Implementations of Riga city water supply system founded on groundwater sources

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Drinking water for Riga city is provided by the groundwater well field complex “Baltezers, Zakumuiza, Rembergi” and by the Daugava river as a surface water source. Presently (2017), the both sources jointly supply

122 thous.metre^{3}day^{-1} of drinking water.

The research on the possibility to use in future only groundwater was done by scientists of Riga Technical university as the task drawn up by the company ”Aqua-Brambis”.

Table 1

Historical survey on well fields for centralized water supply of Riga city

Name of well field	Year of opening	Source of water[c]	Water take out mode	Water treatment required	Yield (thous.metre^{3}day^{-1})		Recharge[a] (thous.metre^{3}day^{-1})
					1991	2015	1991
Baltezers	1904	Q	syphon	yes	58.1	19.0	72.0
Baltezers 1	1959	Q	syphon	yes	27.5	9.6	-
Baltezers 2	1974	Q	syphon	yes	28.5	-	24.2
Rembergi	1962	Q	syphon	no	19.2	12.0	-
Zakumuiza	1935	Q	syphon	no	27.8	10.0	-
Zakumuiza D	2006	D3gj	pumps	no	-	10.5	-
Gauja	1966	Q	pumps	yes	68.4[b]	-	-
Katlakalns	1968	D3gj	pumps	yes	10.0	-	-
			Groundwater total		239.5	61.1	96.2
			Sources of surface water				
Daugava	1978	river	pumps	yes	150.0	63.6	-
Jugla	1967	lake	pumps	yes	40.0	-	-
			Riga total		420.5	124.7	-

[a] No artificial groundwater recharge in 2015

[b] Total yield of Gauja1 and Gauja experimental

[c] Q and D3gj – codes of Quaternary and Devonian aquifers

From information of table 1, the following conclusions can be drawn: since 1991, the drinking water consumption of Riga city has decreased 3.37 times; in 2015, the available capacity of groundwater and surface water sources was exploited only 54% and 42%, accordingly.

It is expected that, in 2030, the water demand of Riga city will be only 122 thous.metre^{3}day^{-1}.

Table 2

Summary on yield of well fields (thous.metre^{3}day^{-1}) for scenarios of water supply

Name of well field	Scenario number				
	1.	2.	3.	4.	5.
Baltezers	19.0	19.0	19.0	19.0	28.0
Baltezers 1	9.6	9.6	9.6	9.6	30.0
Baltezers 1D	-	-	-	15.0	-
Baltezers 2	-	-	-	-	-
Rembergi	12.0	17.0	17.0	17.0	17.0
Rembergi D	-	-	-	15.0	-
Zakumuiza	10.0	17.0	17.0	17.0	17.0
Zakumuiza D	10.5	28.5	30.0	30.0	30.0
Daugava D	-	-	30.0	-	-
Daugava	63.6	31.8	-	-	-
Total	124.7	122.0	122.6	122.6	122.0

(yellow) Submersible pumps used

Scenarios of water supply

The scenario 1 is the current water supply.

For the scenario 2, the yield of the intake Daugava is reduced twice (63.6→31.8). To support the yield 122.0 thous.metre^{3}day^{-1}, productivity of the wells fields Rembergi, Zakumuiza and Zakumuiza D have to be increased.

The scenarios 3, 4, 5 do not use surface water.

For the scenario 3, the intake Daugava is replaced by the new well field Daugava D that uses artesian water of the Devonian aquifer D3gj.

The scenario 4 uses artesian water of the Devonian aquifer D3gj1. The wells of Baltezers1 D and Rembergi D are located along the syphon lines of Baltezers and Rembergi, correspondingly.

For the scenarios 5, all syphons are replaced with submersible pumps.

Surroundings of Riga with the hydrogeological model area

Hydrogeological model (HM) has been created for the Baltezers, Rembergi and Zakumuiza water supply complex of the Riga city, Latvia.

The hydrogeological model area

The HM size is 11.0km×11.45km; the plane approximation step h=55 metres. HM includes eight planes (Table 3). The Groundwater Vistas system is applied to run HM.

