Mapping for the Gauja River Basin District by Using Results Provided by the Hydrogeological Model of Latvia

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Abstract **– In 2010–2012, scientists of Riga Technical University have developed the hydrogeological model of Latvia (LAMO). In 2013, the first practical results have been provided by LAMO. The set of hydrogeological maps and groundwater flow balances has been prepared to update the current water management plan for the Gauja River basin district in Latvia. For aquifers, distributions of groundwater heads and infiltration flows have been prepared. In the maps of heads, directions of groundwater flows and connections of aquifers with rivers are shown. A set of geological profiles has been prepared. A profile represents geological stratigraphy, isolines of groundwater head and directions of groundwater flows. Groundwater flow balances have been prepared for the whole territory of Latvia and for the Gauja River basin district.**

Keywords **– Groundwater flow balance, hydrogeological models, infiltration distributions.**

I. Introduction

The countries of the world and of the European Union are developing hydrogeological models (HM), where by means of computer modelling, the information necessary for the groundwater management planning is obtained. In 2012, scientists of Riga Technical University worked out the regional HM of Latvia (LAMO). In 2013, the first practical application of LAMO has taken place. The set of hydrogeological maps and balances of groundwater flows [2] was prepared. The improved version of these maps is described in this publication. The upgraded results were used for updating of the water management plan of the Gauja River basin district [1]. Location of the district is shown in Fig. 1.

TABLE I
Groundwater Bodies of the Gauja District

Groundwater bodies	Aquifer systems	Area km²	No. of LAMO planes, see Table II
Q_GJ	unconfined Q	101	3-4
D4_GJ	D3pl-aml D2-3ar-am	897	13-16 17-25
D5_GJ	D3pl-aml D2-3ar-am	4732	13-16 17-25
D6_GJ	unconfined Q confined Q D3pl-aml D2-3ar-am	7409	3-4 5-6 13-16 17-25
P_GJ	D1-2	4394	26-27

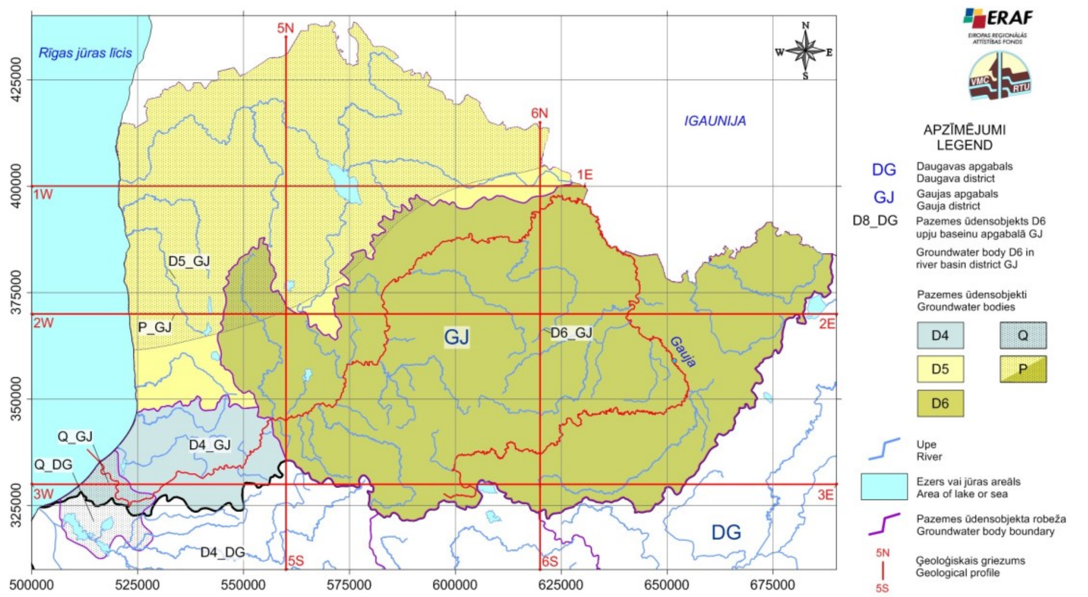

Fig. 1. Location of the Gauja River basin district.

