Using hydrogeological information in planning and positioning mine operations

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Mine Water Management and Treatment – From Planning of Mine Operations to Mine Closure 24.– 25.9.2013

Outline

- Greetings from Australia !
- Hannukainen case
- Rautuvaara case
- Conclusions

IAH 2013
Perth Australia
Solving the Groundwater Challenges of the 21st Century

40th International Association of Hydrogeologists Congress
September 15 – 20, 2013

- 570 oral presentations
- 22 presentations about groundwater and mineral resources
- Over 100 presentations about sw-gw interaction
- Additional 30 presentations about GDEs

References

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Räisänen, M., Väisänen, U., Lanne, E., Turunen, P. & Väänänen, J. 2006. Rautuvaaran kaivoksen rikastuhiekka-altaan kemiallinen nykytila, vaikutukset pinta- ja pohjavesiin ja suositukset jälkihoidolle., Geological Survey of Finland. 43 p.

General

- Environmental issues play an increasingly important role in planning large-scale mining activities.
- Potential impacts are often related to groundwater systems, which may be inadequately understood and assessed.
- This is true especially in Lapland, where subsurface and surface water reserves and their hydraulic connections have rarely been studied.
- Hydrogeological background information is crucial in planning and positioning essential mining operations such as tailings areas in order to prevent any undesirable environmental impact.

Hannukainen and Rautuvaara case: Research collaboration

University of Helsinki, Department of Geosciences and Geography: Prof. Veli-Pekka Salonen, PhD Kirsti Korkka-Niemi, PhD Julien Moreau, PhD Outi Hyttinen, Master student Tiina Nurminen, Master student Talvikki Savolainen, Doctoral student Peter Howett, Doctoral student Anne Rautio, PhD Anu Kaakinen, Master student Noora Karhu, Master student Harri Matikainen

Northland Mines Oy: Managing Director Jukka Jokela, Environmental Manager Joanna Kuntonen- van't Riet, field support: Jussi Anannolli and Ahti Haaparanta

Research topics:

Main targets are

1) to identify the aquifers and aquitards,
2) to measure or calculate hydraulic conductivity of different units and
3) to observe groundwater tables and groundwater flow directions.

The specific aim is also to examine groundwater – surface water connection, which means

4) to preliminary identify the groundwater - surface water interaction sites and
5) to characterize chemical and stable isotopic composition of the waters

Location

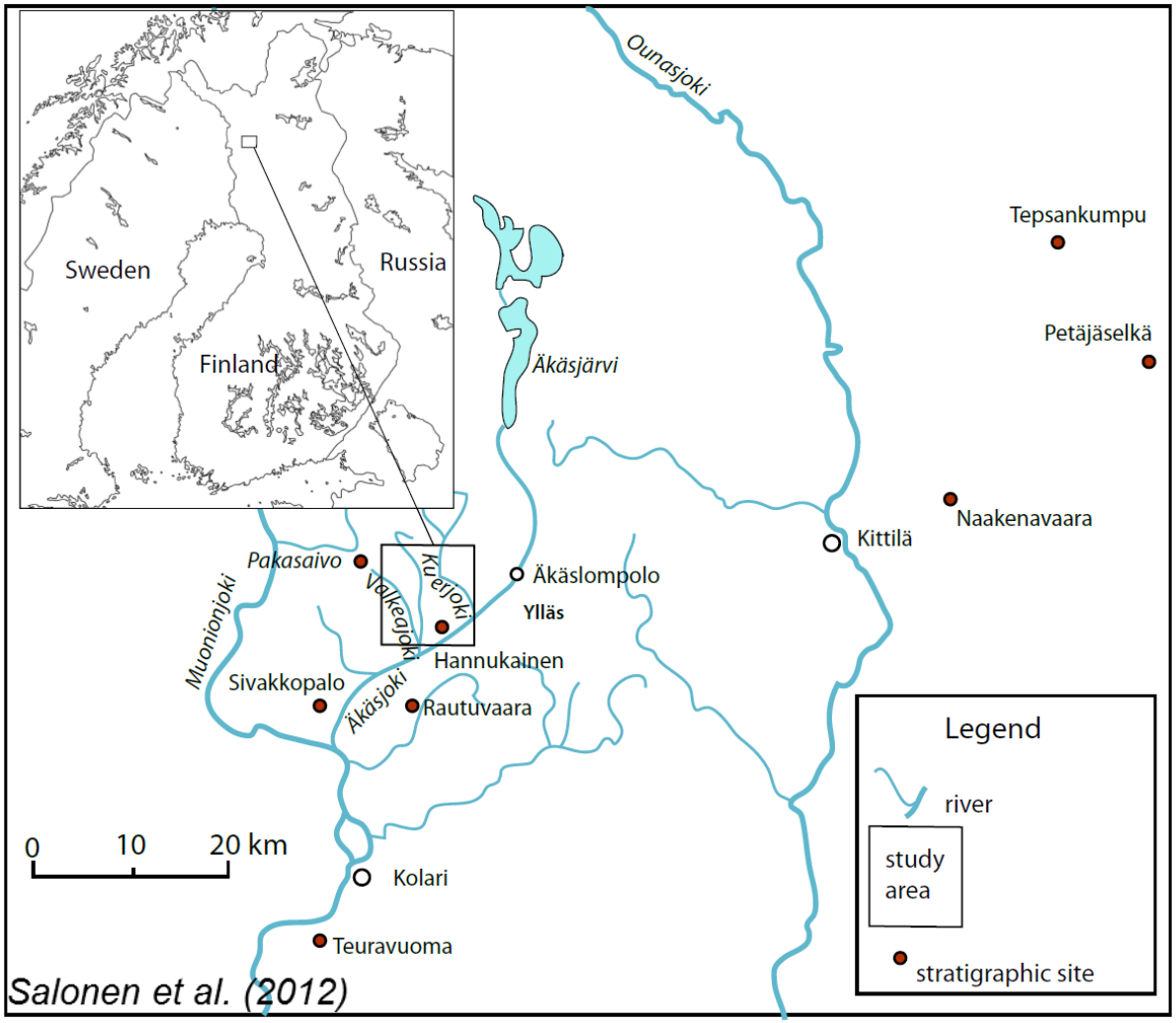
Average monthly flow rate for the River Äkäsjoki is 1.2-20.4 m^3/s.
Average monthly flow rate for the River Kuerjoki is 0.2-5.5m^3/s.

The Hannukainen site is bounded to the south by the River Äkäsjoki, to the west by the River Valkeajoki and to the east by the River Kuerjoki.

Rivers surrounding the mine site are critical spawning grounds for the Sea Trout, an endangered species.

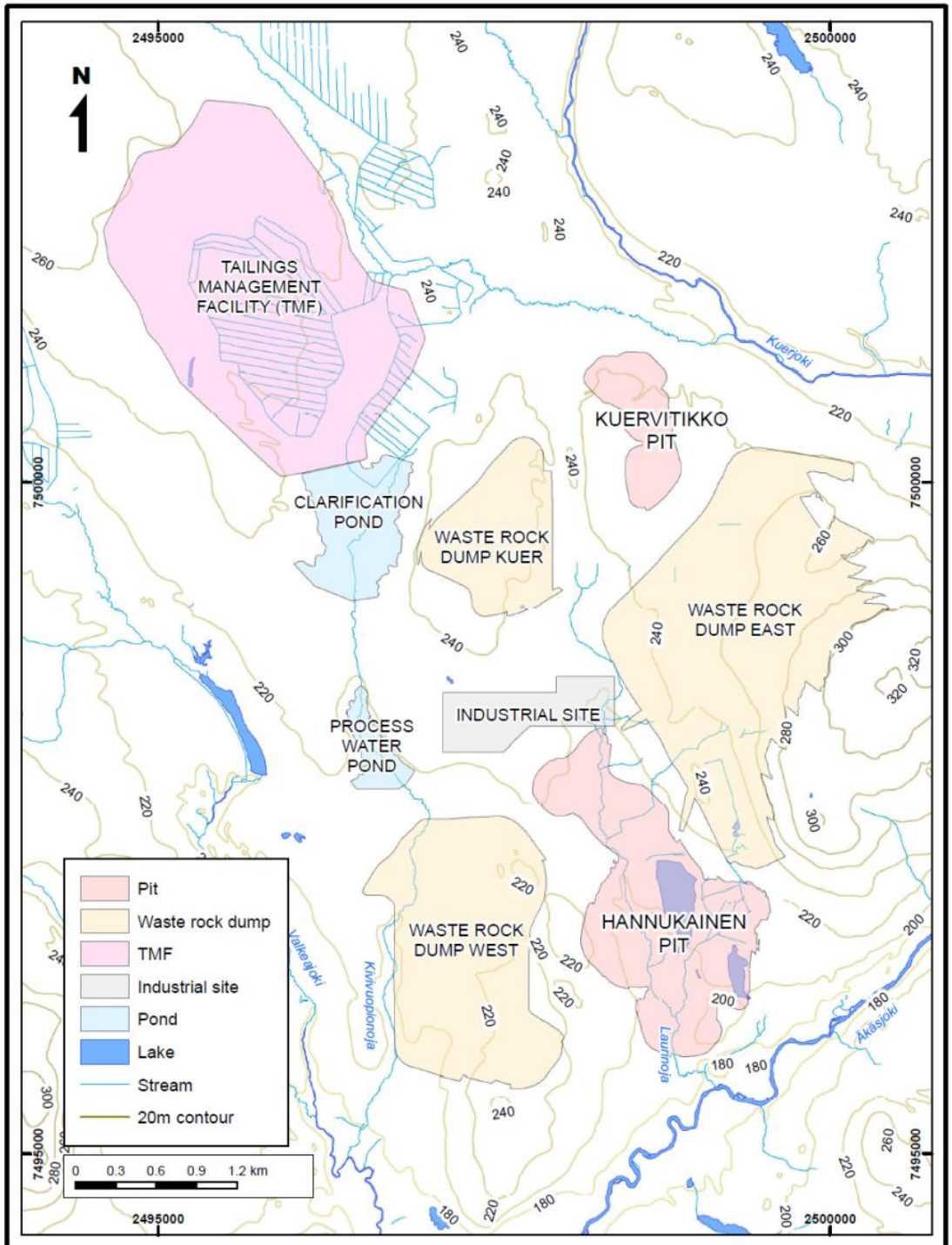
Changes in water quality and quantity could impact the capability of the rivers to support the Sea Trout.

Therefore it is essential to assess the potential environmental impacts of the future mining.



Study site: proposed plan for the operation area

Northland Mines Oy: Hannukainen iron mine development site



SRK (2013)

