Drivers of Groundwater Salinity and Potential for Freshwater Abstraction on a Semi-arid Coral-limestone Island in Sri Lanka

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Problem Statement and Research Objectives

Problem statement:

Salinisation of fresh groundwater reserves is further threatened by the combination of short-term growth in population and tourism, and long-term sea-level rise.

Research objectives:

Evaluate and explain the distribution of fresh and saline waters on Delft Island, Sri Lanka through geophysical surveying and hydrochemical analysis.

Evaluate the abstraction potential of groundwater reserves through numerical modelling.

Figure 1. Location map of Delft Island, Sri Lanka.

Hydrogeological Setting and Methodology

Aquifer Characteristics:

- Karst Limestone
- Unconsolidated Sand

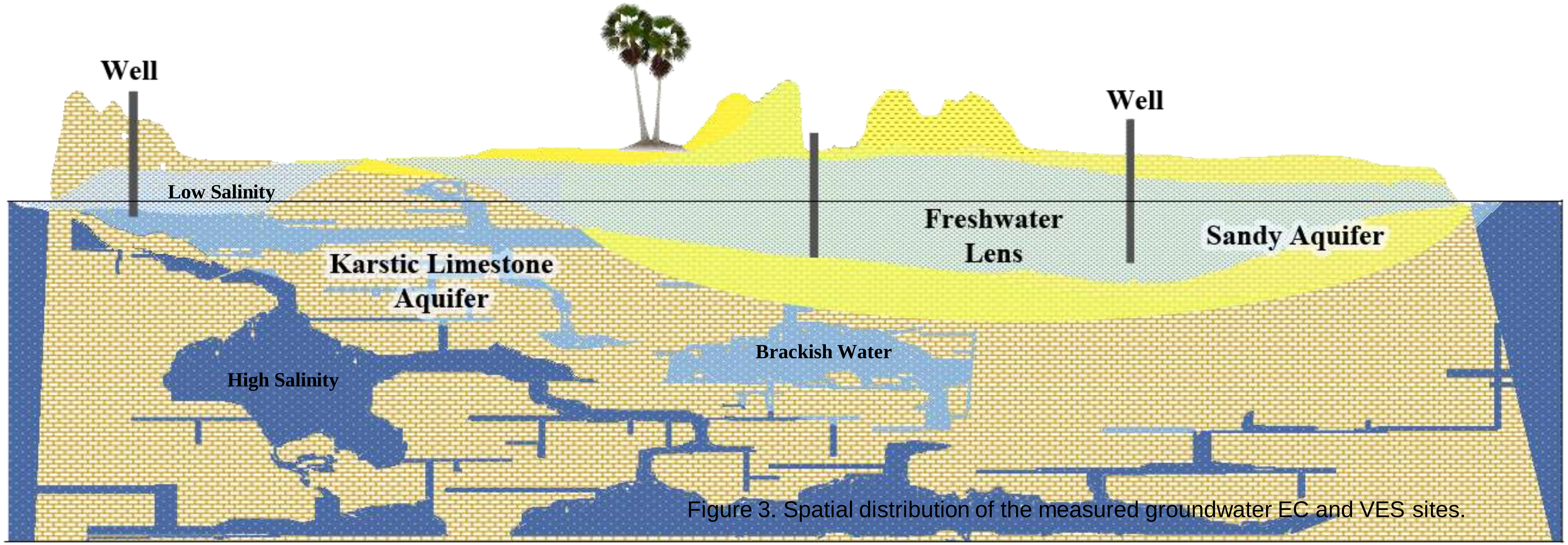


Figure 3. Spatial distribution of the measured groundwater EC and VES sites.

Figure 2. Conceptual model of the possible occurrence of the freshwater lens floating above the highly saline water in a karstic limestone aquifer (left) and sandy aquifer (right).

Hydrogeological Setting and Methodology

Methods:

- Geophysical Survey (Vertical Electrical Sounding)
- Hydrochemistry and Isotope Analysis (water quality measurements)

