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K.H.RENLUNDS STIFTELSE

AA Sakatti Mining Oy

THE EFFECT OF RIVER REGULATION ON THE HYDROLOGICAL CONDITIONS OF THE AAPA MIRE IN A MINING DEVELOPMENT SITE IN NORTHERN FINLAND

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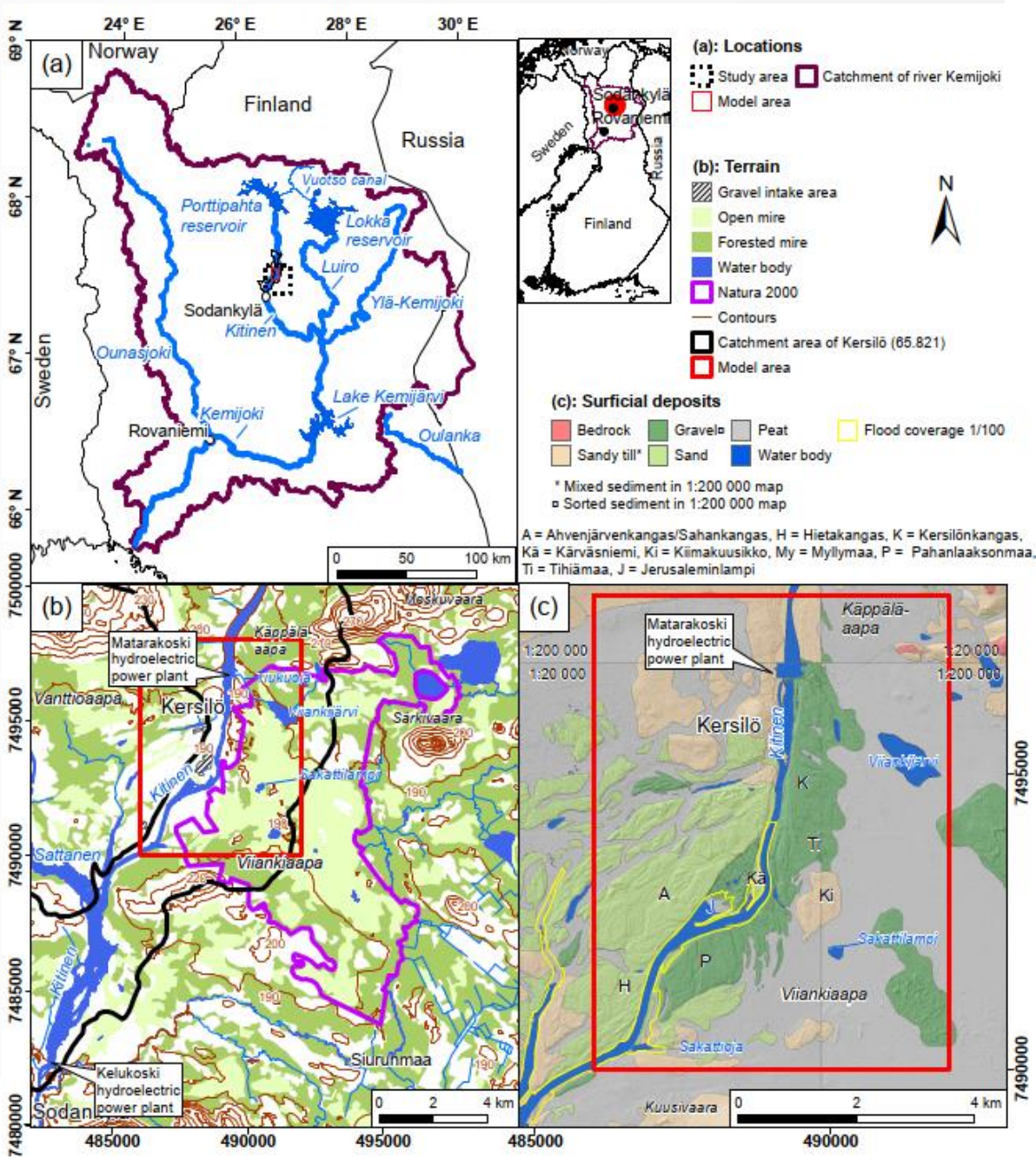
BACKGROUND

- A high-graded Ni-Cu-PGE deposit was found in 2011 occurring 300 m beneath the Natura 2000 –protected Viiankiaapa mire (Brownscombe et al. 2015).
- The Viiankiaapa mire hosts habitats of threatened groundwater influenced plant species such as *Hamatocalis vernicusus, Hamatocaulis lapponicus,* and *Saxifraga hirculus.*
- The study area in Sodankylä, in northern Finland, has been glaciated multiple times during the Quaternary forming complex sedimentary succession with low conductivity till and highly variable sorted sediments, which hydraulic conductivity can be orders of magnitudes higher.
- Planning of mining operations in such environments needs a detailed understanding of water balance, groundwater recharge/discharge and flow patterns.
- Main rivers in northern Finland have been regulated since the 1970s, and surrounding environments are not in their natural stage. An understanding of how much the environments have changed due to the regulation is needed.