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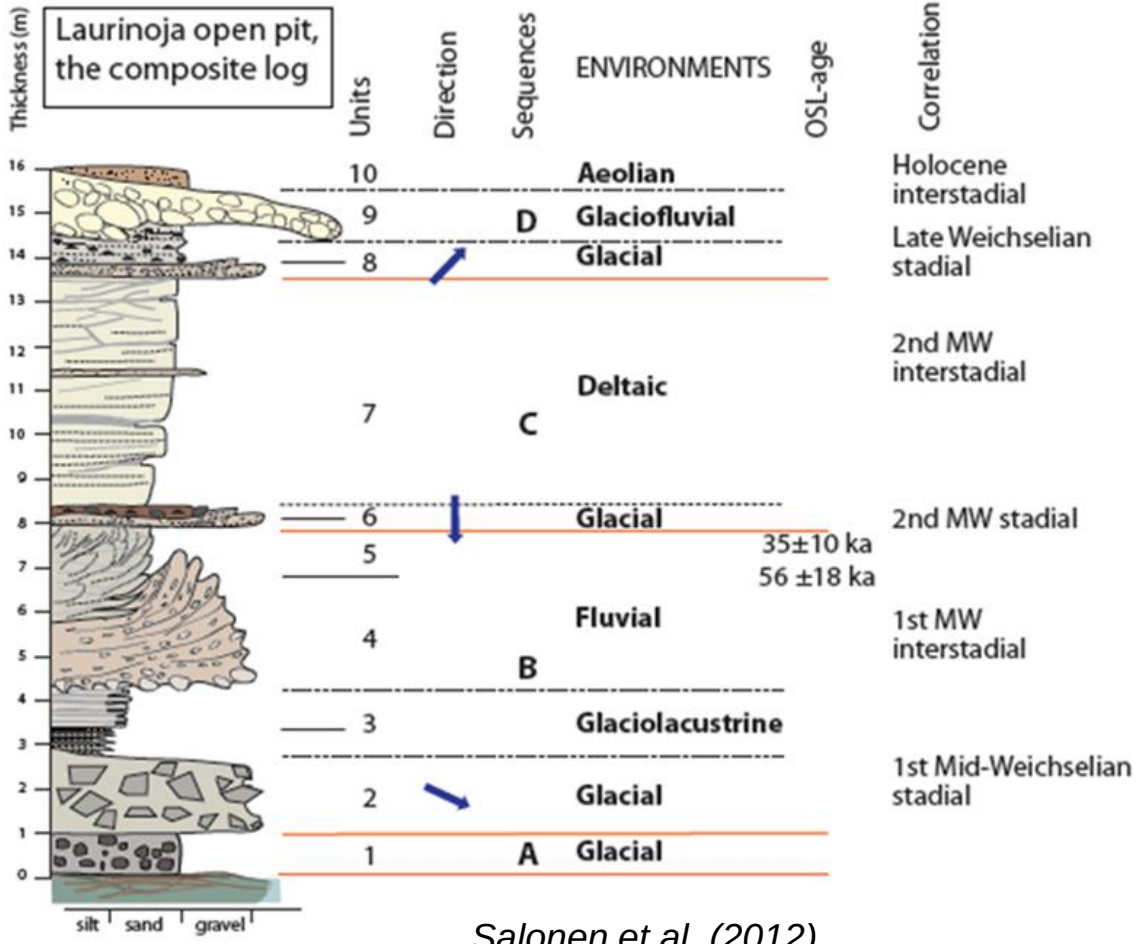
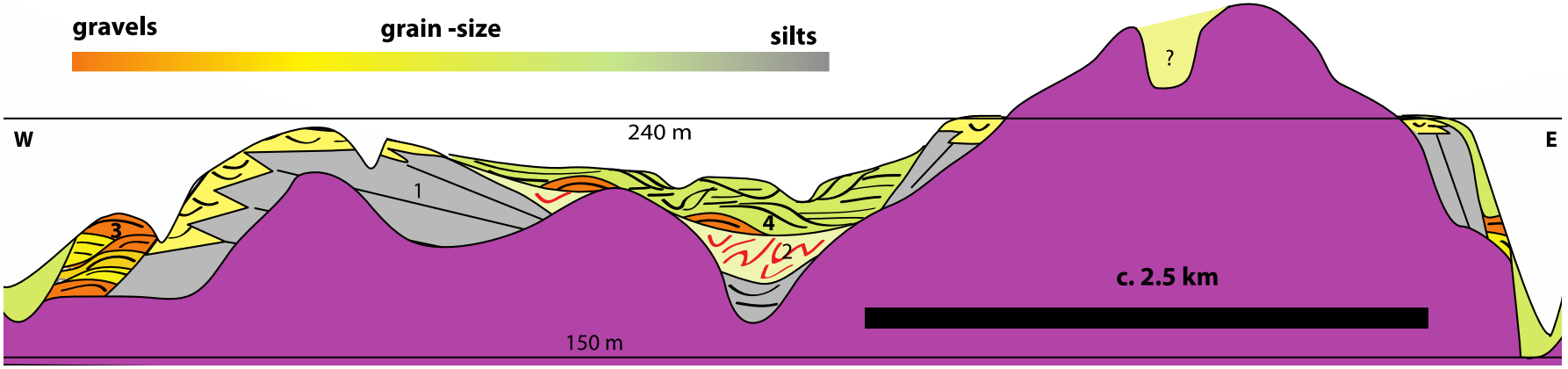
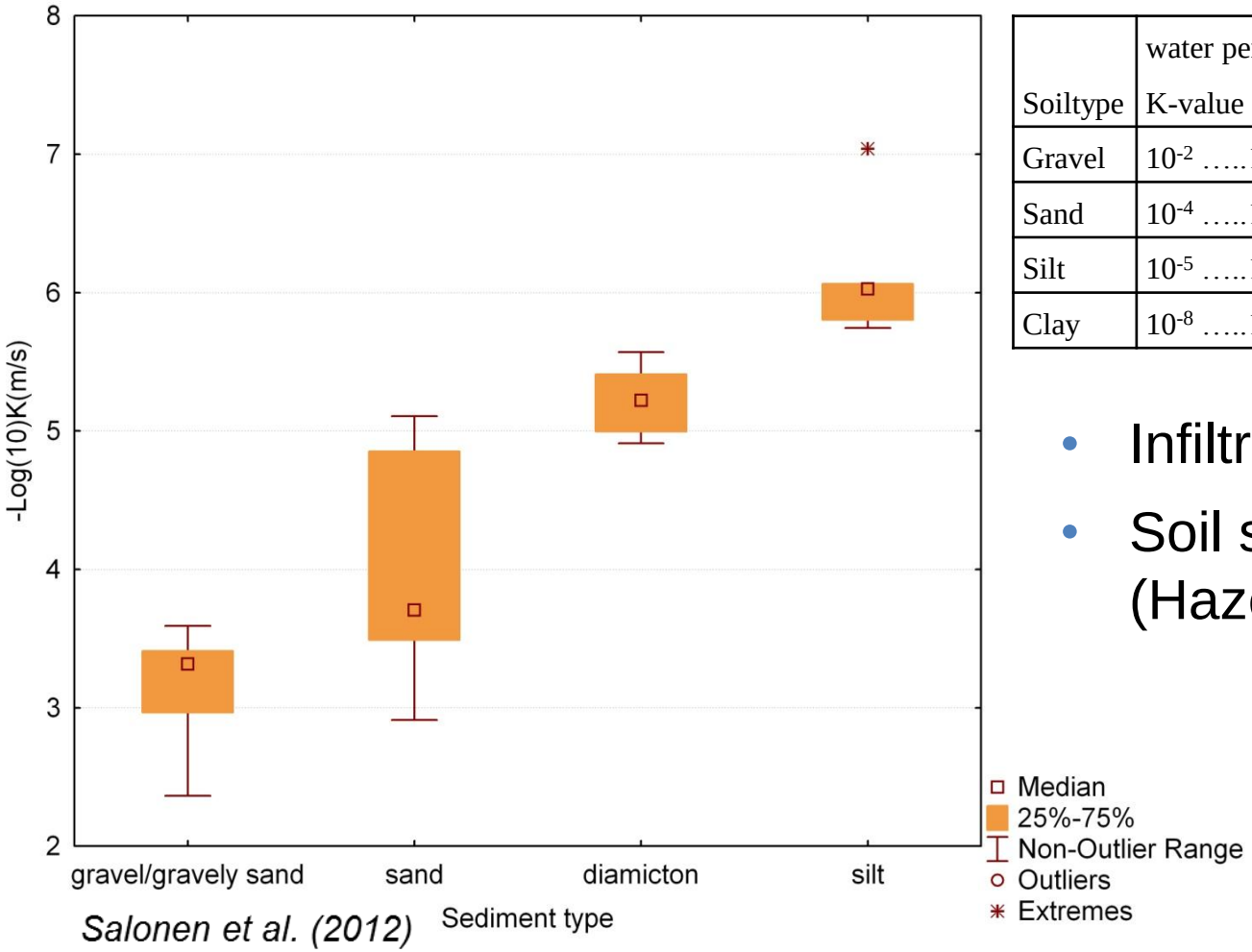
Conceptual model of stratigraphy



Salonen et al. (2012)



Hydraulic conductivity



Salonen et al. (2012)

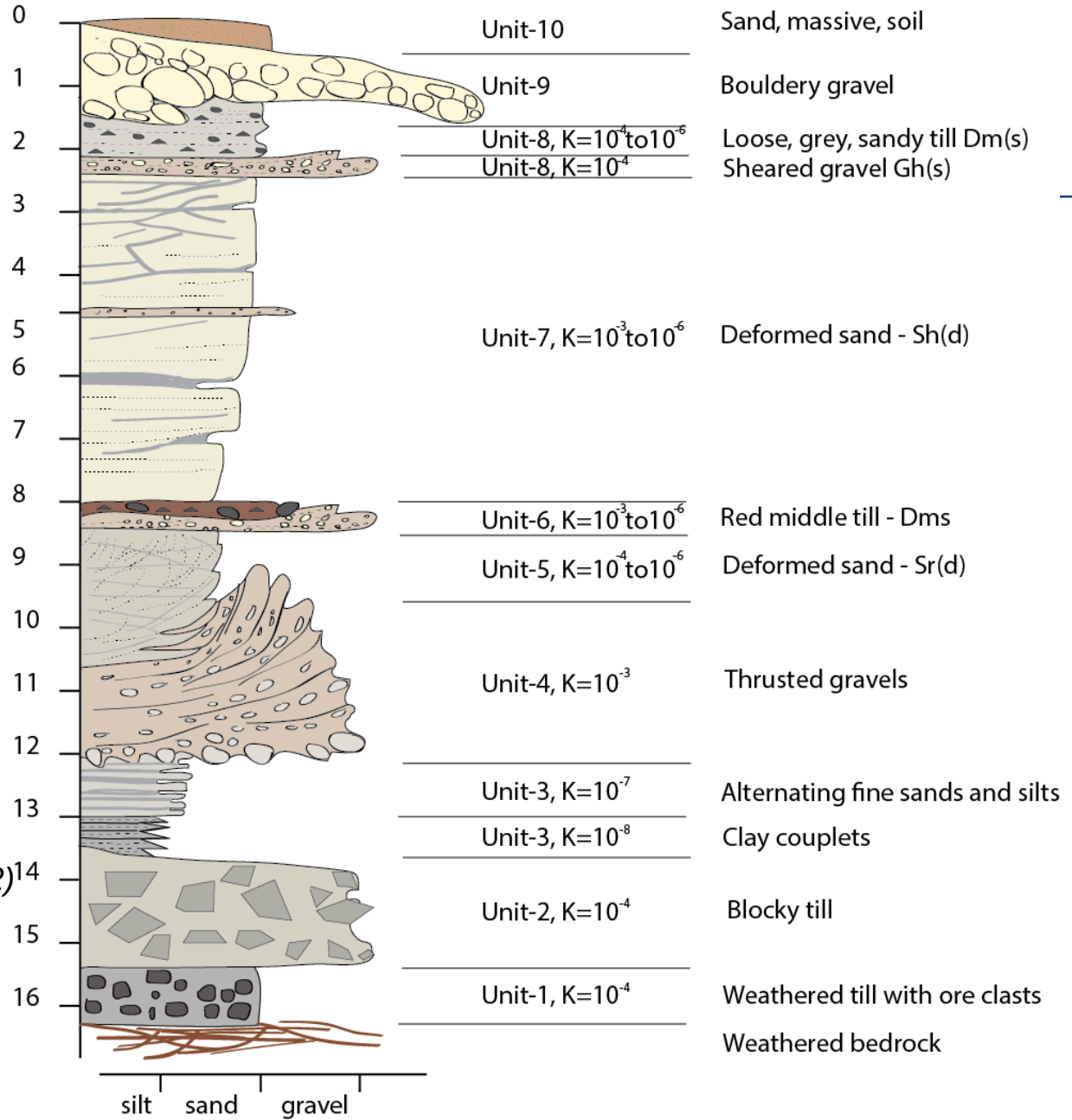
Soiltype	water permeability K-value (m/s)	Info
Gravel	10^{-2} …..10^{-4}	good permeability
Sand	10^{-4} …..10^{-6}	moderate permeability
Silt	10^{-5} …..10^{-9}	poor permeability
Clay	10^{-8} …..10^{-10}	almost no permeability

Rantamäki et al. (1979)

- Infiltration tests in the field
- Soil samples -> K-values (Hazen method)

Laurinoja pit, composite log

7497185.092/2498834.147
212 m. asl

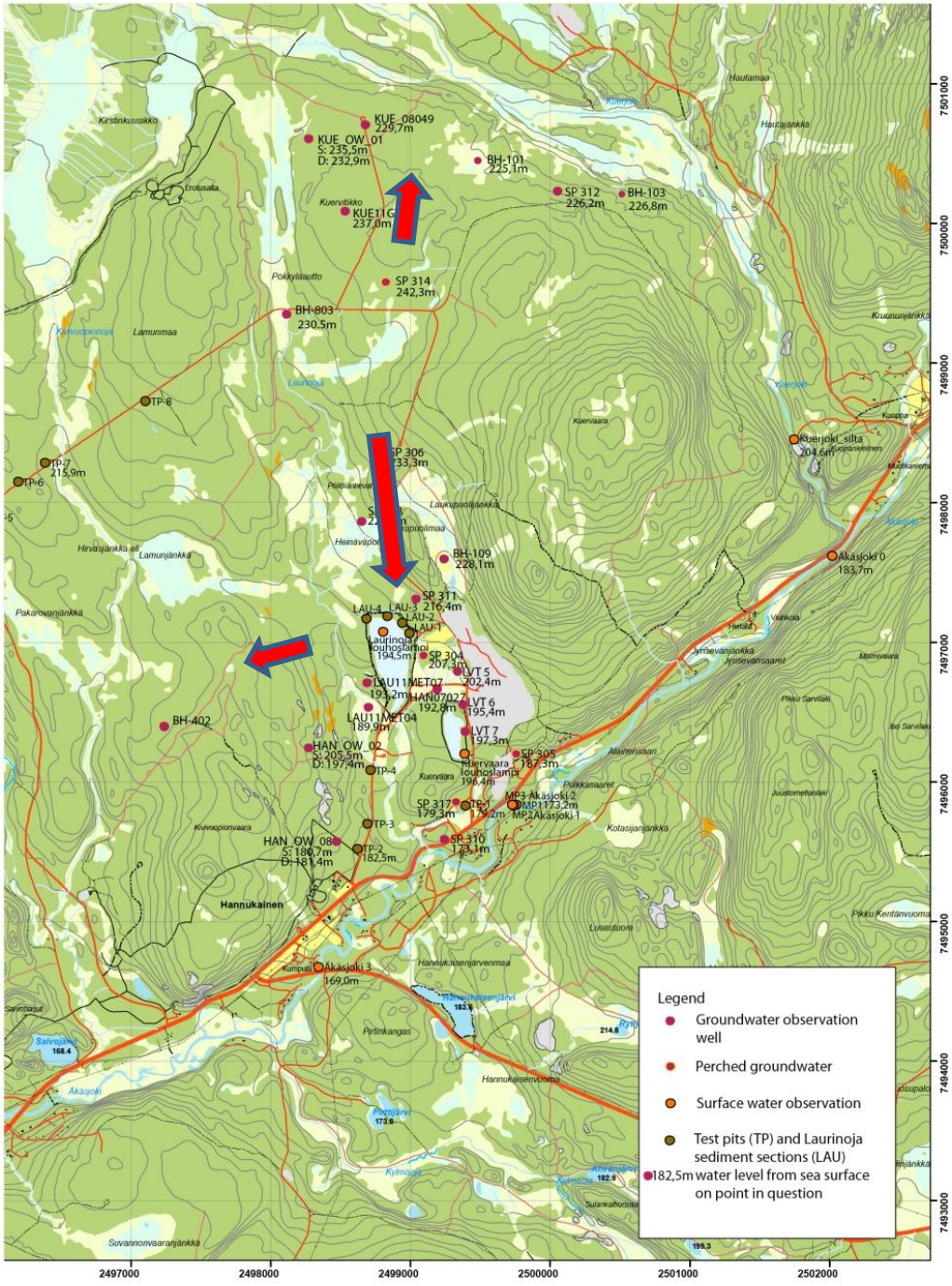


Salonen et al. (2012)

Nurminen (2013)

Groundwater table and flow directions

- Observation wells and mini-piezometers installed through the bottom sediment of the rivers.
- The main groundwater flow direction is from north to the south. Other local flow directions toward the surrounding rivers.

