SEEPAGE TRACING BY STABLE ISOTOPES AND GROUNDWATER MODELLING: EXAMPLE OF PLAVINAS HYDROPOWER PLANT,LATVIA

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INTRODUCTION

Plavinu hydroelectric power plant (HPP) (Fig 1) built on river Daugava near Aizkraukle city (Fig 2) is the largest in the Baltic States and the second largest in European Union. Its annual production of electricity is up to 1991 GWh (in the year 2010). It covers around 30-40 % of total generated electricity in the country.

Relative difference between upstream and downstream level is 40 m. Reservoir covers an area of 35 km^2, with total water volume of 509 mlj. m^3 in it. Building of a dam rapidly changed surrounding and large areas occurred under water after power plant begun to work. As well it changed hydrogeological conditions - some aquifers became more affected and water from reservoir could penetrate in some aquifers at particular distance.

Due to high hydraulic gradients and high water saturation of aquifers extensive artificial discharge of groundwater is maintained to relief high pressures under construction.

Fig 1. ***Site of the Plavinas HPP from the bird fly view.*** *Location in Fig 2.*

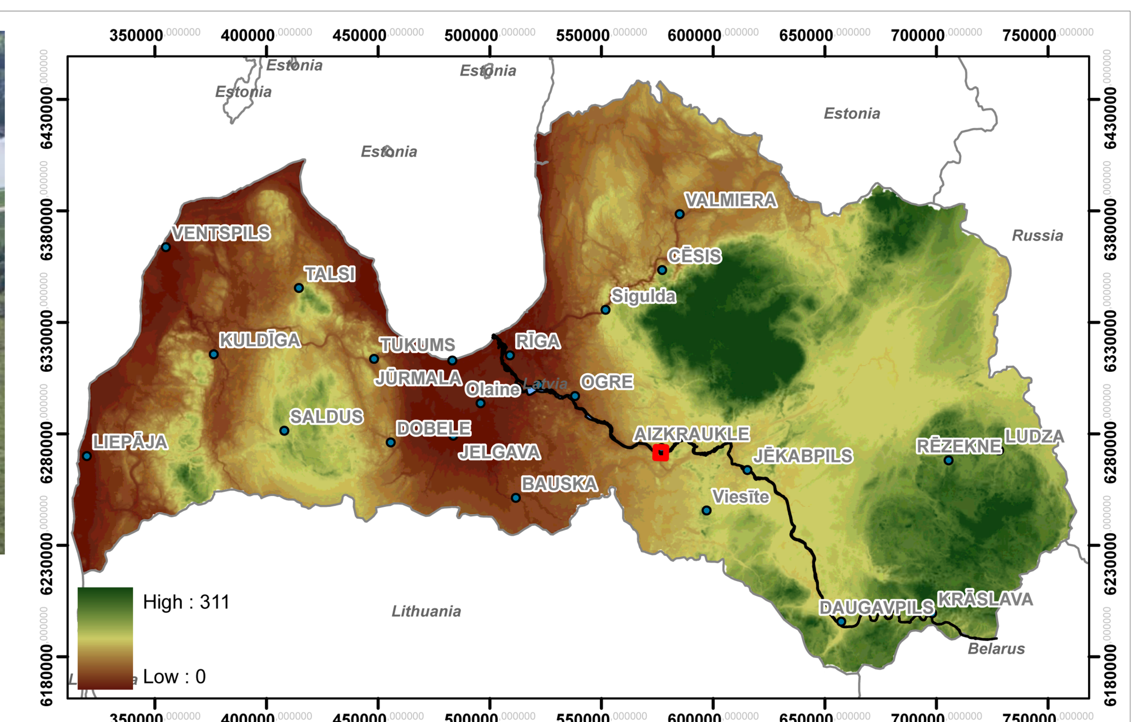

Fig 2. ***Spatial context of the research territory.*** *Location of the Plavinu HPP indicated with red square. Topographic base – digital terrain model developed by Latvian Geospatial Information Agency, EPSG: 25884 projection.*