RESEARCH OBJECTIVES

- To understand how the river regulation affected the hydrology of the Natura 2000 -protected Viiankiaapa mire in the mining development site of AA Sakatti Mining Oy
- Two hypotheses:

1. The regulation of the river has reduced flooding and the elevation of the river stage, affecting the hydrology of the Viiankiaapa mire
2. The regulation has changed the GW flow directions near the Matarakoski dam, which has subsequently affected mire hydrology



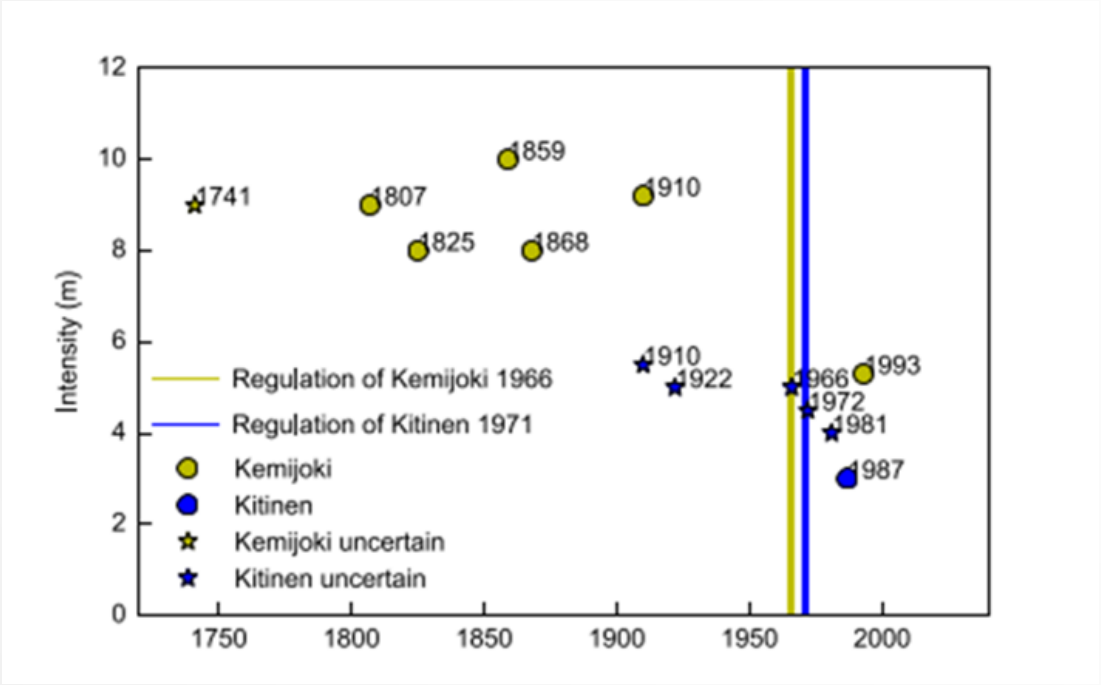
Base maps, terrain polygons: © National Land Survey of Finland, Surficial deposits map: © Geological Survey of Finland. River, lake and catchment area polygons are modified after Finnish Environment Institute (SYKE). Flood coverage is modified and reproduced after AIRIX Ympäristö Oy (2008).Administrative borders of Sweden, Norway and Russia, source GADM 2020.

METHODS

- 3D groundwater flow modelling with MODFLOW-NWT (Niswonger et al. 2011)
  - Influence of the river regulation on groundwater recharge/discharge and flow patterns were studied with two models presenting “present” settings (POST2014) and “pre-regulation” settings (PRE1989)
  - The present distribution of groundwater influenced plant species were compared to modelled groundwater discharge areas
- 2D flood modelling with HEC-RAS (Brunner 1995)
  - Coverages of 1966 and 1987 floods were modelled to study the effect of pre-regulation flooding on the hydrology of the Viiankiaapa mire