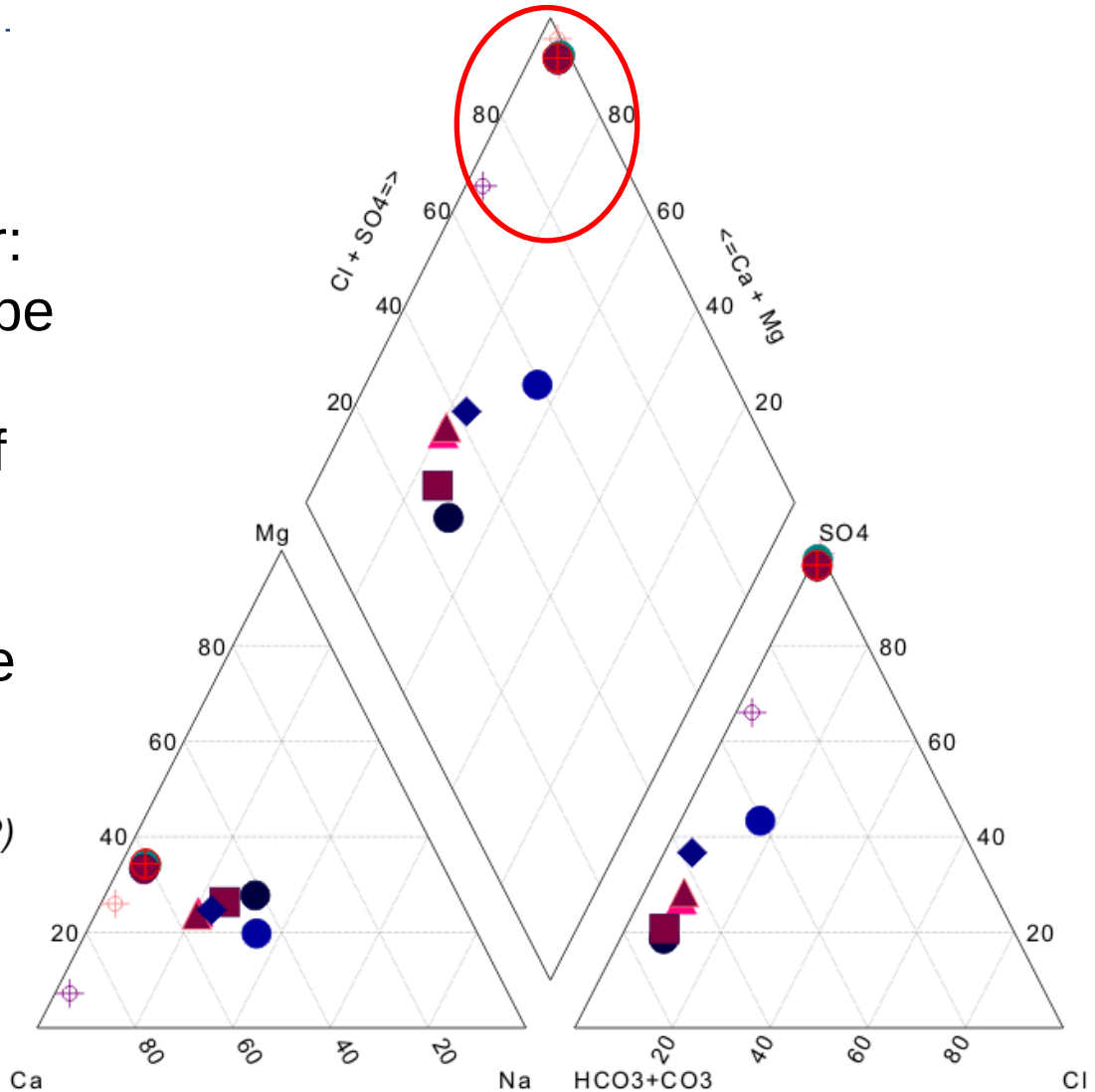


Salonen et al. (2012)

Chemical composition of waters

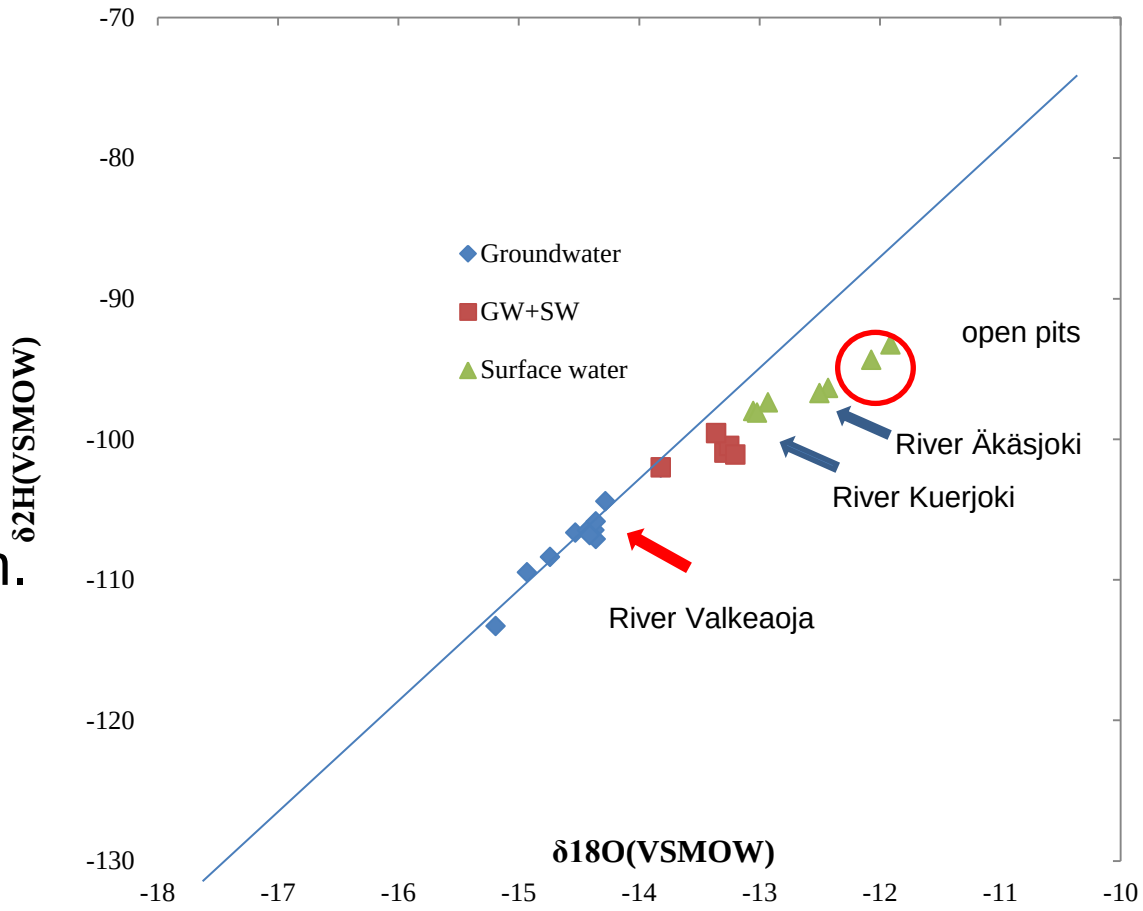
- Natural groundwater: Ca-HCO_3 type
- The effect of the mining activity: Ca-Mg-SO_4 type

Salonen et al. (2012)



Stable isotopes ($\delta^{18}O$ and $\delta^{2}H$)

- δ18O (‰VSMOW) in groundwater is -15 and -14.
- Surface water has less negative values because of evaporation.



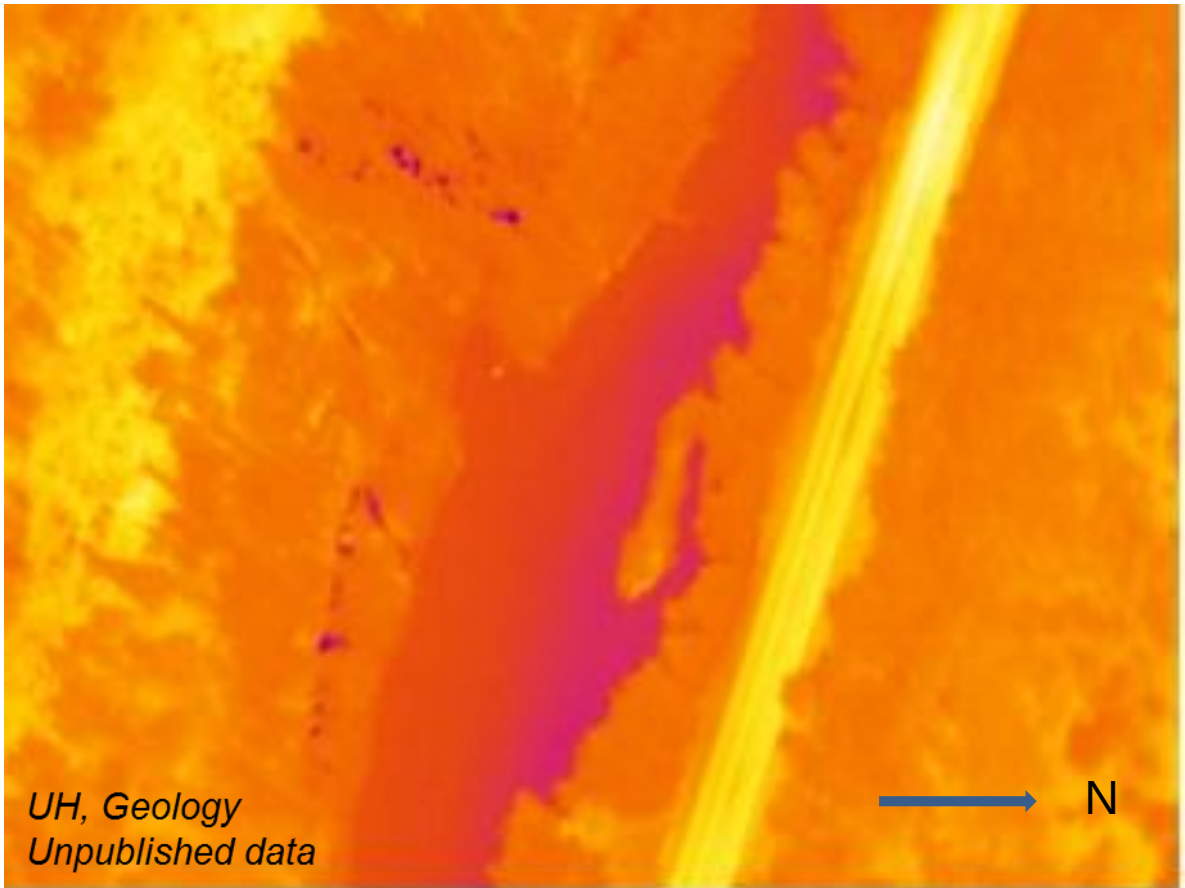
Salonen et al. (2012)

