Universität Basel

Applied & Environmental Geology

# Multivariate statistical analysis of hydrochemical and isotopic environmental tracer data to manage artificial groundwater recharge within a fractured carbonate aquifer

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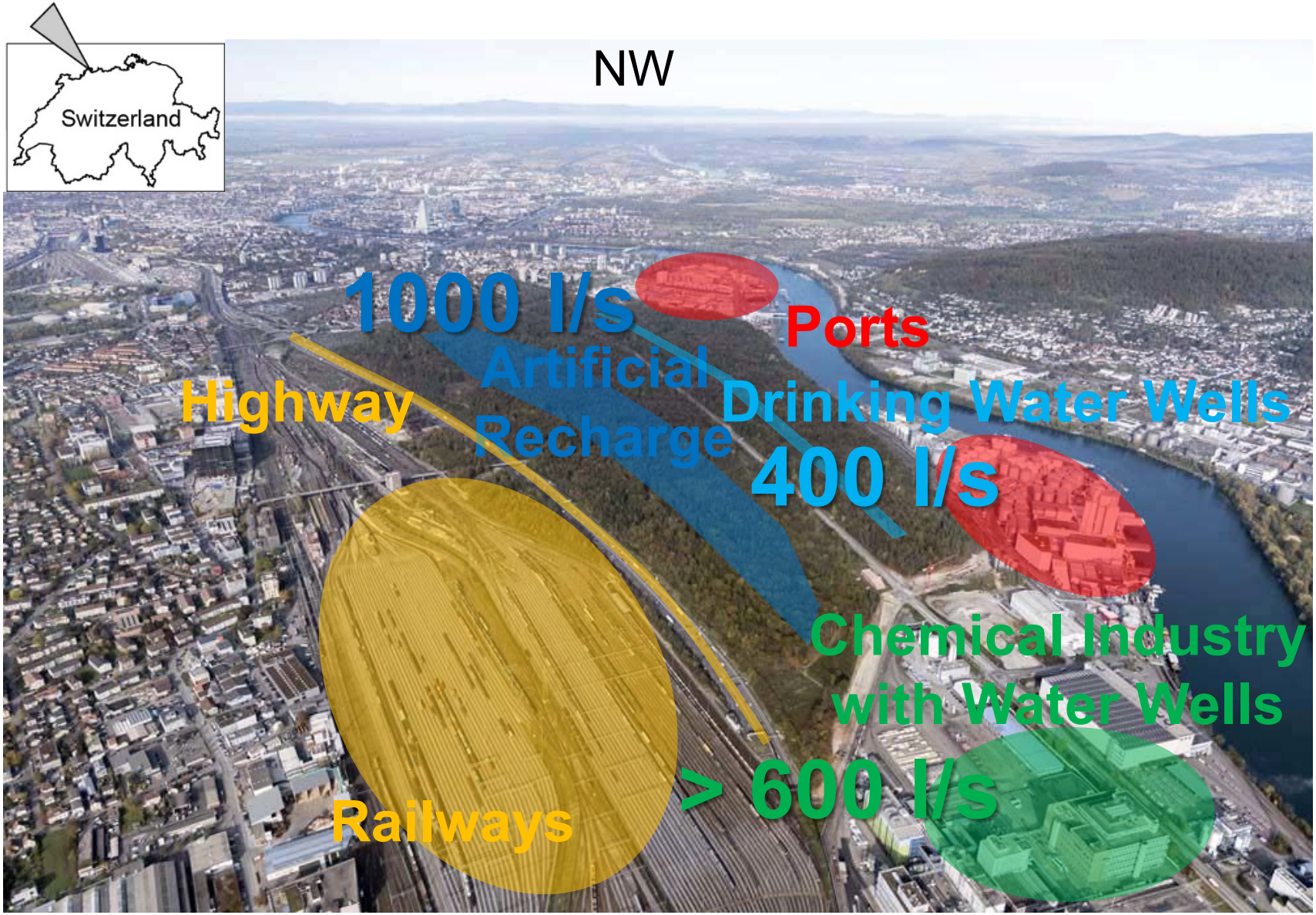
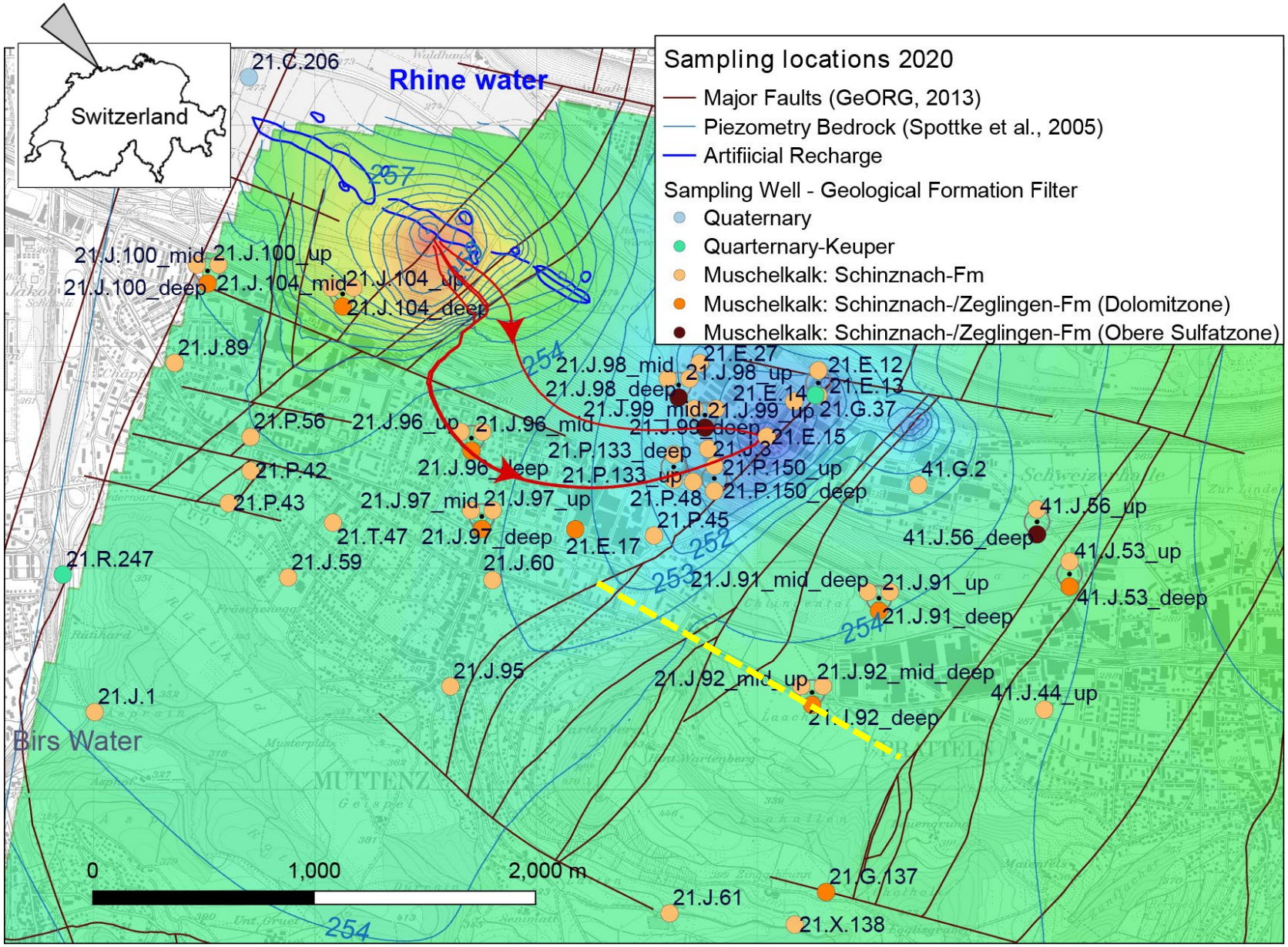
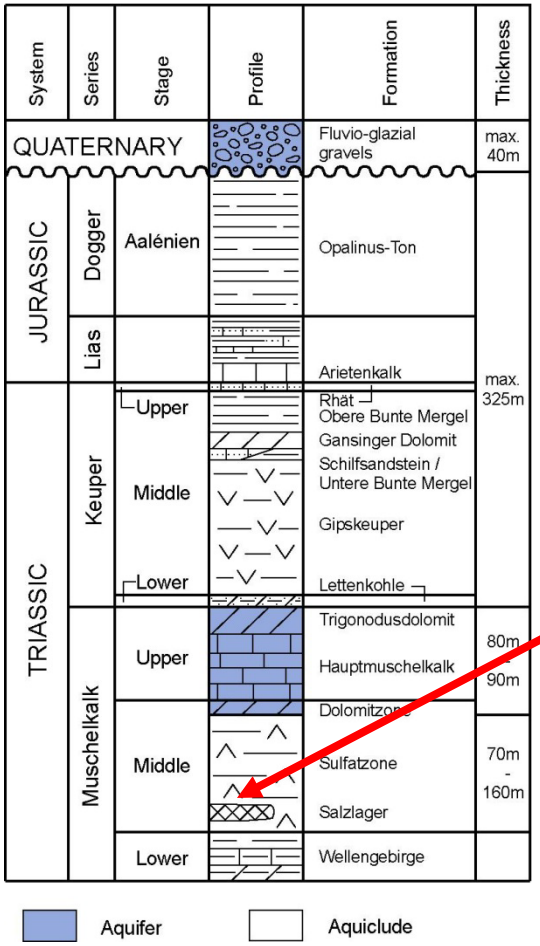
# Introduction, Setting