RIVER REGULATION AND FLOODING

Historical flood records



Regulation scheme of the River Kitinen

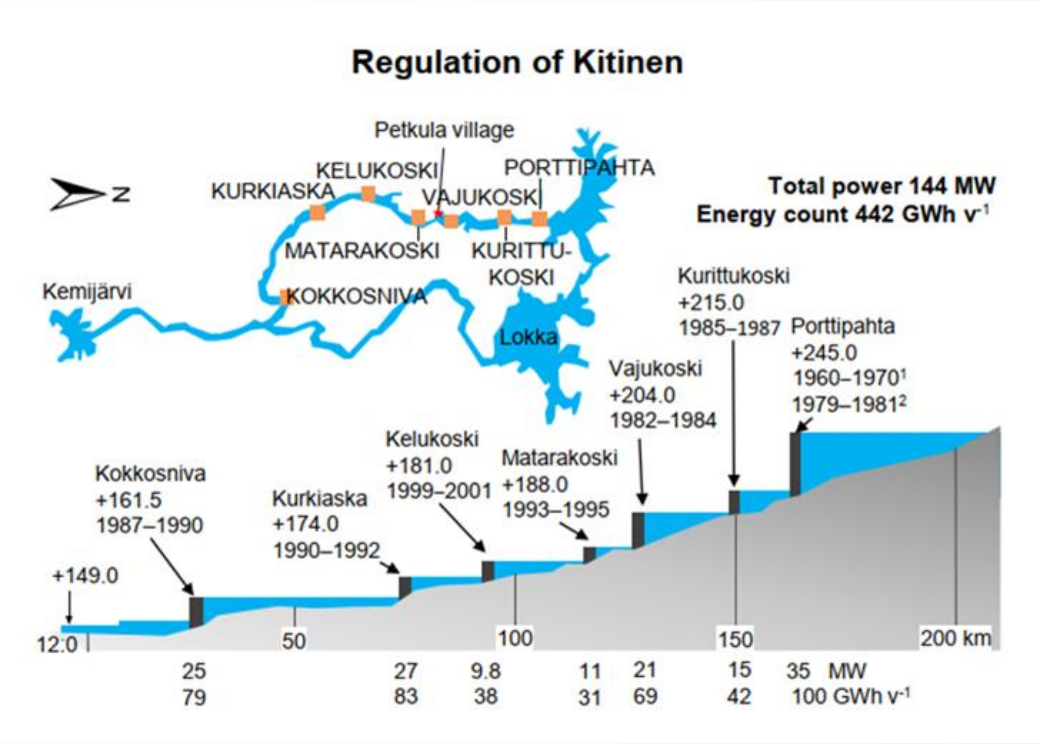
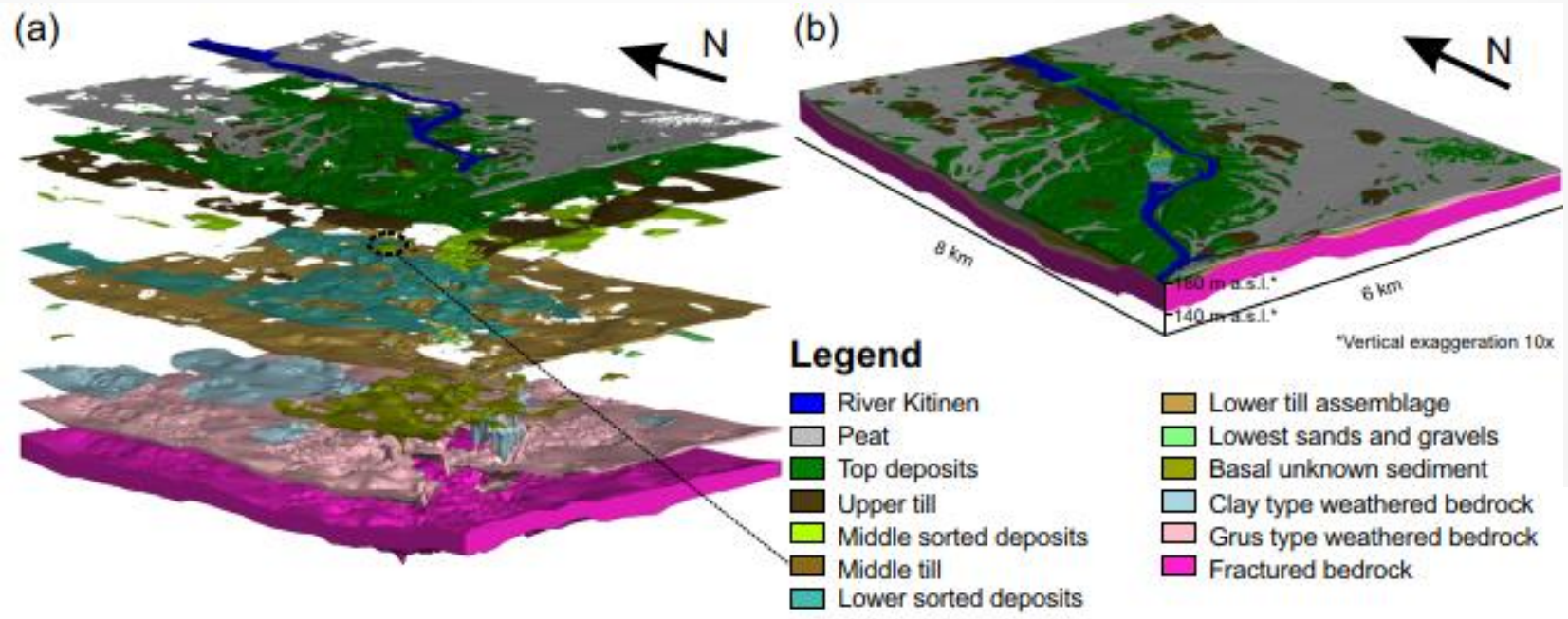