1. GEOLOGICAL AND HYDROGEOLOGYCAL SETTING

Table 1. ***Simplified classification of geological cross section.***

Period	Deposits	Layer	Thickness, m	Hydraulic conductivity, average m/day
Holocene	sand, gravel	Aluvial (Q4)	0-10	2
Pleistocene	till	Glacial (Q2-3)	0-130	0.02-0.001
Upper Devonian (clastic)	dolomite, gypsum	Plavinas-Daugava (D3pl-dg)	0-60	30
Upper Devonian	marl, clay	Plavinas		0,001
Upper middle Devonian (terigenous)	sandstones	Arukila-Amata (D3ar-am)	80-100	2,5-11
Middle Devonian	clay, dolomite, marl	Narva (D2nr)	-	-

Quaternary sequence mainly consists of till with increasing thickness in ancient valley of river Daugava where reach up to 130 meters. Riverside is covered with thinner alluvial deposits, in some areas even pinching out. D3 Frasnian clastic strata is one multi aquifer system that can be distinguished, layer of low permeability absent between them. Under Daugava river deposits of Plavinu-Daugava sequence are eroded, where valley is filled with glacial materaial. These carbonatic rocks are fractured with heterogeneous permeability with increasing hydraulic conductivity closer to the river valley where may reach 50 and more m/day. D3-D2 terigenous strata consist of sandstones which hydraulic conductivity parameters can be compared to clastic ones. This system is isolated from clastic strata by clayly deposits.Below this terigenous system at level -180 m a.s.l. Regional aquitard occour under which brackish groundwater can be observed.

2. MATERIALS AND METHODS

Water stable isotopes were used to track possible origin of discharged water in high yield relief wells. Sampling procedure was organized to cover one year period collecting samples monthly and it took part from March 2011 till March 2012. Totally 63 samples were collected for stable oxygen and deuterium content in surface and groundwater samples, thus from upstream and downstream, 4 monitoring wells set in different aquifer layers one discharge collector, drain and several spring samples were collected as well at the end of sampling campaign (Fig 3). Sampling from wells and river maintained using bailer type sampler to take sample in particular depth. Measurements were done in the Institute of Geology at Tallinn University of technologies. Stable oxygen and deuterium ratios measured with Picarro Isotopic Water Analyzer. Calibrated mathematical hydrogeological model has already been developed previously for this study area (Bethers et al., 1998) with minor changes it has been used in this study as well.

