Hydrogeology of an urban weathered basement aquifer in Kampala, Uganda

Jan Willem Foppen / December 2023

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Background and aim of the study

https://t-group.science/

https://wash.futureclimateafrica.org/projects/hycristal/overview

- Understand the hydrogeological system (groundwater flow, chemistry, age, (and recharge) along a flow transect);
- Wide relevance to many parts of Africa (weathered basement terrains);

Nyenje et al. (2022)

Methods

- ERT;
- Drilling;
- Groundwater monitoring;
- Spring water monitoring;
- Aquifer properties;
- Hydrochemistry and isotopes;

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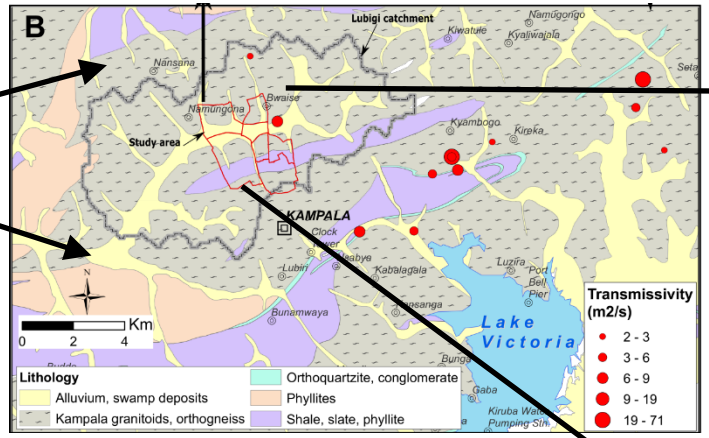
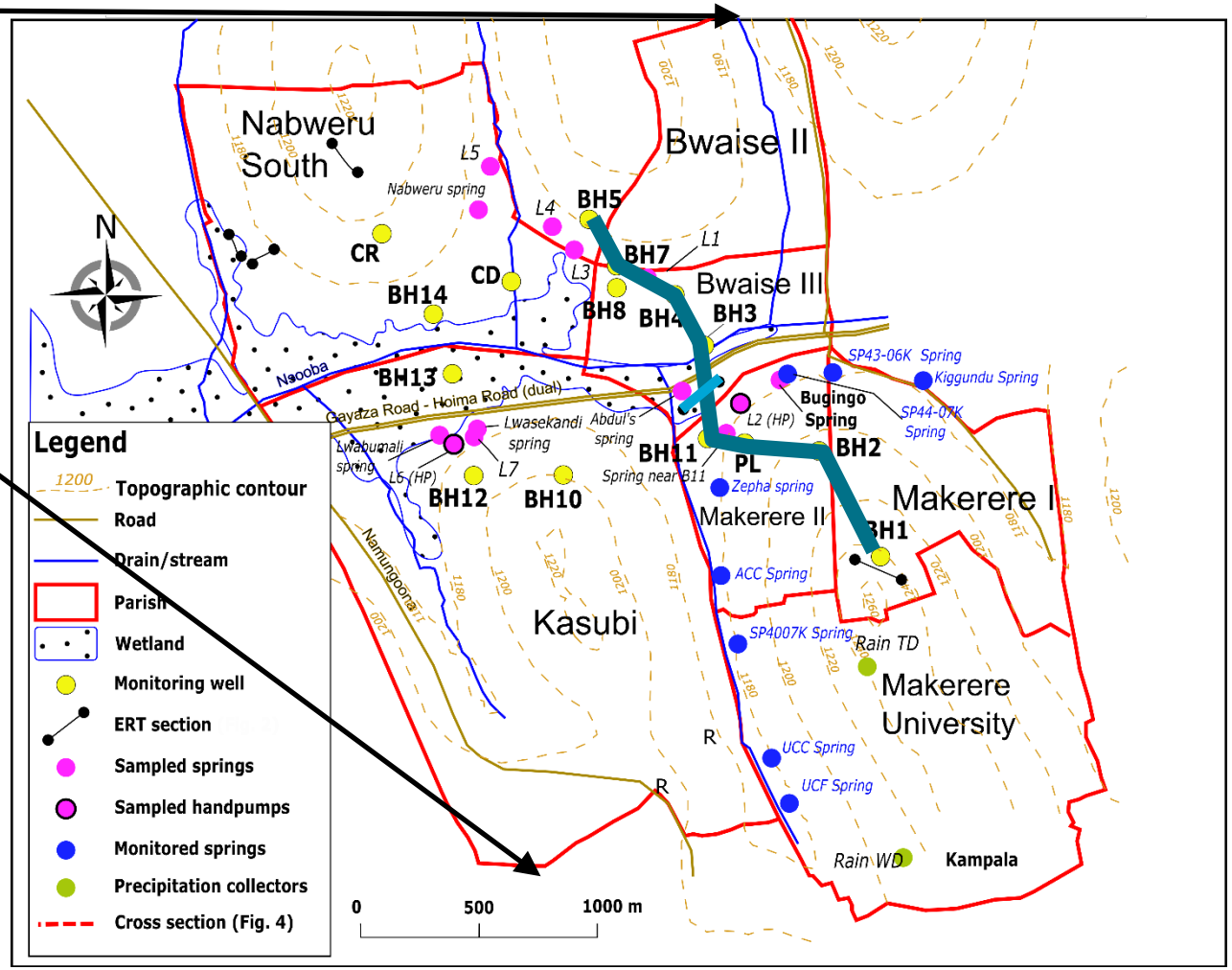
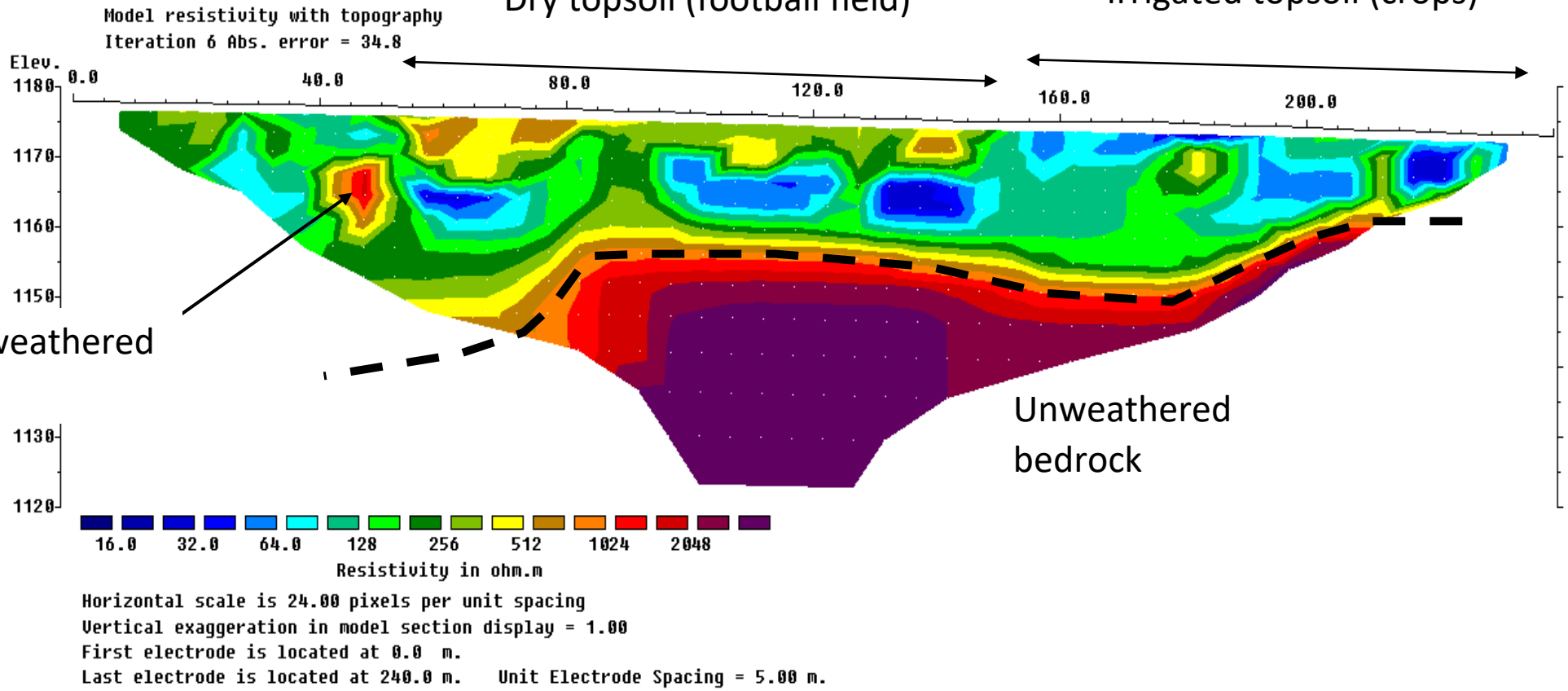
Monitoring network and sampling locations