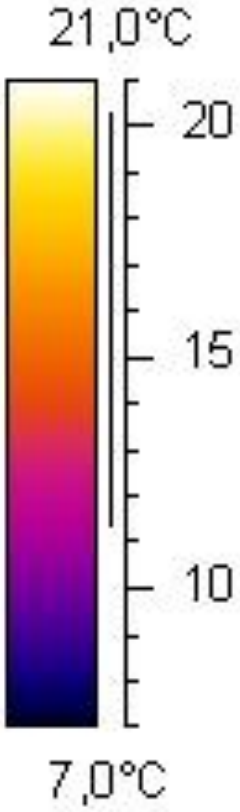
Thermal methods

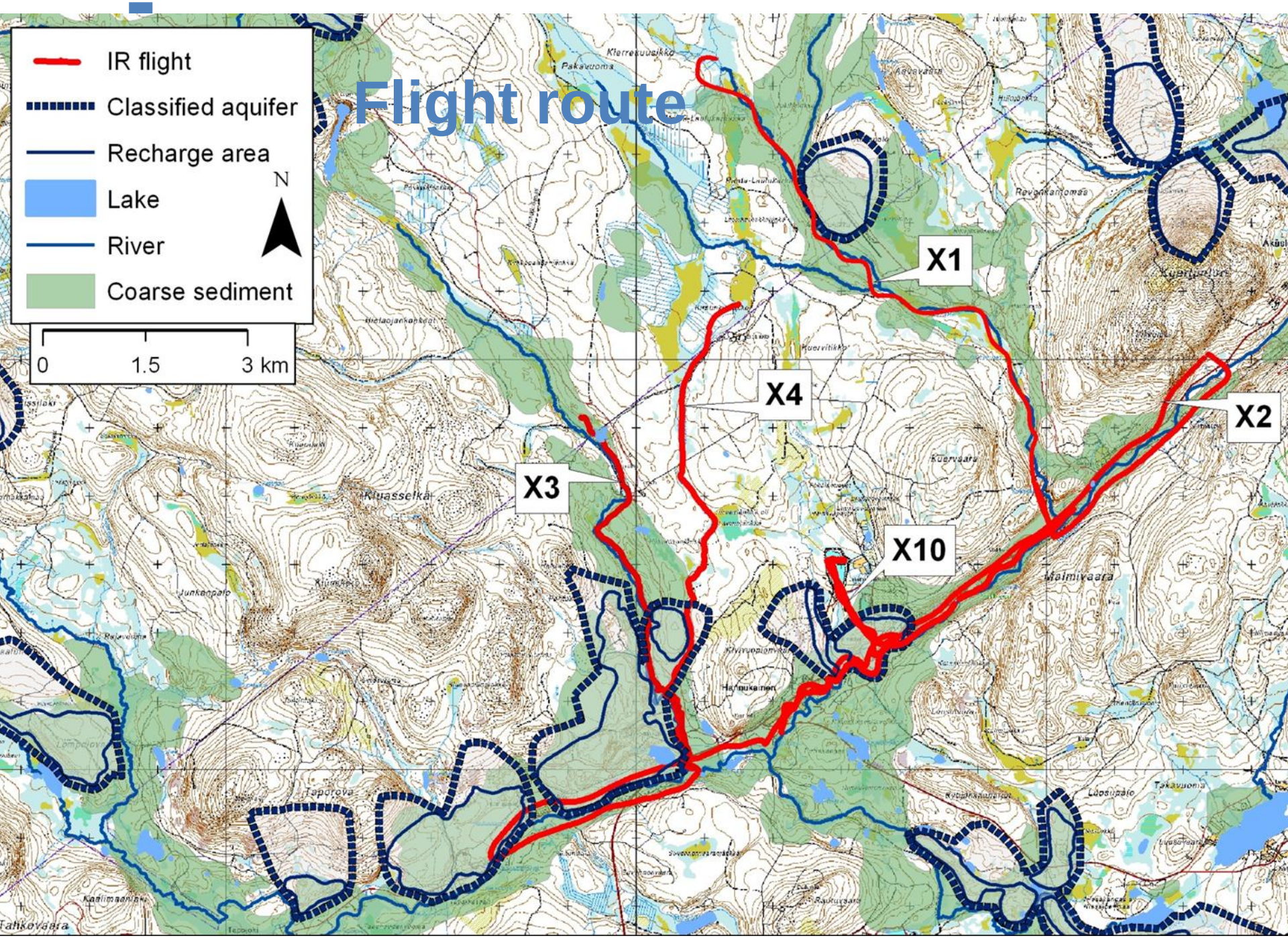
•Aerial IR surveys (FLIR ThermoCam P60) in July 2012 and August 2013
•*in situ* water and river bed sediment temperature measurements

AIR Survey

About 70 km/ 1 hour, altitude 50-100 m a.g.l

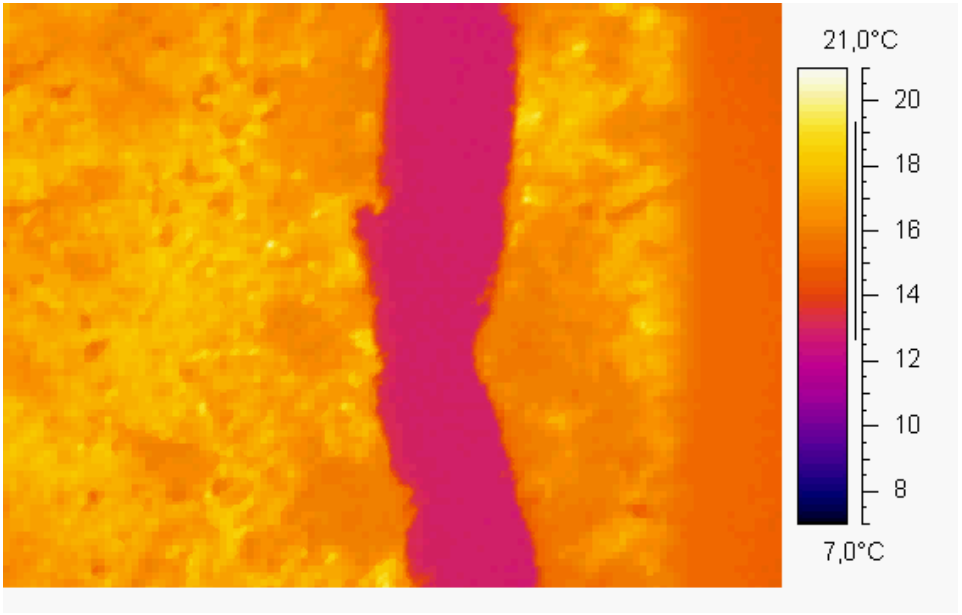




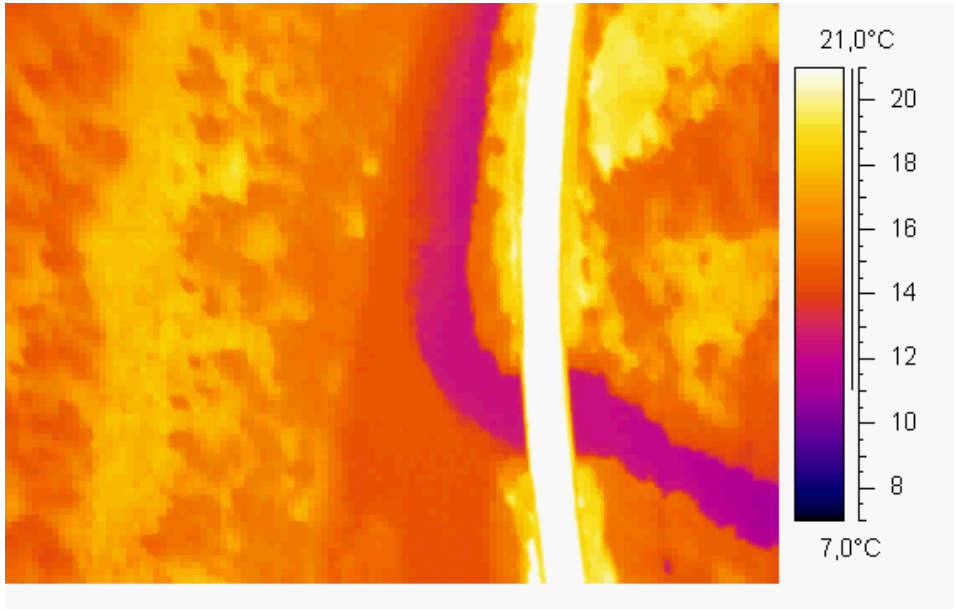

IR flight
Classified aquifer
Recharge area
Lake
River
Coarse sediment
N
0
1.5
3 km
Flight route
X1
X2
X3
X4
X10

