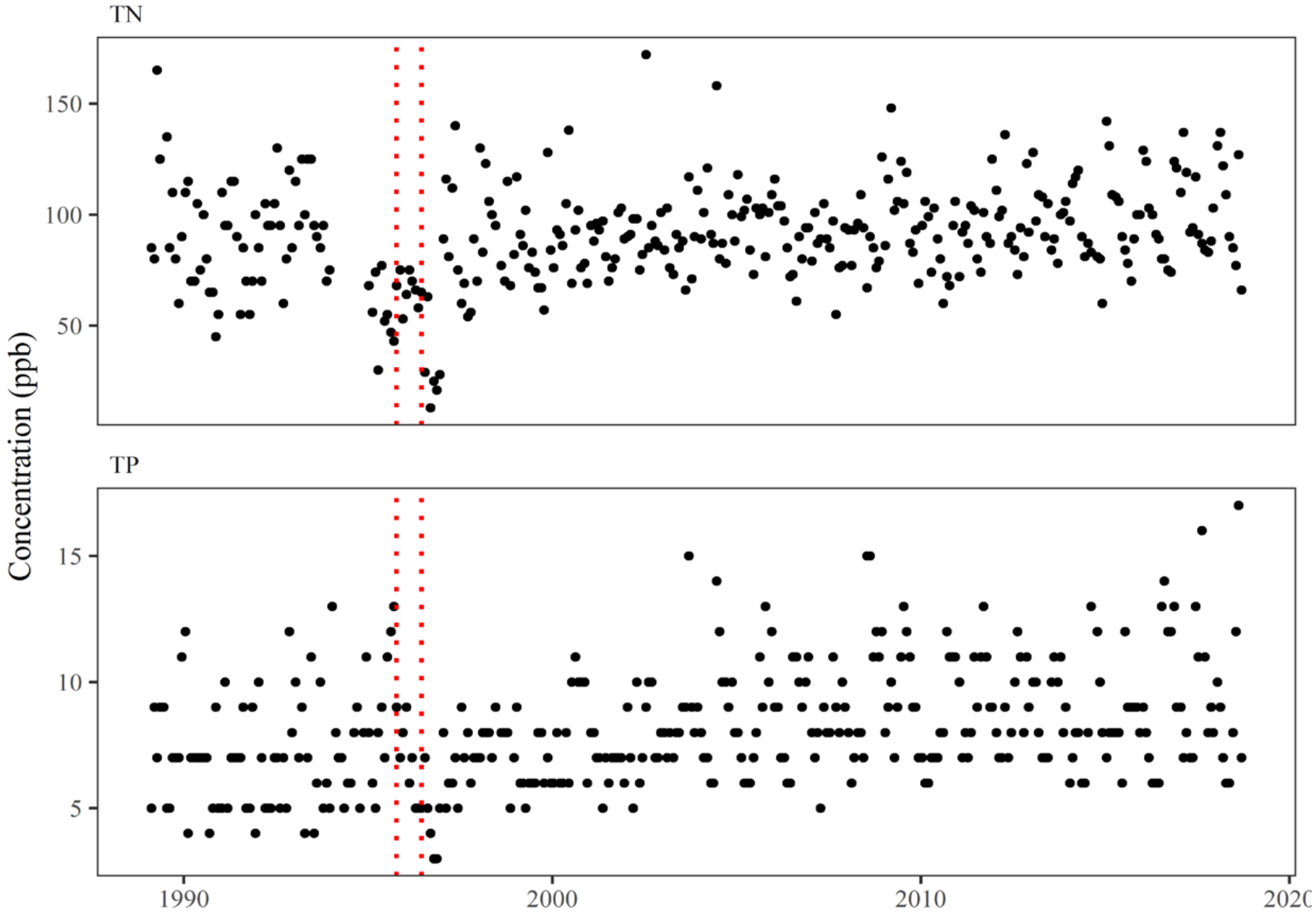
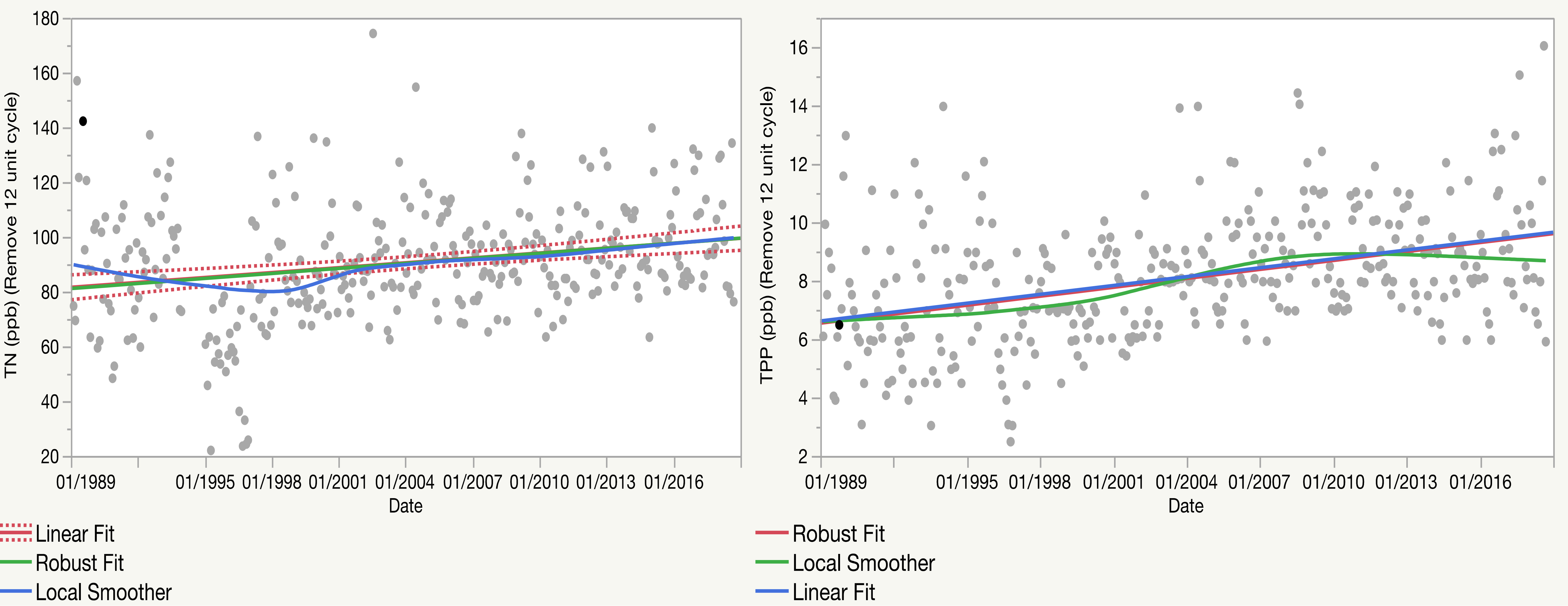


Figure 10: Trends



It’s the canopy that matters.