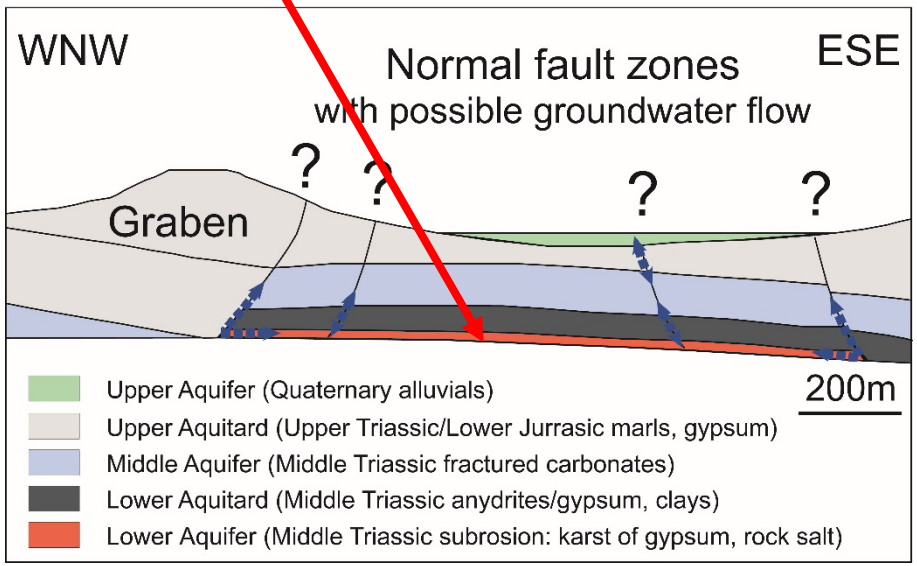
# Hydrogeological Setting, Sampling Wells