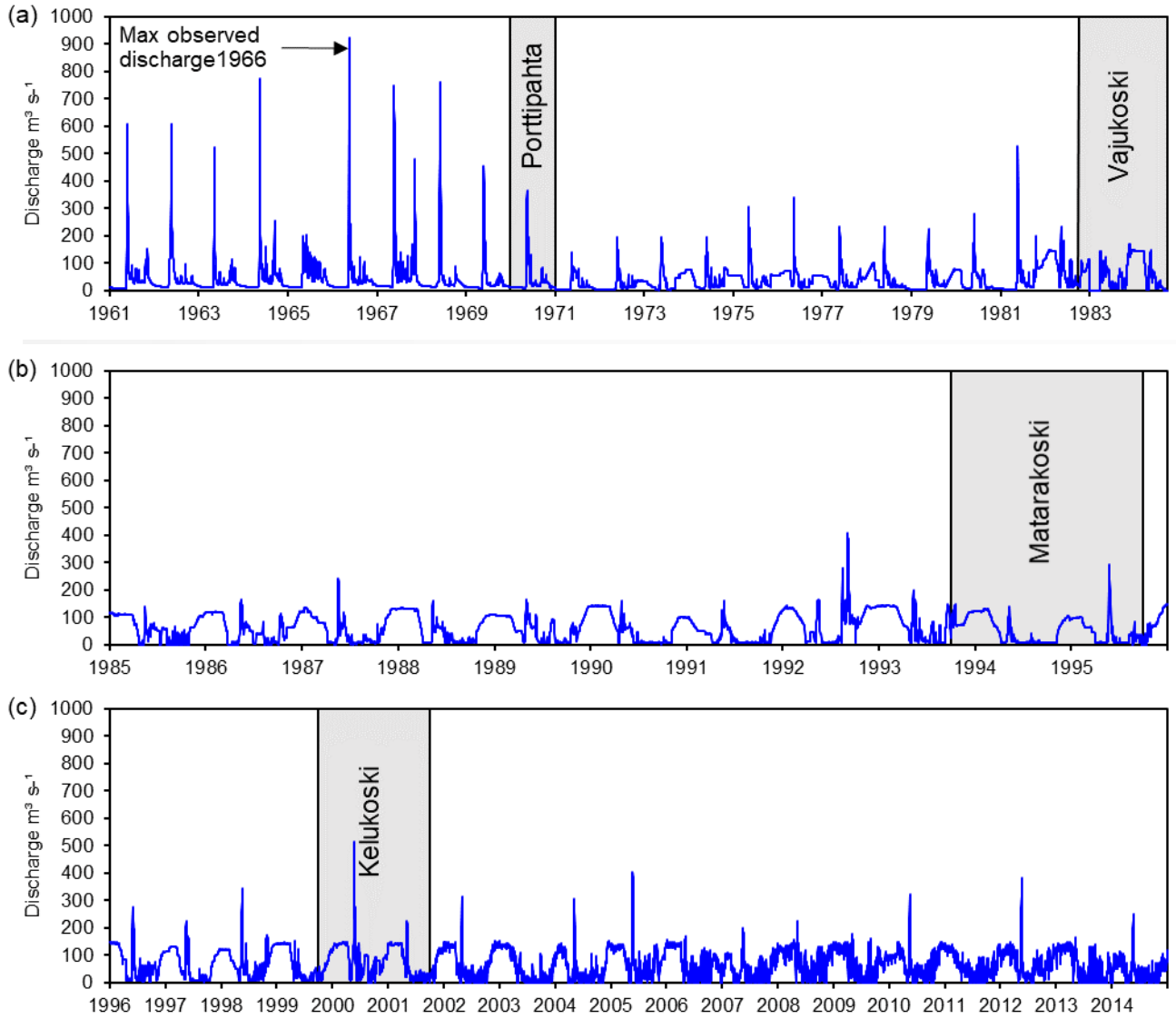
Figure is modified after Kemijoki Ltd (unpublished data)