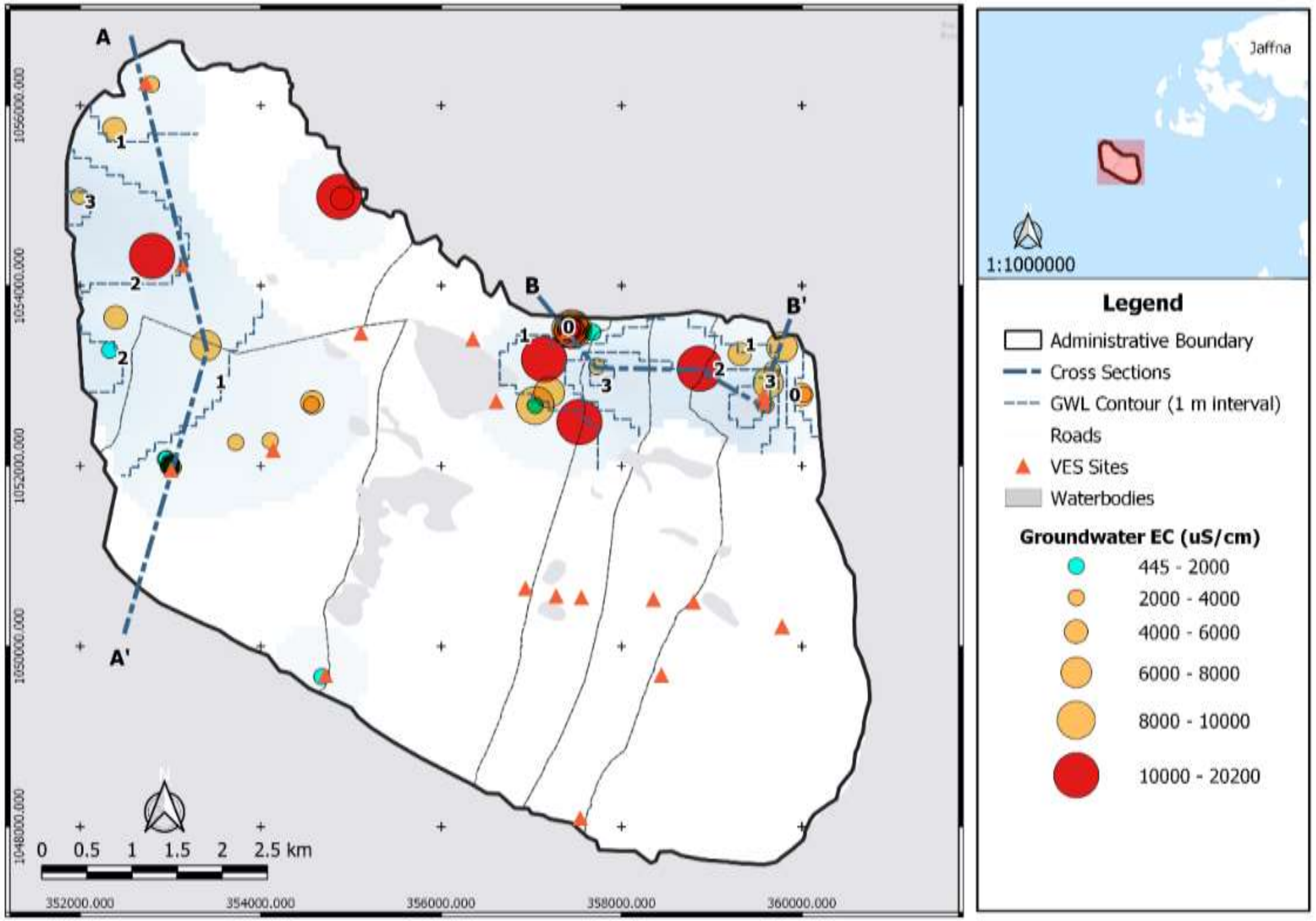
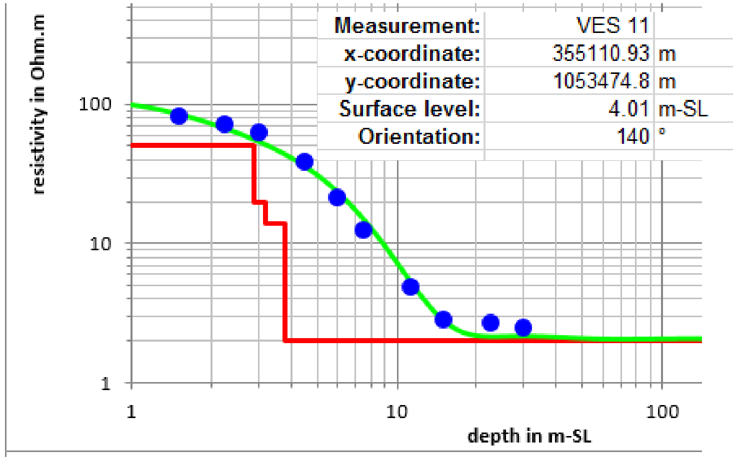


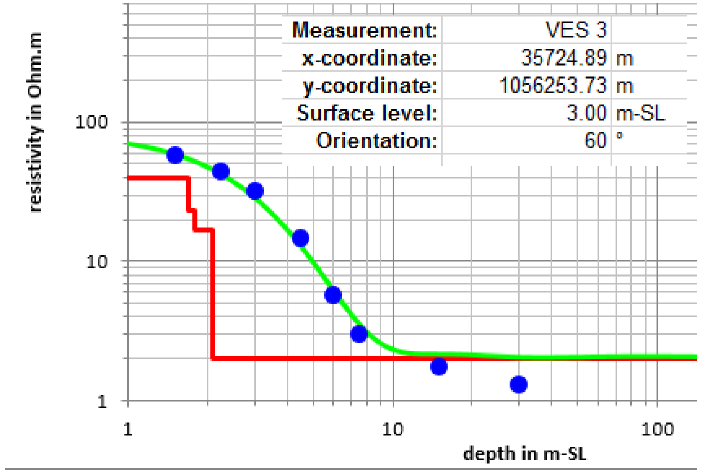
Figure 3. Spatial distribution of the measured groundwater EC and VES sites.