Nyenje et al. (2022)

Example ERT cross-section



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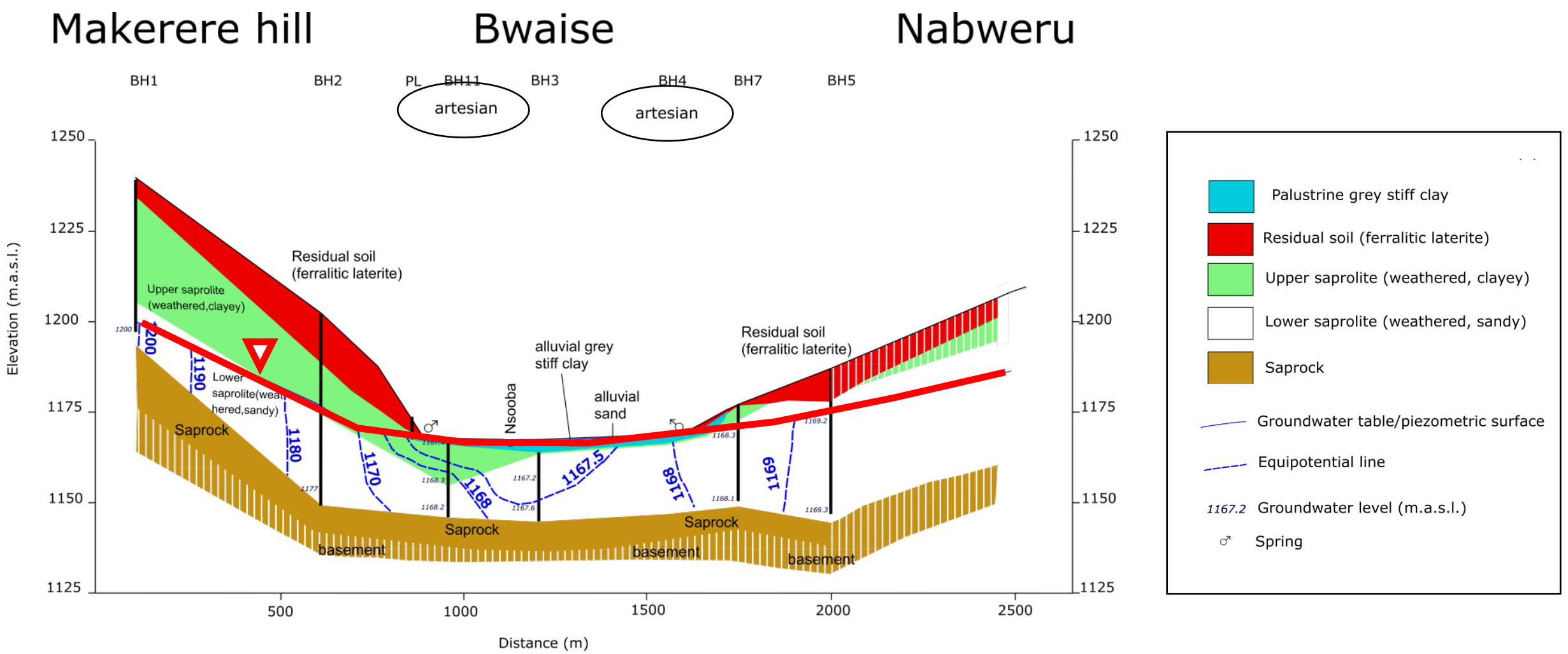
Nyenje et al. (2022)

