Useful Statistics for Describing Hydraulic Conductivity of the Quaternary Strata From the Latvian Borehole Log Data

Jānis JĀTNIEKS , Konrāds POPOVS, Jānis UKASS, Tomas SAKS, Aija DĒLIŅA
University of Latvia, Faculty of Geography and Earth Sciences, Alberta 10, Riga, Latvia, e-mail: janis.jatnieks@lu.lv

Introduction

Borehole log data in the territory of Latvia is highly variable in quality, spatial distribution and accuracy of georeferencing, making direct comparisons between different boreholes difficult. It is, however, useful to compile some global statistics describing the broader geological characteristics present in the Quaternary strata. Results presented here have been compiled for reference during work on the representation of Quaternary strata in the regional groundwater model MOSYS V1 using data available to the project „Establishment of interdisciplinary scientist group and modelling system for groundwater research" (PUMa).

Data and Methods

Borehole log data from two data bases was used – Estonian Hydrogeological database (cadastre) and data from Latvian Borehole database (Figure 1). The Estonian data here was used for comparing the number of aquifer-aquiclude transitions with Latvia. The regional groundwater modelling system for Baltic artesian basin - MOSYS V1 required hydraulic conductivities for the Quaternary strata. To derive this we started by looking at the ways to compare the quality of the borehole log data available. To make the log structures comparable in a universal form useful for finding structural patterns, a range normalization for all layer depth entries in all boreholes was performed. This range-normalized borehole log data is used to generate 1000 bin histograms for boreholes that have at least 2 layers in the Quaternary part of the log data. A 1000 bin histogram (Figure 2) was selected because 1 unit of normalized depth represents, on average, 4.5 cm of the log depth in the Quaternary sequence, thus providing an adequate precision for this analysis as well as allowing for an amount of "noise" in the log data precision.

Results

For generalization of the lithology structure in the Quaternary sediments a simplified 4 layer model was used in MOSYS V1 (Seņņikovs, 2011). This was founded in the results of a generalized aquifer-aquiclude transition statistics (Tables 3-6) of the borehole logs using litholgy classification from Table 1. For the regional model layers composed of clay, loam, sandy loam and silt where regarded as aquicludes. There are two such transitions for 81% of boreholes in Latvia (Table 3). A comparison with the available Estonian data (Table 5) shows that for 95% of boreholes in Estonia have only one such transition in the Quaternary sediments. This difference is due to the fact that Quaternary cover in Estonia is thinner, especially in northern part of the territory. Overall this suggests that a simplified yet representative version of Quaternary deposits can, for regional modelling purposes, be represented with 4 layers - 2 aquifers and 2 aquicludes respectively, with each aquifer on top of an aquiclude.

To further improve this model another set of layer transition counts were performed. Using the lithology classifier for aggregation of lithological codes into more general groups of sedimentary rock types, a global count of all transitions between rock type classes was performed using the SQL database language.

The most common layer transitions are sand-loam, loam-sand and sand-silt transitions (Table 2).

The normalized layer transition histogram shows that some transitions are particularly numerous (Figure 2), such as the 0.500, 0.333, 0.250, 0.200, 0.666 normalized depth transitions in the Quaternary sediments.

This may be an indicator pointing towards a requirement for borehole log quality control.

The aquifer-aquiclude counts allow for a coarse generalization of hydraulic conductivity in a simplified 4 layer model of the Quaternary strata. The layer transition counts for aggregate lithology types serve as a reference for work on a sequence based interpolation of inter-cluster boundary transition gradients for spatial clusters of similar lithological structure in the Quaternary part of the borehole logs.

Conclusion

This data has been gradually complied during the PUMa project using available data. It may, however, be possible for other studies to benefit from these results as reference.

