Waimea Plains
Groundwater Isotope Analyses

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Waimea Plains

- Use of nitrates since the 1940s

- Elevated nitrate concentrations have been measured in the Waimea Plains since the late 1960s

- Highest concentrations in a narrow band along the east side of the UCA

- Surrounded by a broader nitrate anomaly, particularly at the northern extent of the UCA

- Hydrogen isotope sampling since 1972
- Nitrogen isotope sampling since 1998

- Main report: Stewart et al. (2011)

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Groundwater Isotopes

^{3}H Hydrogen isotopes (Tritium)

- Age of the groundwater
- Mean residence time of groundwater

^{18}O Oxygen isotopes

- Can differentiate recharge sources
- Recharge via river leakage verses rainfall infiltration

^{15}N Nitrogen isotopes

- Can differentiate nitrate sources
- Animal wastes vs inorganic fertiliser vs natural organic nitrogen

Hydrogen Isotopes (Tritium)

- Mean residence time (mrt) of groundwater
  - i.e. time since surface water entered the ground

- Represents a distribution of ages

- Reflects that the sample comprises groundwater travelling to the bore along multiple pathways drawing in groundwater from different parts of the aquifer and hence of different ages.

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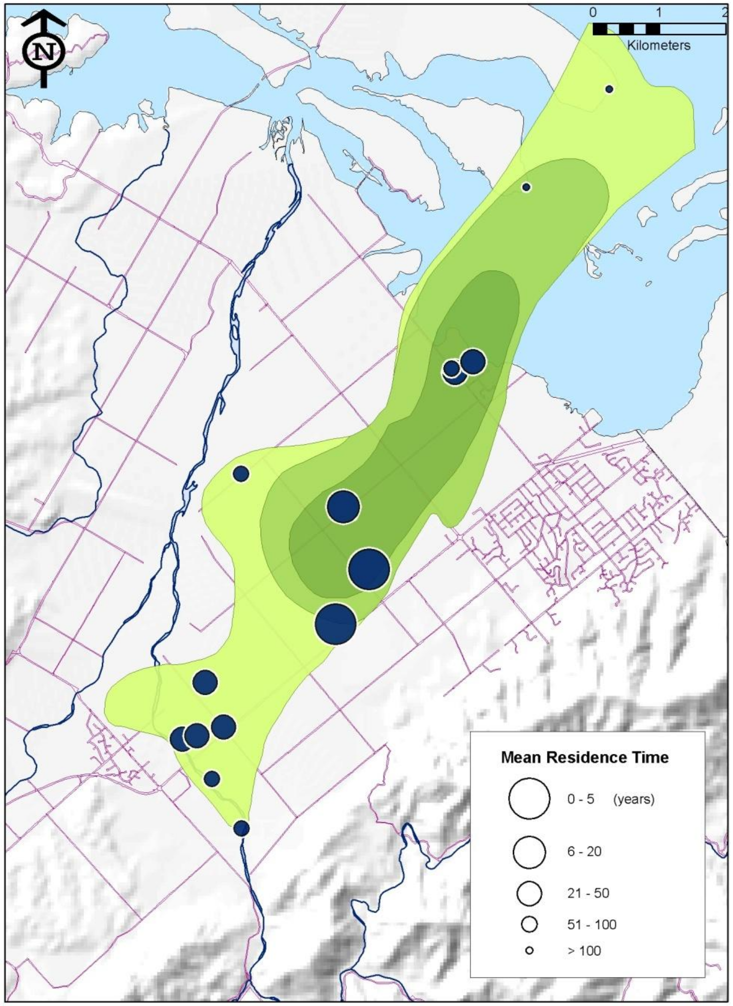
Hydrogen Isotopes