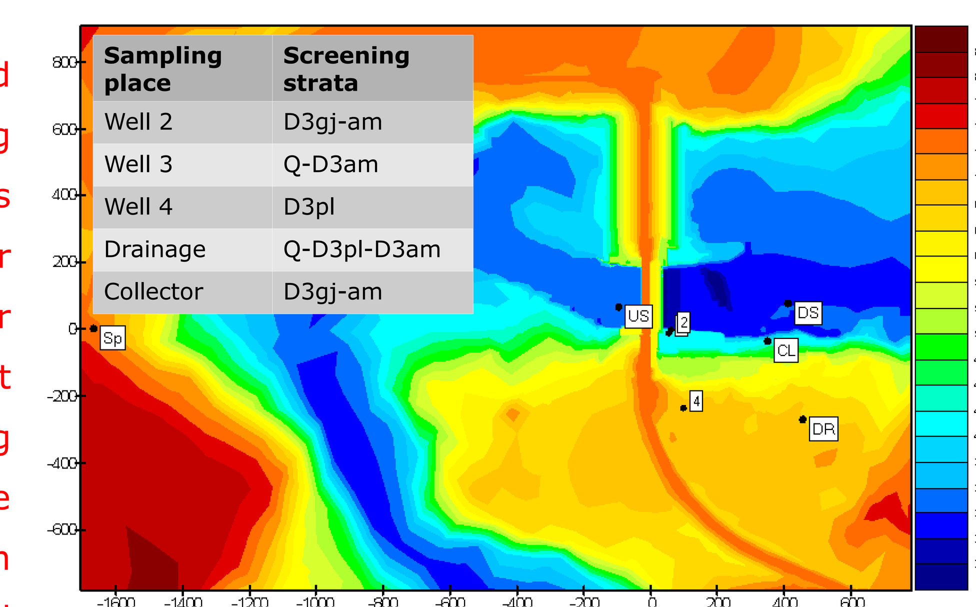

Fig 3. ***Sampling sites.*** *US - Upstream; DS - Downstream; CL - Collector; DR - Drainage; SP - Springs; 2,3,4 – Wells. Local projection.*

3. MODELLING RESULTS

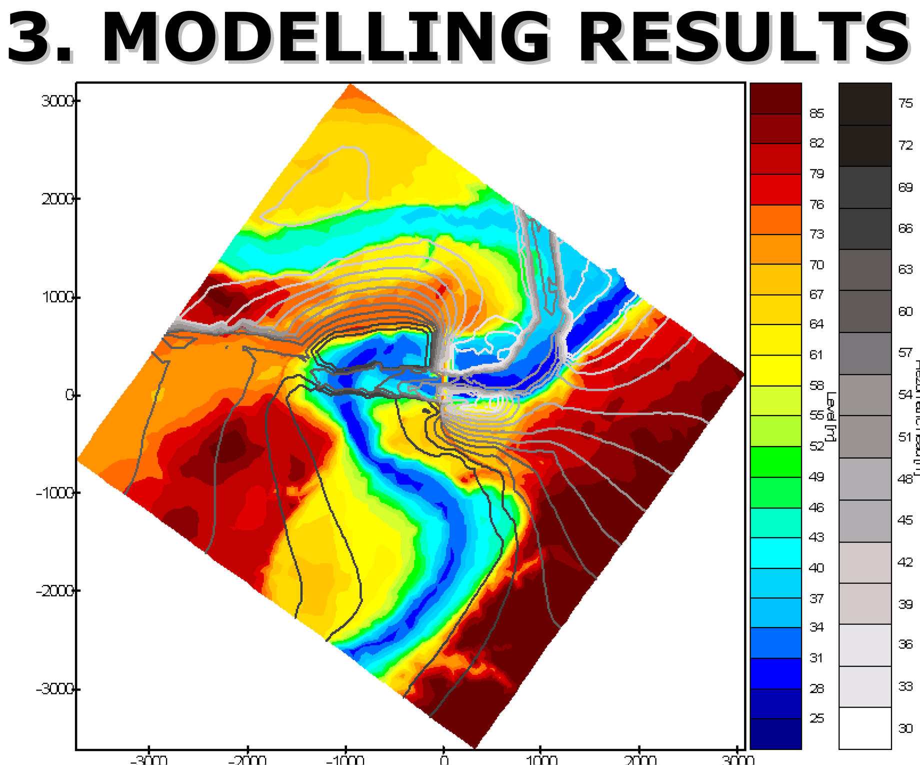

Fig 4. ***Piezometric levels in Upper Devonian clastic multi aquifer system on topographic surface, meters above sea level.*** *Local projection*