TABLE II

VERTICAL SHEMATIZATION OF LAMO

HM plane Nr.		Name of strata	Geological code	**HM code**	Name of HM plane	Comments
1.		Reljefs	relh	**relh**	Reljefs	Boundary conditions
2.		Aerācijas zona	aer	**aer**	Aerācijas zona	Formal aquitard
3.		Bezspiediena. Q	Q4-3	**Q2**	Kvartārs Q2	
4.		Augš. morēna	gQ3	**gQ2z**	Augšējā. morēna	
5.		Spiediena kvartārs vai Jura	Q1-3 J	**Q1#**	Kvartārs Q1	Included J
6.		Apakšējā morēna vai Triass	gQ1-3 T	**gQ1#z**	Apakšējā morēna	Included T
7.		Perma Karbons Šķerveles Ketleru	P2 C1 D3šķ D3ktl	**D3ktl#**	Ketleru	D3fm#
8.		Ketleru	D3ktl	**D3ktlz**	Ketleru z	D3fm#z
9.		Žagares Svētes Tērvetes Mūru	D3žg D3sv D3tr D3mr	**D3zg#**	Žagares	D3fm#
10.		Akmenes	D3ak	**D3akz**	Akmenes	D3fm#z
11.		Akmenes Kursas Jonišķu	D3ak D3krs D3jn	**D3krs#**	Kursas	D3fm#
12.		Elejas Amulas	D3el D3aml	**D3el#z**	Elejas	D3fm#z
13.		Stipinu Katlešu Ogres Daugavas	D3stp D3ktl D3og D3dg	**D3dg#**	Daugavas	D3pl-aml
14.		Daugavas Salaspils	D3dg D3slp	**D3slp#z**	Salaspils	D3pl-aml
15.		Pļaviņu	D3pl	**D3pl**	Pļaviņu	D3pl-aml
16.		Pļaviņu Amatas	D3pl D3am	**D3am#z**	Amatas z	D3pl-aml
17.		Amatas	D3am	**D3am**	Amatas	D2-3ar_am
18.		Augšējā Gauja	D3gj2	**D3gj2z**	Augšējā Gauja z	D2-3ar_am
19.		Augšējā Gauja	D3gj2	**D3gj2**	Augšējā Gauja	D2-3ar_am
20.		Apakšējā. Gauja	D3gj1	**D3gj1z**	Apakšējā. Gauja z	D2-3ar_am
21.		Apakšējā. Gauja	D3gj1	**D3gj1**	Apakšējā. Gauja	D2-3ar_am
22.		Burtnieku	D2brt	**D2brtz**	Burtnieku z	D2-3ar_am
23.		Burtnieku	D2brt	**D2brt**	Burtnieku	D2-3ar_am
24.		Arikula	D2ar	**D2arz**	Arikula z	D2-3ar_am
25.		Arikula	D2ar	**D2ar**	Arikula	D2-3ar_am
26.		Narvas,	D2nr2, D2nr1	**D2nr#z**	Narvas z	D12
27.		Pērnavas	D2prn	**D2prn**	Pērnavas	D12 boundary conditions

-sprostslānis aquitard   #-apvienotais ūdens horizonts united aquifer   #z-apvienotais sprostslānis united aquitard

The Gauja district area is 13167 km^2 that covers 20.2% of Latvia. The district includes five groundwater bodies D4_GJ, D5_GJ, D6_GJ, Q_GJ, P_GJ, the LAMO hydrographic network (49 rivers, 8 lakes; Gulf of Riga). Locations of geological profiles are shown. The profile along the Gauja River was also prepared (Fig. 8). Table I includes data of groundwater bodies for the district (aquifer systems, their area, number of LAMO planes that simulate groundwater bodies). The vertical schematization of LAMO is presented in Table II. For example, in LAMO, the D6_GJ body is simulated by planes 3 and 4 (Q2, gQ2z); 5 and 6 (Q1#, gQ1#z); 13, 14, 15, 16 (D3dg#, D3slp#z, D3pl, D3am#z); 17-25 (D3am, D3gj2z, D3gj2, D3gj1z, D3gj1, D2brtz, D2brt, D2arz, D2ar).

In the Gauja district, the geological strata (D3ktl#, D3ktlz, D3akz, D3krs#, D3el#z (LAMO planes 7-12) do not exist.

II. Results of Mapping

By using data of LAMO, 30 maps were prepared for the Gauja district. The maps represented four types of hydrogeological information:

- the digital relief and distributions of groundwater heads for aquifers (11 maps);
- the infiltration distributions (10 maps);
- the maps where areas of inflow, outflow and transit areas of groundwater flows were shown (3 maps);
- geological profiles (6 maps).