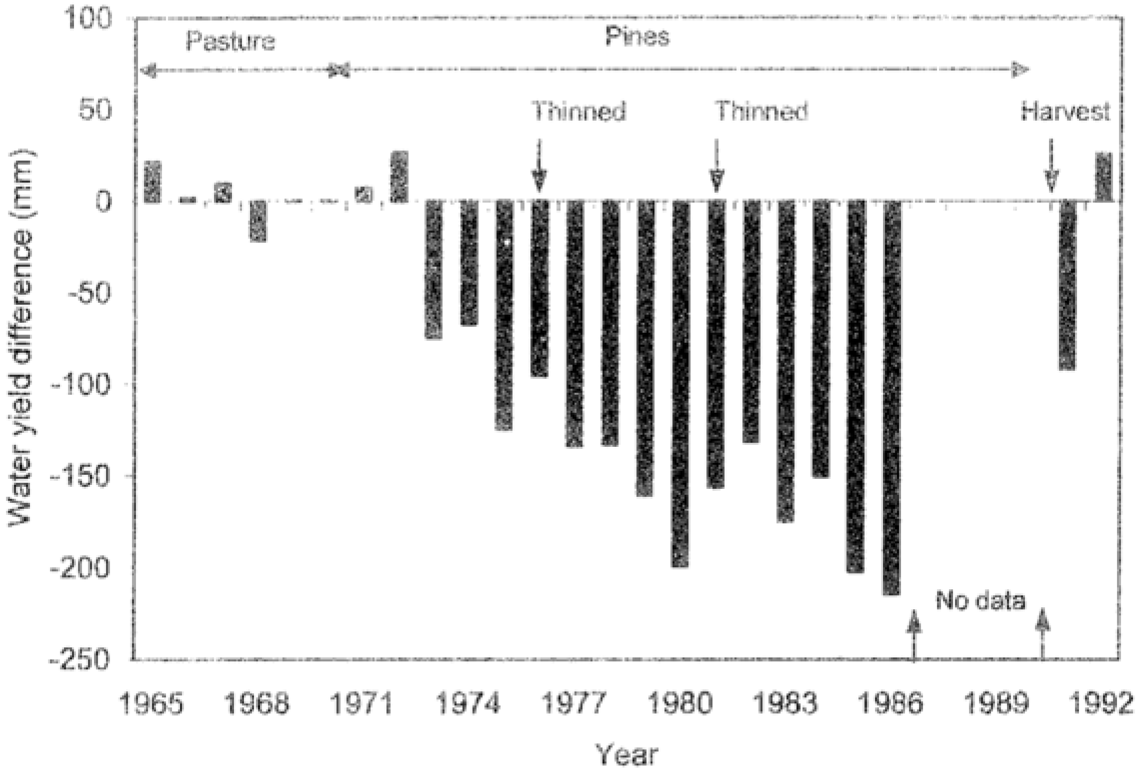


Figure 33.2 Differences in annual water yield between the control catchment in pasture (C5) and the catchment planted in pines (C14) in 1970, Moutere experimental catchments, Nelson, 1965–1992.

Flow varies with rainfall/elevation (near Rotorua)

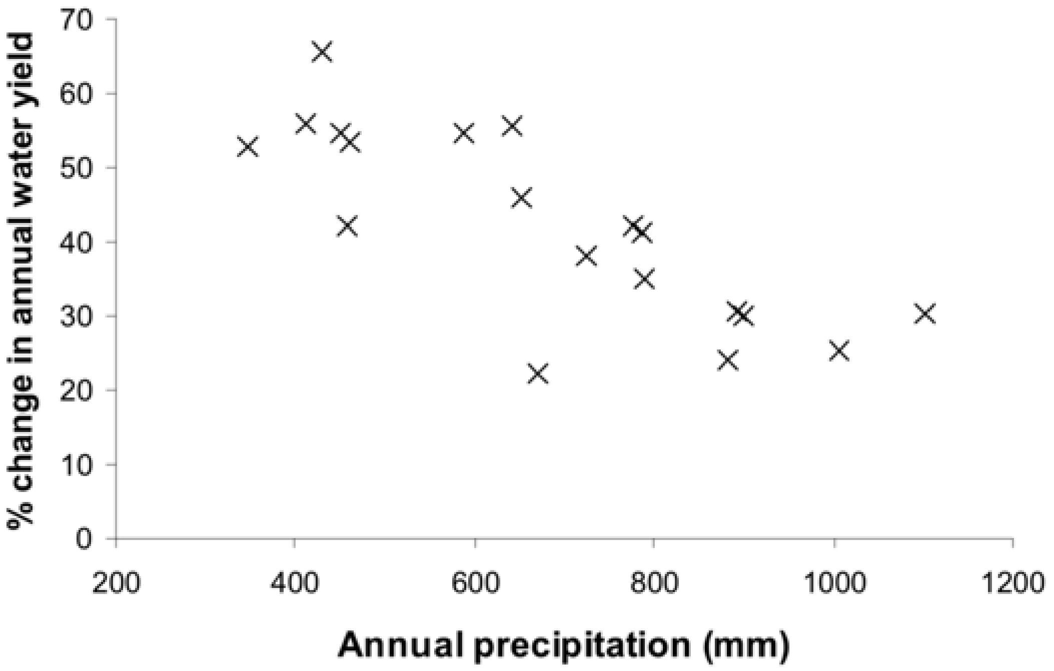
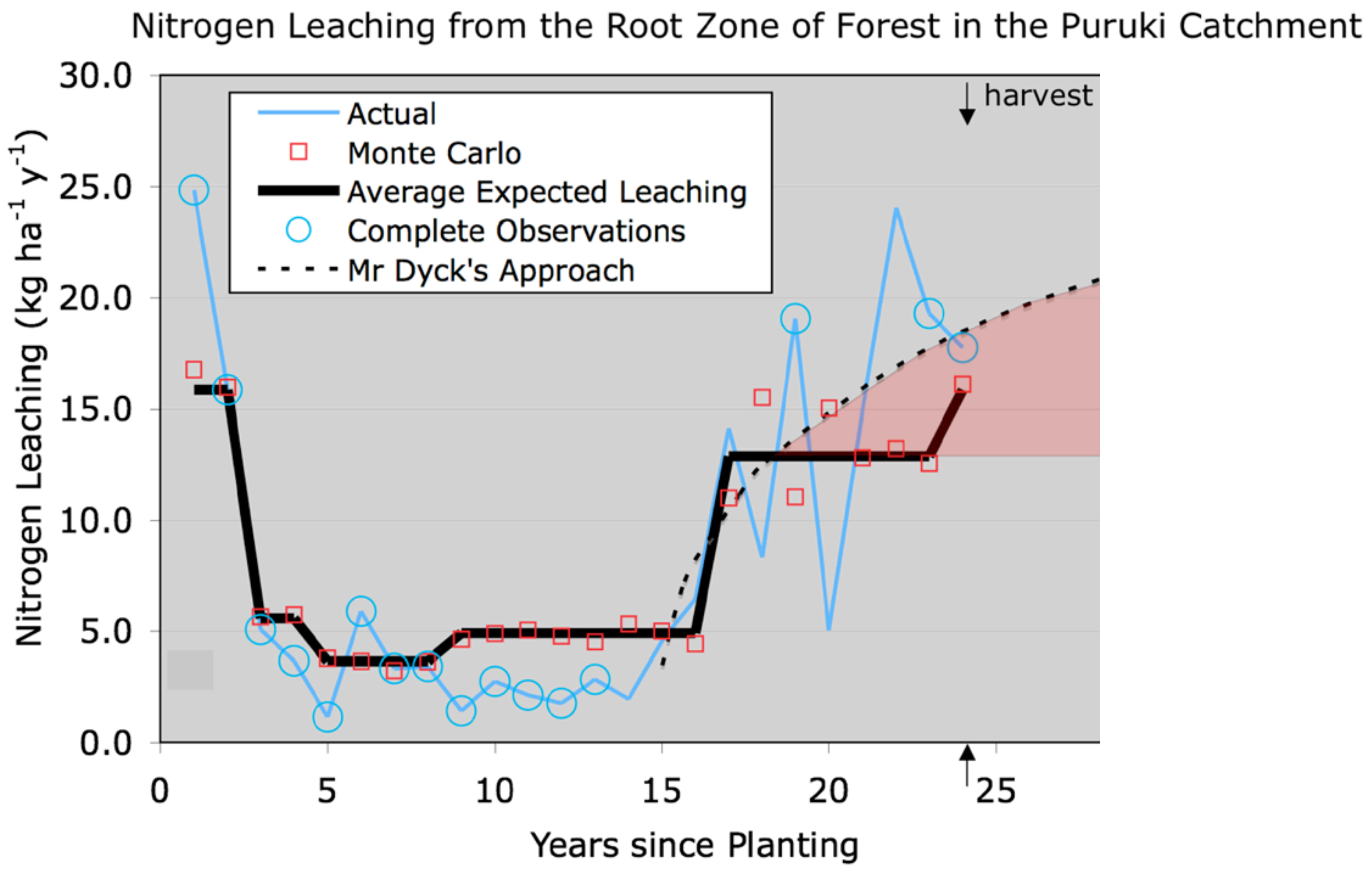