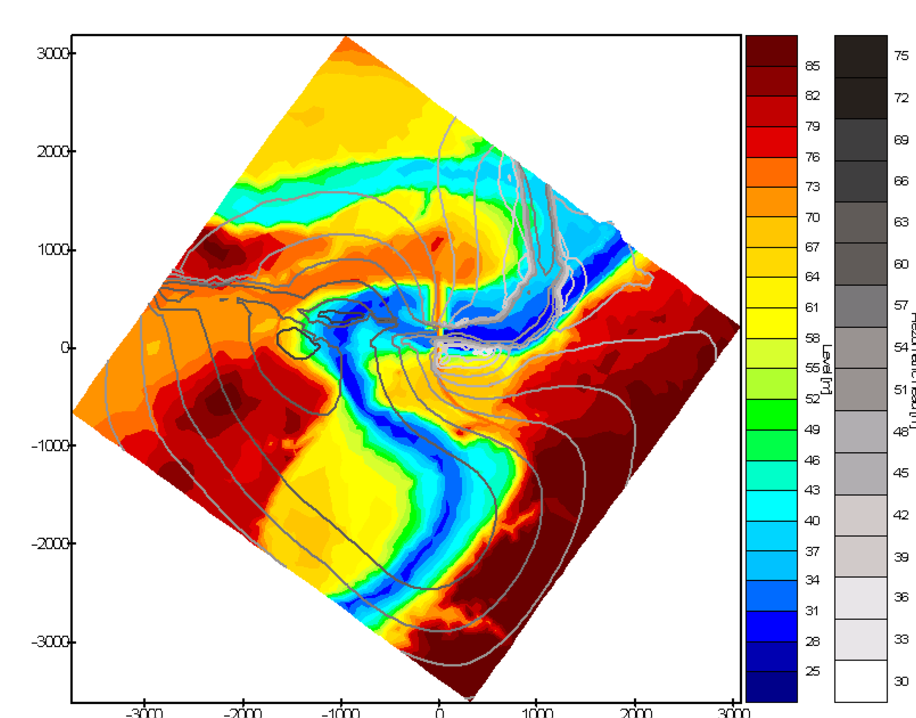

Fig 5. ***Piezometric levels in Upper Devonian terrigenous multi aquifer system on topographic surface, meters above sea level.*** *Local projection*

Piezometric levels in Quaternary aquifer is repeating elevation levels and is in range of 30-70 meters ASL with highest levels in the upstream and lowest in the downstream. Devonian clastic multi aquifer system have insignificantly lower piezometric levels below water reservoir and higher piezometric levels in downstream (Fig 4). Piezometric levels in Devonian terigenous aquifers are also higher in upstream (Fig 5).