Curve fitting and interpretation of VES data

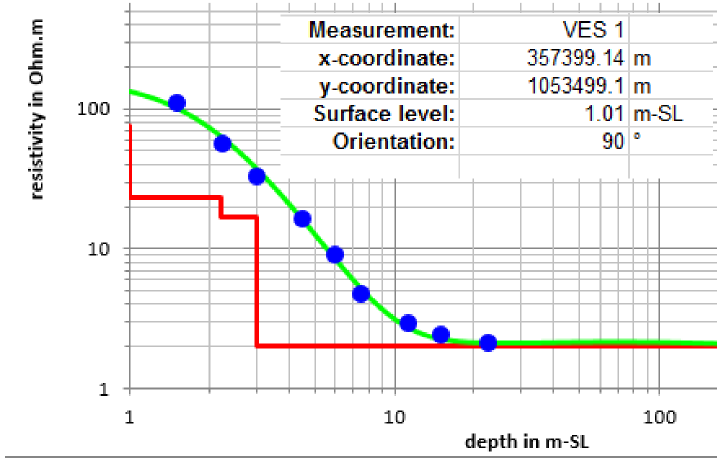
Qpsyb – with freshwater in second layer



Qpsyb – with freshwater in second layer



Qrsb – with freshwater in second layer



Qrsb with freshwater in second layer

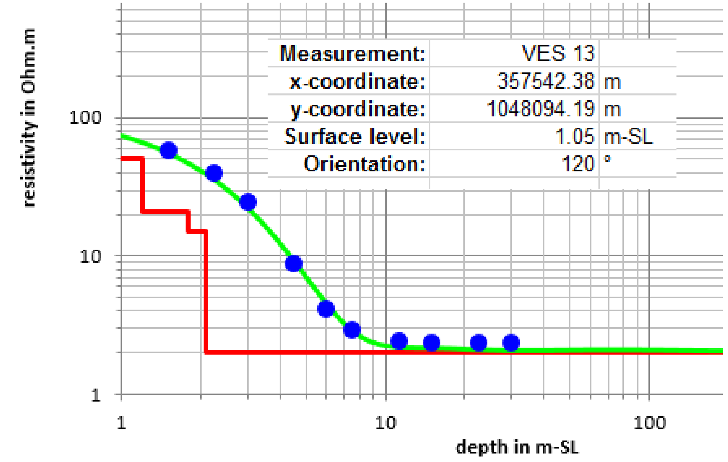
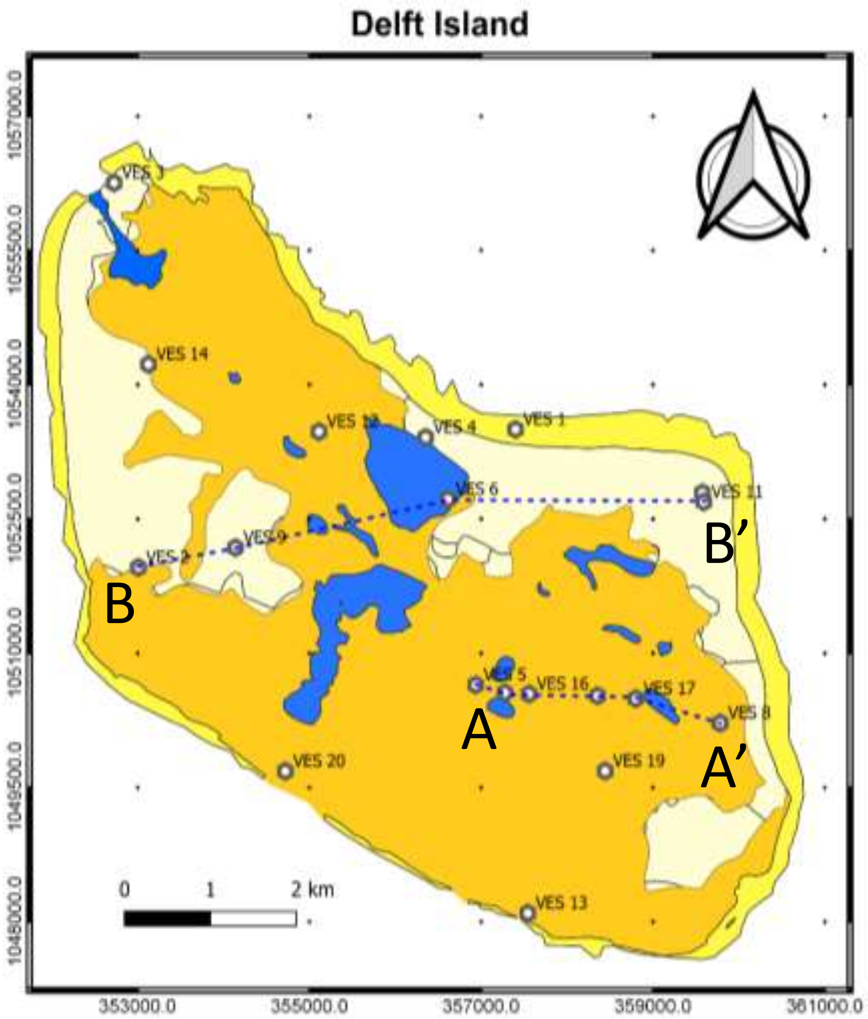