Figure 5: Percentage change in annual runoff following afforestation plotted against the equivalent years annual rainfall total. The data are for the Purukohukohu suite of catchments.

http://icm.landcareresearch.co.nz/knowledgebase/publications/public/Forestry&water%20yield-the_NZ_example.pdf

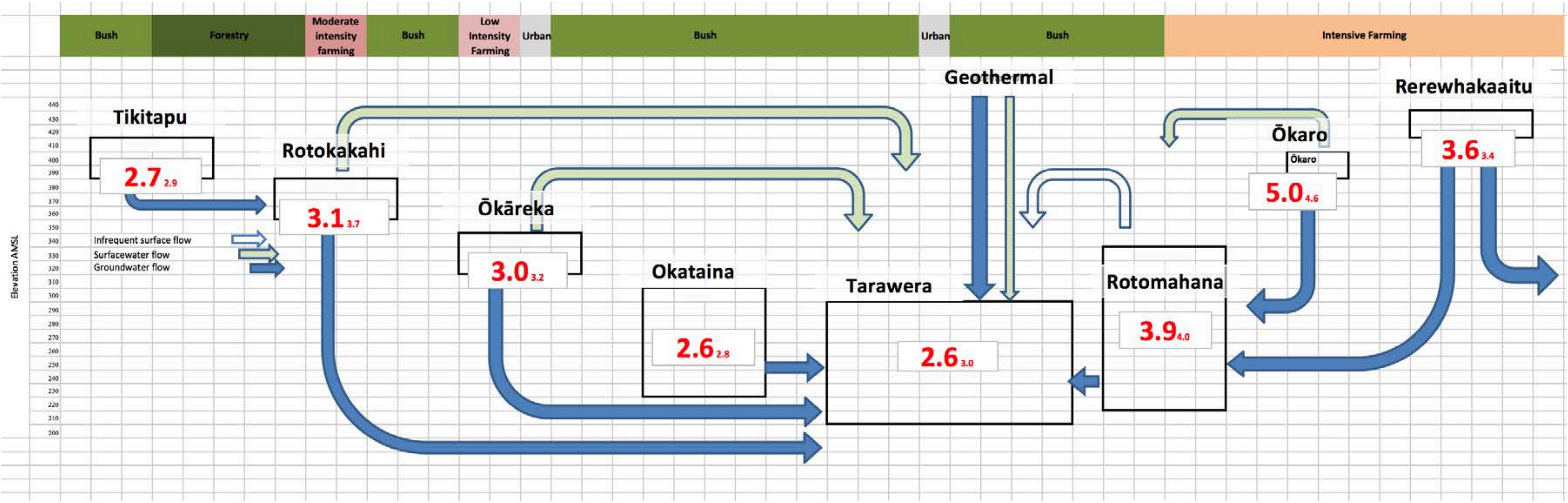
Harvesting forests

- N losses – in the long term N leaching in forests drops to 2-3 kg N ha^{-1} y^{-1}, but…
  - Mature forests planted into improved pasture have high N loss
  - Recovers after harvest due to understory or canopy uptake



Alastair's Diagram: Connectivity into Tarawera

→ How can this be?



- Can low TLI lakes exist below high TLI lakes?
- How do we connect up all this?

Simplicity in lake models (focus on TP for now)

Vollenwieder models fall out of a mass balance equation:

$dPV/dt = M_{in} – PQ – S$ = Inputs – Outflow – Sedimentation

Convert to rates → $PV = M_{in} (\rho_w – \sigma)$ → $P = L_p / z_{mean} (\rho_w – \sigma)$

Mass balance underpins, yet empirical fits are chosen in log-log plots.

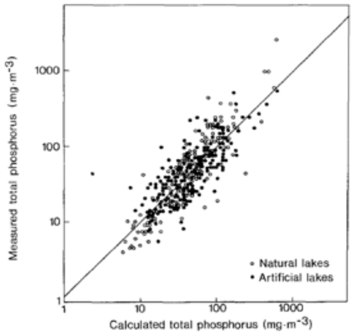


Fig. 3. Relation between predicted and measured lake P concentrations according to eq. (21). (Modified after Canfield & Bachmann, 1981).