4. STABLE ISOTOPE DATA

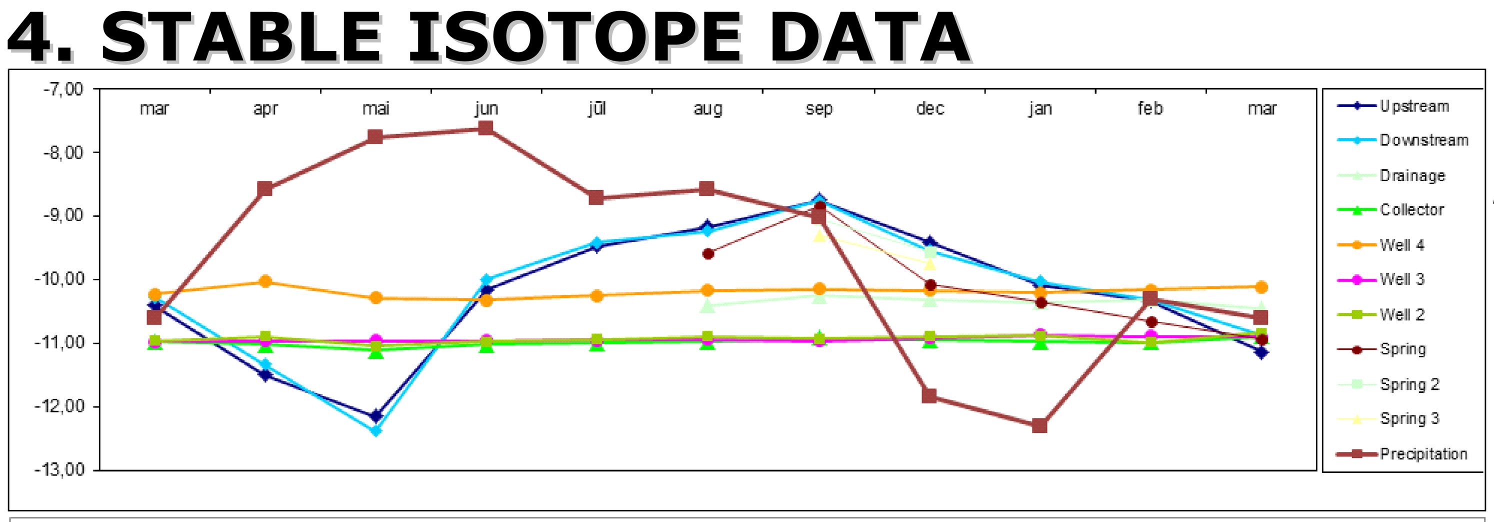

Fig 6. ***Monthly variation of oxygen-18 values in collected samples and precipitation. All values are in Δ‰ VSMOW. Precipitation from IAEA, 2006.***

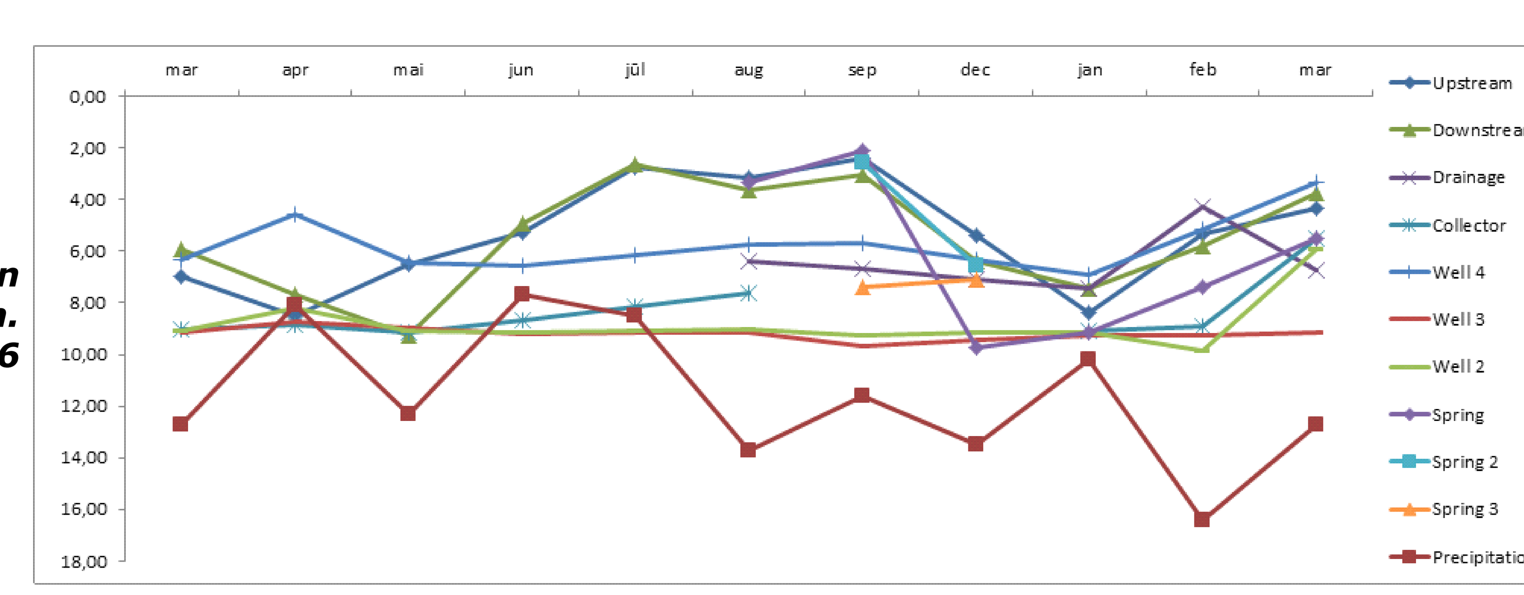

Fig 7. ***Monthly variation of d-excess in collected samples and precipitation. Precipitation from IAEA, 2006***