AIR Survey

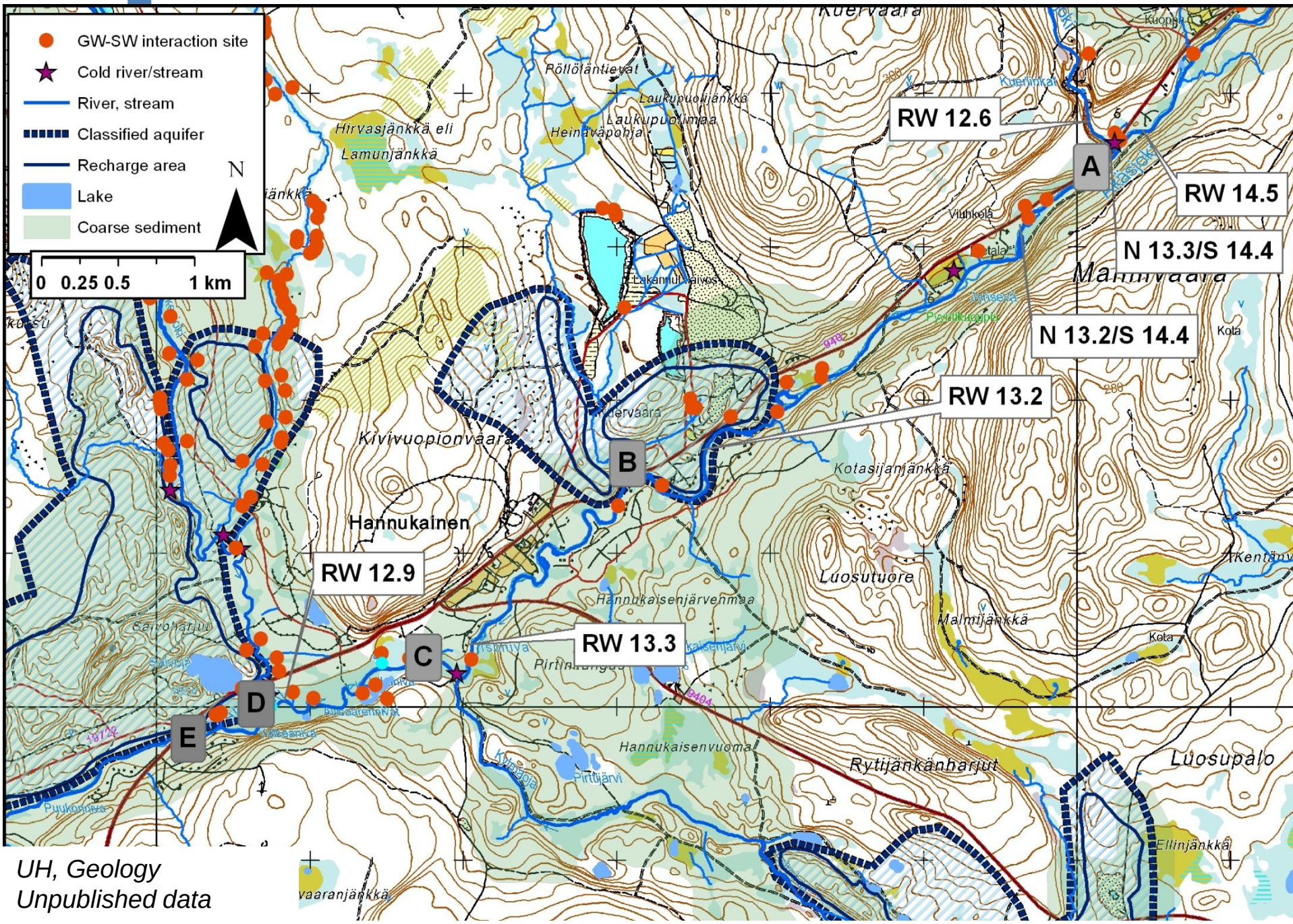
X1



X2



UH, Geology
Unpublished data



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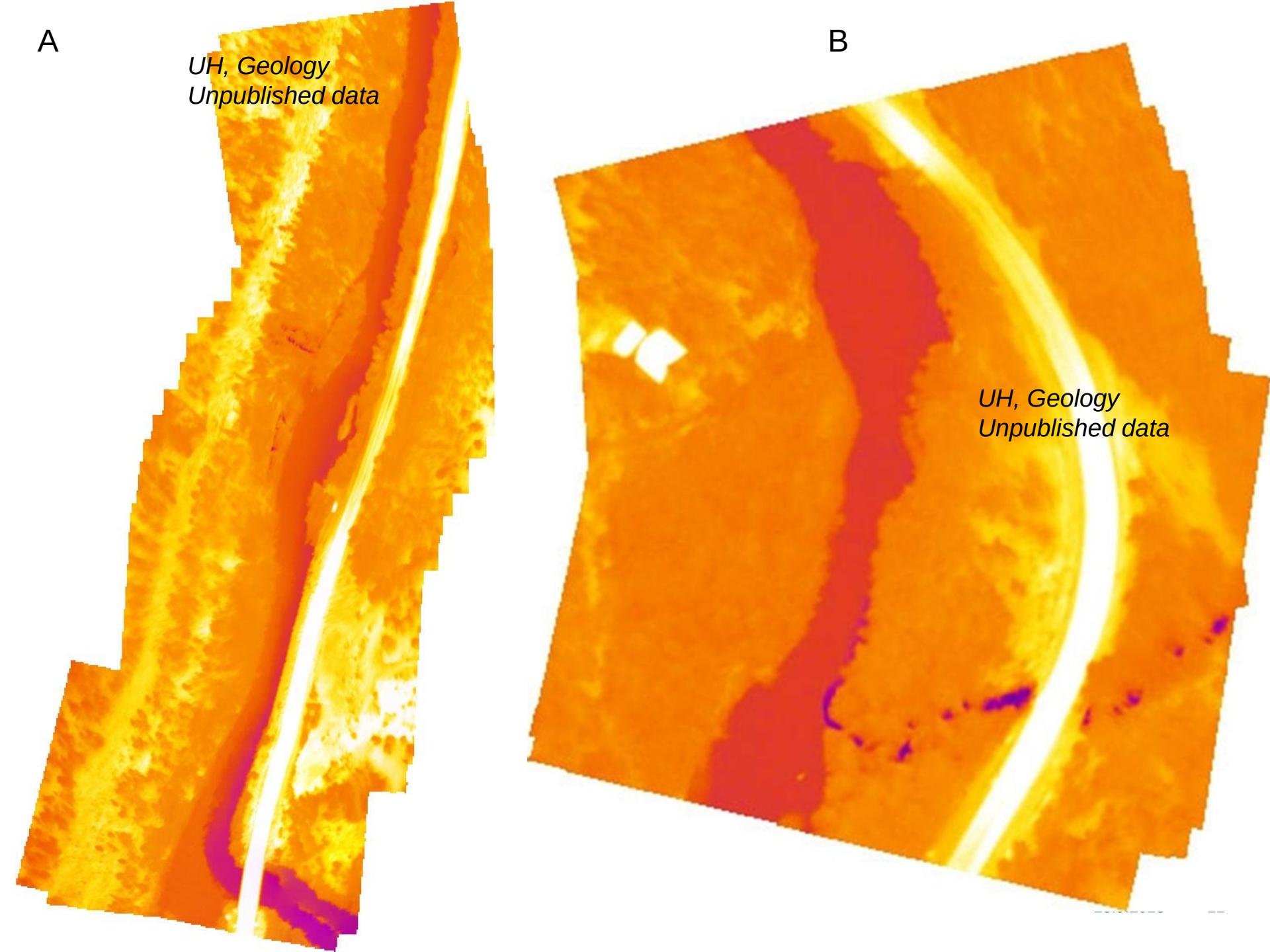
Unpublished data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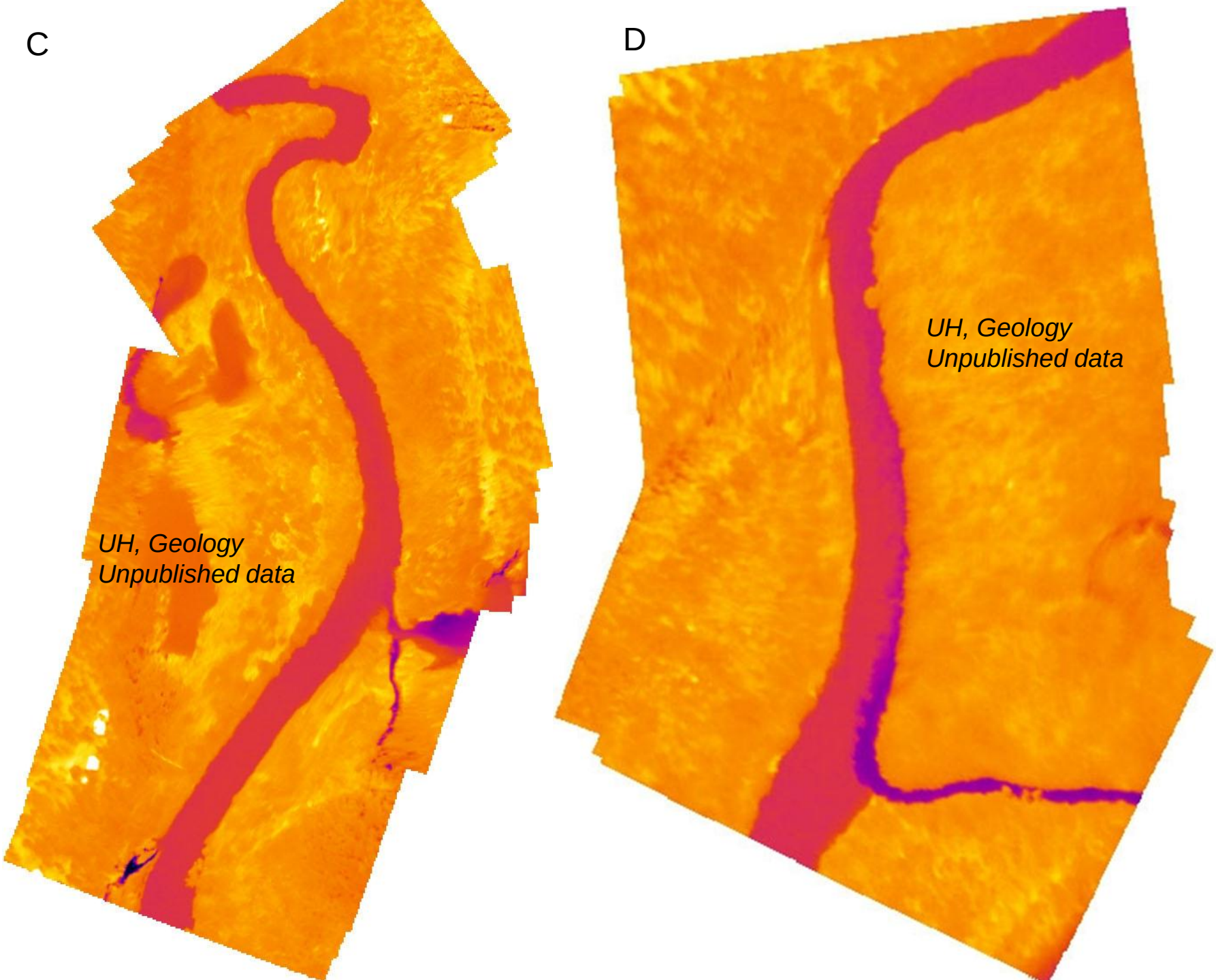
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D
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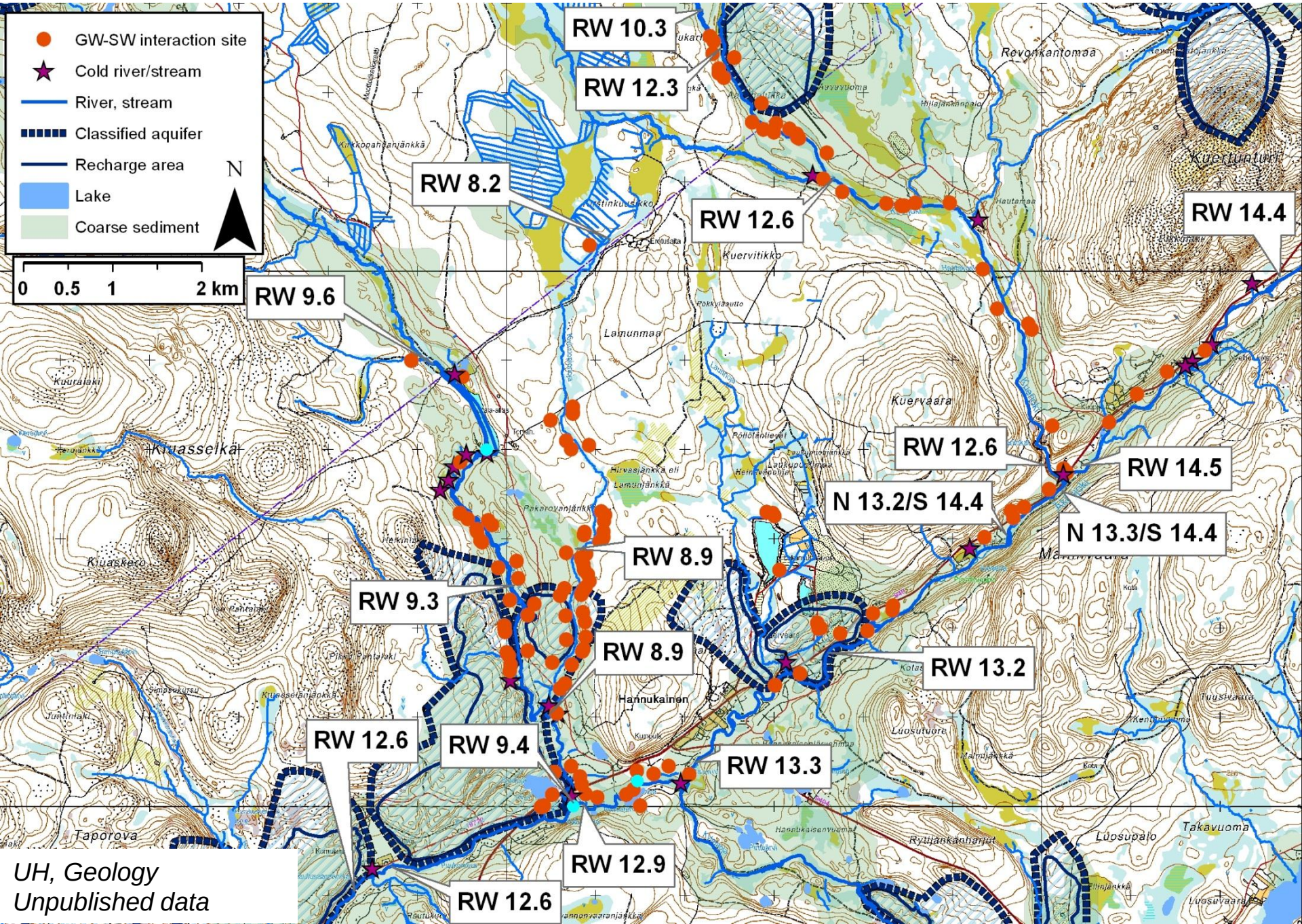
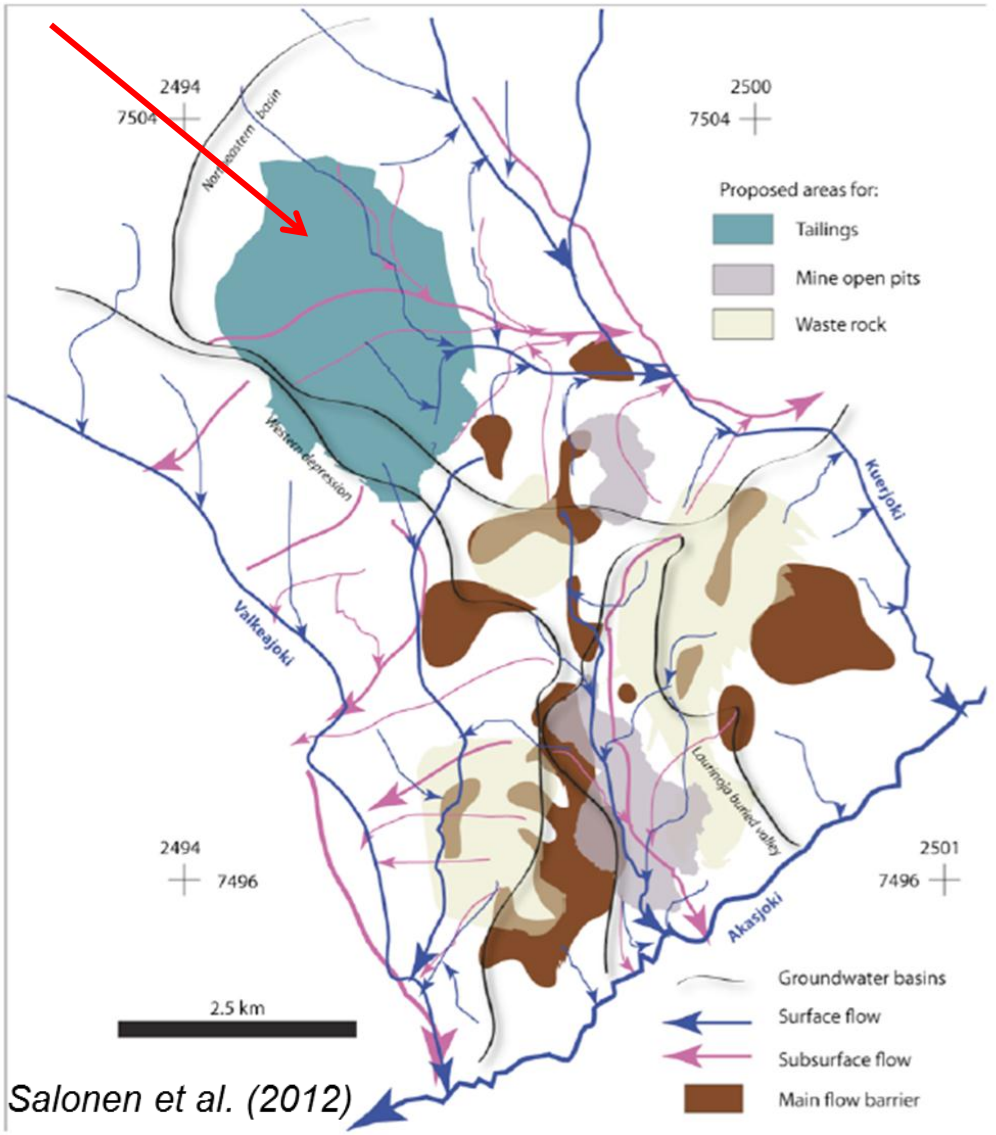
Thermal methods confirmed without any doubt that all rivers are fed by gw.



UH, Geology
Unpublished data

A synthesis model of water flows and connections

- All the surface waters flow towards River Äkäsjoki direct or through the tributaries.
- Groundwater system can be separated into three parts: **western depression, Laurinoja valley** and **the northern basin**.
- From western depression groundwater discharge into the rivers Kivivuopio and Valkeajoki, from Laurinoja valley directly into the river Äkäsjoki and from Northern basin into the river Kuerjoki.