Lower Confined Aquifer

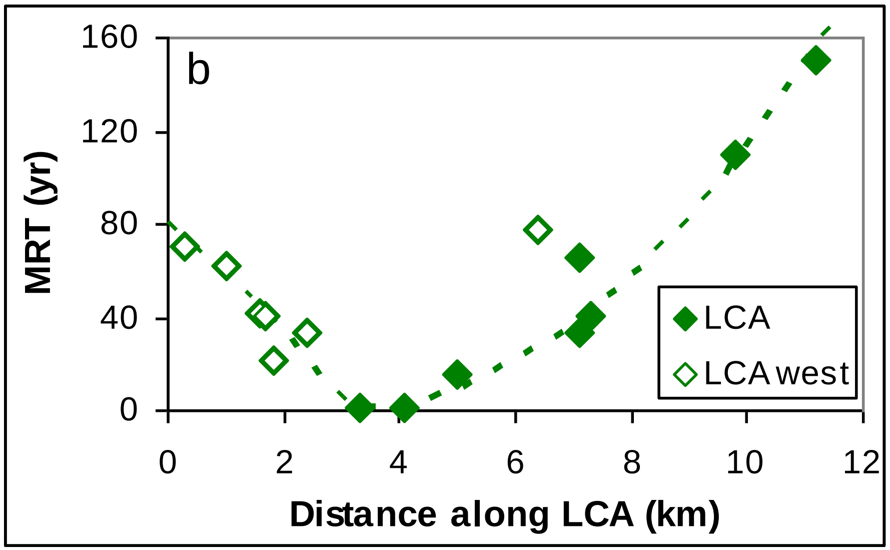
- Older groundwater at the southwestern end of LCA (≈40 years mrt).
- Oldest groundwater to the northeast (>100 years mrt)
- Youngest groundwater near the middle (<10 years mrt, ≈4 km along the aquifer)



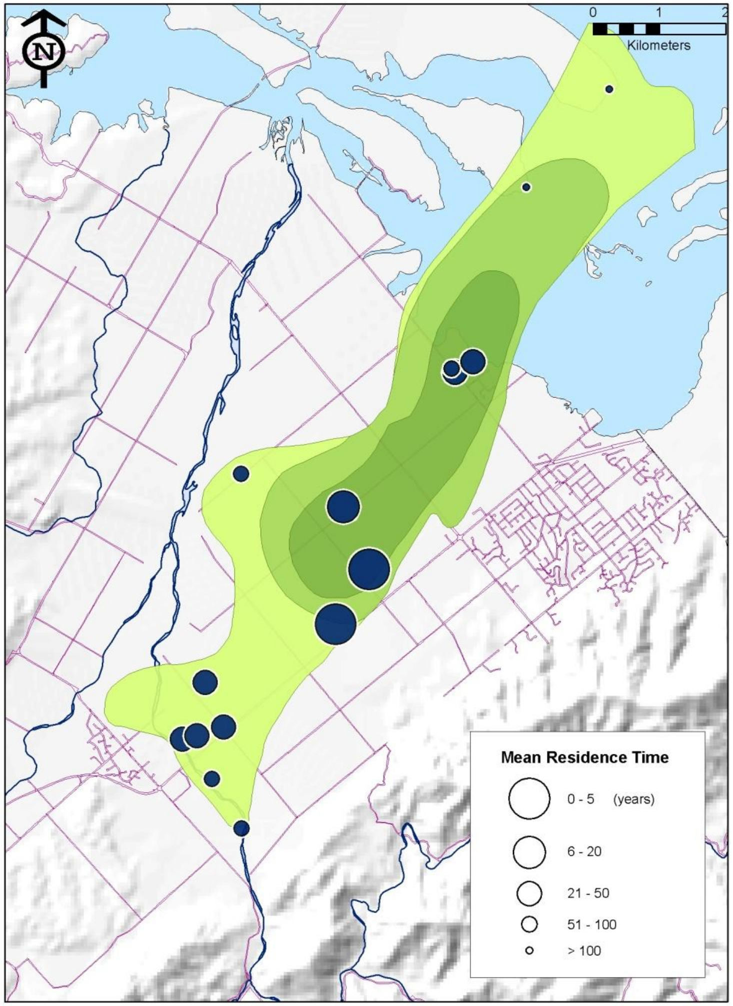
Mean residence times of groundwater

Hydrogen Isotopes

Lower Confined Aquifer



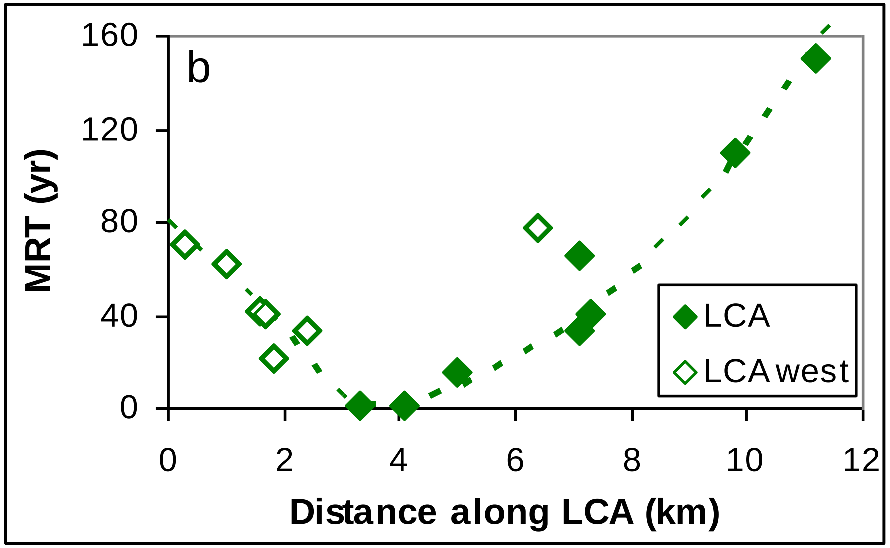
- Youngest groundwater ≈4 km along the aquifer