→

Just published…

Environmental Science & Technology

Article

pubs.acs.org/est

Quantifying the Extent of Anthropogenic Eutrophication of Lakes at a National Scale in New Zealand

Jonathan M. Abell,[*,†] Deniz Özkundakci,[‡,§] David P. Hamilton,[‡,∥] Paul van Dam-Bates,[†] and Richard W. Mcdowell[∥,⊥]

Simplicity in lake models (focus on TP for now)

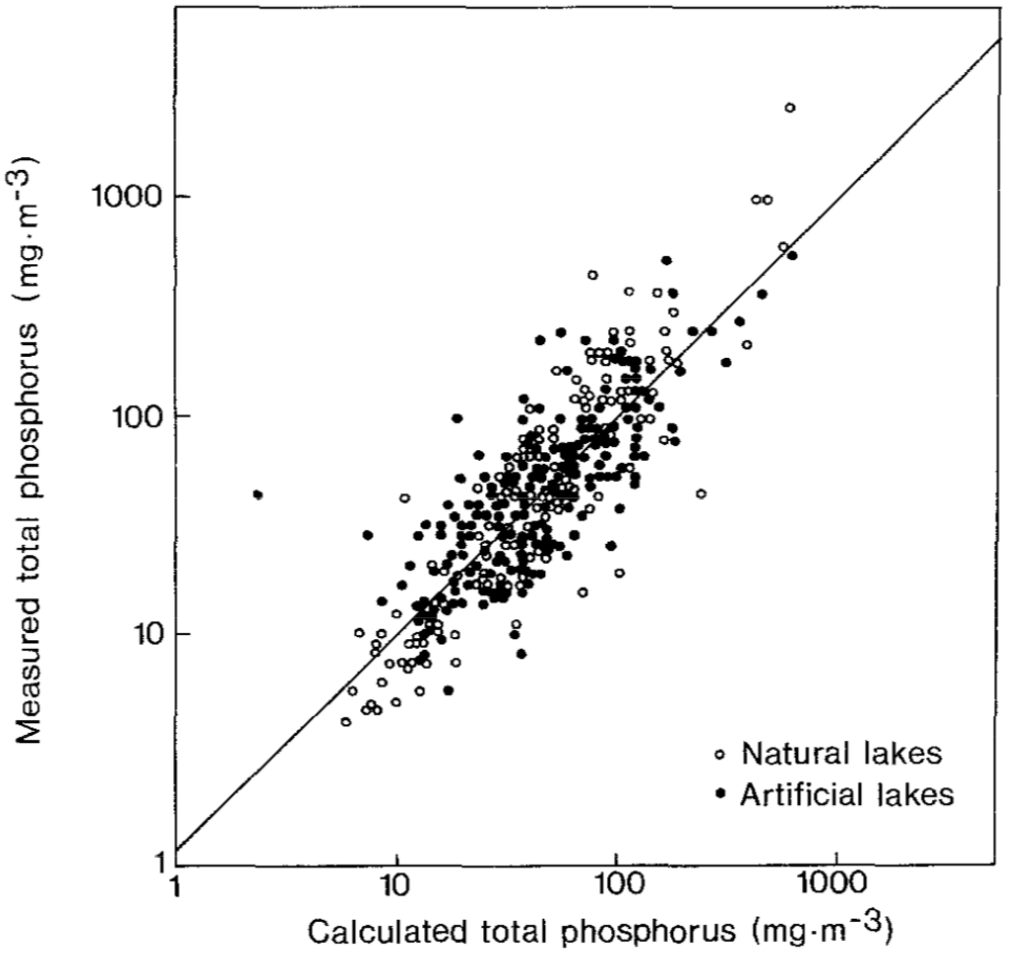


Fig. 3. Relation between predicted and measured lake P concentrations according to eq. (21). (Modified after Canfield & Bachmann, 1981).

Ahlgren et al 1988 Hydrobiologia 170:285

→

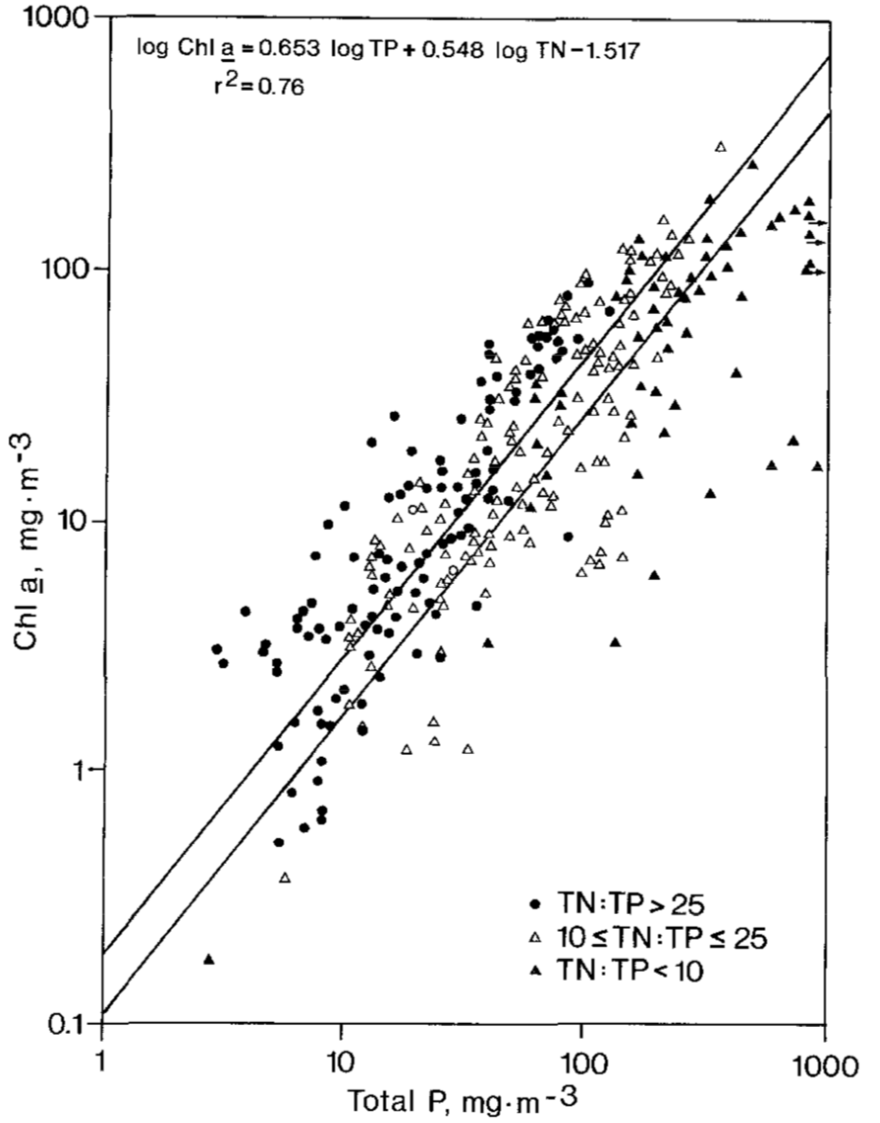


Fig. 11. Relation between chlorophyll a and total P at different N:P ratios (after Smith, 1982).