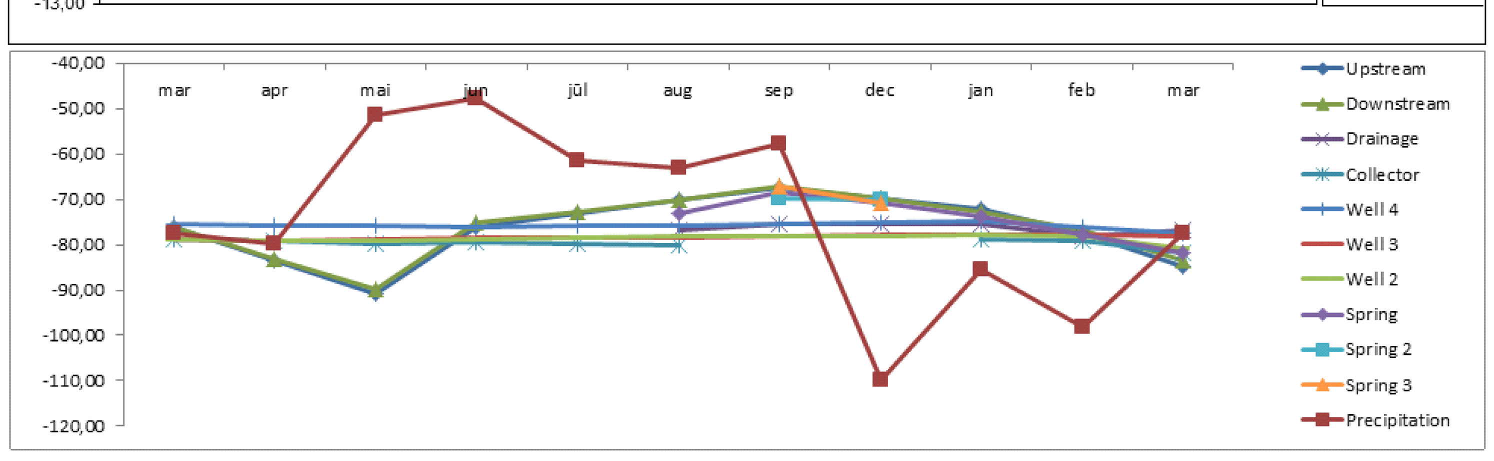

Fig 8. ***Monthly variation of deuterium values in collected samples and precipitation. All values are in Δ‰ VSMOW. Precipitation from IAEA, 2006.***

CONCLUSIONS

1. Taking into consideration flow paths and piezometric levels of aquifers, it is more likely, that bedrock aquifers aren't hydraulically connected with river reservoir in the study area, which is approved by stable isotope data. Although it is possible that in some local areas surface water has an impact on Devonian aquifers, however it is not significant enough to change isotopic content seasonally. Due to high pressures in aquifers small amount of water can penetrate into aquifers near reservoir and during this study weren't observed.
2. Devonian aquifers have lower pressures on the left bank of river Daugava as well low permeable Quaternary deposits are missing in that area. it is possible, that more noticeable amount of surface water can penetrate in these aquifers. No samples were collected from Devonian aquifers from the left bank, therefore additional investigation need to be carried out, to approve hypothesis.
3. It is obvious that river Daugava had seasonal fluctuations with more depleted stable isotope values during cold period and less depleted values in summer. However compared to long term precipitation data variation range is narrower and seasons change with few month retention.
4. Wells 2, 3 and collector has similar values are more or less equally constant, which can indicate that they have similar or the same recharge conditions and are hydraulically connected. For drainage and well nr. 4, the fluctuations are in wider range, however they are still stable during the year.
5. Springs near power plant directly recharge from river, however observed fluctuations can show seasonal fluctuations of precipitation as well, otherwise springs should have very fast recharge from reservoir and should have disappeared during the low season. However, it sure that sampled springs aren't groundwater discharge.

References

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