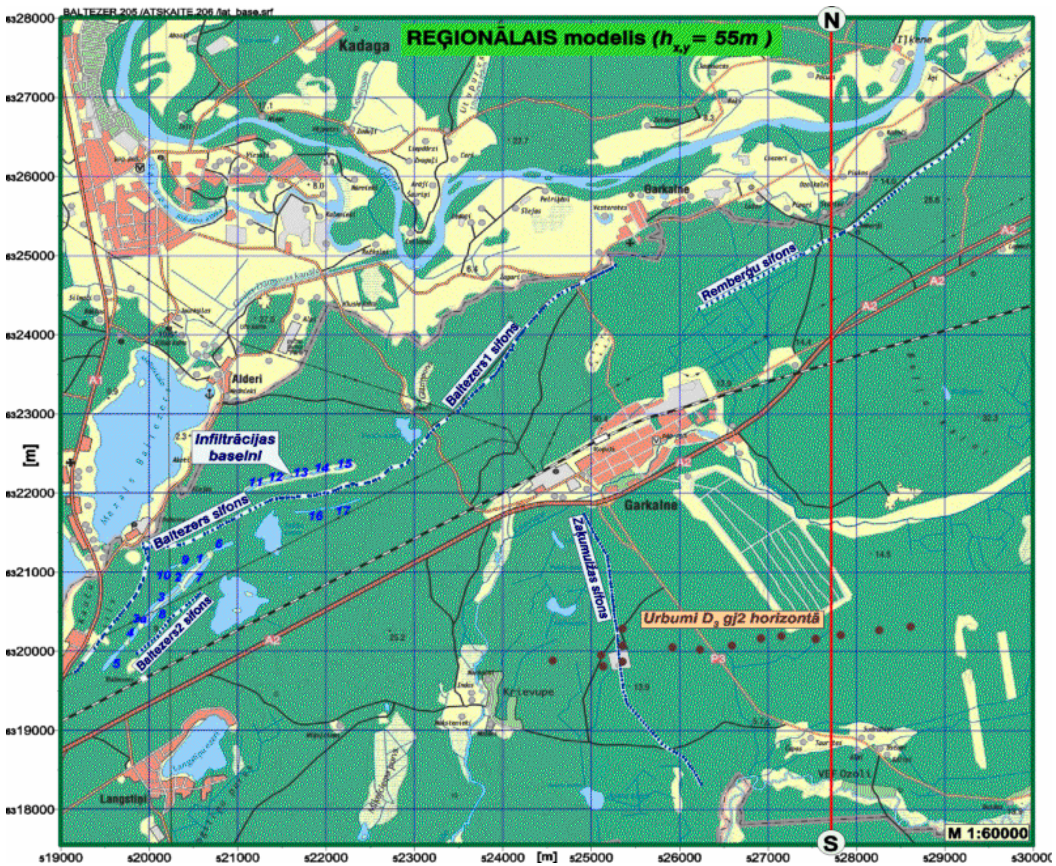


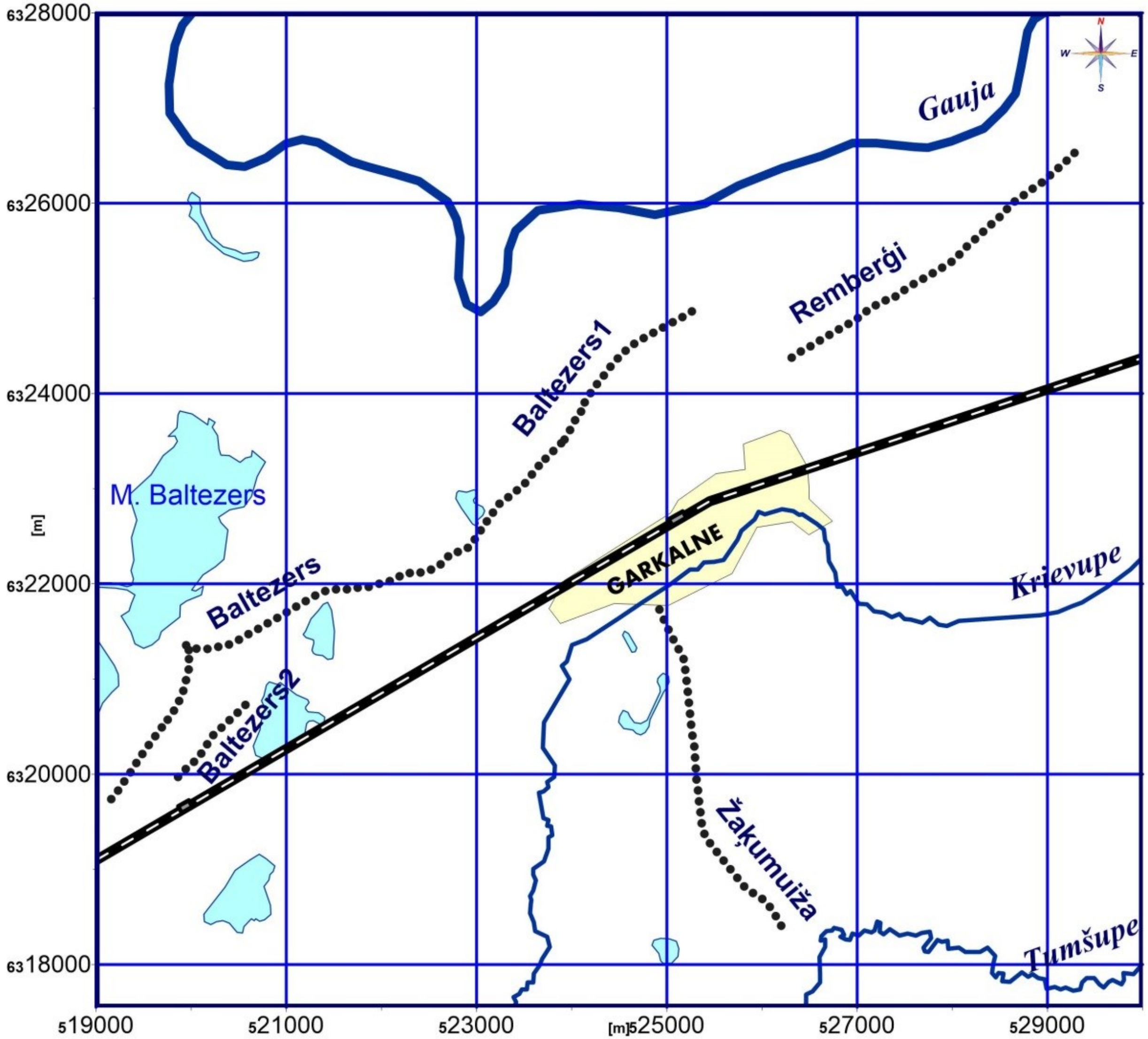
Table 3

Vertical schematisation and parameters of hydrogeological model

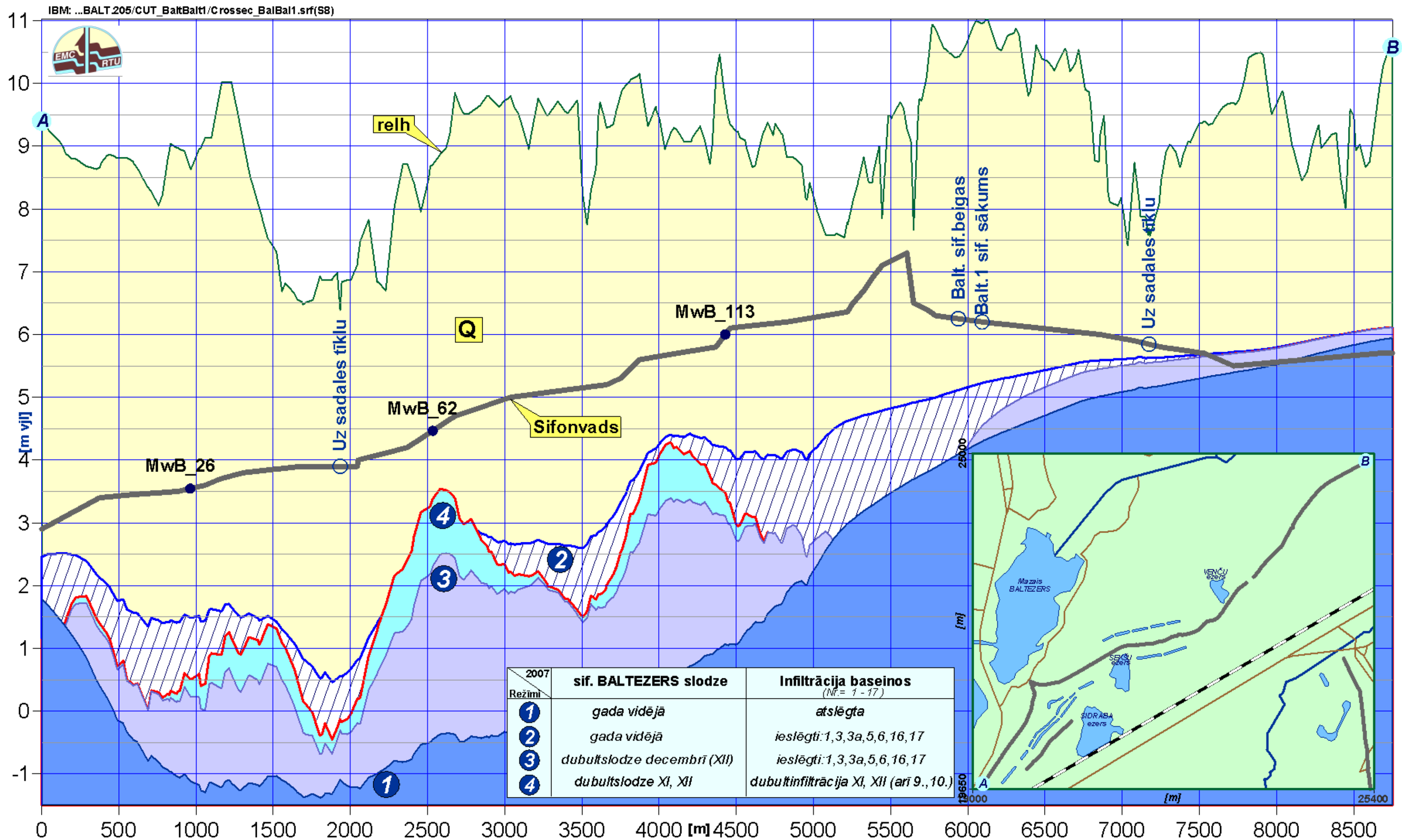
No of HM layer	[a]	Name of layer	Code of layer	m_{mean} (metre)	k_{mean} (metre day^{-1})	Notes
1		Relief	relh	0.02	10.0	Boundary conditions
2	▤	Aeration zone	aer	3.0	$3.4\ 10^{-4}$	
3		Quaternary sand	Q1	14.2	32.2	Connected with lakes and rivers
4		Quaternary sand	Q2	14.2	32.2	Connected with wells
5	▤	Quaternary moraine	gQz	10.8	$2\ 10^{-4}$	
6		Upper Gauja	D3gj2	22.0	10.0	Connected with wells
7	▤	Lower Gauja	D3gj1z	9.1	$2\ 10^{-4}$	
8		Lower Gauja	D3gj1	28.6	10.0	Connected with wells
[a]	▤	aquitard				