3D GEOLOGICAL MODELLING

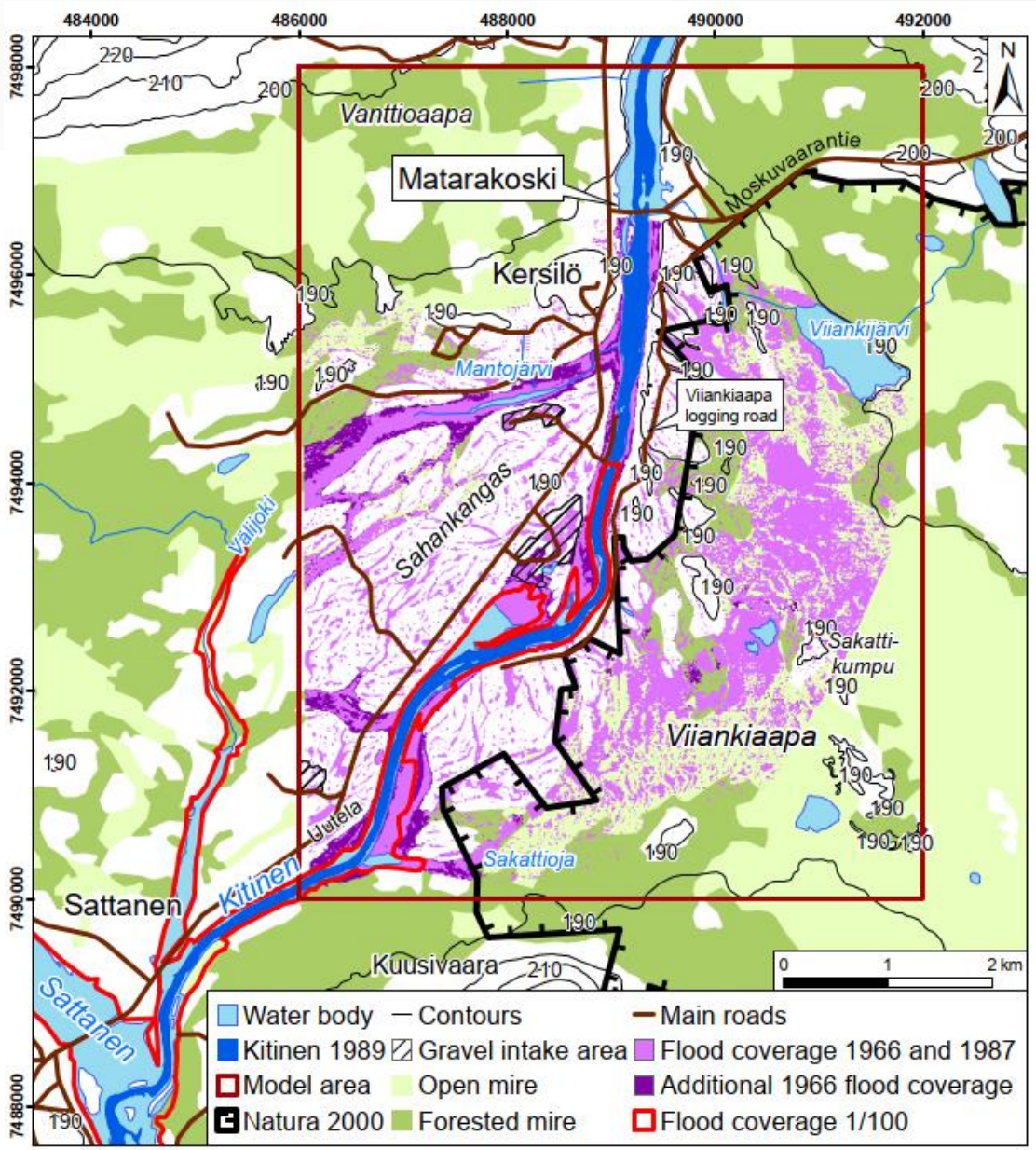
- Detailed geological 3D modelling was used as a base for the hydrostratigraphic model used for groundwater flow modelling
- According to Åberg et al. (2021), hydrostratigraphically detailed models are needed to simulated groundwater recharge/discharge patterns in adequate detail if the high variation of hydraulic conductivity is present