In the maps of the groundwater head distributions, the parts of rivers are marked that are joined with aquifers. These connections may be very complex. For example, the Gauja River (profile of Fig. 8), on its run, is joined with aquifers Q2, D3dg#, D3pl, D3am, D2brt, D3gj1, D3gj2, Q2. Information regarding connections of rivers with aquifers is used when rivers are immersed into LAMO. Directions of groundwater flows are also shown. No isolines of groundwater heads are shown for a nonexistent part of an aquifer (Fig. 3 for aquifer D3gj1). An exception is the groundwater head distribution map of the prequaternary aquifers preQ (Fig. 2). The distribution is superposition of visible head distributions of primary aquifers that can be observed from the bird's eye view.

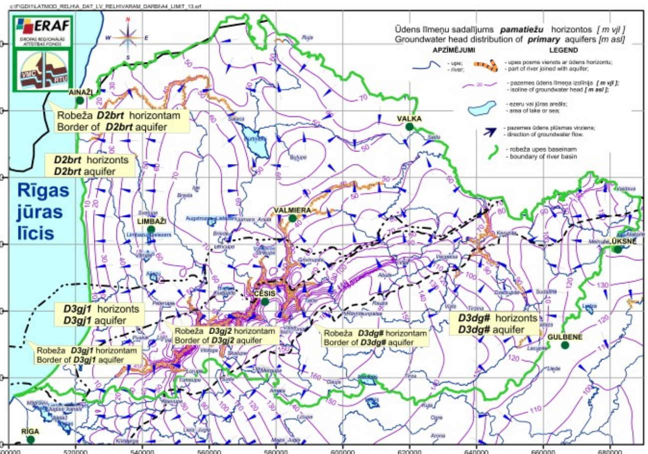

Fig. 2. Groundwater head distribution of primary preQ aquifers [m asl].

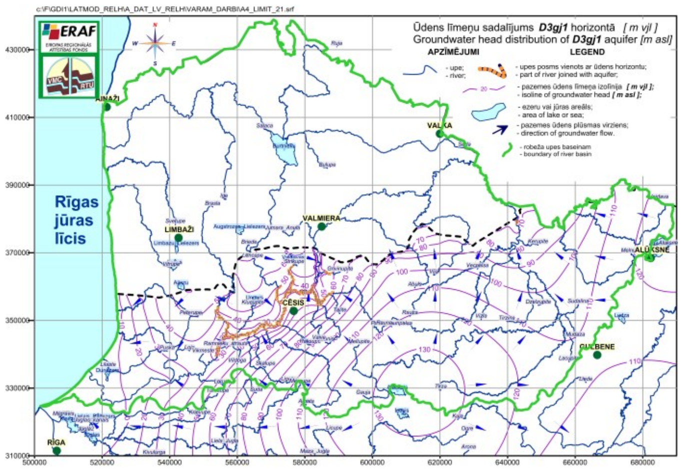

Fig. 3. Groundwater head distribution of D3gj1 aquifer [m asl].

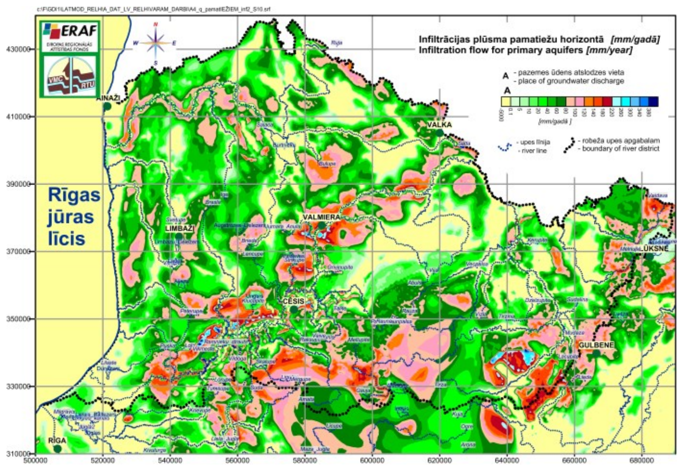

Fig. 4. Infiltration flow for primary preQ aquifers [mm/year].