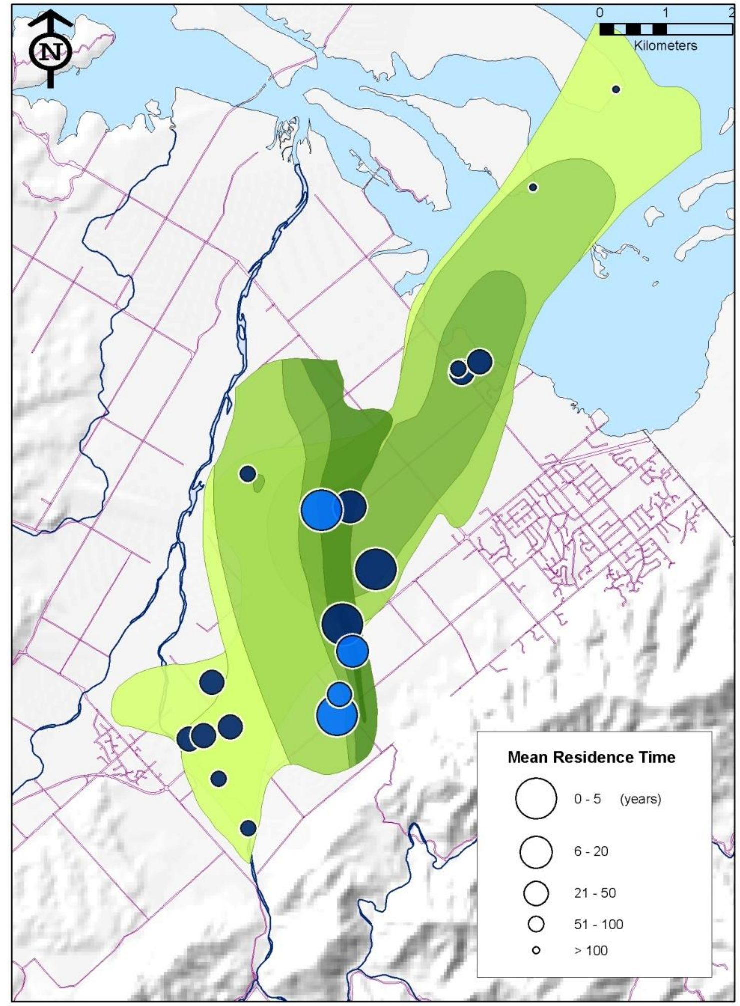
Mean residence times of groundwater

Hydrogen Isotopes

Lower Confined Aquifer



- Youngest groundwater ≈4 km along the aquifer
- This is where the UCA crosses over the LCA.
- Some recharge from the UCA to the LCA