FLOOD MODELLING



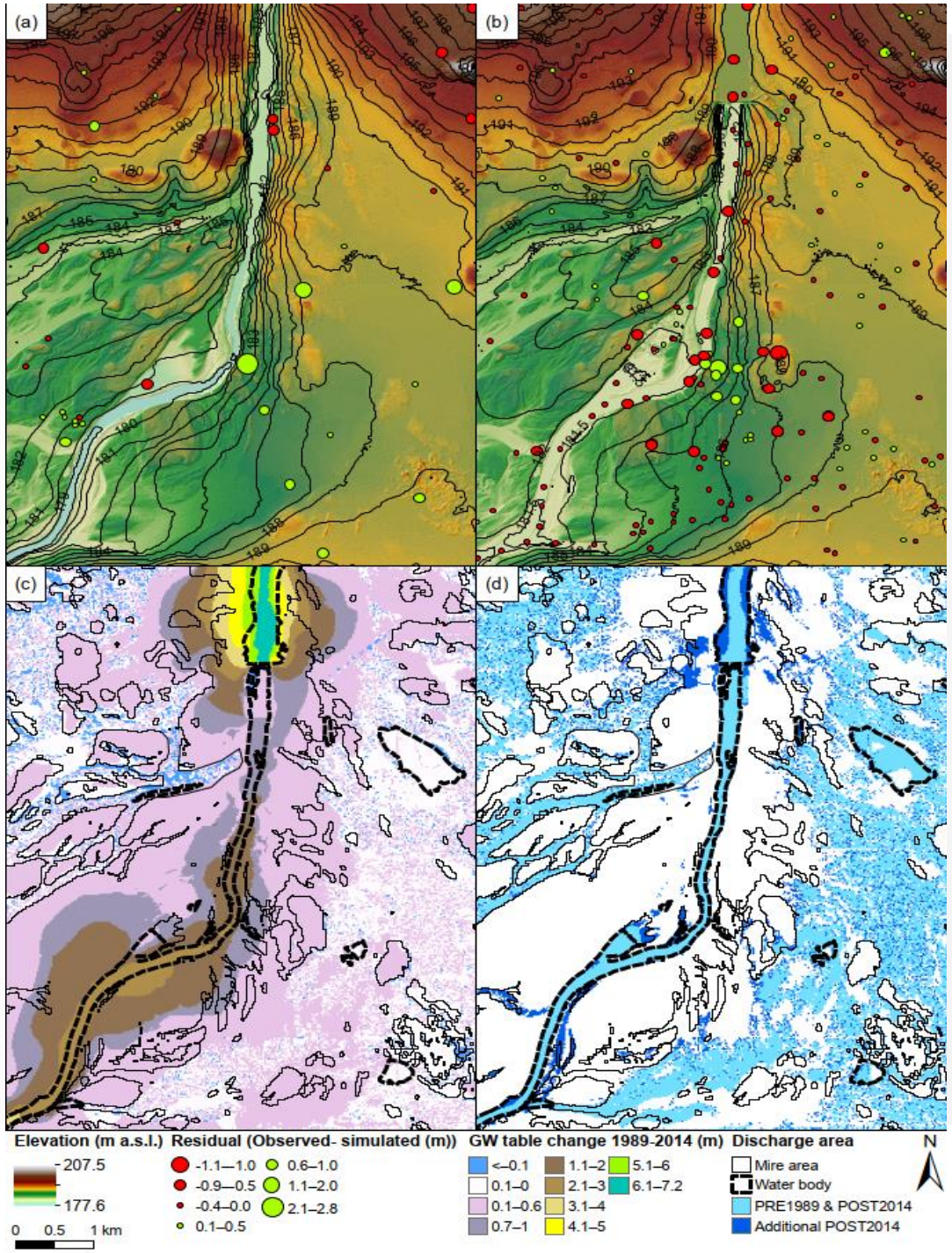
The river discharge data are from Kemijoki Ltd (unpublished data).



Kitinen 1989 is modified after the 1989 base map of NLSF. Terrain polygons and contours are modified and reproduced after the National Land Survey of Finland. Flood coverage 1/100 is modified and reproduced after AIRIX Ympäristö Oy (2008).