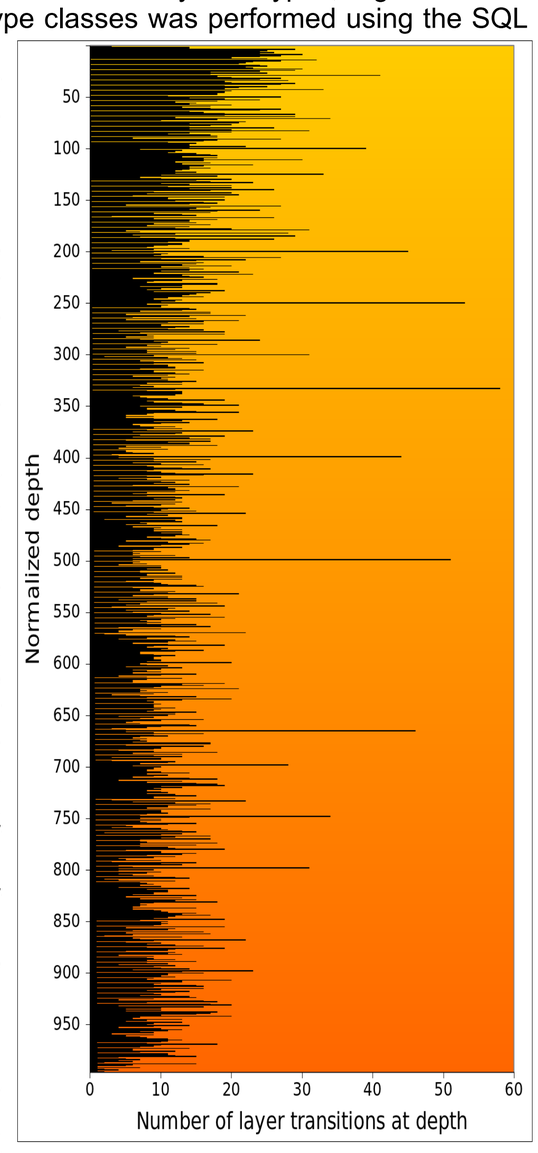

Figure 2: Histogram of layer transitions normalized against the borehole depth in Quaternary deposits. 1000 bins.

Transition type	Number of transitions
sand-loam	5753
loam-sand	4465
sand-silt	4149
sand-sandy loam	3765
sandy loam-sand	3660
silt-sand	3342
sand-clay	2339
gravel-loam	2083
loam-gravel	1990
sand-gravel	1966
silt-loam	1954
clay-sand	1838
sandy loam-loam	1530
clay-loam	1502
sandy loam-gravel	1442
silt-sandy loam	1371
loam-sandy loam	1357
loam-silt	1276
gravel-sand	1195
soil-sand	1177
gravel-sandy loam	1173
sandy loam-silt	1024
loam-clay	896
silt-clay	860
soil-sandy loam	845
clay-sandy loam	776
sandy loam-clay	577
peat-sand	539
clay-silt	529
silt-gravel	479
gravel-silt	380
clay-gravel	368
soil-loam	341
soil-clay	169
gravel-clay	166
peat-loam	161
soil-silt	153
peat-silt	142
gyttja and other biogenic sediments-sand	140
soil-peat	118
peat-sandy loam	104
soil-gravel	87
peat-clay	76
sand-gyttja and other biogenic sediments	71
sand-peat	66

Table 2: Types of layer transitions between lithology classes from Table 1, sorted by rank. Limited to transition combinations with more than 50 occurrences in the Latvian borehole log data.

class	lithology
1	sandstone
2	sandstone-low conductivity
3	sandstone-high conductivity
4	limestone
5	limestone-low conductivity
6	dolomite-high conductivity
7	dolomite
8	domerite (clayey dolomite)
9	clay
10	loam
11	sandy loam
12	silt
13	sand
14	gravel
15	gypsum
16	peat
17	gyttja and other biogenic sediments
18	soil
19	other

Table 1: Main lithology classifier table.

Number of transitions	In number of boreholes	Percent of boreholes
1	3071	95.40%
2	118	3.67%
3	24	0.75%
4	5	0.16%
5	1	0.03%

Table 5: Transitions of type aquifer - aquiclude (aquifer on top) in Estonian borehole log data, in 3219 boreholes.

Number of transitions	Number of boreholes	Percent of boreholes
1	1194	59.14%
2	445	22.04%
3	214	10.60%
4	68	3.37%
5	55	2.72%
6	23	1.14%
7	9	0.45%
8	6	0.30%
9	1	0.05%
10	3	0.15%
12	1	0.05%

Table 3: Transitions of type aquifer-aquiclude (aquifer on top) in Latvian borehole log data, in 2019 boreholes.