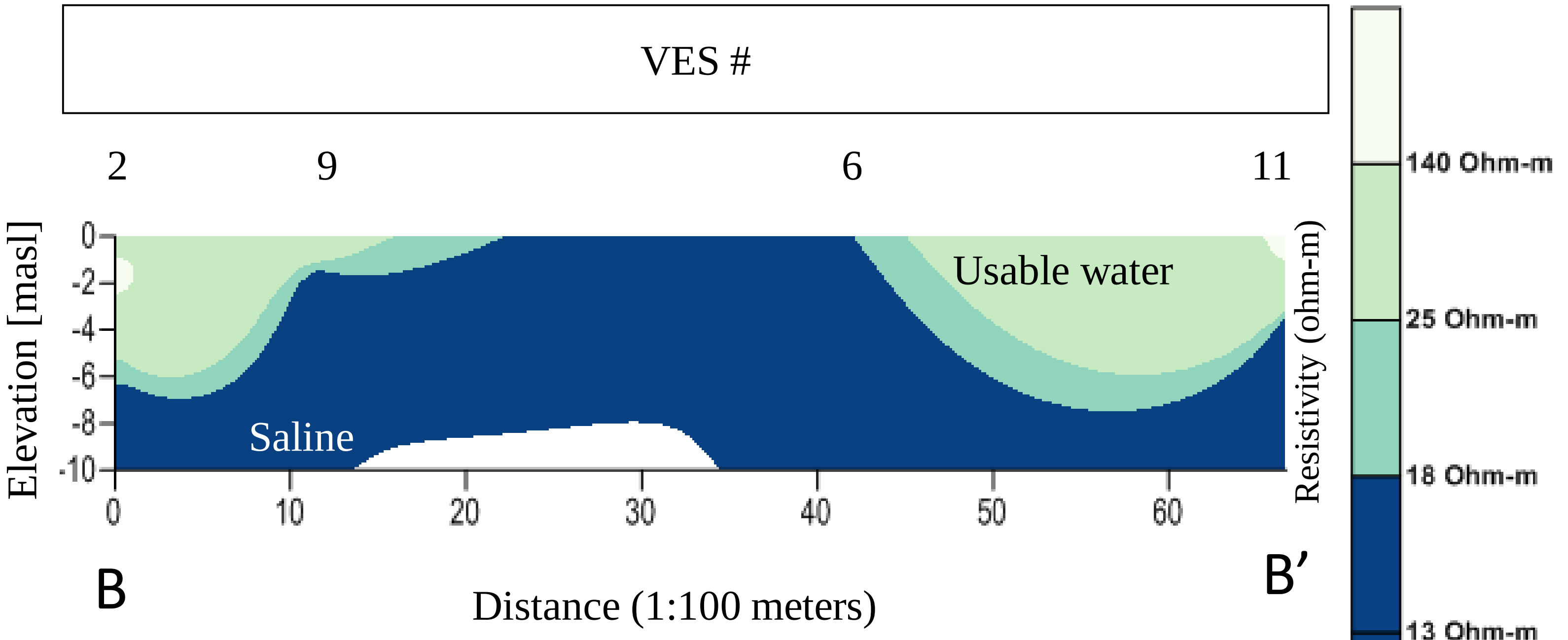


Figure 4. Curve fitting of resistivity data from VES measurements.

2D VES resistivity map





SW to NE Cross-section of Delft Island.

VES SURVEYS from SW to NE are: 2, 9, 6, 11. Scale 1 m : 100 m

Figure 5. Interpolated 2D VES resistivity map and the estimated thickness of usable (fresh) water.