3D GROUNDWATER FLOW MODELLING

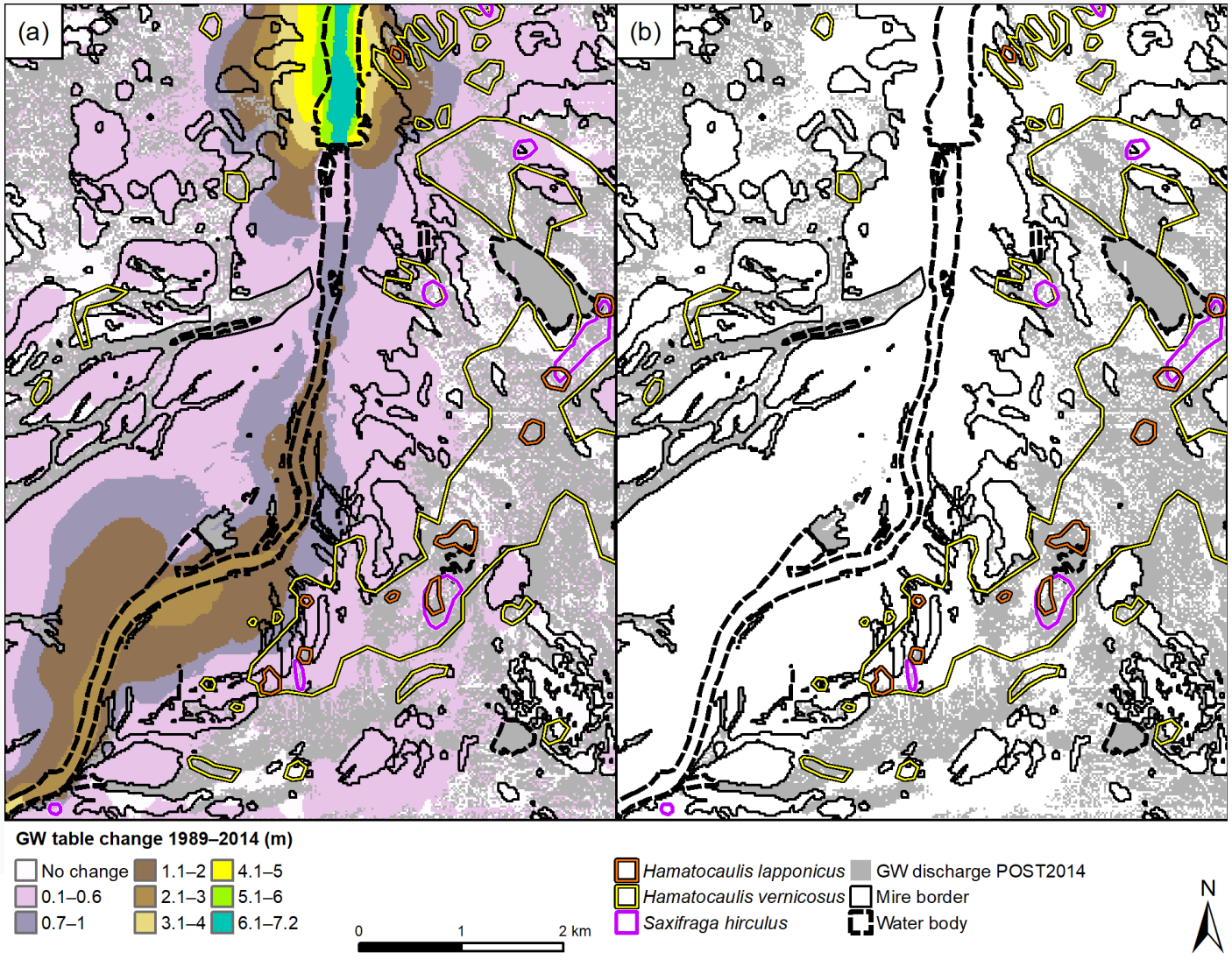
- (a) Simulated groundwater table contours of the pre-regulation model (PRE1989)
- (b) Simulated groundwater table contours of the post-regulation model (POST2014)
- (c) The difference of groundwater table between PRE1989 settings and POST2014 settings
- (d) The difference of groundwater discharge areas between PRE1989 settings and POST2014 settings



LiDAR DEM, Mire area and Water body are modified and reproduced after National Land Survey of Finland.