Hydrogeology and equipotential lines in a borehole cross-section



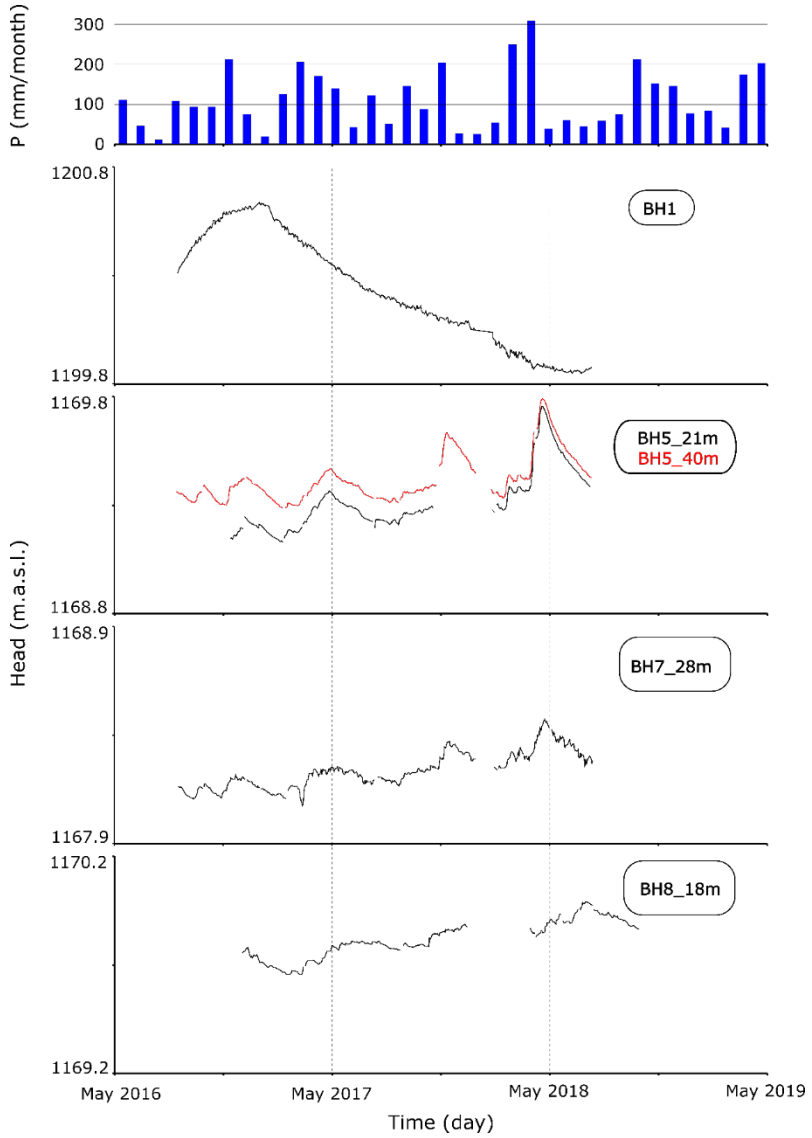
Nyenje et al. (2022)

High resolution groundwater hydrographs (20 minute interval)