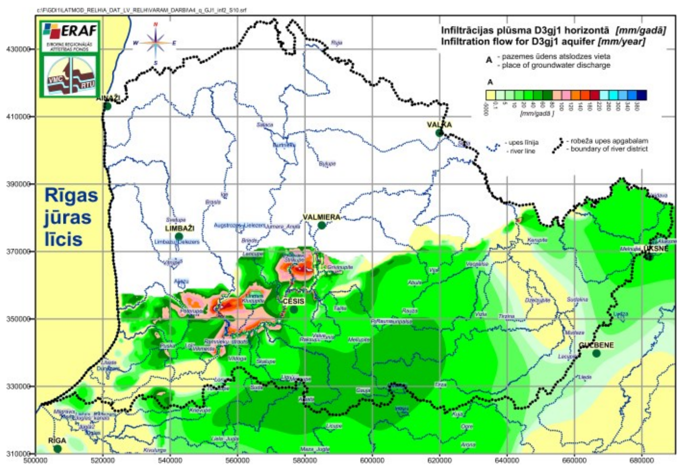

Fig. 5. Infiltration flow for D3gj1aquifer [mm/year]

By using the groundwater head distributions, the maps of permeability and thickness of geological strata, the distributions of infiltration flows were computed for aquifers. As examples, the distributions for the aquifers preQ (Fig. 4) and D3gj1 (Fig. 5) are presented. The distribution of Fig. 4 is

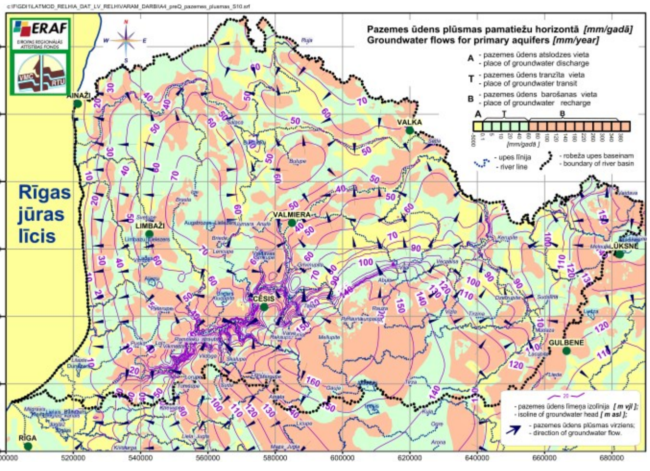

Fig. 6. Infiltration flow for preQ aquifers [mm/year].

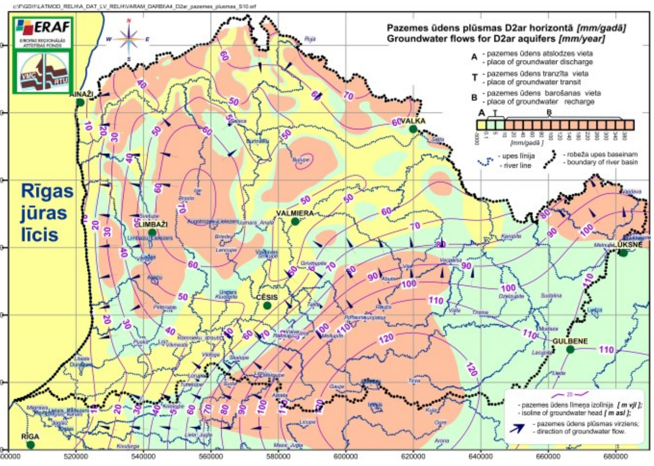

Fig. 7. Infiltration flow for D2ar aquifer [mm/year].

very complex. The LAMO infiltration intensity depends on the flow through the aeration zone aer. The flow is controlled by the digital relief relh (boundary conditions) and by the variable conductivity of the aeration zone aer (Table II). Maximal inflows coincide with hilly areas, but outflows are in the areas of lowlands, lakes and rivers.