Simplicity in lake models (focus on TP for now)

Vollenwieder models fall out of a mass balance equation:

$dPV/dt = M_{in} – PQ – S$ = Inputs – Outflow – Sedimentation

Convert to rates → $PV = M_{in} (\rho_w – \sigma)$ → $P = L_p / z_{mean} (\rho_w – \sigma)$

, yet empirical fits are chosen in log-log plots.

More importantly, P retention (R_P) can be defined:

$R_P = 1 –$ “attenuation” $= 1 – \rho_w / (\rho_w + \sigma) = \sigma / (\rho_w + \sigma)$

So… a simple empirical function of flushing and sedimentation rates?

Simplicity in lake models (focus on TP for now)

So… a simple empirical function of flushing and sedimentation rates?

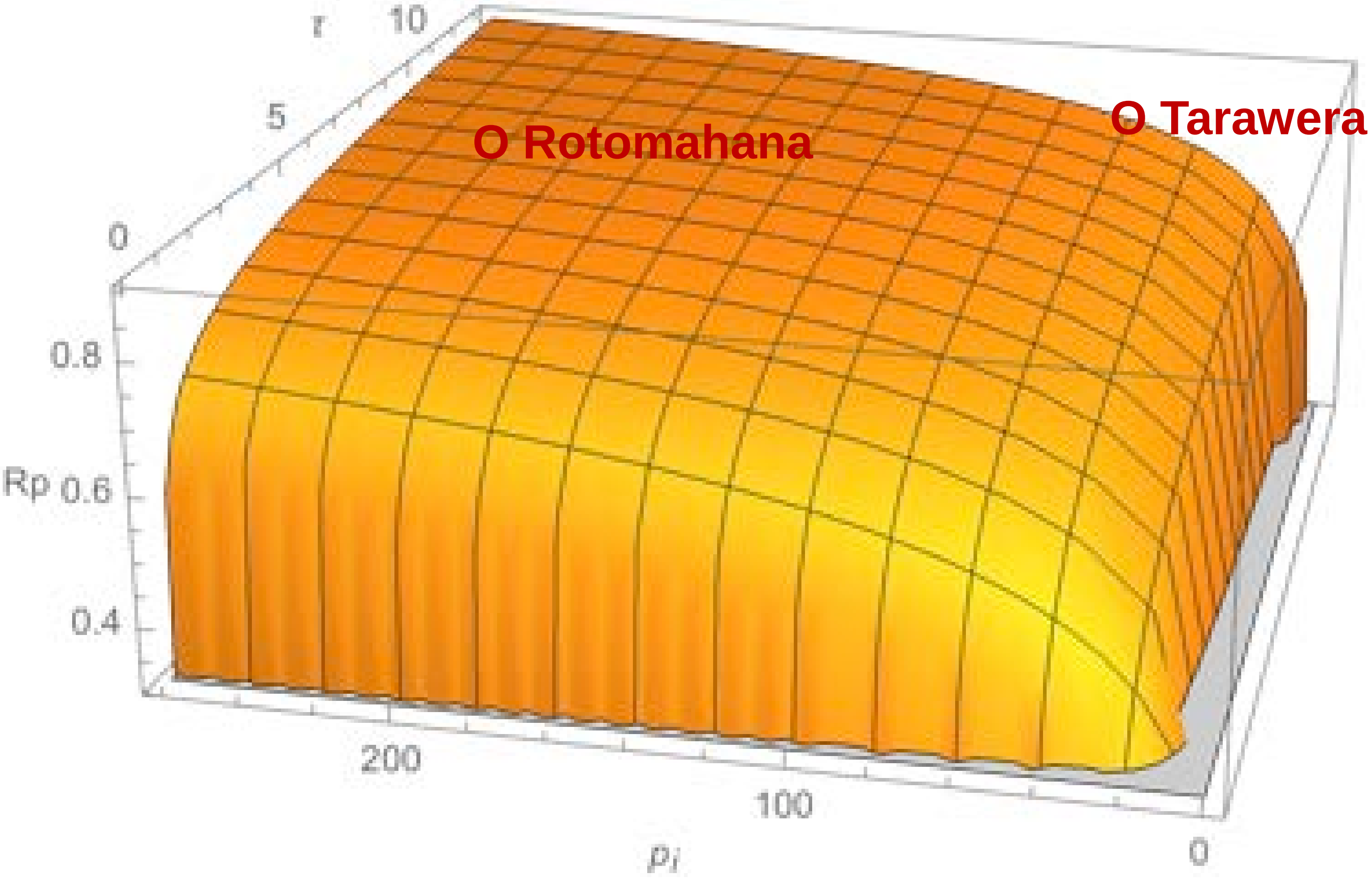
$R_P = \sigma / (\rho_w + \sigma)$

$$\mathbf{R_p} = 0.129\,\tau_w^{0.451}\mathbf{P_i}^{0.549} / (1 + 0.129\,\tau_w^{0.451}\mathbf{P_i}^{0.549})$$

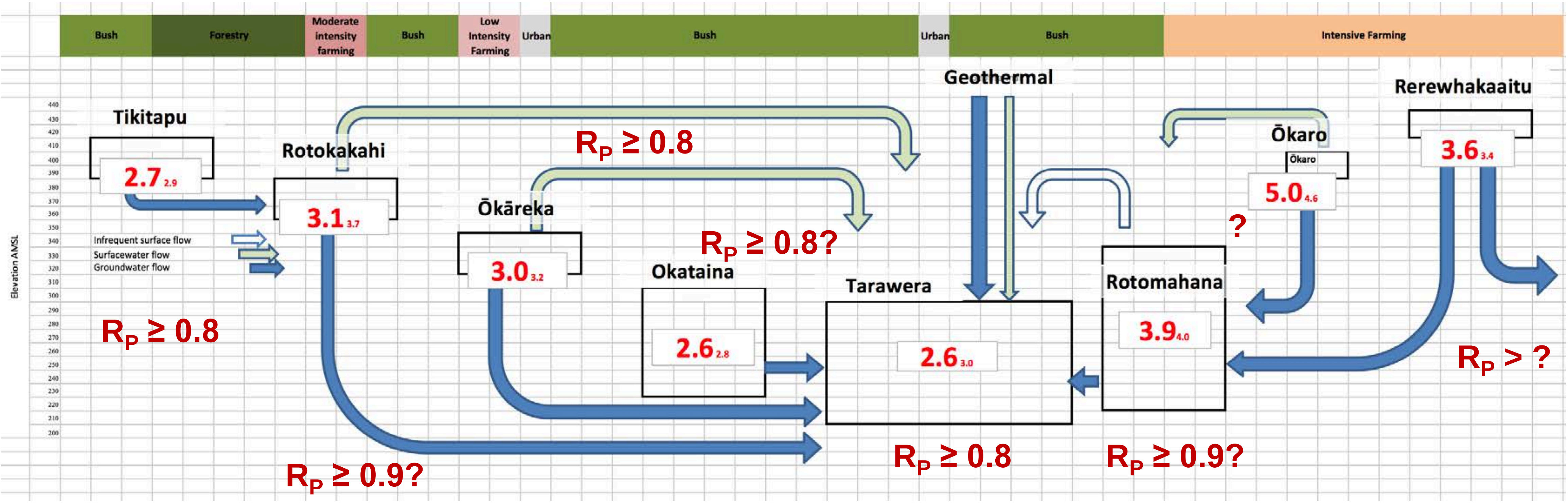
P_i = inflow TP conc.