phreatic – no or very delayed response

confined response

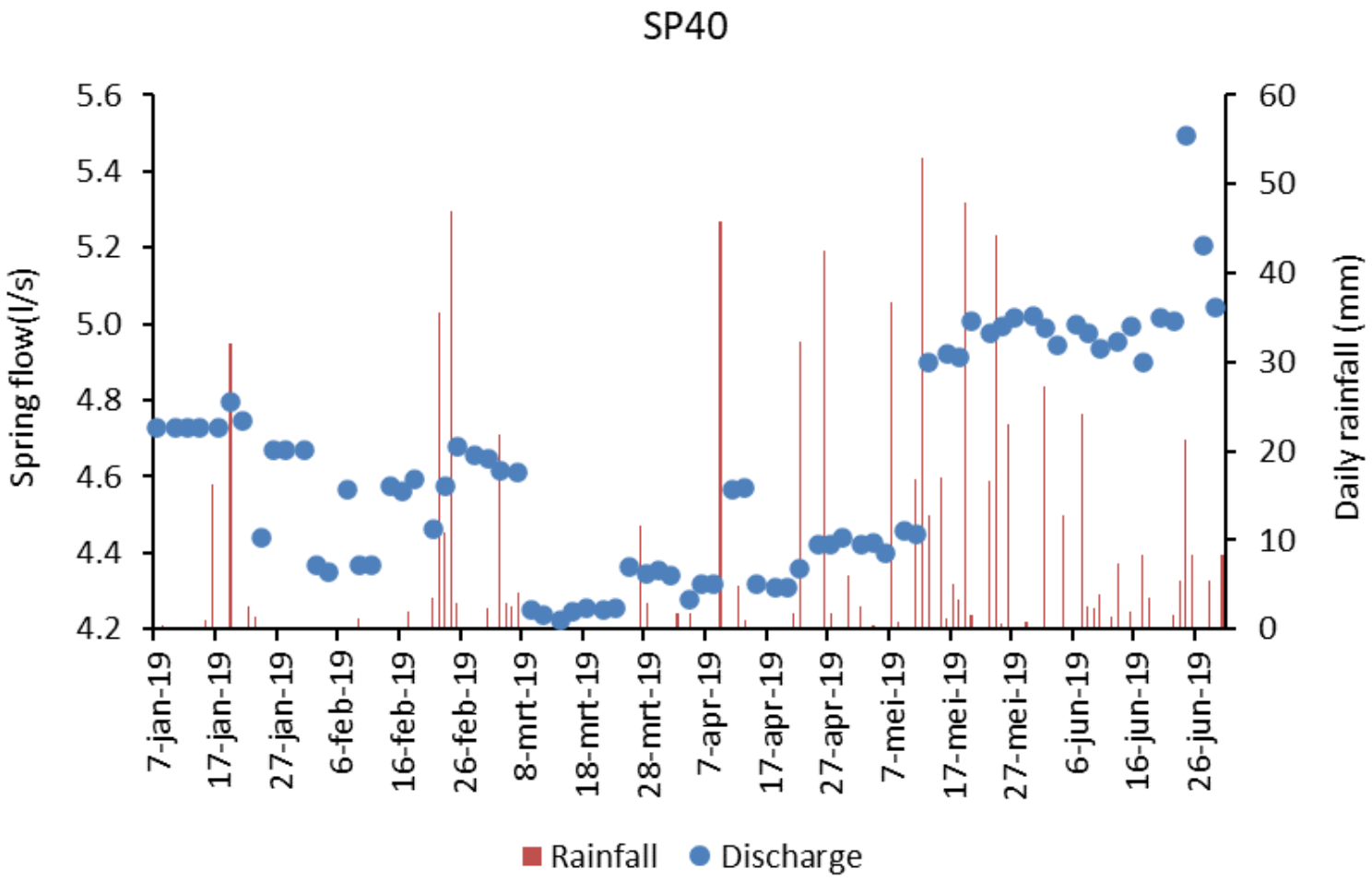
unclear – delayed response



Precipitation [mm/month] at Makerere hill station

Nyenje et al. (2022)

Flows of springs and daily rainfall



- Some response in flow to rainfall events;
- Responses were not consistent across events;

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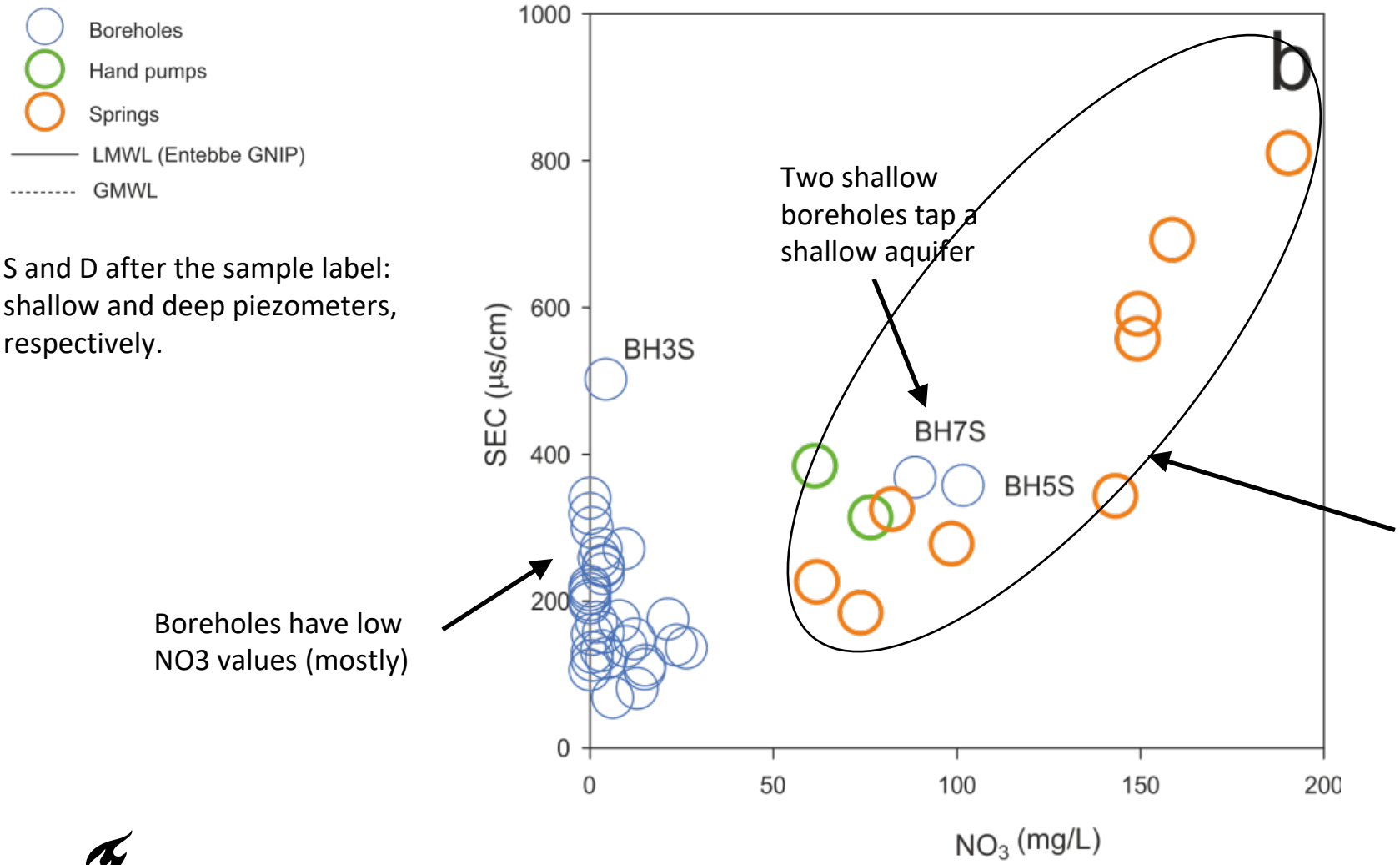
Nyenje et al. (2022)