Cl$^-$ concentration (mmol/L) and δ^{18}O composition (‰)

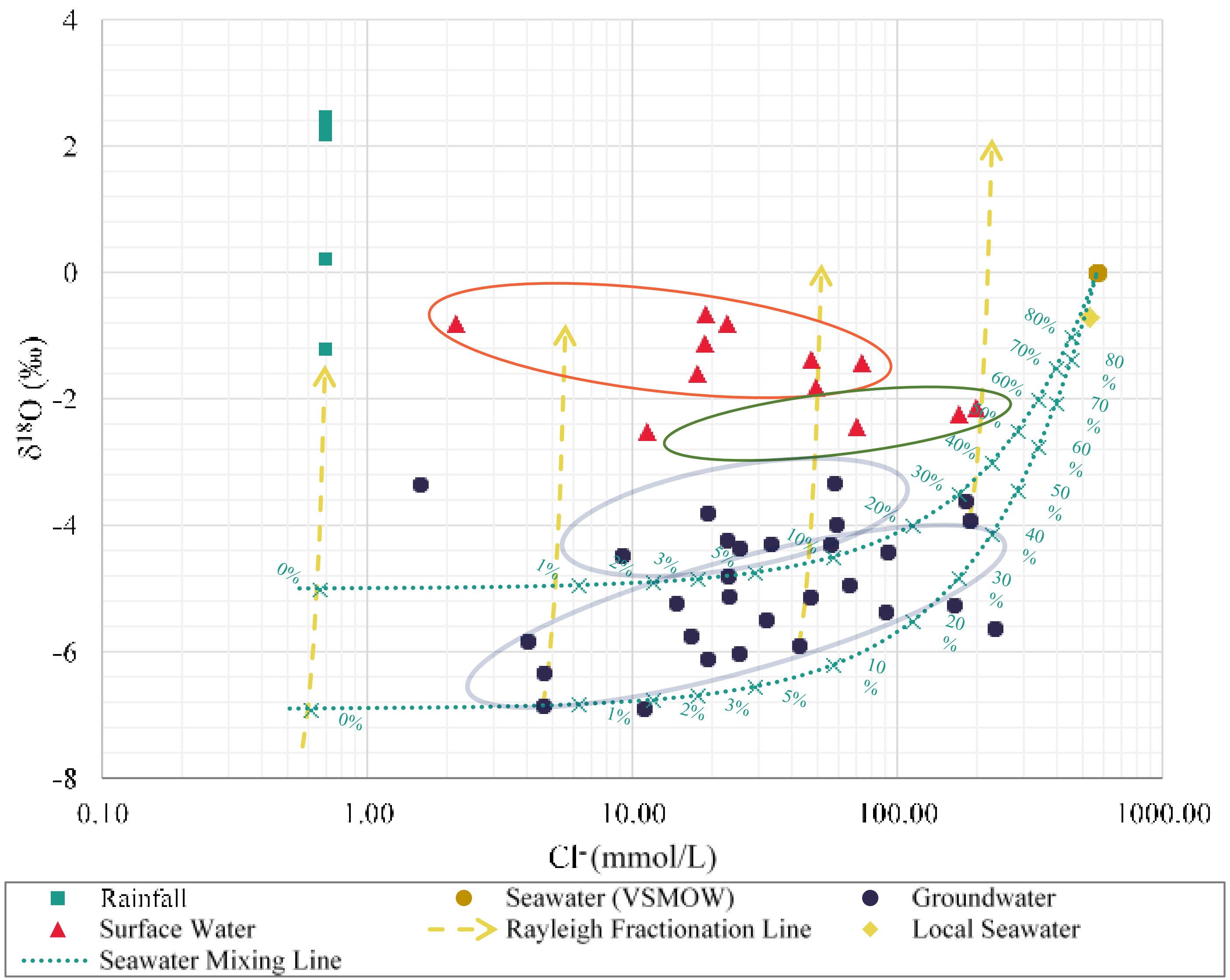


Figure 6. Plot of Cl$^-$ concentration (mmol/L) and δ^{18}O composition (‰) of collected water samples.

- Preferential recharge during the wet season when rainfall isotope composition is relatively depleted
- In surface water samples, the effects of evaporation (Rayleigh fractionation) and seawater mixing (conservative line) can be recognised.
- [Cl$^-$] increase was caused mainly by mixing of groundwater with high salinity water (salinization) and slight evaporation.