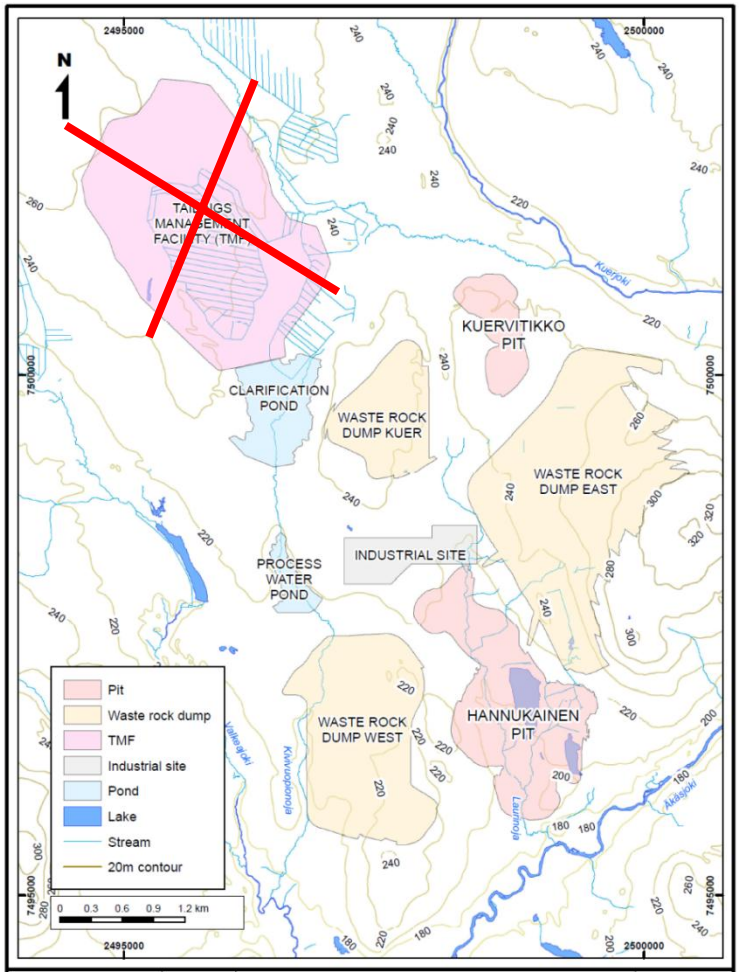


Conclusions

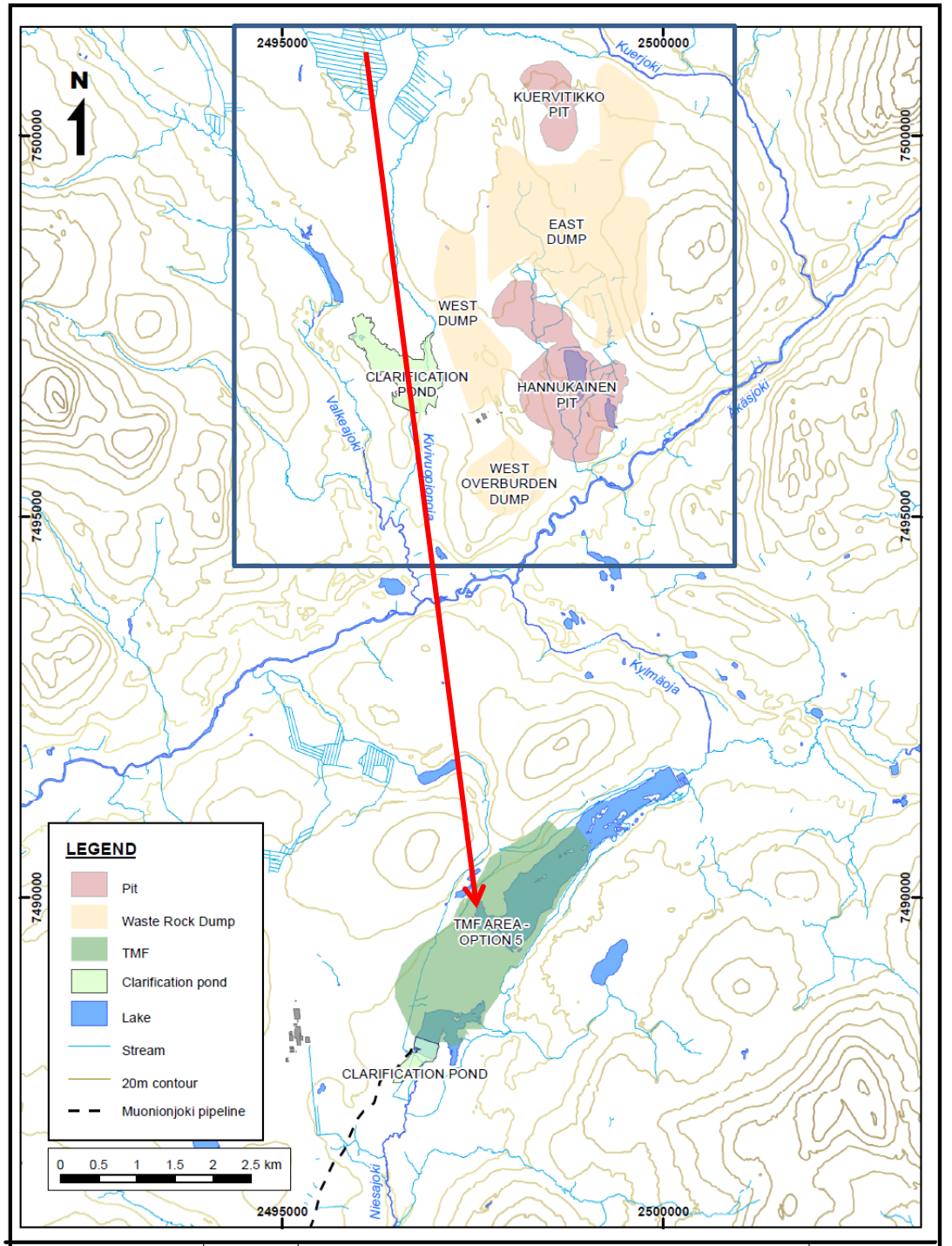
- The Hannukainen mine development site hosts a complicated aquifer system with notable connections to natural river systems.
- There are aquifers related to fluvial and glaciofluvial sands and gravels and aquitards related to tills and/or fines causing perched water bodies.
- Rivers Kuerjoki and Valkeajoki are strongly fed by groundwater. Groundwater is discharging into the River Äkäsjoki from the open pit area, as well.
- This hydrogeological background information is crucial in planning and positioning essential mining operations such as tailings areas in order to prevent any undesirable environmental impact.

Response

+1 year in planning
+7 MUSD
less env. impacts

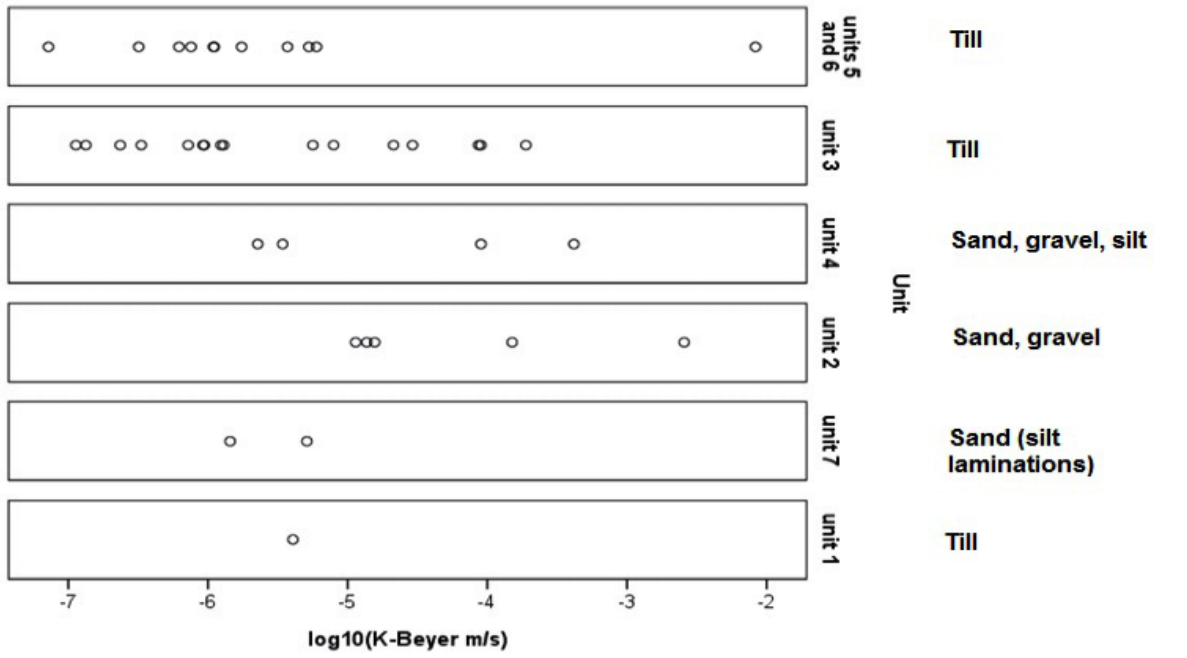


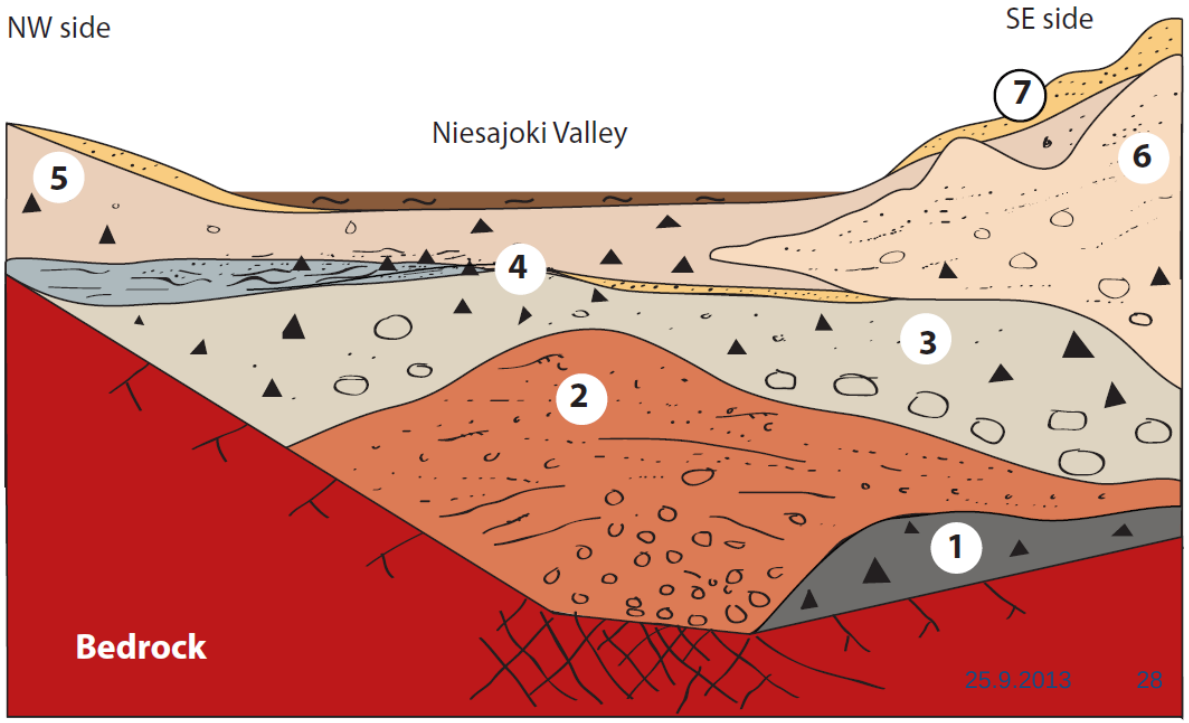
SRK (2013)



Hydrogeology of Rautuvaara

Results: Hydraulic conductivity of sediment units





Salonen et al. (2013)

Water sampling locations, test pits and observation wells

Salonen et al. (2013)