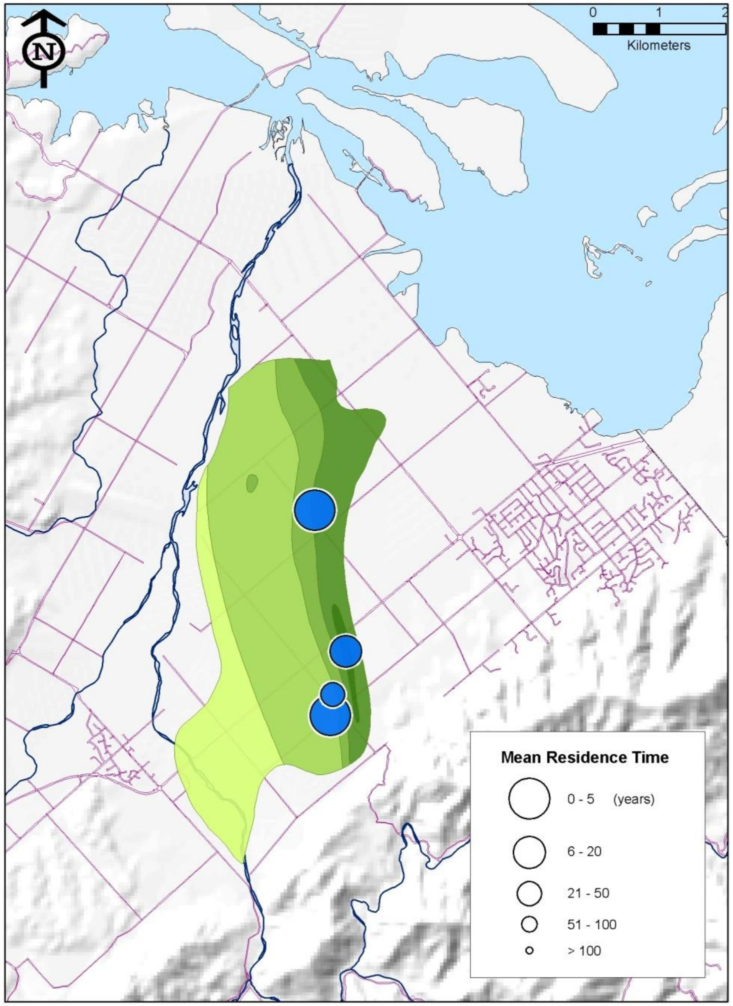


Mean residence times of groundwater

Hydrogen Isotopes

Upper Confined Aquifer

- Generally young groundwater (<5 years mrt).
- Some older groundwater present (≈20 years mrt)
- No data from the western extent where river recharge dominates



Mean residence times of groundwater

Oxygen Isotopes

- Useful for delineating the source of recharge water
- δ^{18}O values reflect the altitude that rainwater fell
- Rainfall on the Waimea plains and eastern hills $\delta^{18}O \approx -6.2^{0}/_{00}$
- Wairoa, Wai-iti and Waimea rivers
  with higher altitude catchments $\delta^{18}O \approx -7.2^{0}/_{00}$
- Can identify recharge via river leakage verses rainfall infiltration

Oxygen Isotopes

- Unconfined aquifers
  - Close to the rivers – Recharge from river leakage
  - Away from the rivers – Recharge from rainfall and runoff from eastern hills

- Confined aquifers
  - UCA and LCA – Recharge from river leakage at southeastern ends of aquifer
  - UCA – Recharge from rainfall and runoff from eastern hills
  - LCA – Leakage from overlying UCA