m_{mean} and k_{mean} – the mean thickness and permeability of layers

Location of syphons

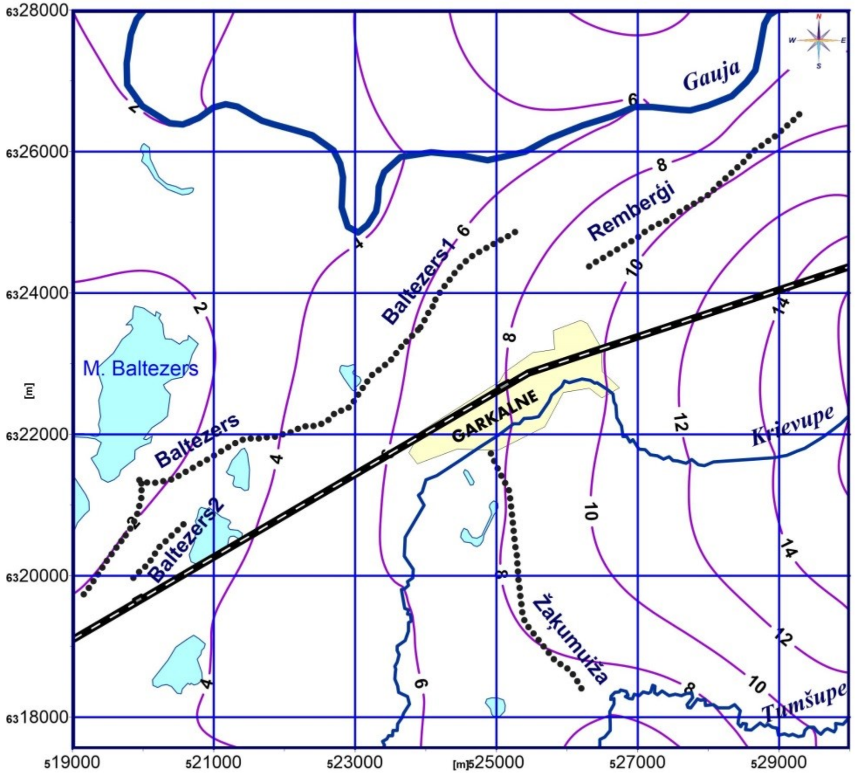


Vertical cross section along syphons Baltezers and Baltezers1

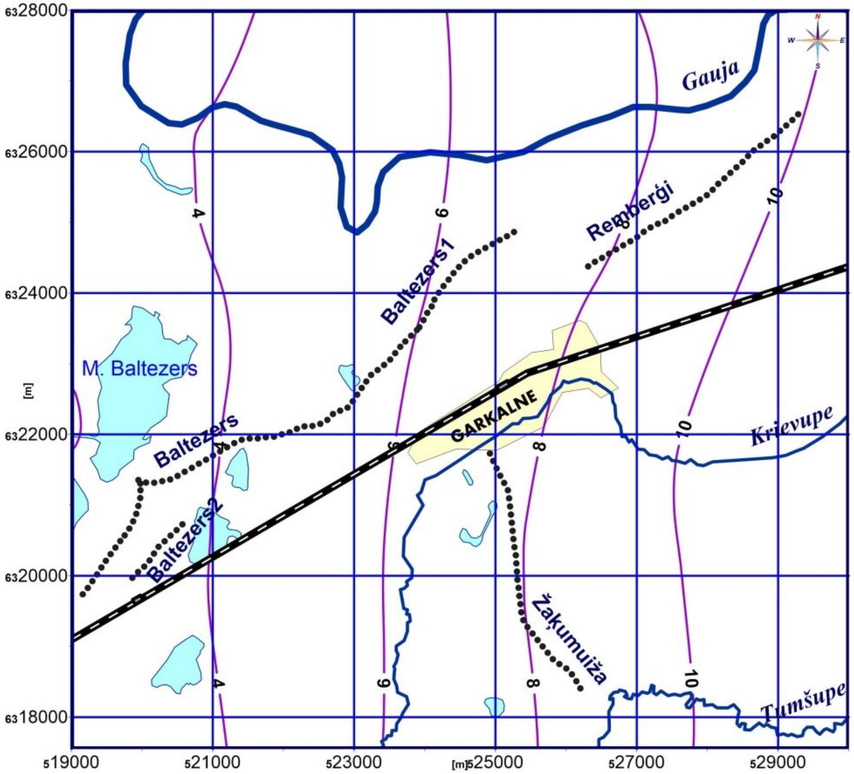


Undisturbed head (m asl) images

aquifer Q2



aquifer D3gj2

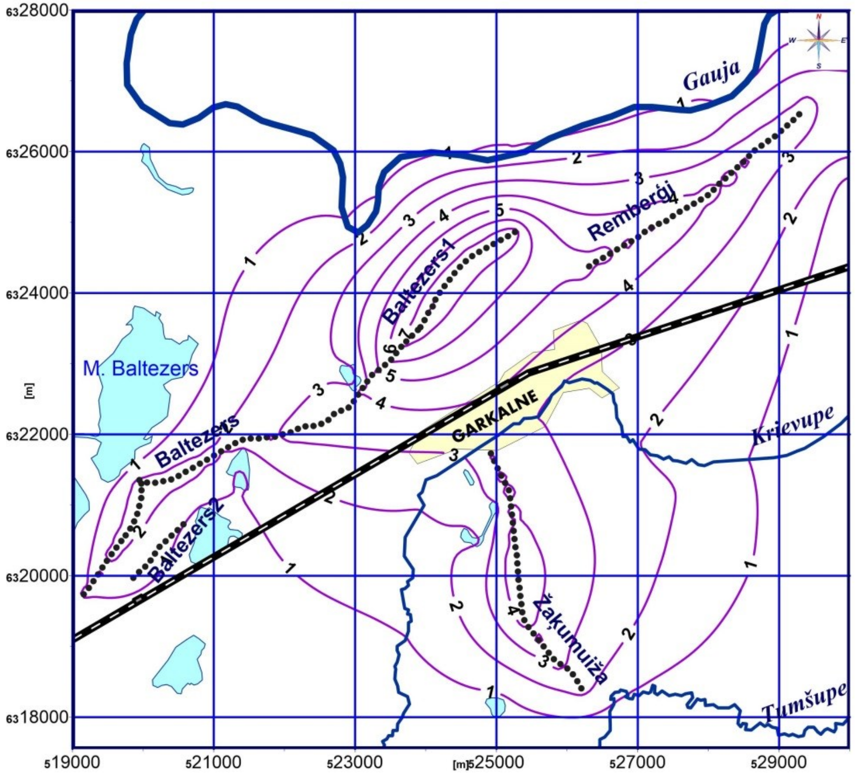


Groundwater abstraction results in decreased head distribution φ_{din}. The difference φ_{und} - φ_{din} = S (metre) is the depression cone of the well field.

The maximal value of S (depth of the cone) for syphons is 6-7 metre. For the submersible pumps, the depth of a cone is limited only by drying of the aquifer.

Depression cones (metre) for the scenario 5; (The scenario applies maximal groundwater intakes for the aquifers Q2 and D3gj2)