THE EFFECT OF GROUNDWATER TABLE CHANGE TO STUDIED PLANT SPECIES

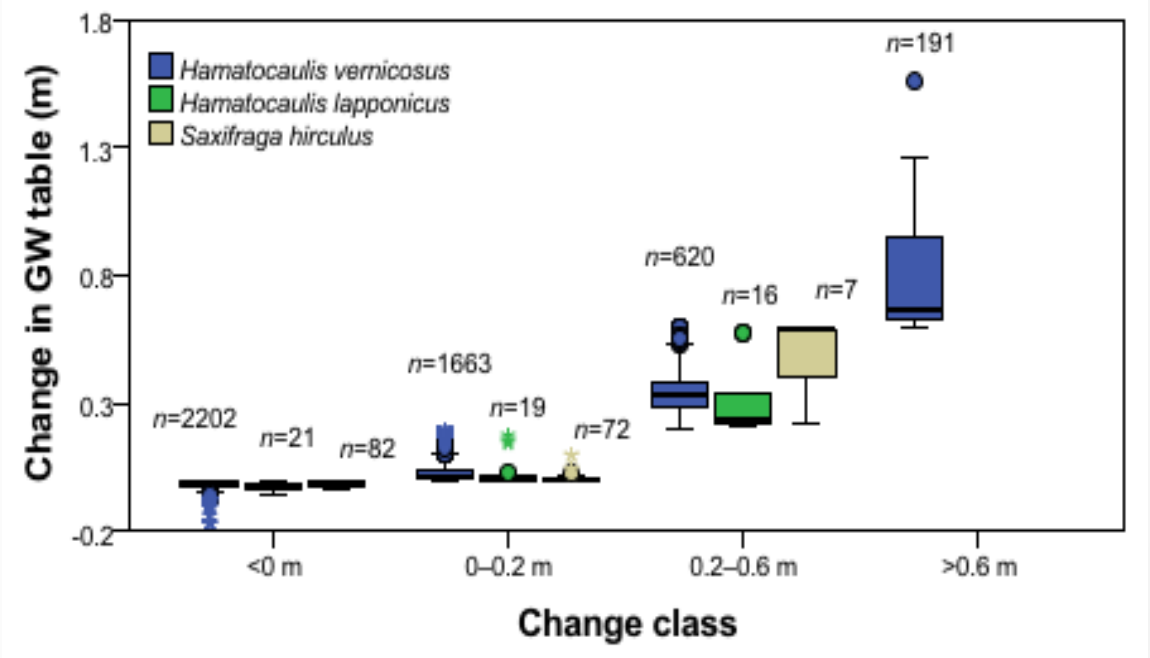
- (a) The difference of groundwater table between PRE1989 settings and POST2014 settings compared to studied groundwater influenced plant species
- (b) Groundwater discharge areas of the POST2014 settings compared to studied groundwater influenced plant species



GW-influenced species modified after the biological database of AASMOY (2021, unpublished data). Mire area and Water body are modified and reproduced after National Land Survey of Finland.

GROUNDWATER INFLUENCED PLANT SPECIES VS. GROUNDWATER TABLE CHANGE

- Almost half of the studied groundwater influenced plant species occurred in regulation-affected areas
- The simulated groundwater discharge areas covered half of the present occurrences of groundwater influenced plant species
- *H. vernicusus* might favour high water table (Ulvinen and Sallantaus 2009)
- Pre-regulation observations would be needed for further conclusions



GW-influenced species data is from the biological database of AASMOY (2021, unpublished data).

CONCLUSIONS

- The model results indicate that the western part of Viiankiaapa mire is influenced due to the regulation of the River Kitinen by the hydroelectric power plants since the 1990s.
- The river stage rise reduced the hydraulic gradient towards the river, raising the groundwater table in the river banks and western part of the Viiankiaapa mire.
- Annual water table variations decreased due to reduction of the flooding, and the regulation created a more stable hydrological environment in the mire area.
- The stabilization of the hydrological environment, as well as the rising of the water table, might have affected the distribution of habitats of vulnerable moss species.
- The mire might have become more favourable for *Hamatocaulis vernicosus*, which is resistant to flooding and a high water table..

REFERENCES

AIRIX Ympäristö Oy: Kelujärvi-Rajala osayleiskaava 1:50 000 Tulvatiedot, Tulvatiedot, AIRIX Ympäristö Oy, 2008.

Brownscombe, W., Ihlenfeld, C., Coppard, J., Hartshorne, C., Klatt, S., Siikaluoma, J. K., and Herrington, R. J.: Chapter 3.7 - The Sakatti Cu-Ni-PGE Sulfide Deposit in Northern Finland, in: Mineral Deposits of Finland, edited by: Maier, W. D., Lahtinen, R., and O'Brien, H., Elsevier, 211–252, 2015.

Brunner, G. W.: HEC-RAS River Analysis System. Hydraulic Reference Manual. Version 1.0, Hydrologic Engineering Center Davis CA, 1995.

Niswonger, R. G., Panday, S., and Ibaraki, M.: MODFLOW-NWT, a Newton formulation for MODFLOW-2005, US Geological Survey Techniques and Methods 6-A37, 44 p, 44 p pp., 2011.

Ulvinen, T.: Hamatocaulis vernicosus – vaarantunut., in: Suomen uhanalaiset sammalet, edited by: Laaka-Lindberg, S., Anttila, S., and Syrjänen, K., Suomen ympäristökeskus, 119–121, 2009.

Åberg, S. C., Åberg, A. K., and Korkka-Niemi, K.: Three-dimensional hydrostratigraphy and groundwater flow models in complex Quaternary deposits and weathered/fractured bedrock: evaluating increasing model complexity, Hydrogeology Journal, https://doi.org/10.1007/s10040-020-02299-4, 2021.

The manuscript of this research: *Åberg, S.C., Korkka-Niemi, K., Rautio, A. & Åberg, A.K. The effect of river regulation on groundwater flow patterns and the hydrological conditions of an aapa mire in northern Finland* has been submitted to Hydrology and Earth System Sciences.