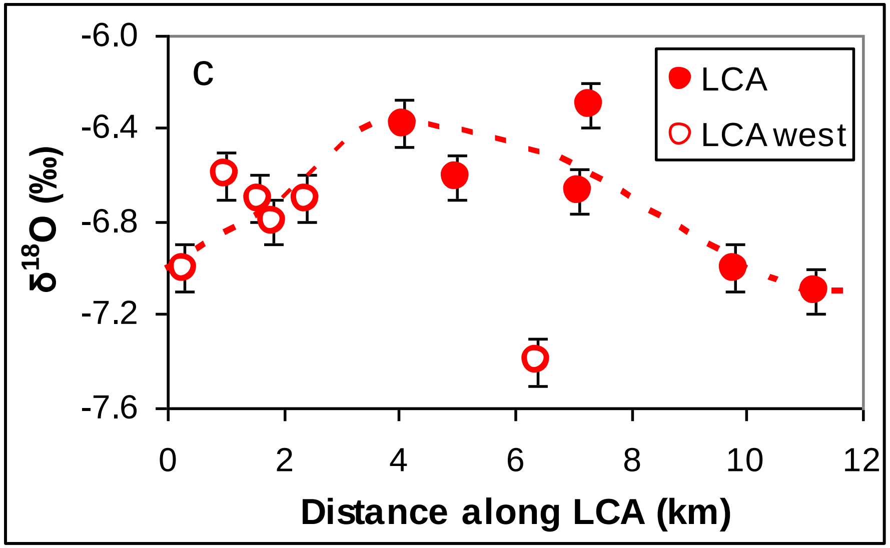
Oxygen Isotopes

Lower Confined Aquifer

- Mixture of recharge sources in LCA

- Increased portion of rainfall infiltration around the 4 km mark

  This is where UCA passes over LCA



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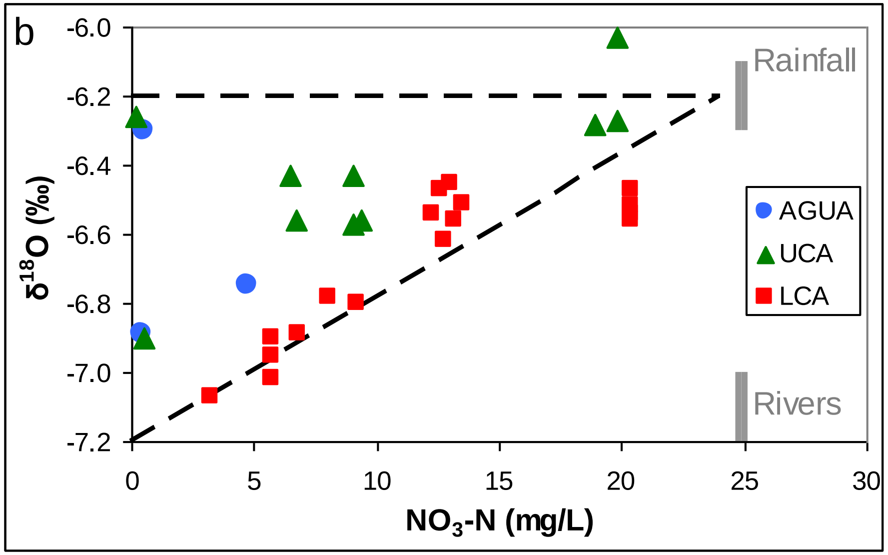
Oxygen Isotopes

- Highest nitrate concentrations associated with rainfall infiltration

- Lower nitrate concentrations where recharge dominated by river leakage

- UCA recharged from <u>both</u> rainfall and river



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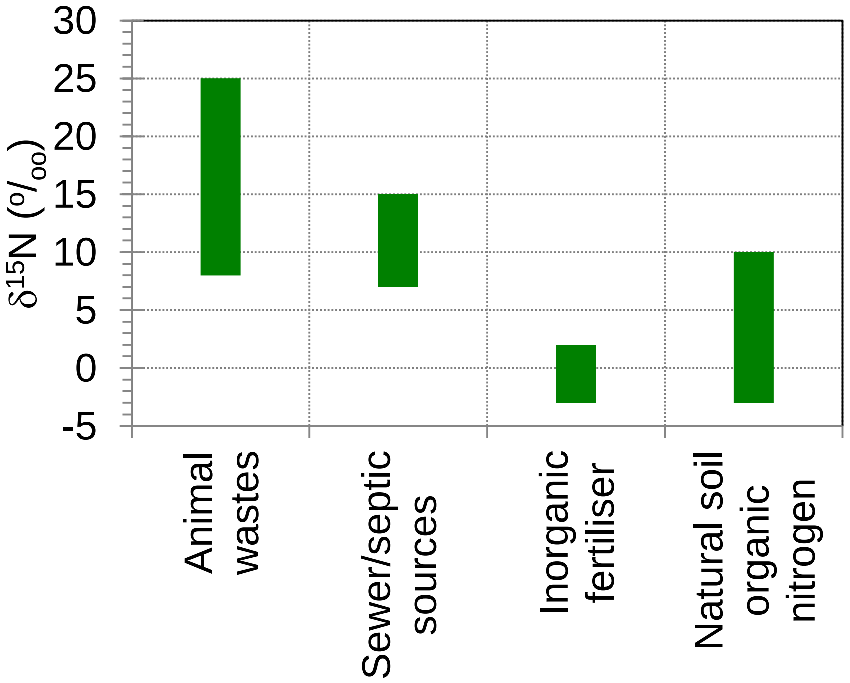
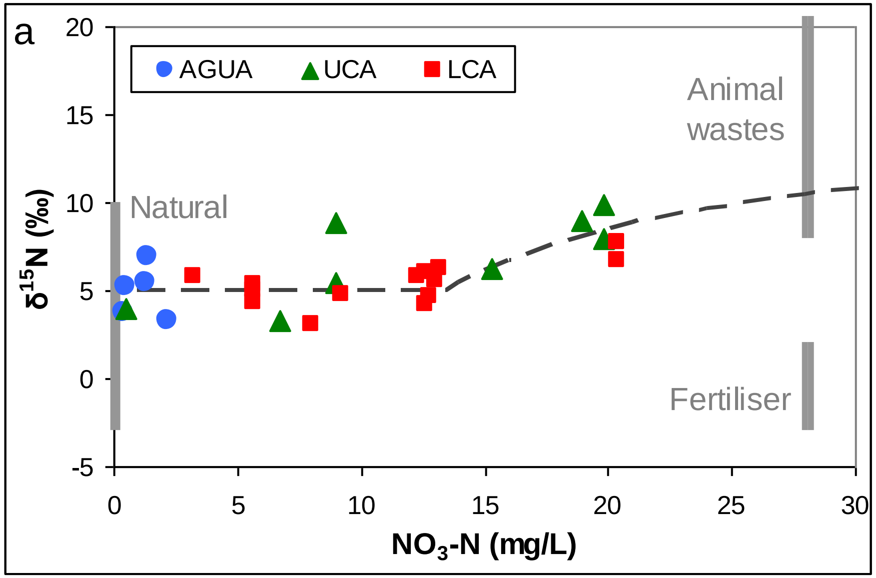
Nitrogen Isotopes