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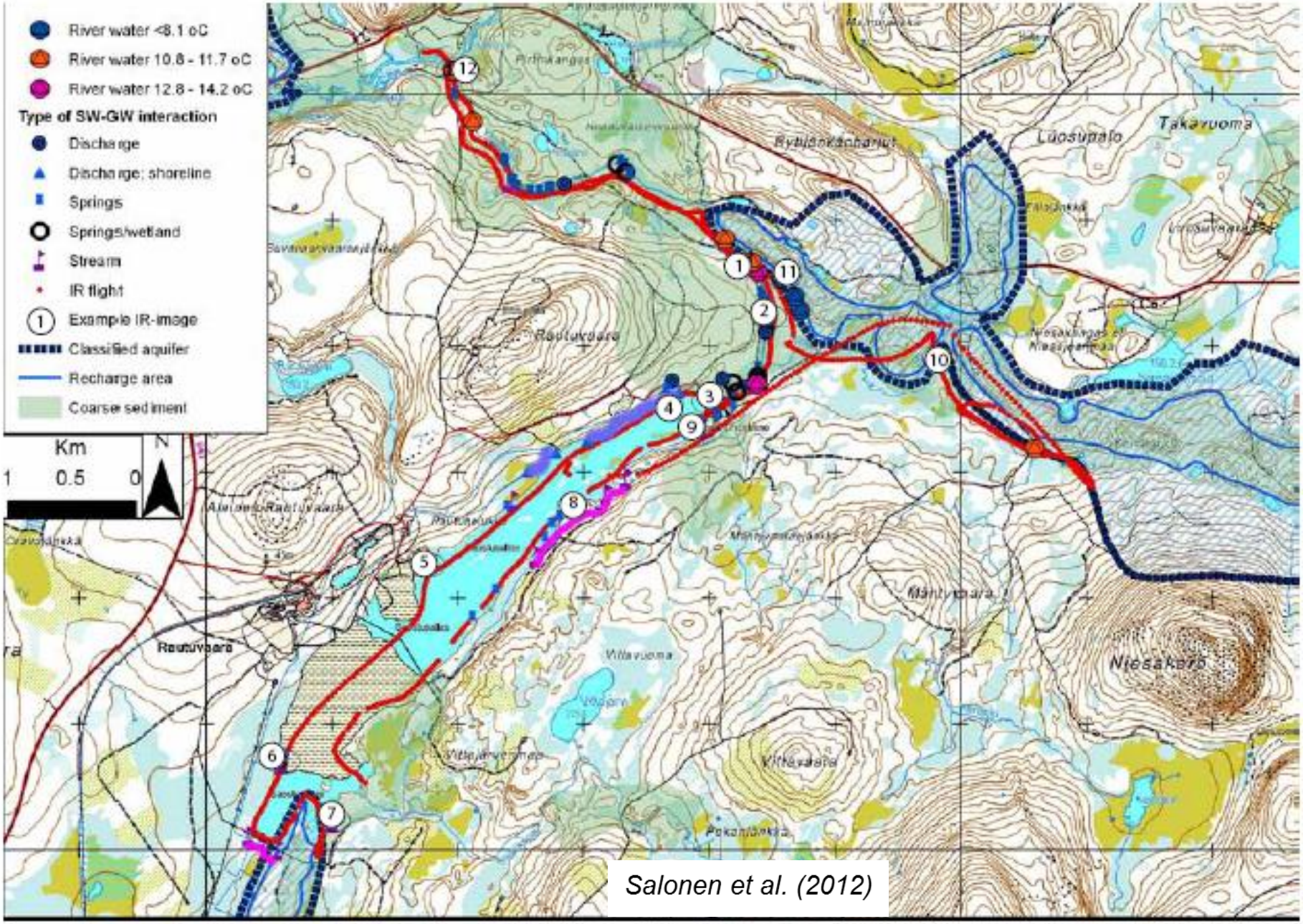
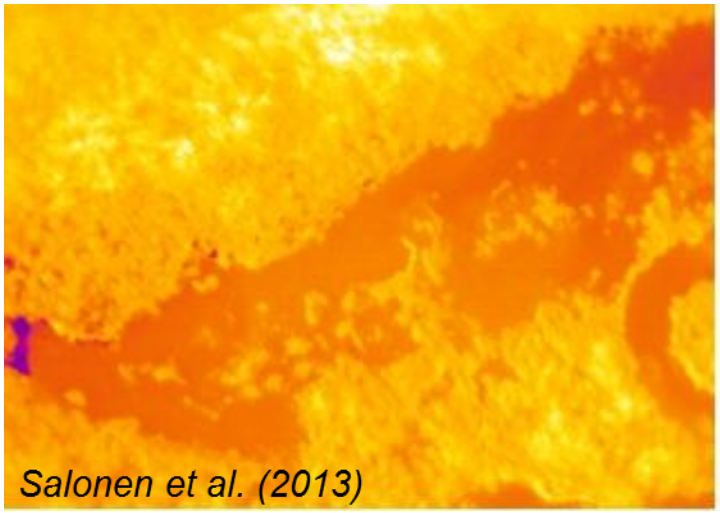
Aerial infrared survey 2012

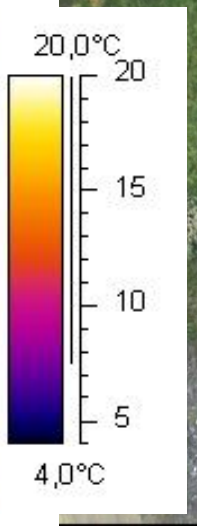


Salonen et al. (2012)

Eastern side of hill Rautuvaara:
Groundwater is discharging into the River Kylmäoja and into the northmost small pond next to the dam (3). There is also groundwater seepage at the forest line.

3)





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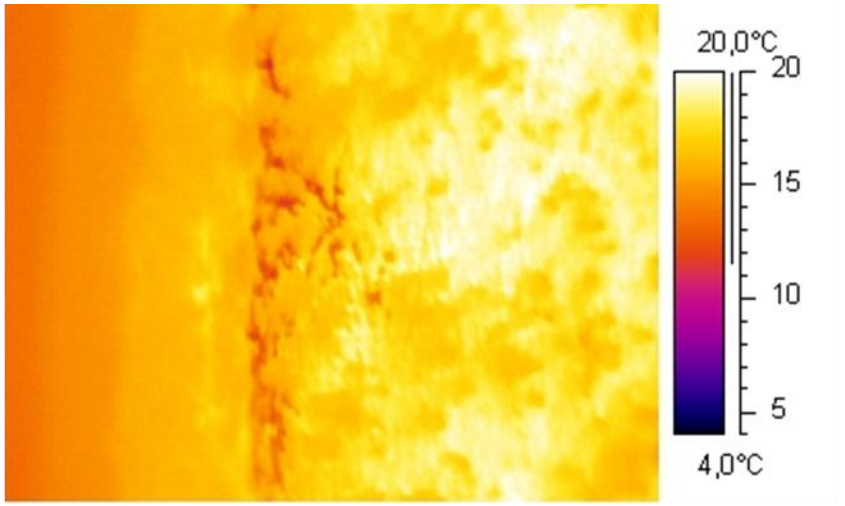
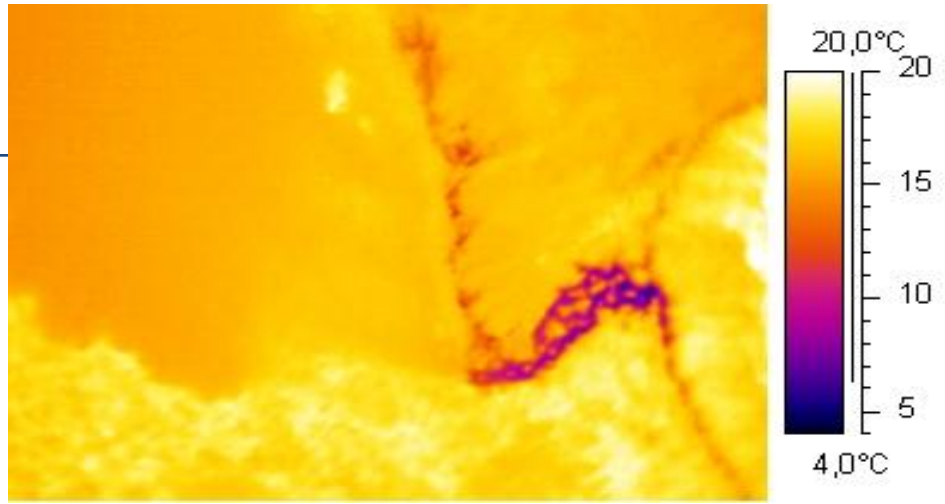


Northern shoreline of the larger settling pond:
Groundwater is discharging along the whole northern shoreline from dam to tailings area.

Salonen et al. (2013)

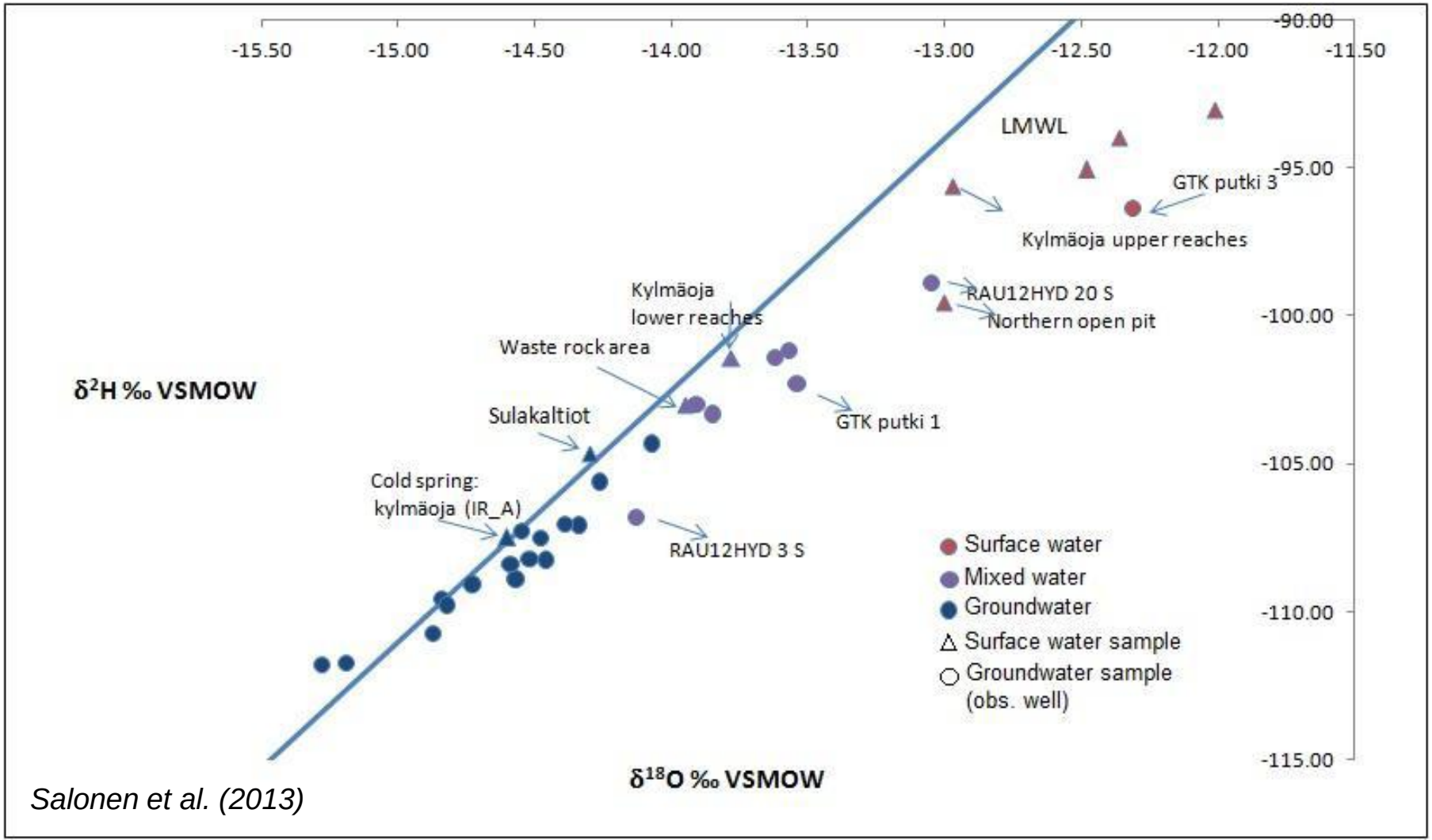
5)



Tailings area:
Groundwater is discharging into the tailings area next to the shoreline from the old mining site.

Salonen et al. (2013)

Results: Stable isotope compositions indicating surface water – groundwater interactions

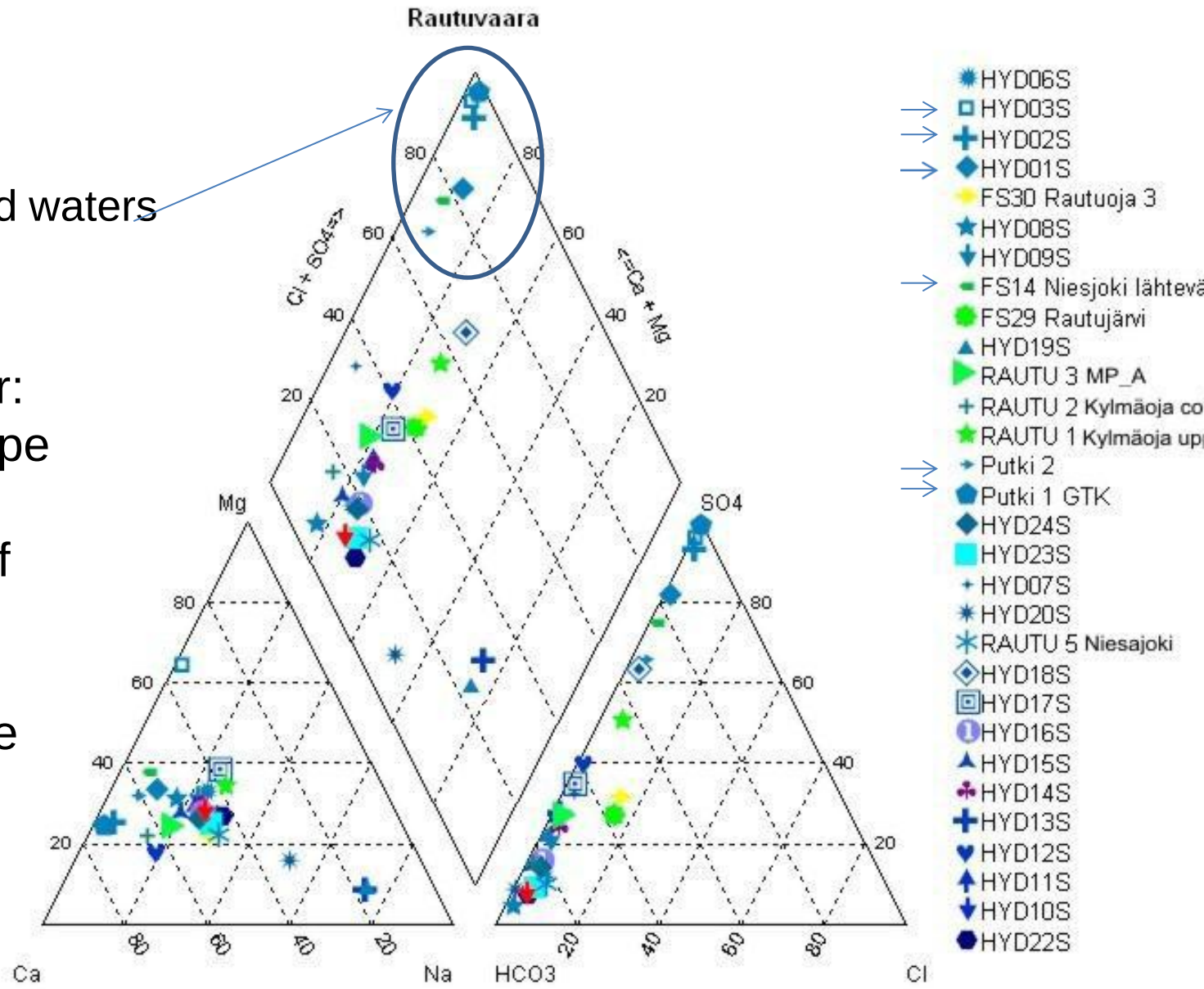


Salonen et al. (2013)