τ_w = lake water residence time

Similar to attenuation (α)



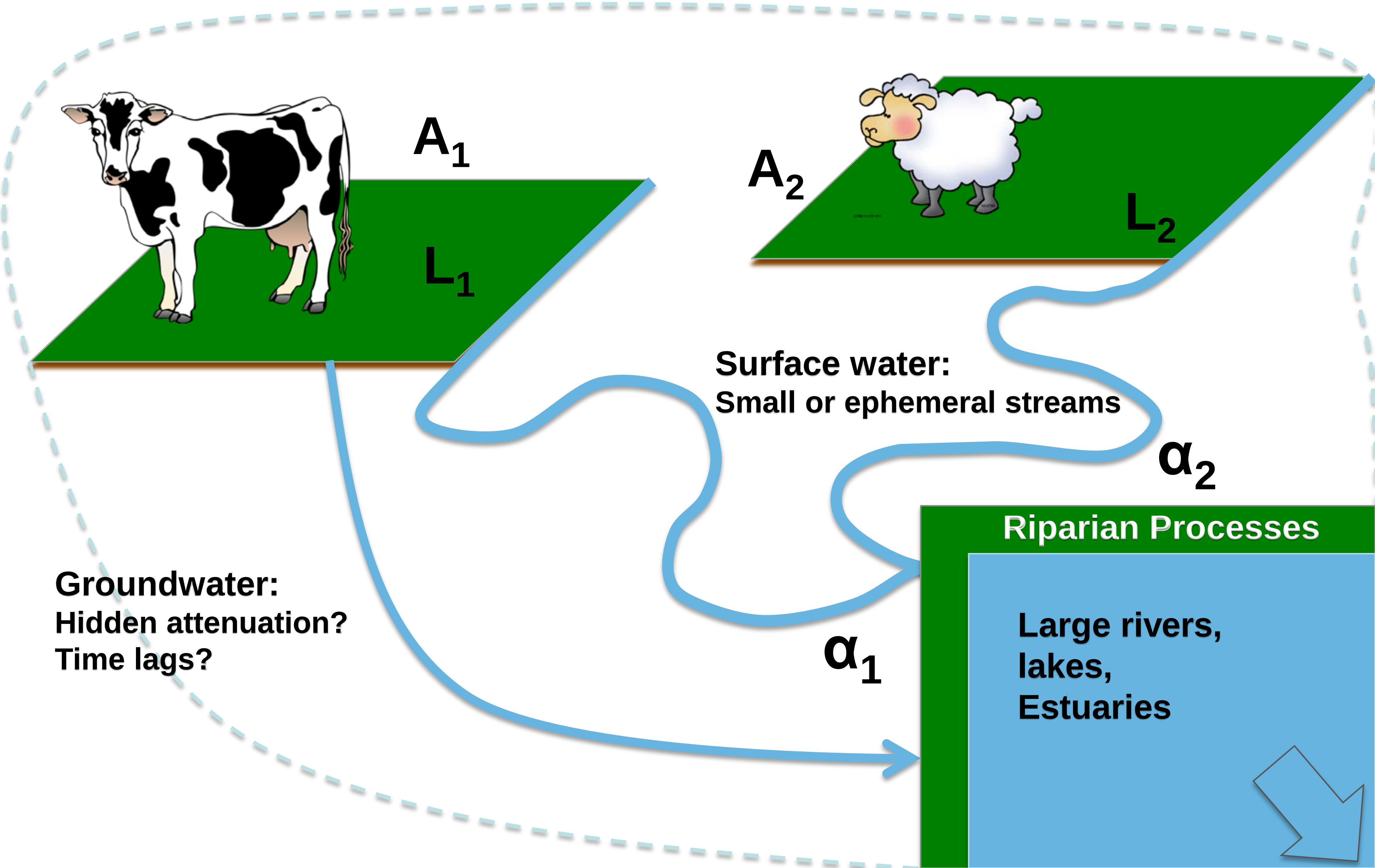
Alastair’s Diagram: Connectivity into Tarawera