- Nitrate sources
- Animal wastes verses inorganic fertiliser
- Natural sources produce low (<1.6 g/m^3-N) nitrate concentrations in groundwaters



Nitrogen Isotopes

- Groundwater at a particular location is a mixture sources
- Trend line based on a mixing model fitted to data
- Highest nitrate concentrations show an increase in animal waste as a source



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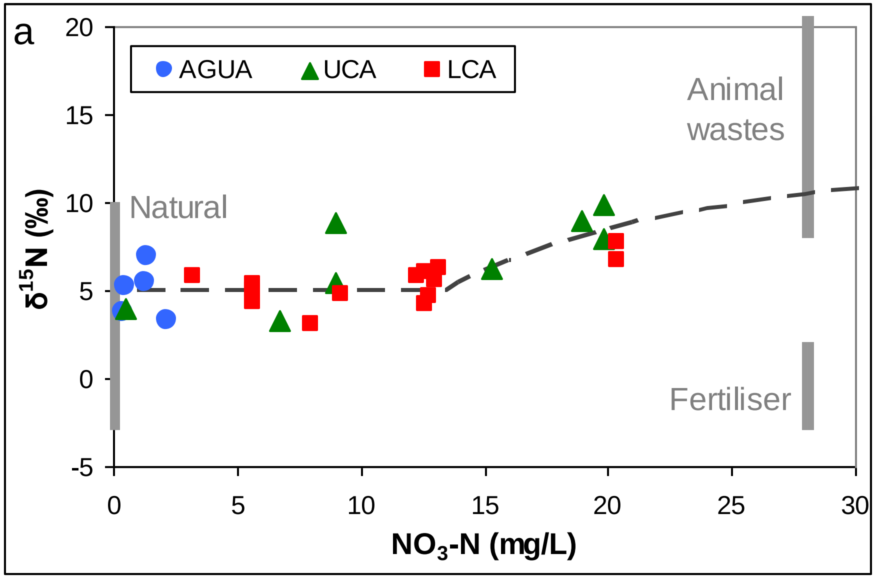
Nitrogen Isotopes

- Highest nitrates located at and down gradient of historic piggery and market gardening area
- Constant portion of trend line
  - Nitrate derived from both inorganic fertiliser and animal sources
  - Diffuse input over the plains (where rainfall infiltration occurs)
- Sampling sites targeted areas of nitrate contamination



History and future of nitrate concentrations

- Wide age distributions of UCA and LCA groundwaters
- Mixture of older and newer groundwaters
- Measured nitrate concentrations a reflection of both recent and historic influences

- Bimodal input to the UCA

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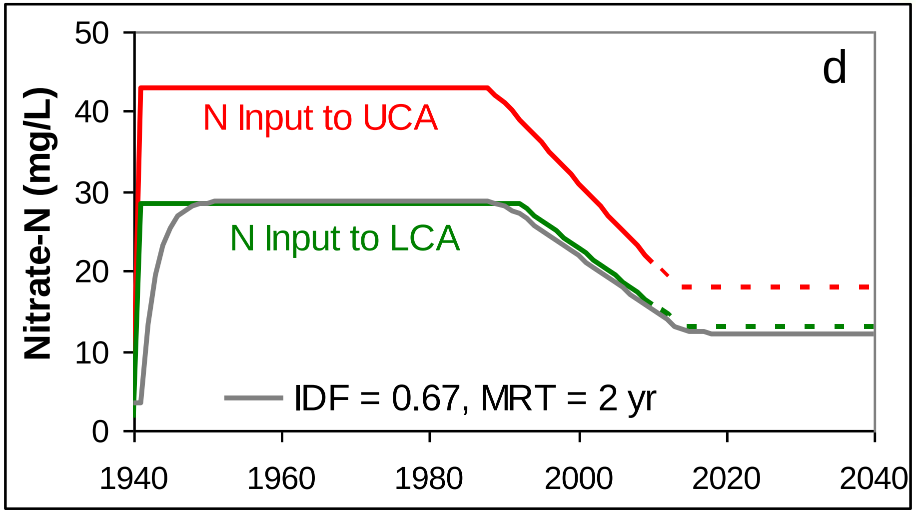
History and future of nitrate concentrations