Spatial distribution of Cl- concentration (mmol/L) and δ2H content (‰)

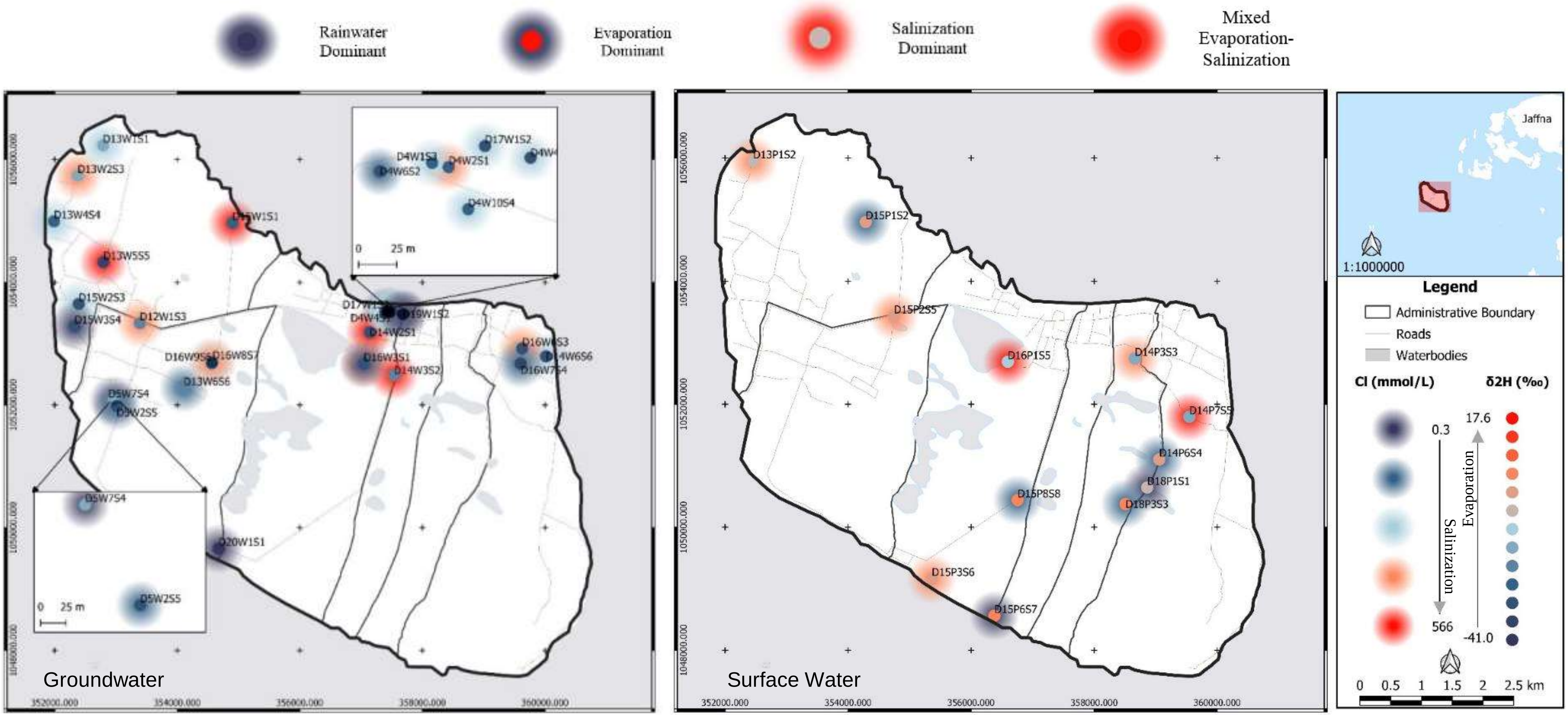


Figure 7. Spatial distribution of the chloride concentration (mmol/L) and δ^2H concentration (‰) of groundwater (left) and surface water (right) samples showing possible salinization and evaporation.