# Hydrogeological Setting, Subrosion process of evaporites

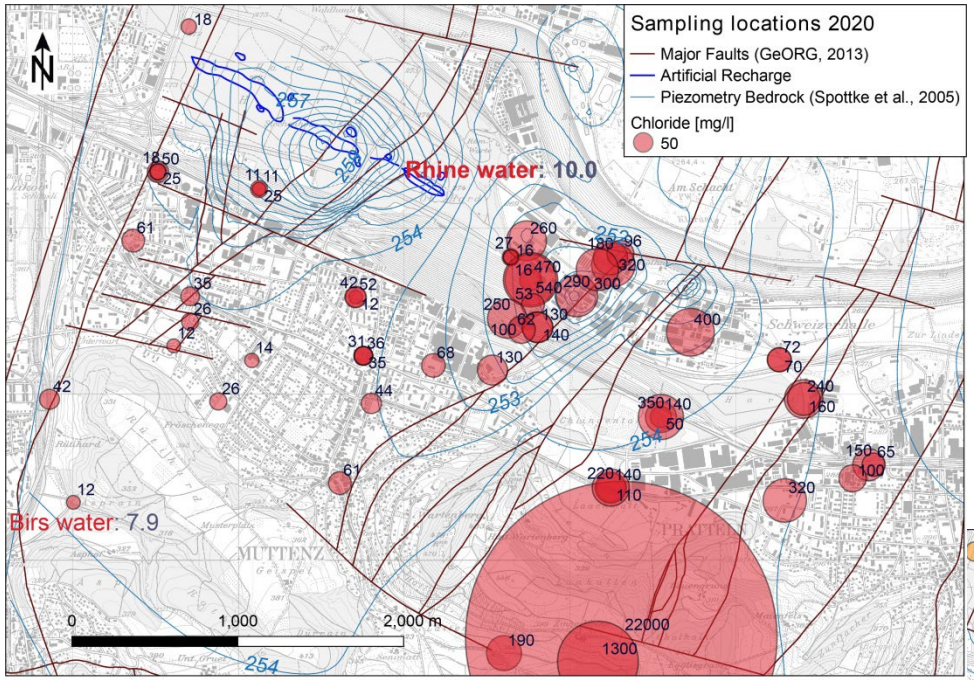


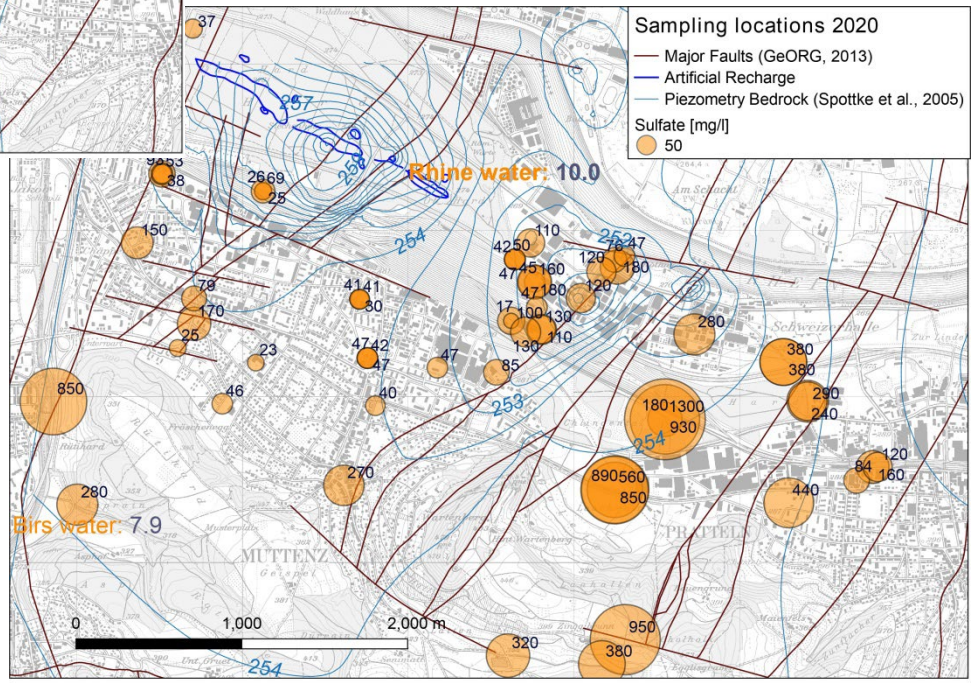

**Subrosion (evaporite karst):**
**Source for major ions e.g. Ca, Na, Cl, $SO_4$**



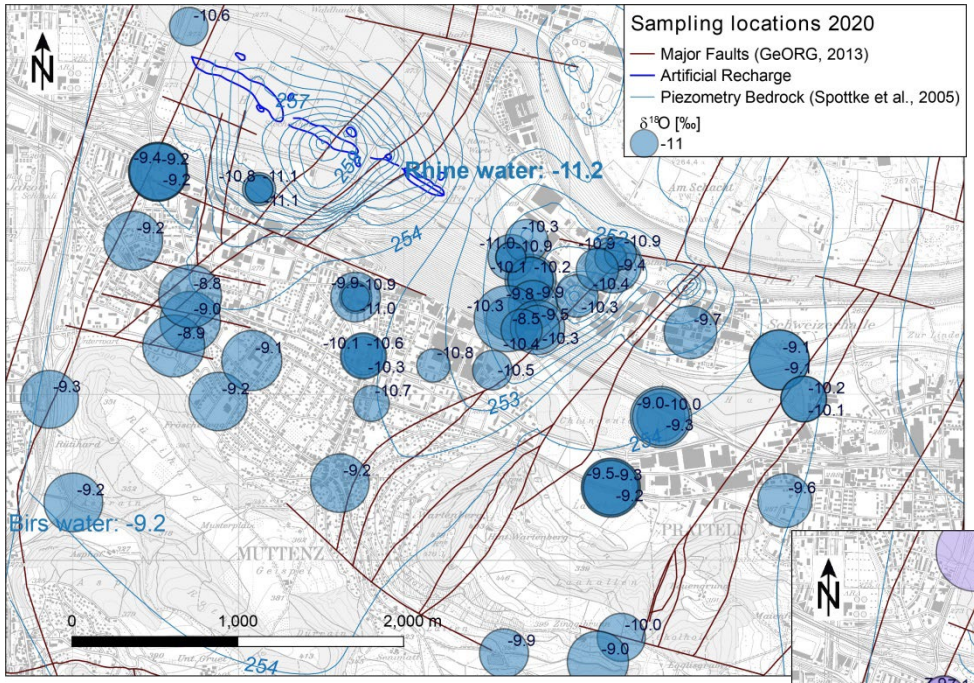

Zechner E., Konz M., Younes A., Huggenberger P., 2011: Effects of tectonic