- The nitrate inputs have been simulated based on the mixing models determined from the tritium data

- Based on assumed nitrate inputs to UCA

- Chosen to match measured nitrate concentrations in WWD162 and WWD37

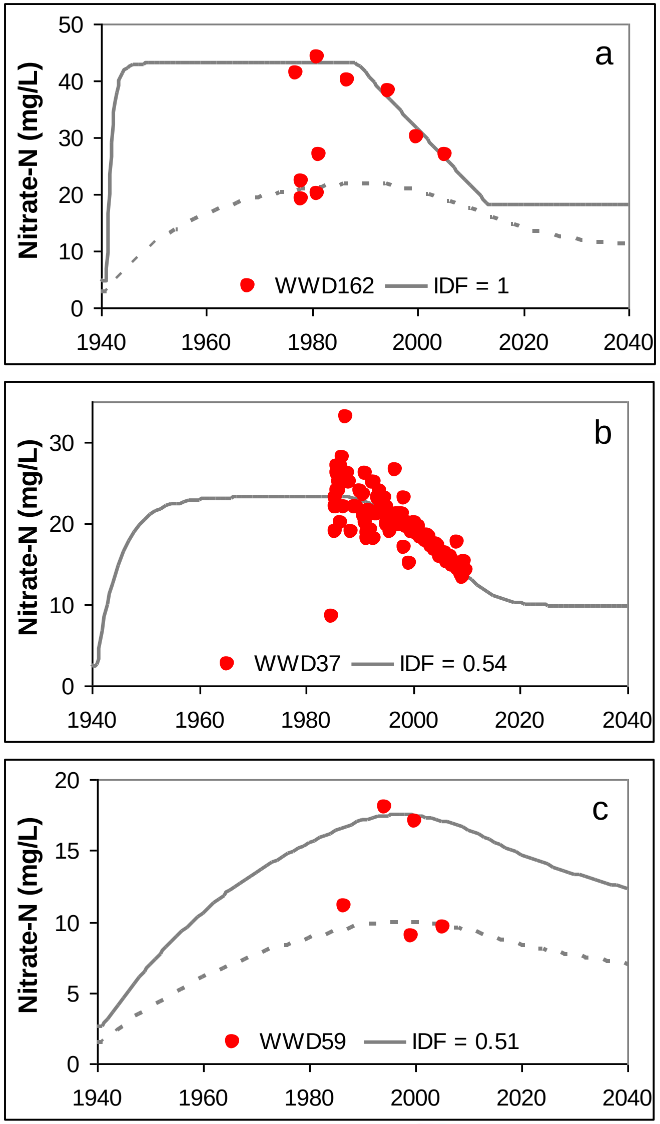


IDF = input dilution factor

History and future of nitrate concentrations

Upper Confined Aquifer

- WWD162 - bimodal nitrate inputs
  - Lower nitrate inputs ≈20 years mrt
  - Higher nitrate inputs <1 year mrt
- WWD37 - relatively short (4.5 years) mrt
  - Short lag time from nitrate input
- WWD59 - bimodal nitrate inputs
  - Lower nitrate inputs ≈35 years mrt
  - Higher nitrates much younger
  - Higher nitrates $\delta^{15}N$ value indicate animal waste input