$$A_1 L_1 \alpha_1 + A_2 L_2 \alpha_2 = B$$

attenuation = α

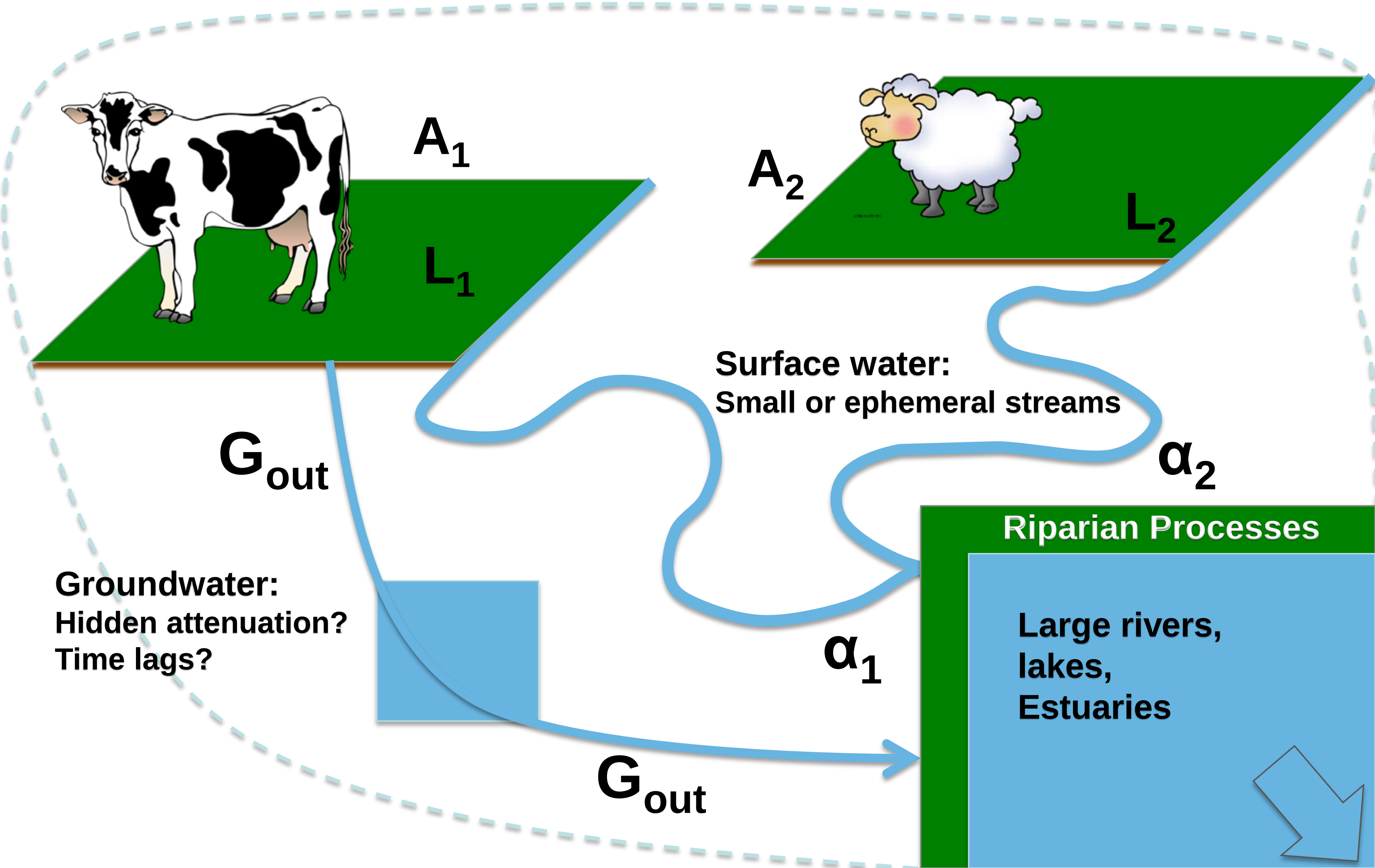
→ $1 - R_P$



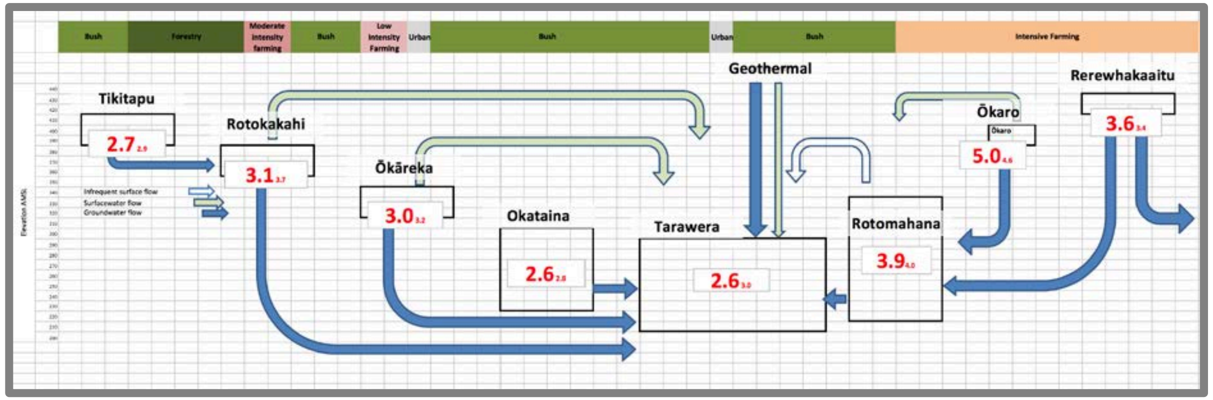
$$A_1 L_1 \alpha_1 + A_2 L_2 \alpha_2 + [G_{out} - G_{in}] = B$$

attenuation = α

→ $1 - R_P$



Where to from here?



→ *towards an accounting framework*

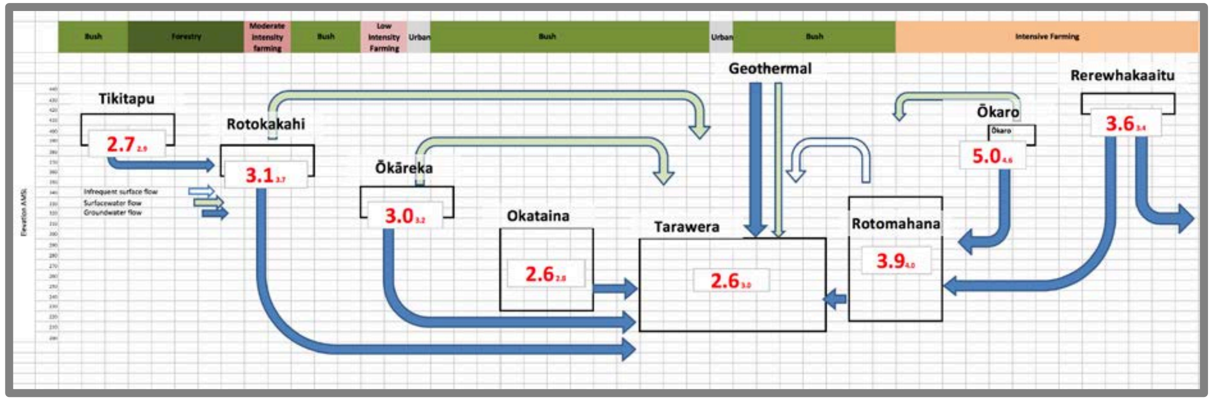
- Connect chain of catchment areas and removal coefficients
  - Same as ‘attenuation’ or ($1 – R_P$), same problem ROTAN addresses

- N mirrors P; Water flow matters also.

- Develop uncertainty methods, focused on decisions and risk

- Translate complex model results back to a simple table of water and nutrient flows & removals.

Complications?