Conceptual model of freshwater lens

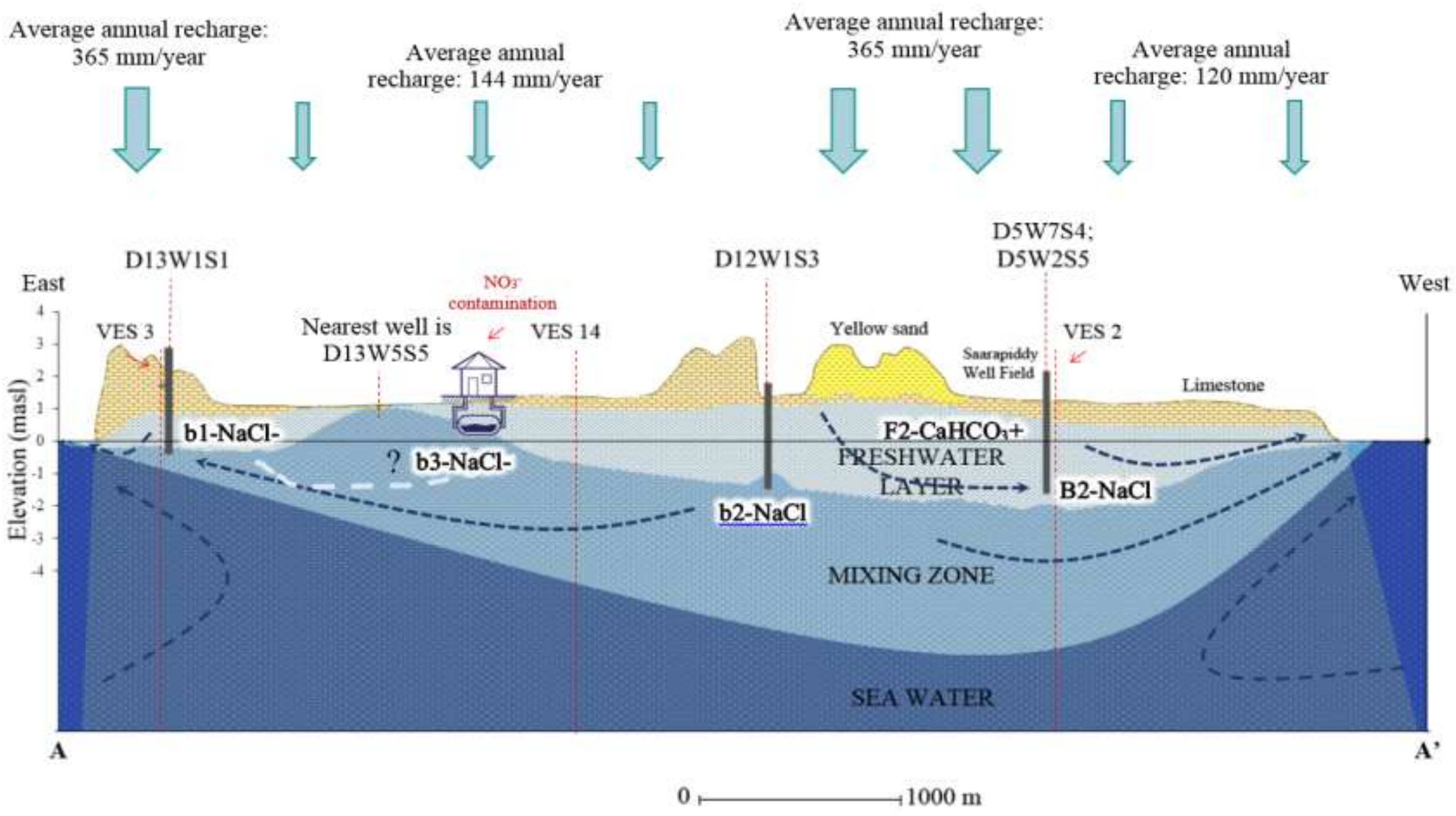
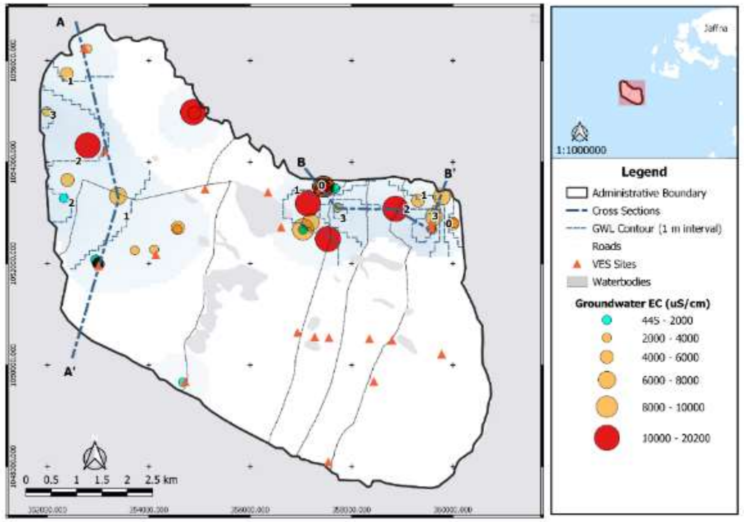


Figure 8. Conceptual model of the freshwater lens based on well data and VES results.



- Recharge rates and flow direction are based on recharge assessment and computed hydraulic head in wells
- Uncertainty due to lack of data is denoted by question mark and broken light blue line