structures, salt solution mining, and density-driven groundwater hydraulics on evaporite dissolution (Switzerland), Hydrogeology J., 7, 1323-1334, DOI: 10.1007/s10040-011-0759-5.

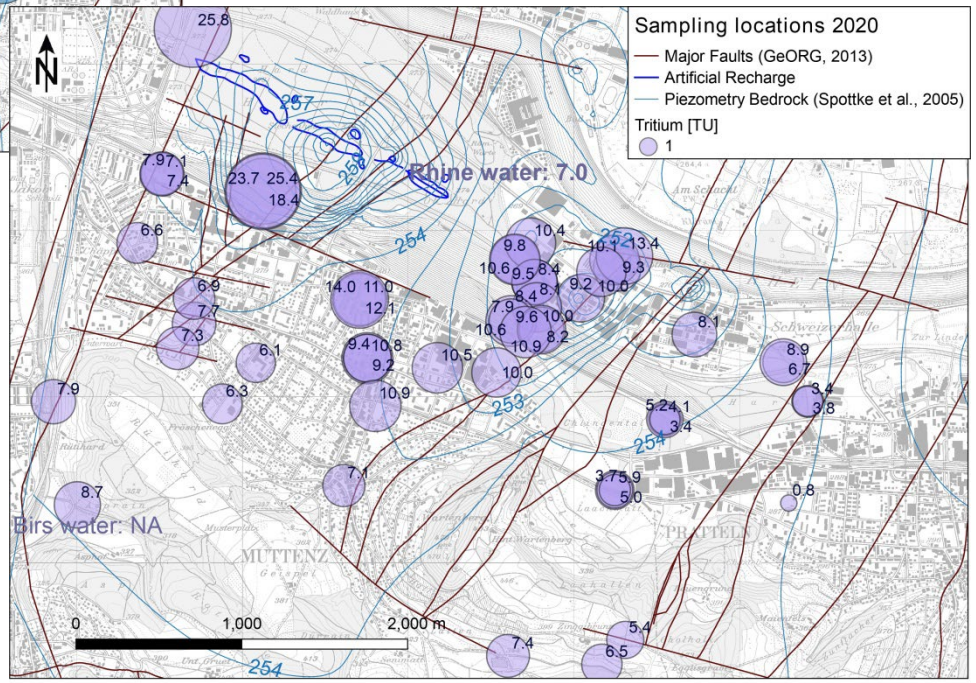
# Hydrochemistry: Chloride, Sulfate



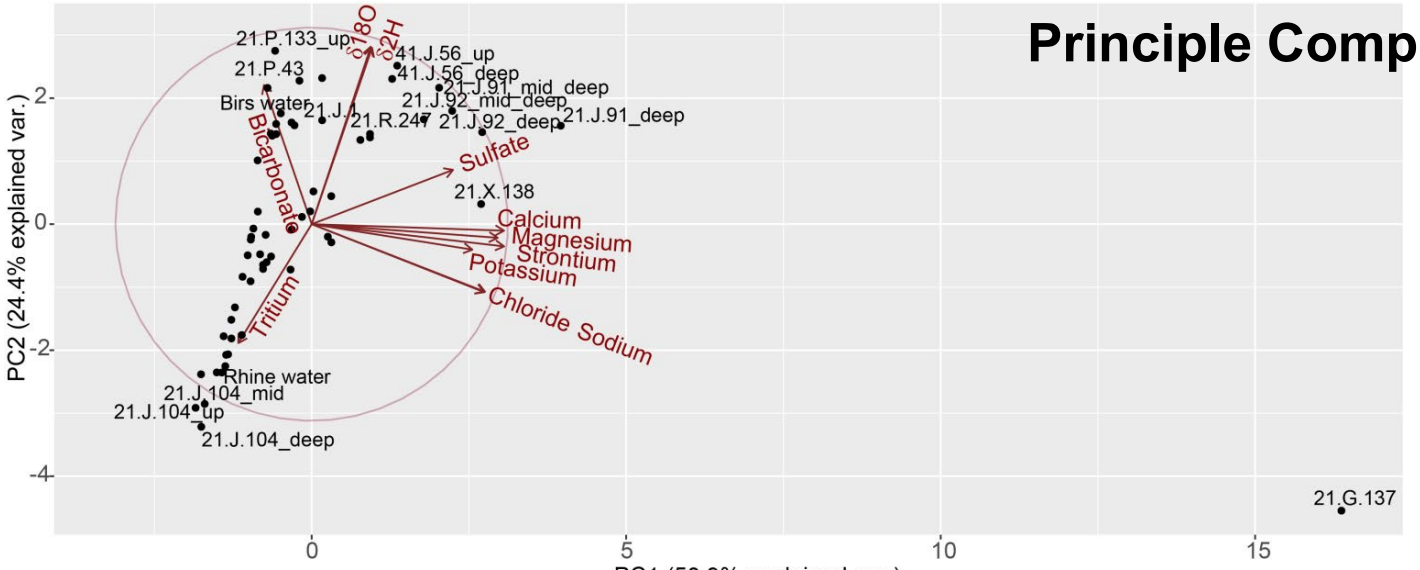
# Water Isotopes: $^{18}O$, ($^{2}H$), Tritium