Number of transitions	In number of boreholes	Percent of boreholes
1	1250	91.24%
2	97	7.08%
3	15	1.09%
4	7	0.51%
5	1	0.07%

Table 6: Transitions of type aquiclude - aquifer (aquiclude on top) in Estonian borehole log data, in 1370 boreholes.

Number of transitions	In number of boreholes	Percent of boreholes
1	703	52.11%
2	334	24.76%
3	166	12.31%
4	75	5.56%
5	39	2.89%
6	16	1.19%
7	9	0.67%
8	3	0.22%
9	3	0.22%
11	1	0.07%

Table 4: Transitions of type aquiclude -aquifer (aquiclude on top) in Latvian borehole log data. In 1349 boreholes.

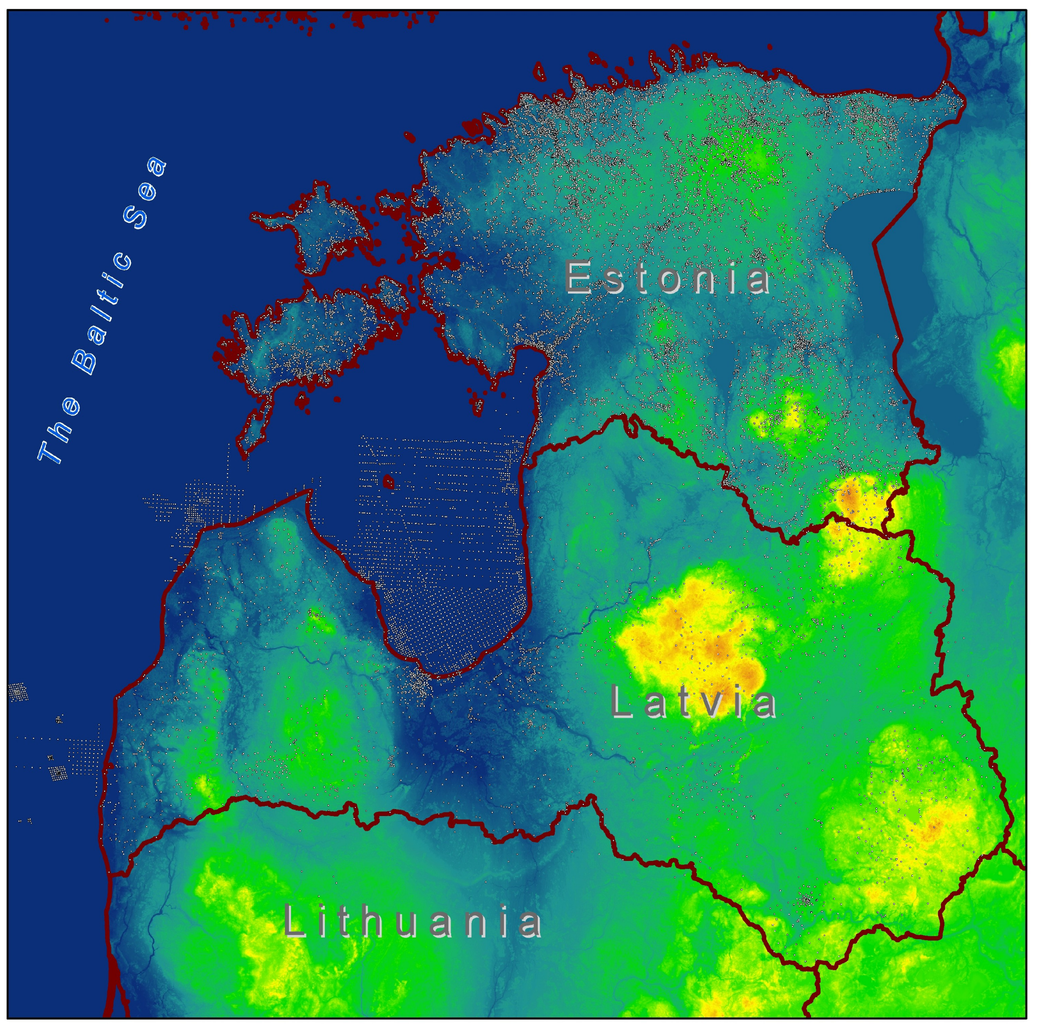

Figure 1: Locations of boreholes used in calculations for this poster presentation.

References:

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