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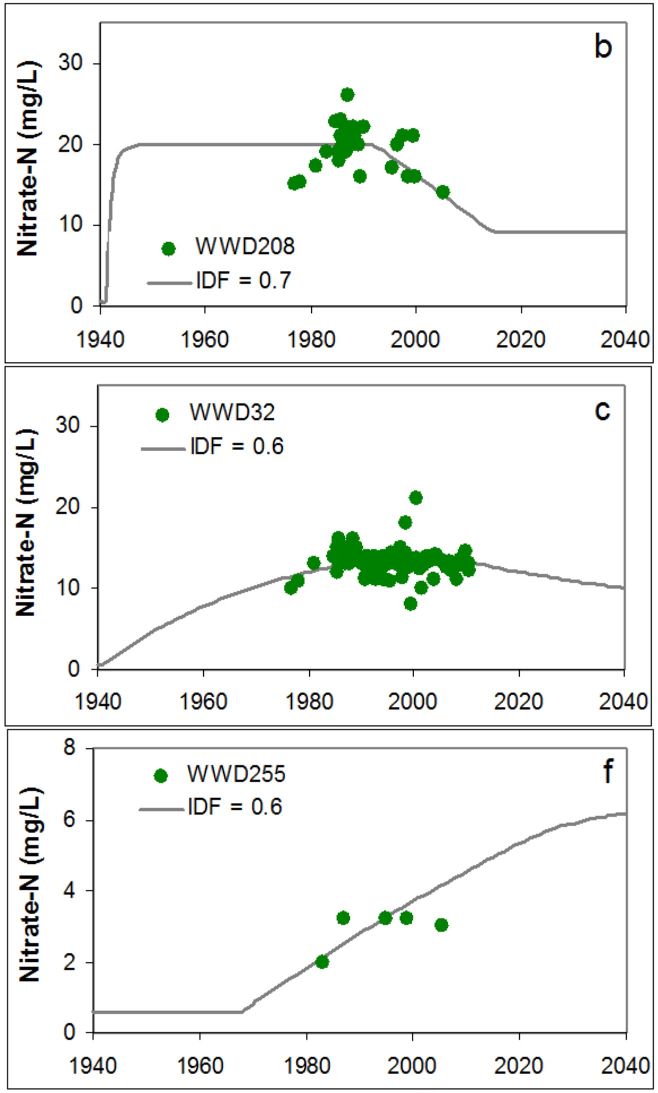
History and future of nitrate concentrations

Lower Confined Aquifer

- WWD208 - Dilution factor 0.7 and low (1 year) mrt
- WWD32 – Dilution factor 0.6 and 33.5 year mrt
  - Gentle rise, peaking around 2000
  - Gradual decrease now taking place
- WWD255 - Dilution factor 0.6 and <150 year mrt
  - Nitrate likely to continue rising for 20 years regardless of potential decreases in future inputs



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Summary

- Two kinds of nitrate contamination:
  a) Diffuse nitrate inputs attributed to the combined use of inorganic and manure fertilisers
  b) Strong point source attributed to piggery effluent

- Both the diffuse and point sources were present since the 1940s

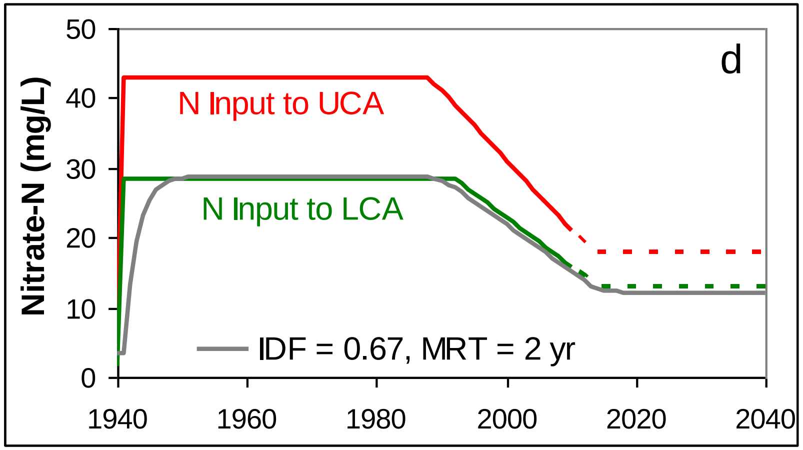
Summary

- Historic nitrate contamination primarily in the vicinity and south of Hope
  - Groundwater recharge areas
  - Nitrate contamination of UCA and LCA
  - Nitrates moving northwards through the aquifer systems
  - Will take decades to flush through the aquifer systems

- Groundwater elsewhere on the Waimea Plains
  - Relatively low nitrate concentrations
  - River and/or rainfall recharge with low nitrate concentrations

Summary

- Legacy of historic nitrate concentrations in parts of the Waimea Plains
  - Historic nutrient management not sustainable
- Uncertainty about current levels of nitrate leeching to aquifers
- Historic nitrate contamination may be masking current land use impacts inputs



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Summary

- Need to ensure that current land use practices are sustainable
  - That nutrient leeching is, and remains, within acceptable limits

- Intensification of Waimea Plains land use will require careful nutrient management

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M.K. Stewart, G. J. Stevens, J.T. Thomas, R. van der Raaij, V. Trompetter 2011: Nitrate Sources and Residence times of Groundwater in the Waimea Plains, Nelson in *Journal of Hydrology (NZ)* 50(2): 313-338 2011

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