Vertical (point) vs distributed abstractions

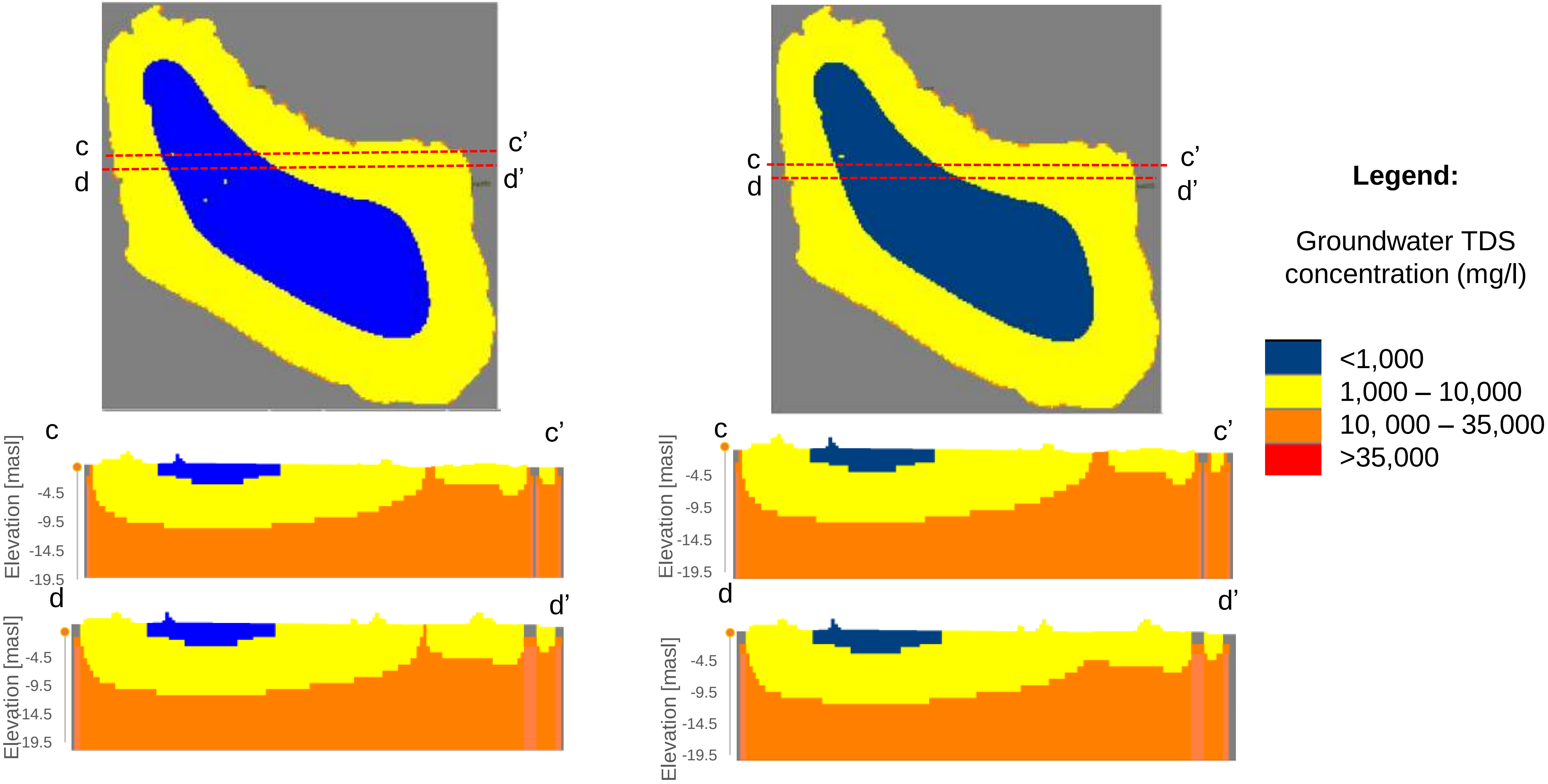


Figure 9. Vertical or point (left) vs distributed (right) abstractions in the Manatharai Wellfield.

Numerical Modelling

- The aquifer has low potential for abstractions (>10 m^3/day) from point sources, which would result in upconing at abstraction points. Distributed abstractions would ensure lower rates of upconing.

- The location of abstraction galleries or a distributed abstraction method is important. As lateral saltwater intrusion can be exacerbated in areas nearer the coastline eg. Manatharai wellfield;

- Sensitivity analysis showed that the groundwater head is more sensitive to changes in recharge and uncertainties in hydraulic conductivity; thickness of the transition zone is more sensitive to uncertainties in the dispersion factors. Overall, the thickness of FWL are most sensitive to changes in the dispersion factors and recharge

Conclusion

- With a direct relationship between rainfall, recharge and the thickness of the freshwater lens and transition zone, methods must be put in place to mitigate the negative impacts of below average rainfall periods (alternative means must be in place to meet the water demands of the current and growing population of Delft Island);

- Rising sea level can reduce the extent of the freshwater lens as land is claimed by the sea. With the existing thin FWL it is possible that in a period of drought and rising sea levels that no fresh groundwater reserves will be available;

- To mitigate the imminent threats of climate variability and rising sea level, alternative methods must be in place to ensure fresh groundwater reserves to the residents of Delft Island;

- Artificial recharge and horizontal abstractions are two methods towards achieving this goal.

Questions?