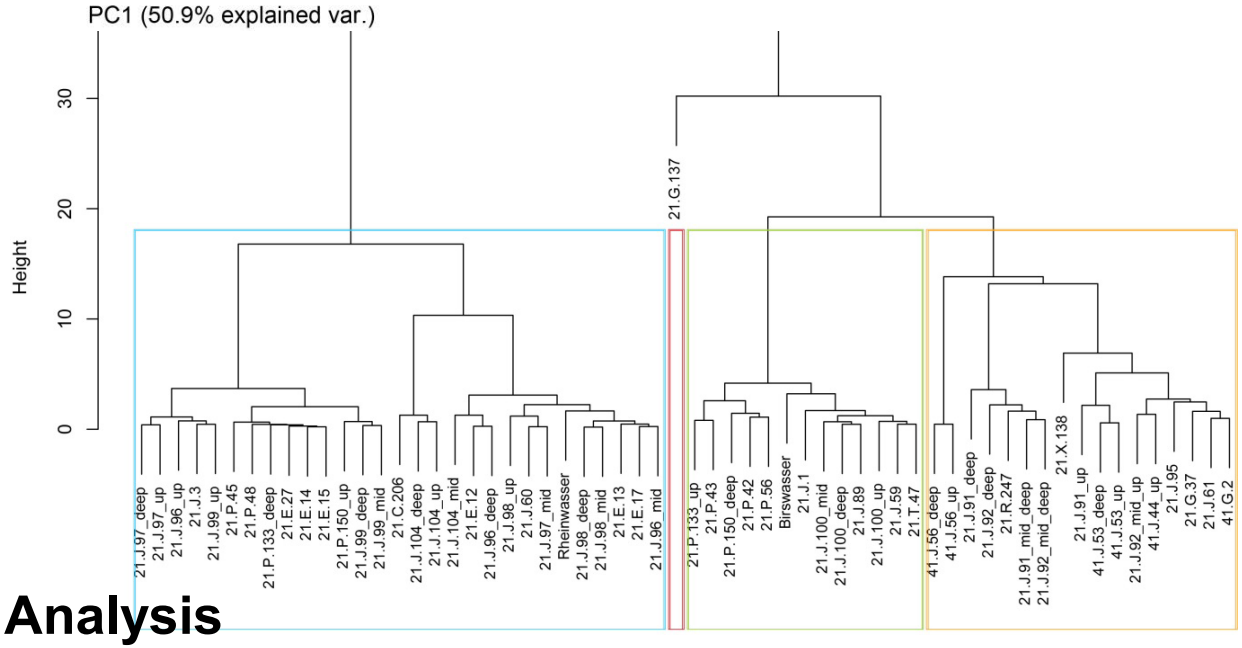


# Multivariate statistical analysis: 8 Major Ions, 3 Water Isotopes

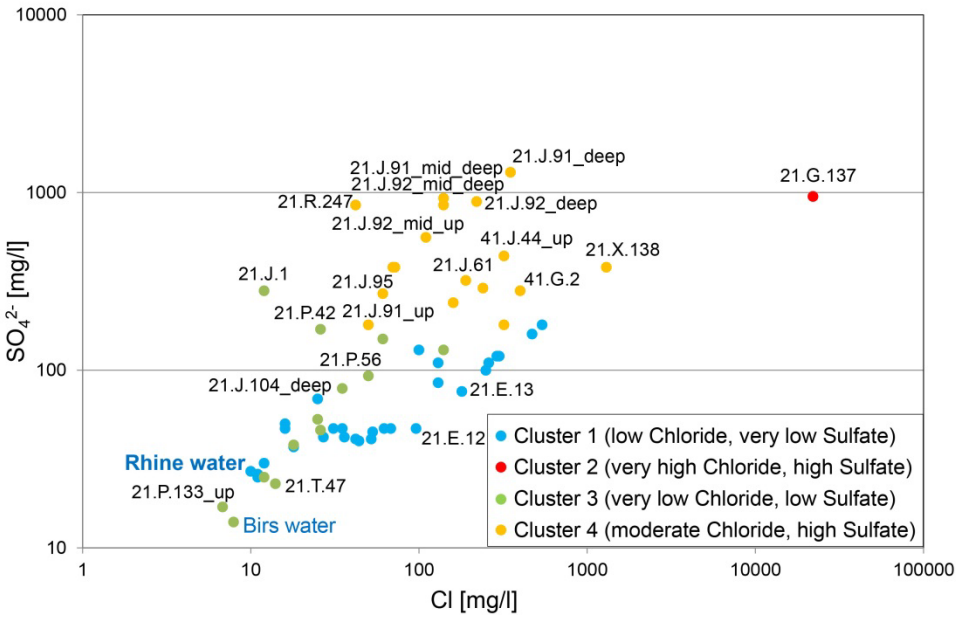
## Principle Component Analysis

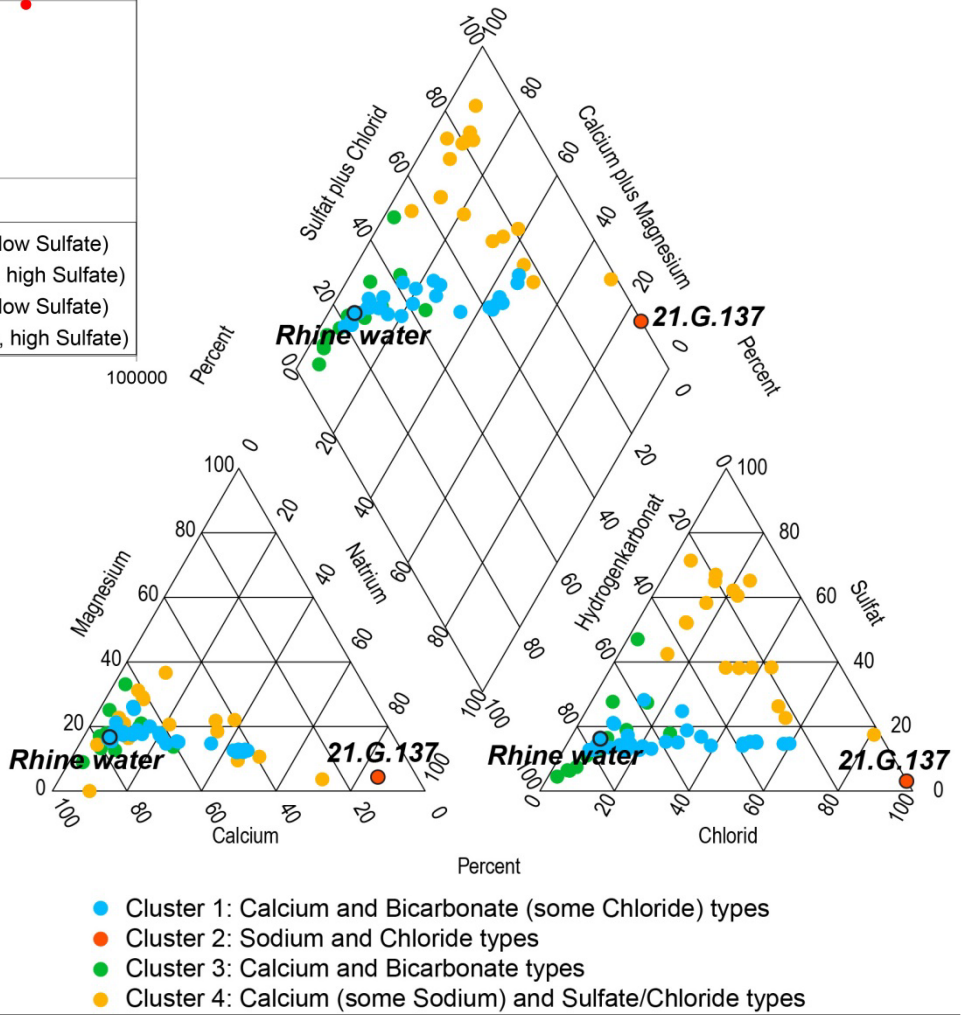


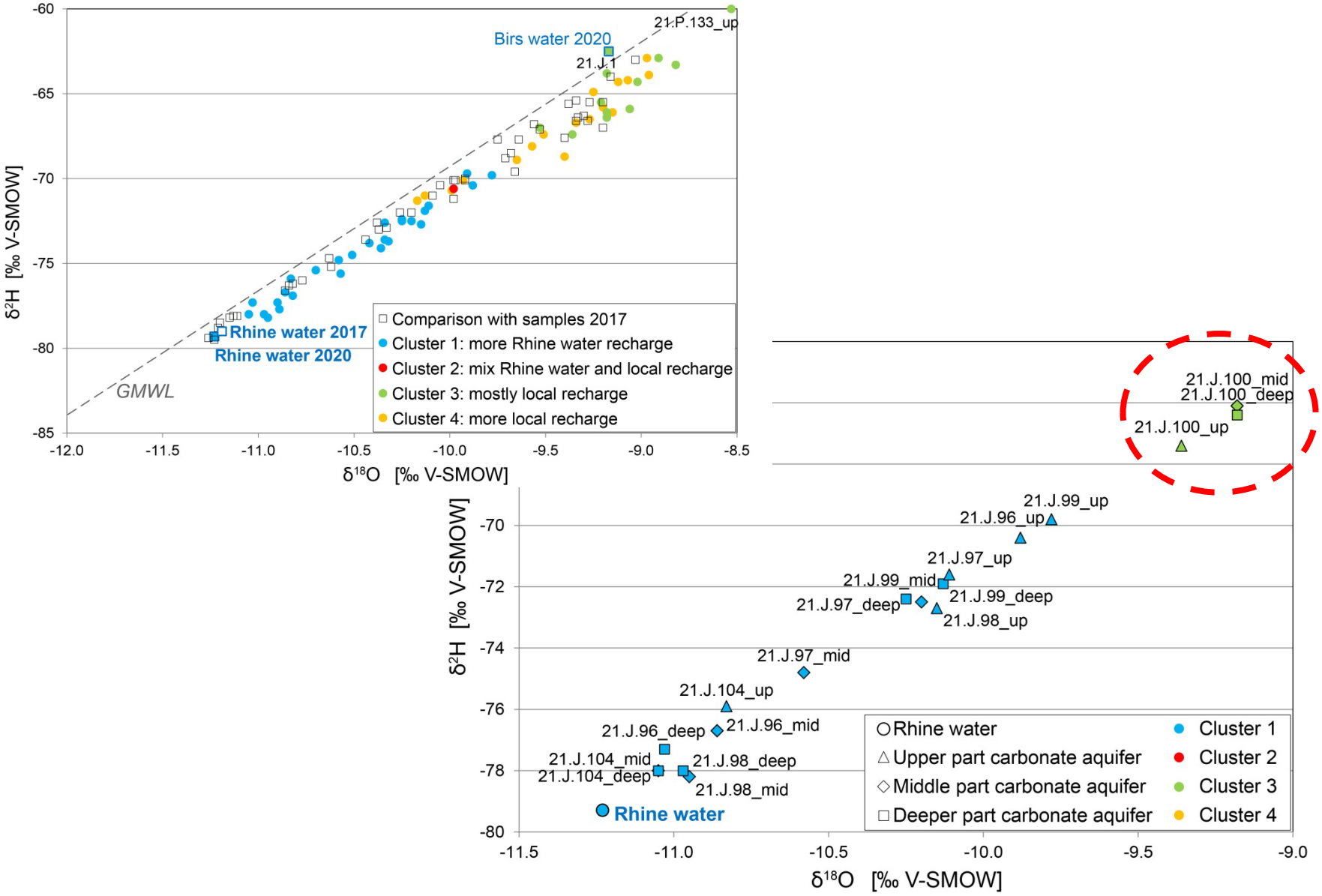

## Hierarchical Cluster Analysis

# Clustering: Major Ions, e.g. Sulfate vs Chloride



# Clustering: Stable Isotopes $^{18}O$ vs $^{2}H$



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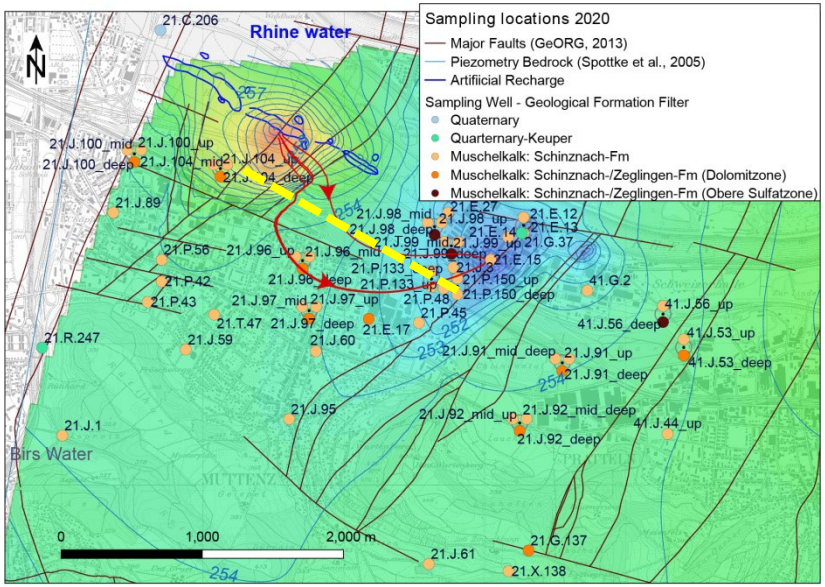