Results: Water types

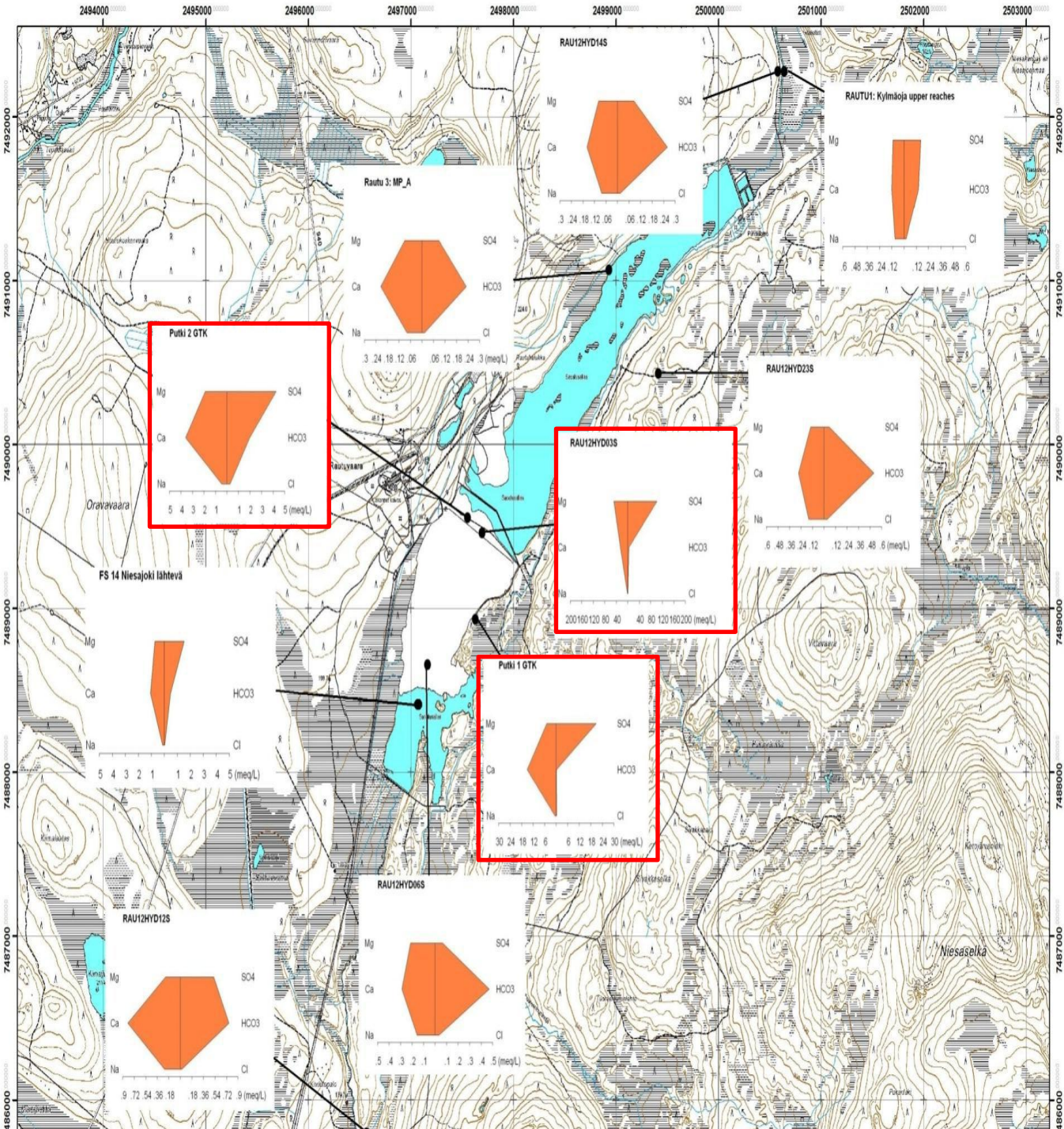
Tailings-impacted waters

- Natural groundwater: Ca-HCO_3 type
- The effect of the mining activity: Ca-Mg-SO_4 type



Salonen et al. (2013)

Tailings-affected and pristine waters



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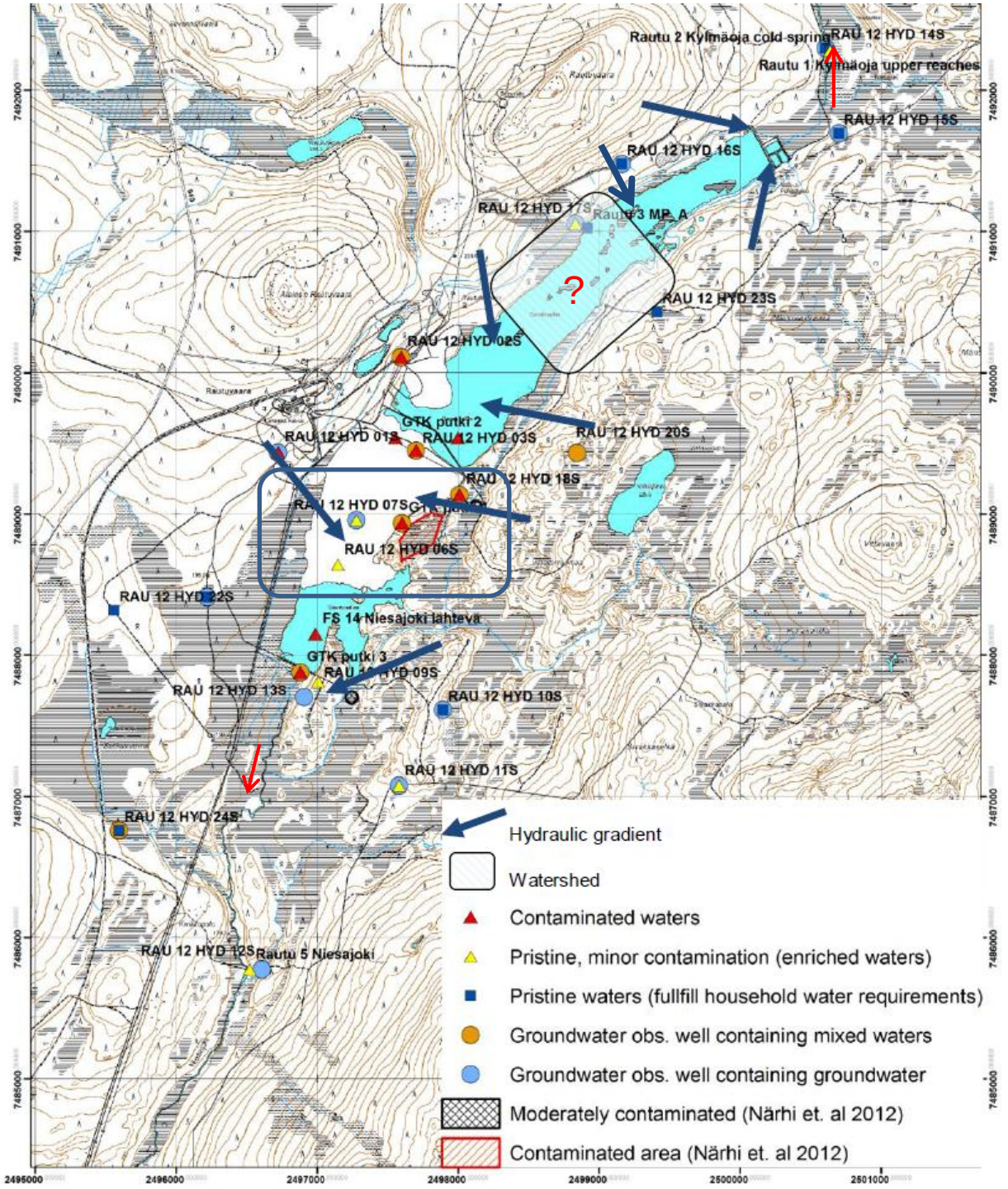
Savolainen (2013)

Flow directions and water quality



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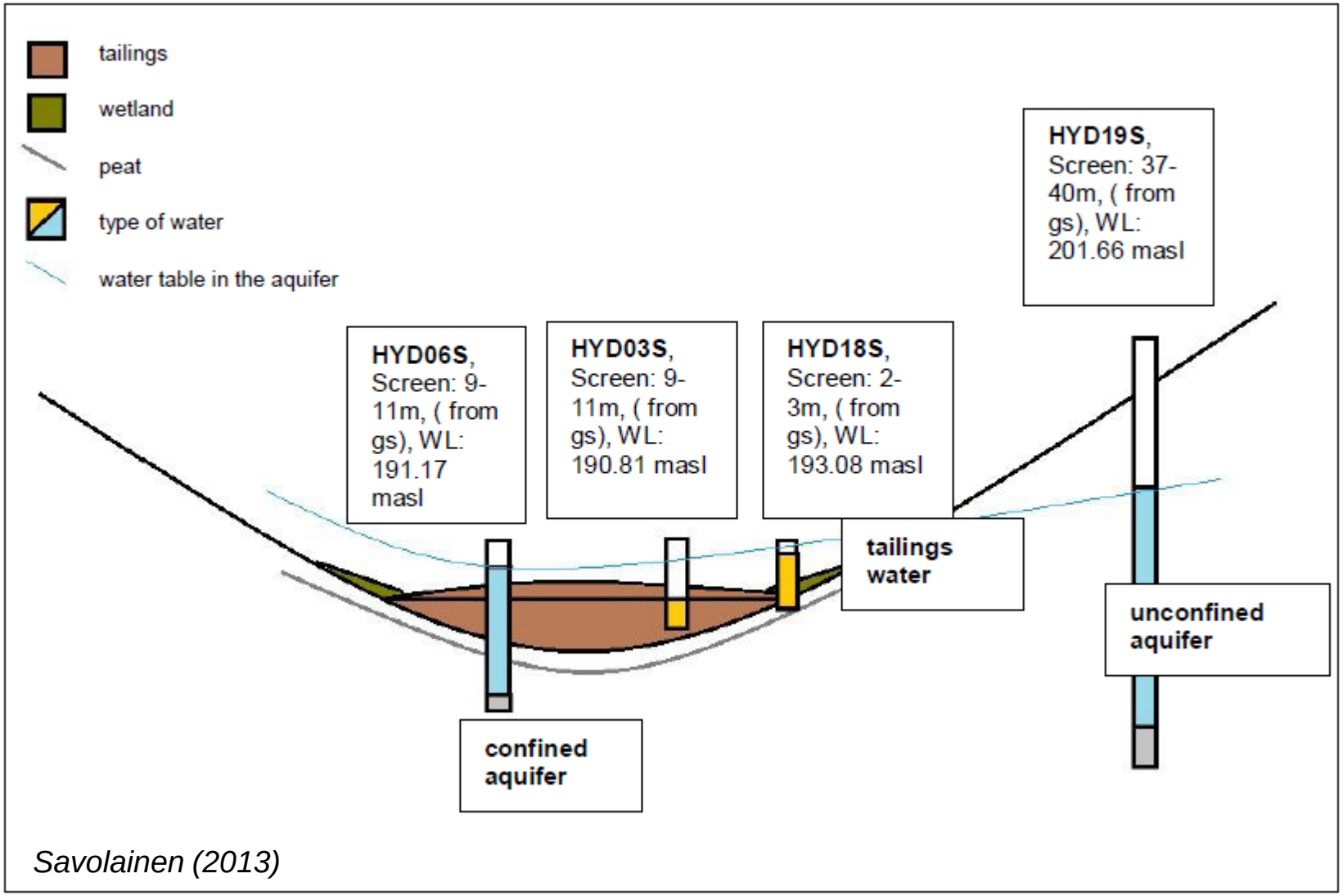
Savolainen (2013)

Results: Water tables in the tailings area



Savolainen (2013)

Take home message:

1) Identify the aquifers and aquitards and their hydraulic properties = hydrostratigraphical model
2) Define groundwater flow patterns
3) Characterize chemical and stable isotopic composition of the groundwater and surface waters
4) Define the locations and extent of groundwater – surface water interaction

-> Modelling of water flows

-> Simulation of positioning mining activities/dewatering/mining operations/closure

Thank you for your attention!

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Acknowledgements: Northland Mines Oy and K.H. Renlund Foundation