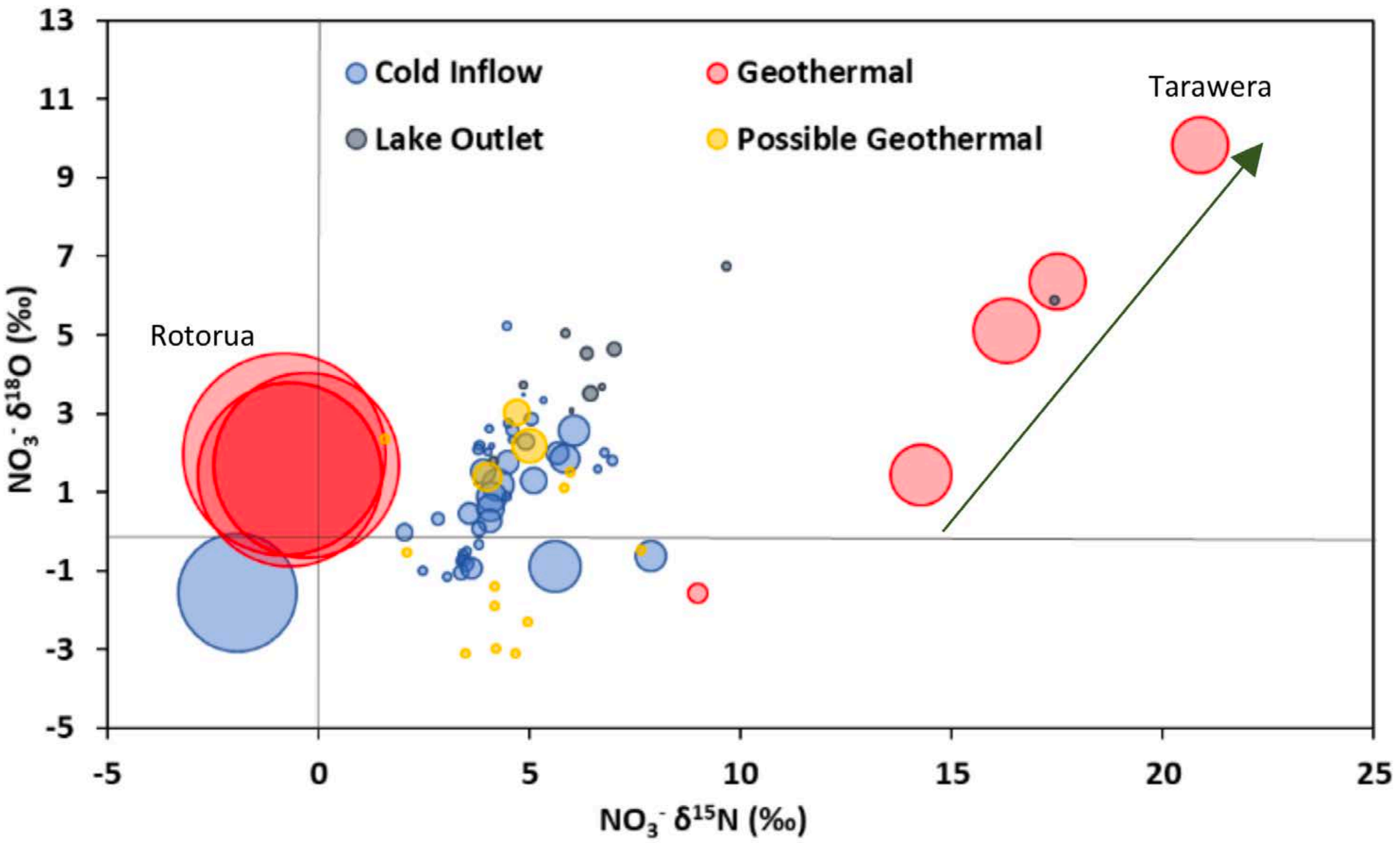


- Geothermal inflows need attention
  - As:P and δ^{15}N appear to distinquish geothermal P & N

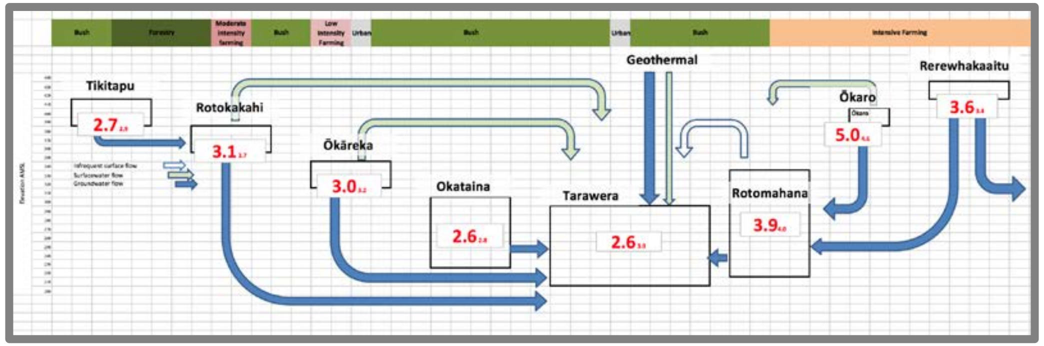
- Groundwater inflows need attention
  - Water mass balance, water isotope, and chemical lag times, tracers

- Stratification: what goes where; and when do T, DO, etc matter?
  - When do local contaminant inputs matter more?

Using N isotopes:



What will we do?

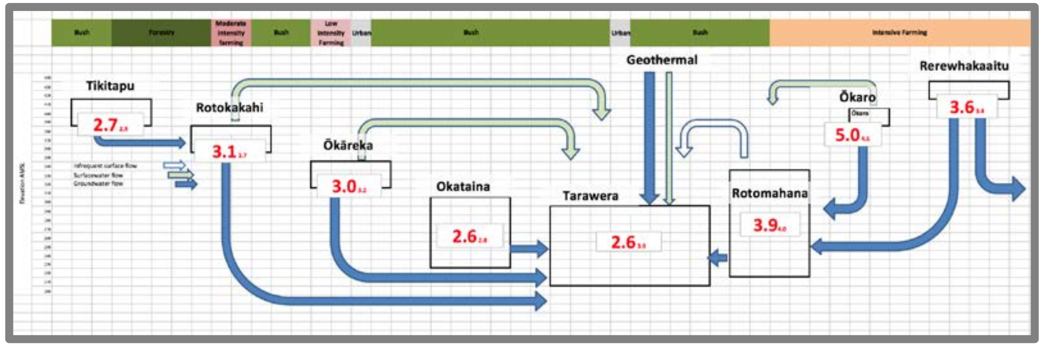


- Connect chain of catchment areas and removal coefficients
  - Same as ‘attenuation’ or (1 – R_P)
  - Mass-balance for water, N, and P

- Develop uncertainty methods, focused on <u>decisions</u>
  - Baseline, trends, reasons for trends, recommended reductions
  - Give regard to NPS-FM as required
  - Support clear communication of key concepts; early community engagement.

- Develop models including ensembles and coupled catchment-lake-groundwater
  - Model(s) that capture key dynamic mechanisms driving trends,
  - but must translate back to table of water and nutrient flows & removals; and
  - focus on measurements enabling structured adaptive management

Take home messages



- **Nutrient loads are driven by water flows**
  - Vary with climate and land cover

- **Reanalysis of trends and baselines is possible**
  - Changes the picture relative to discontinuous data of varying quality
  - Not a crisis, but significant trends are a reason for concern

- **We have a range of models at our disposal**
  - Simplest may be best?