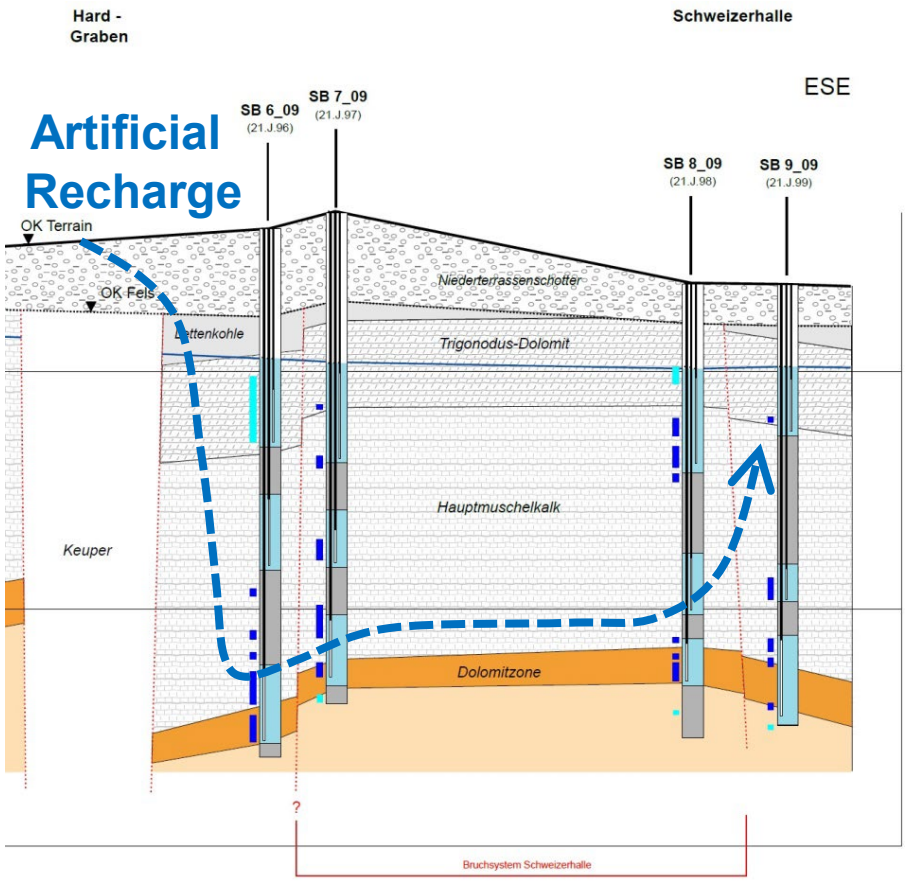
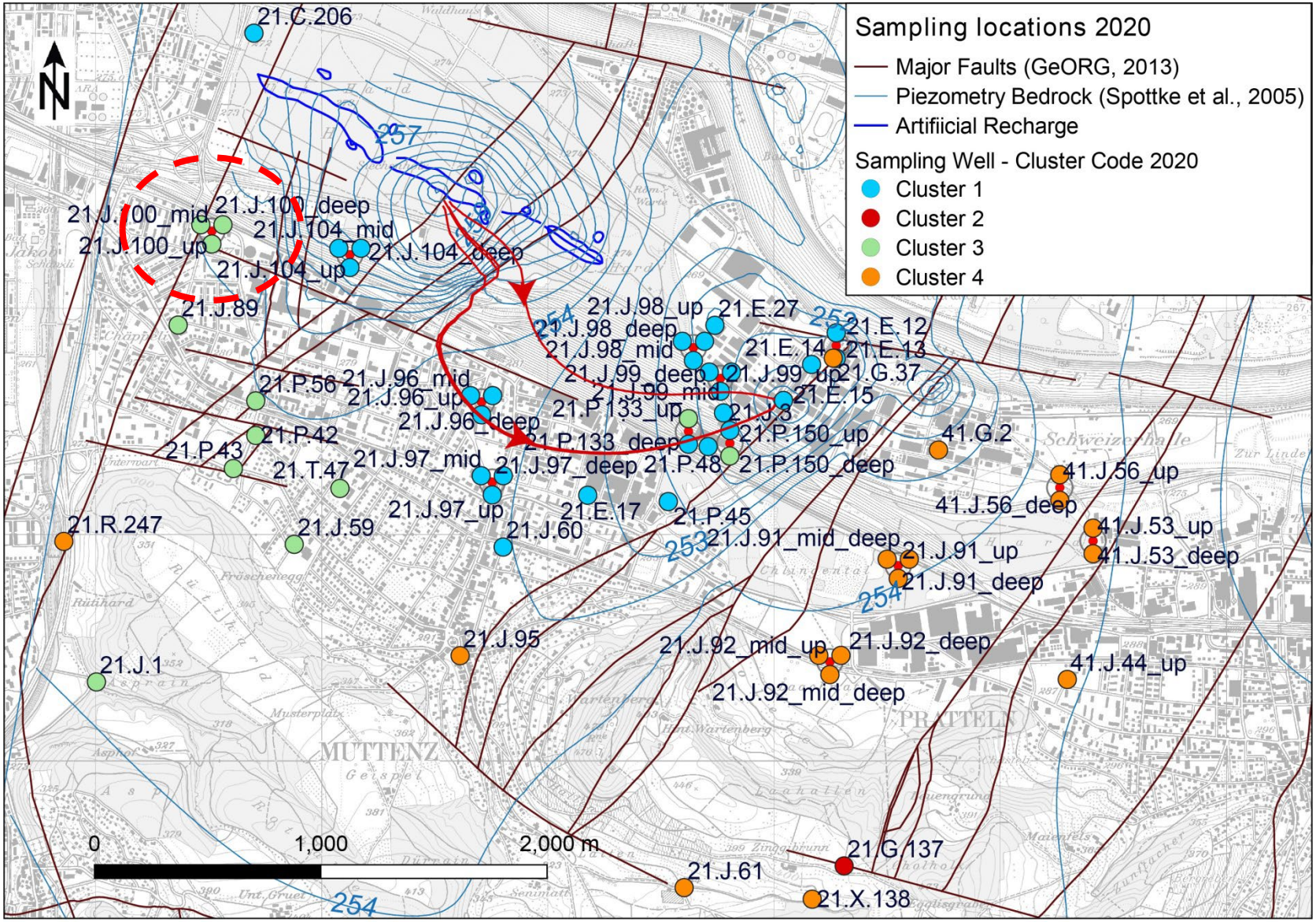



Meyer, M., Guldenfels, L., 2010: Errichtung von Grundwassermessstellen 2009 - 2010, Geologisch - hydrologischer Bericht, Kanton Basel-Landschaft, Amt für Umweltschutz und Energie.

# Clustering: Characterization of Artificial Recharge



# Conclusions

Effectiveness of Artificial Recharge for drinking water production and protection was observed with:

- Sampling groundwater wells reaching depths between 2m and 273m located in Quaternary Alluvial Aquifer and (mostly) in a Triassic Carbonate Aquifer;

- Selection of groundwater parameters which characterize the mixing process in the Aquifers:
  - Major ions due to the subrosion of Triassic Evaporites
  - Water isotopes signatures from artificial recharge with Rhine water and from recharge due to local rainfall;

- Principle component analysis and hierarchical cluster analyses with 8 Major Ions and 3 Water Isotopes;

- Cluster graphs and maps show lateral and vertical extend of artificial recharge in the Triassic Carbonate Aquifer mostly SE towards groundwater wells for industrial use, which is (mostly) in accordance with simulated advective transport from a 3D groundwater flow model (Spottke et al. 2005).