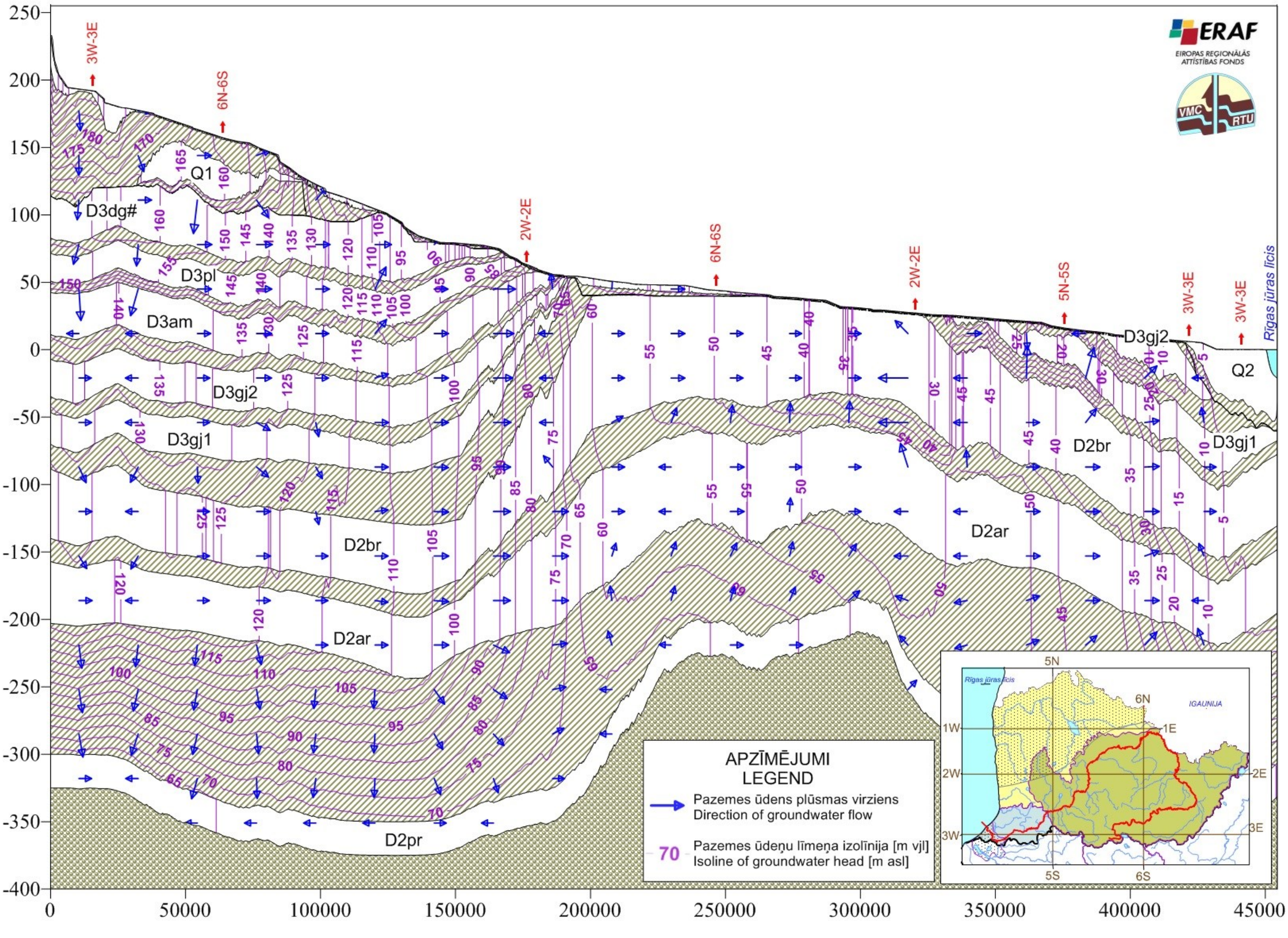

Fig. 8. Geological profile along the Gauja River.