NO3 and EC



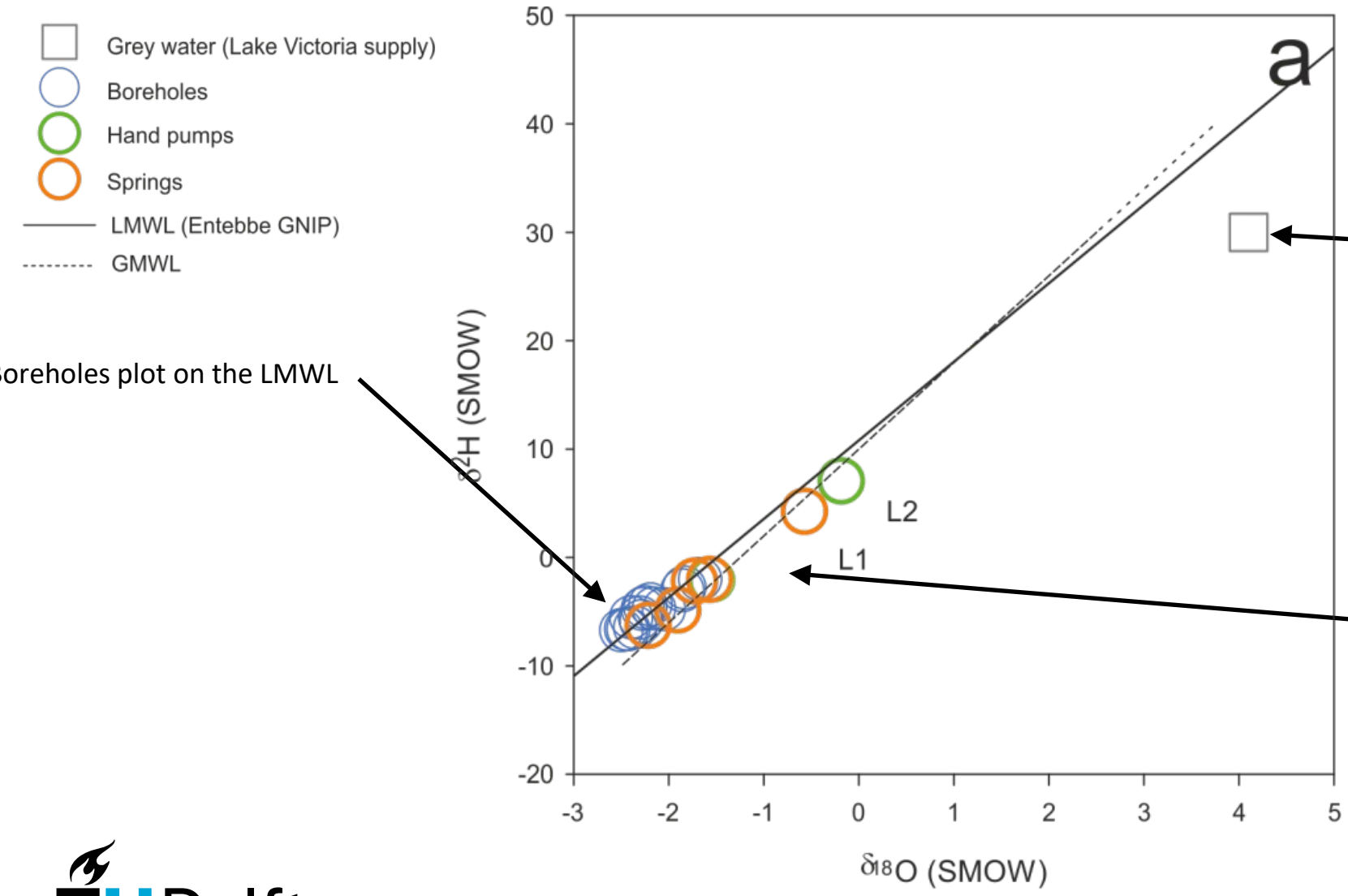
S and D after the sample label: shallow and deep piezometers, respectively.

Boreholes have low NO3 values (mostly)

Springs and handpumps have high NO3 values, large variability

Nyenje et al. (2022)