aquifer Q2



aquifer D3gj2

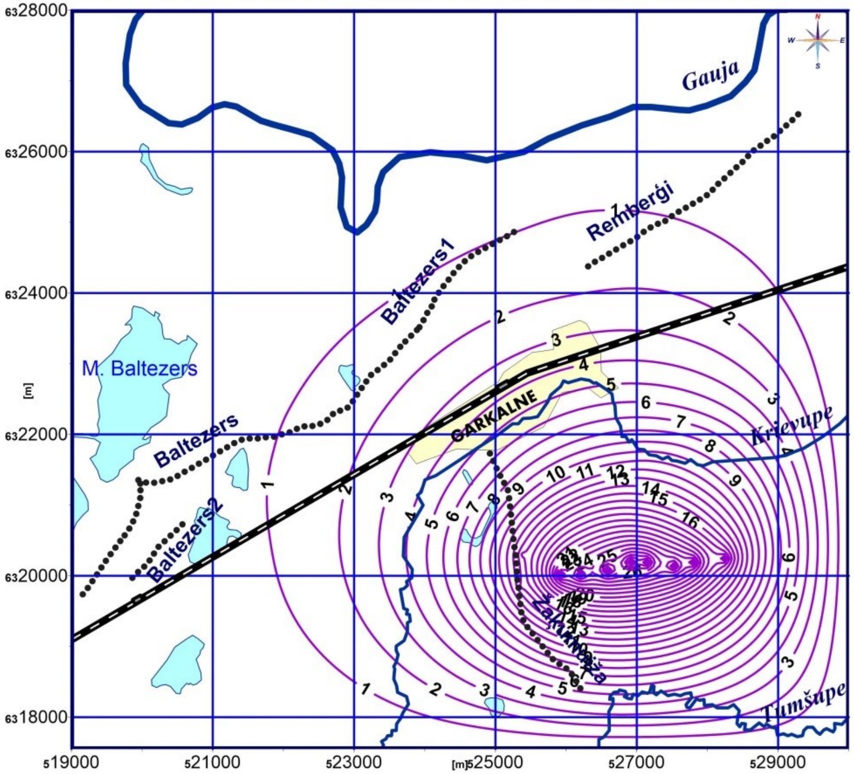


Table 4

Depth of depression cones (metre) for water supply scenarios

Name of well field	Depth of cone (metre) for scenarios Nos 1-5				
	1	2	3	4	5
Baltezers	2.2	2.4	2.4	2.4	3.9
Baltezers 1	2.9	3.2	3.4	3.4	7.8
Baltezers 1D	-	-	-	22.5	-
Rembergi	3.0	4.0	4.3	4.3	5.3
Rembergi D	-	-	-	22.5	-
Zakumuiza	2.5	4.2	4.3	4.3	4.8
Zakumuiza D	11.2	30.6	32.8	32.8	32.8
Daugava D	-	-	35.4	-	-

(highlighted cells) submersible pumps used

In Table 5, the flow balances for undisturbed conditions, scenarios 1 and 5 are given.

The flow balance shows how the groundwater withdrawal by exploitation wells is supported by the infiltration flow, rivers and lakes.

Table 5

Groundwater flow balance (thous.metre^{3}day^{-1})

Aquifer	Top	Bottom	Infiltration	Rivers	Lakes	Borders	Wells
1	2	3	4=2+3	5	6	7	8
			Undisturbed condition				
Q1	55.34	0.78	56.12	-33.89	-22.04	-0.19	0
Q2	-0.78	0.28	-0.50	0	0	0.50	0
D3gj2	-0.28	-1.16	-1.44	0	0	1.44	0
D3gj1	1.16	0	1.16	0	0	-1.16	0
		Total	55.34	-33.89	-22.04	0.59	0
			Scenario 1				
Q1	68.17	-45.70	22.47	-22.43	-4.99	4.95	0
Q2	45.70	-0.77	44.93	0	0	5.67	-50.60
D3gj2	0.77	1.36	2.13	0	0	8.57	-11.70
D3gj1	-1.36	0	-1.36	0	0	1.36	0
		Total	68.17	-22.43	-4.99	20.55	-62.30
			Scenario 5				
Q1	80.72	-85.93	-5.21	-10.98	7.51	8.68	0
Q2	85.93	-3.45	82.48	0	0	9.52	-92.00
D3gj2	3.45	5.10	8.55	0	0	21.45	-30.00
D3gj1	-5.10	0	-5.10	0	0	5.10	0
		Total	80.72	-10.98	7.51	44.75	-122.00

The Daugava river splits Riga city into two parts: the western and eastern Riga (RW and RE). Presently, RE contributes about 88 thous.metre^{3}day^{-1}.

The Daugava river and the new well field Daugava D provide water for RW (scenarios 1, 2, 3).

This feature eases the problem of water transfer between RW and RE; since the 1978, water distribution network has been developed to provide the biggest share of supply from Daugava river.

Table 5

Summary on yields of water sources (thous.metre^{3}day^{-1}) of water supply scenarios for the eastern and western parts of Riga (RE and RW)

Scenario No	Total yield (thous.metre^{3}day^{-1})	Yield (thous.metre^{3}day^{-1}) of water source		Transfer RW → RE[a] (thous.metre^{3}day^{-1})
		RW	RE	
1	124.7	63.6	61.1	-26.9
2	122.9	31.8	91.1	-3.1
3	122.6	30.0	92.6	-4.6
4	122.6	0.0	122.6	-34.6
5	122.0	0.0	122.0	-34.0

[a] if RE water consumption is 88.0 thous.m^3/day

For the scenarios 4 and 5, water sources are located only at RE and about 34 thous.metre^{3}day^{-1} should be transferred to RW. This circumstance causes the problems of water distribution reliability and safety.

Indicative hydraulic estimates showed that change of water supply only from RE (scenarios 4 and 5) requires relatively big investments to optimise volumes and distribution of water reservoirs within the network and strengthening water supply mains which provide water from RE side to RW side of the city.

It requires more detailed analysis of supporting water pressure in the network, to ensure economically feasible and cost effective water supply for the city in the near future.

Conclusions

It follows from investigation of the possible scenarios of water supply for Riga city than the water consumption 122 thous.$metre^3 day^{-1}$ can be provided using only groundwater sources.

However, then the water distribution network reliability and safety issues shall be solved.

Thank you for attention