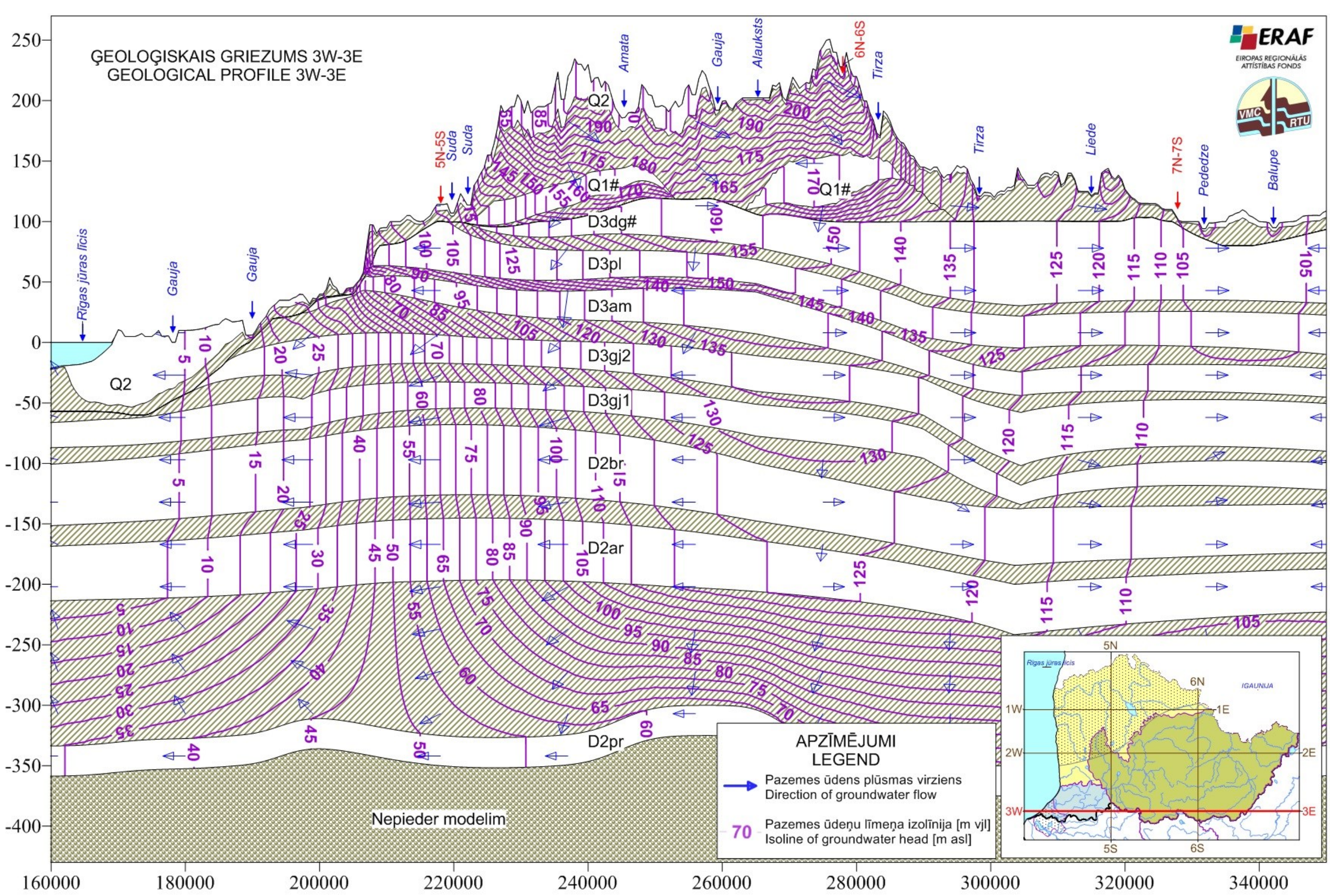

Fig. 9. Geological profile 3W-3E.

Like the map of Fig. 2, the infiltration map of Fig. 4 also presents the superposition of visible infiltration areas of primary aquifers. For the deep aquifers (Fig. 5 for D3gj1), the intensity of infiltration decreases. However, the areas of maximal infiltration coincide with uplands simulated by the digital relief.

For aquifers Q2, preQ, D2ar, special maps were prepared. In these maps, areas of inflow, outflow and transit areas of groundwater flows are shown (Fig. 6 for preQ; Fig.7 for D2ar). The maps were obtained by joining data carried by distributions of groundwater heads and of the infiltration. To mark the areas, the simplified colour scale of infiltration was applied. The width of transit zone was decreased for D2ar aquifer. For aquifers Q2, preQ, the zone (0–60)mm/year was used, but the transit zone (0-10)mm/year was used for the aquifer D2ar. Otherwise, it was not possible to mark the inflow area of the aquifer D2ar, where the infiltration intensity was smaller.

The geological profiles provide valuable information about hydrogeological processes. As an example, the profile for the Gauja River is presented (Fig. 8). It gives the geological stratification, the set of isolines for groundwater head, directions of groundwater flows. To graph the isolines of head, it was taken into consideration that in aquifers the isolines had to have vertical orientation, because the vertical hydraulic gradient was very small. Special methods were used to obtain distributions, where different behaviors of isolines within aquifers and aquitards were accounted for.

Information was prepared about the groundwater flow balance of the Gauja basin district. This result is considered in the publication [3]. Survey of methods that were used to develop LAMO is presented in the publications [4-13].

III. Conclusions

In 2013, by using data provided by the hydrogeological model of Latvia (LAMO), mapping for the Gauja/Koiva River basin district has been carried out by scientists of Riga Technical University. These results have served as the prototype of mapping for all river basin districts of Latvia (Gauja, Daugava, Lielupe, Venta). Due to application of data of LAMO, the quality of water management plans of the river basin districts has been considerably improved.

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