Stable isotopes



Lake Vic = source of piped drinking water

Boreholes plot on the LMWL

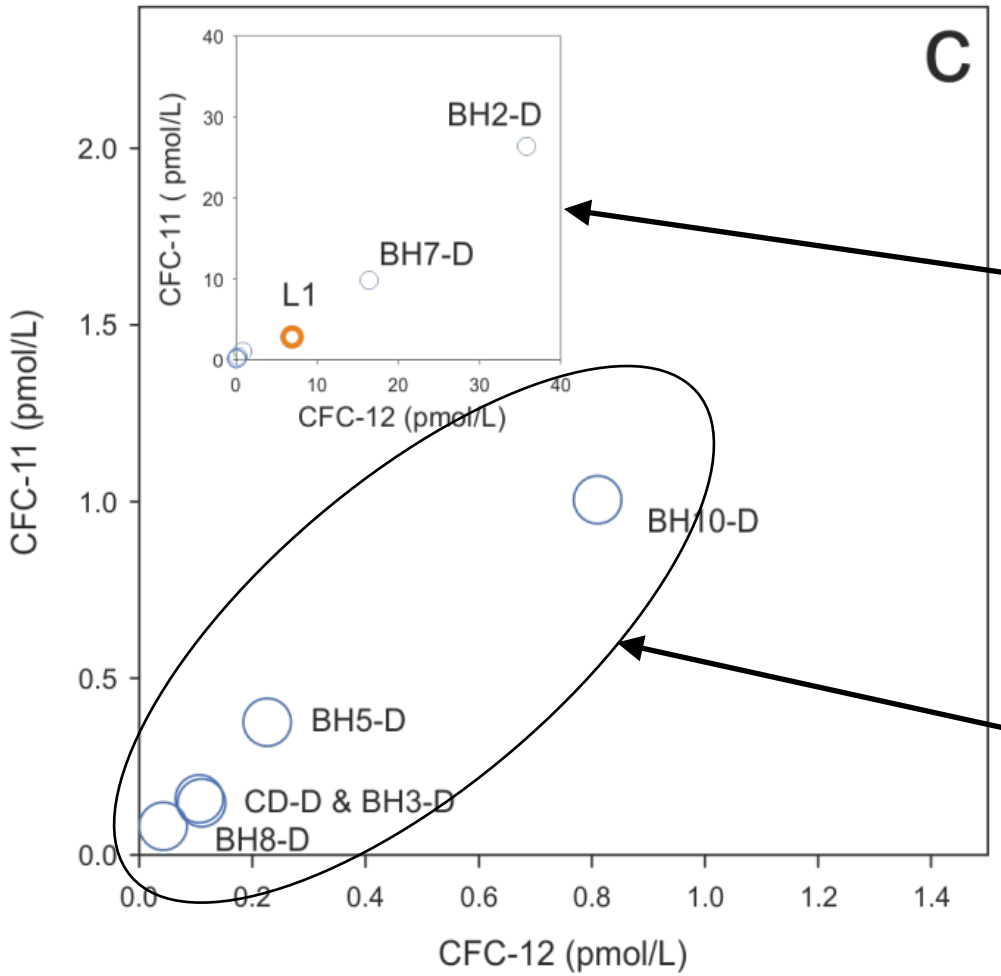
Springs and handpumps plot slightly below the LMWL, slightly enriched, greater variability than boreholes

Nyenje et al. (2022)

CFCs

Grey water (Lake Victoria supply)
Boreholes
Hand pumps
Springs
LMWL (Entebbe GNIP)
GMWL

S and D after the sample label: shallow and deep piezometers, respectively.



High CFC signature (some localized source)

Positively related, but low concentrations

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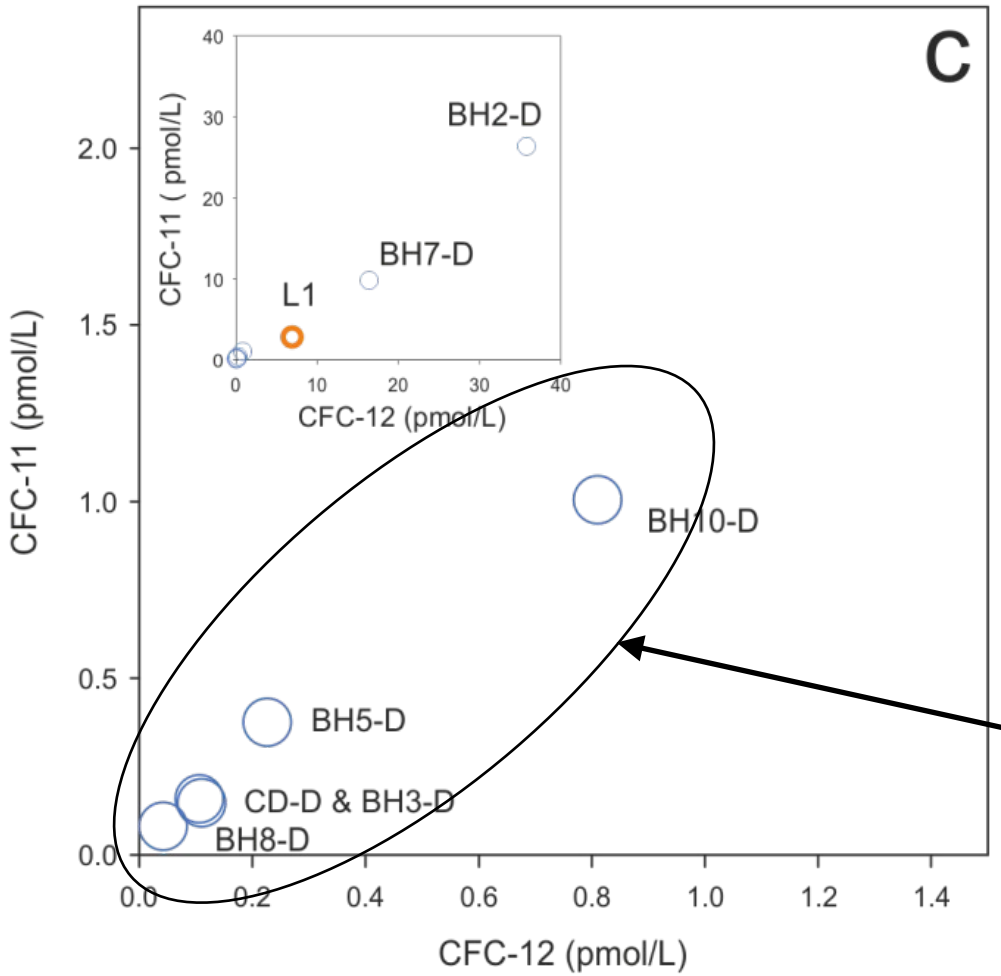
Nyenje et al. (2022)

CFCs

Grey water (Lake Victoria supply)
Boreholes
Hand pumps
Springs
LMWL (Entebbe GNIP)
GMWL

S and D after the sample label: shallow and deep piezometers, respectively.



Low CFC groundwaters have mean residence times that are considerably older than the CFC contaminated sites. Hydraulically isolated.

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Nyenje et al. (2022)

CFCs

Grey water (Lake Victoria supply)
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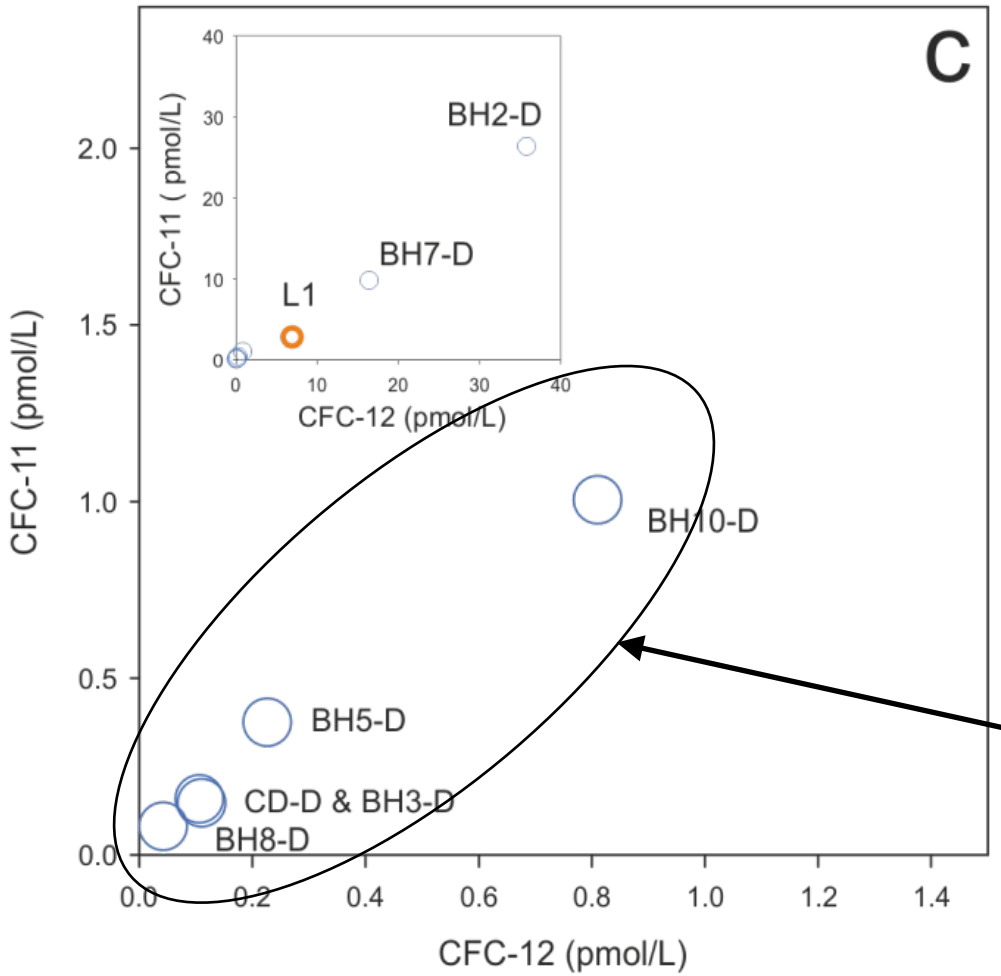
S and D after the sample label: shallow and deep piezometers, respectively.



Piston flow model: MRT 40-65 yr;

Binary mixing model: 3-15% percent modern water;

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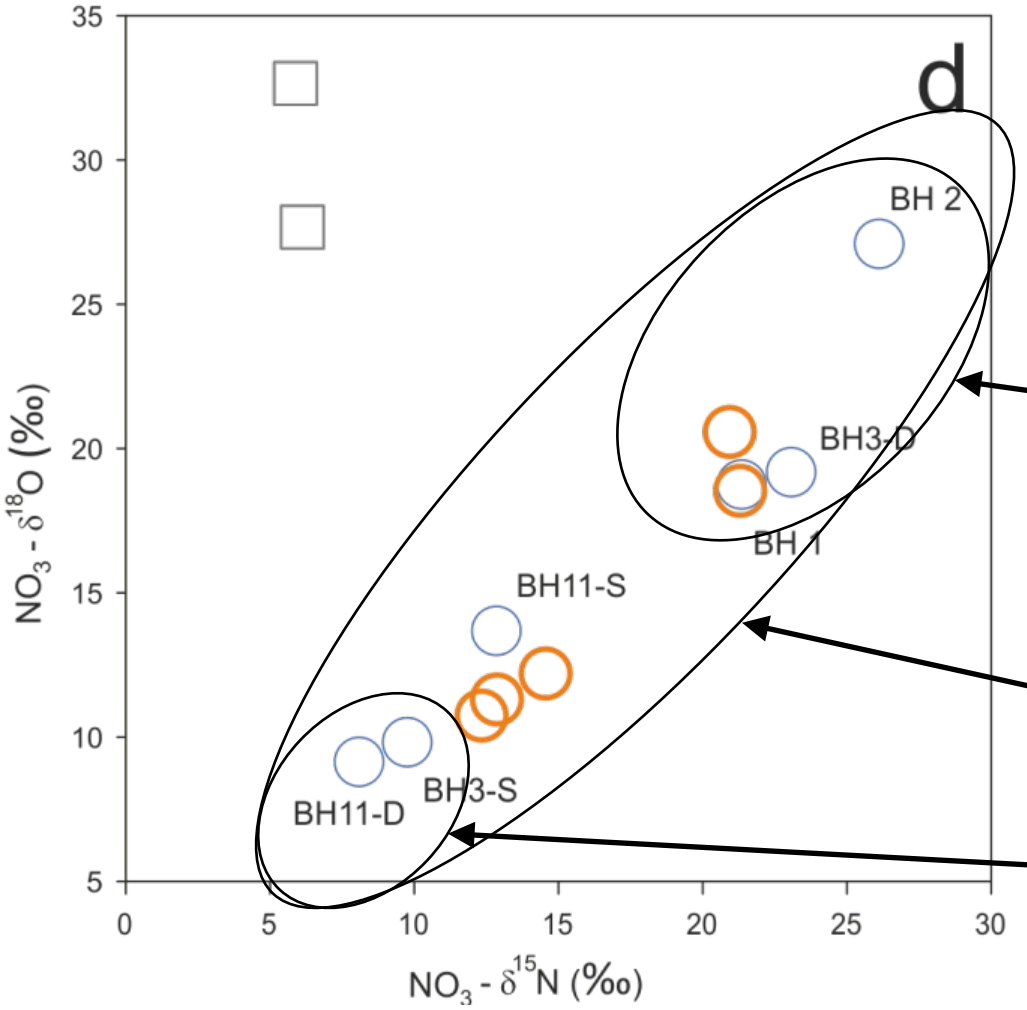
Nyenje et al. (2022)

NO3 isotopes

Grey water (Lake Victoria supply)
Boreholes
Hand pumps
Springs

S and D after the sample label: shallow and deep piezometers, respectively.



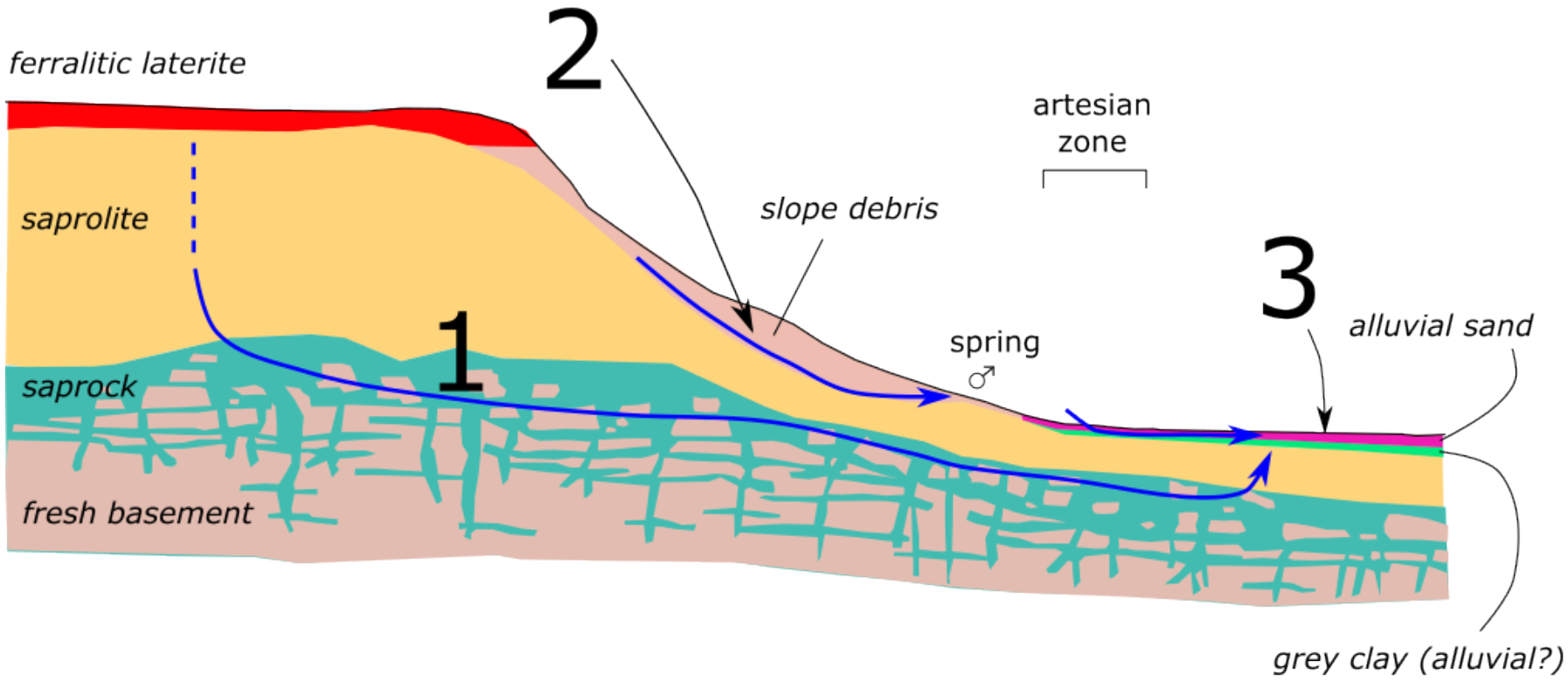
Enriched values possibly indicate denitrification

Spring and borehole samples plot along a line;

Downgradient depleted values

Nyenje et al. (2022)

Simplified schematic of groundwater flow and spring systems in the upper Lubigi catchment, Kampala



1: aerobic, low EC, low NO3, pH 6-6.5, residence time 30-60 yr, CFC-11/CFC-12 low

2: aerobic, perched, moderate EC, high NO3, low pH (<5), residence time < 30 yr, CFC-11/CFC-12 sometimes high

3: anaerobic, high EC, no NO3, pH ~7-8 (not discussed here; previous work)

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after Nyenje et al. (2022)

Conclusions

- Hydrochemically stratified groundwater system with a shallow flow component (stable isotope enrichment, higher nitrate, and EC and CFC tracers) and a deeper component (no stable isotope enrichment, low nitrate, EC, and CFC) in the saprock and fractured bedrock, which is largely hydraulically isolated from the shallow system.
- Low groundwater yields (not specifically discussed this presentation); therefore, only small-scale abstractions for private or self-supply by communities are possible. However, direct consumption without treatment should be discouraged because of the low quality of this groundwater. Recharge is (partly) by wastewater infiltration.
- Artesian conditions in the deeper groundwater system in the valley bottom. This deeper regional groundwater has better chemical quality than groundwater from springs. Local authorities could explore this resource using boreholes tapping the saprock for small-scale local consumption as a low-cost water supply alternative to springs. Also: treatment!

Thank you

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